(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
19 June 2025 (19.06.2025)

WIPO | PCT

(10) International Publication Number
WO 2025/123732 A1

(51) International Patent Classification:
H04W 8/14 (2009.01)

(21) International Application Number:
PCT/CN2024/111241

(22) International Filing Date:
09 August 2024 (09.08.2024)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant: **LENOVO (BEIJING) LIMITED** [CN/CN]; 6 Shangdi West Road, Haidian District, Beijing 100085 (CN).

(72) Inventors: **LEI, Haipeng**; Lenovo Hq East, Building No. 1, No. 10 Xibeiwang East Road, Haidian District, Beijing 100094 (CN). **SUN, Zhennian**; Lenovo Hq East, Building No. 1, No. 10 Xibeiwang East Road, Haidian District, Beijing 100094 (CN). **YU, Xiaodong**; Lenovo Hq East, Building No. 1, No. 10 Xibeiwang East Road, Haidian District, Beijing 100094 (CN).

(74) Agent: **LEE AND LI-LEAVEN IPR AGENCY LTD.**; Suite 1202, Tower A, Hehua Mingcheng Building, No. 7 Jianguomen South Avenue, Dongcheng District, Beijing 100005 (CN).

(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, 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).

(54) **Title:** METHODS AND APPARATUSES FOR INCREASING SUSTAINABLE OPERATION TIME FOR AMBIENT INTERNET OF THINGS COMMUNICATION

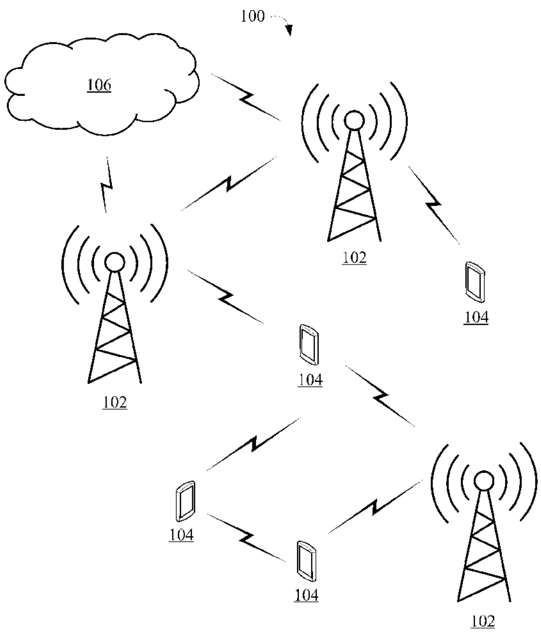

FIG. 1

(57) **Abstract:** Embodiments of the present disclosure relate to methods and apparatuses for increasing sustainable operation time for ambient IoT communication. A first device may: transmit, to a group of second devices, a first state indication signal indicating each second device of the group of second devices to switch to a first state; determine, at a first time instance, that at least a percentage of second devices within the group of second devices have received the first state indication signal; and transmit, to the group of second devices, signaling for ambient IoT communication.

WO 2025/123732 A1

[Continued on next page]

WO 2025/123732 A1

Published:

— *with international search report (Art. 21(3))*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*
— *upon request of the applicant, before the expiration of the time limit referred to in Article 21(2)(a)*

METHODS AND APPARATUSES FOR INCREASING SUSTAINABLE OPERATION TIME FOR AMBIENT INTERNET OF THINGS COMMUNICATION

TECHNICAL FIELD

[0001] Embodiments of the present disclosure generally relate to wireless communication technology, and more particularly to internet of things (IoT) technology.

BACKGROUND

[0002] A wireless communication system may include one or multiple network communication devices, such as base stations (BS), which may support wireless communication for one or multiple user communication devices, which may be otherwise known as user equipment (UE), or other suitable terminology. The wireless communication system may support wireless communication with one or multiple user communication devices by utilizing resources of the wireless communication system (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like)) or frequency resources (e.g., subcarriers, carriers, or the like). Additionally, the wireless communication system may support wireless communication across various radio access technologies including third generation (3G) radio access technology, fourth generation (4G) radio access technology, fifth generation (5G) (which is also known as new radio (NR)) radio access technology, among other suitable radio access technologies beyond 5G (e.g., sixth generation (6G)).

SUMMARY

[0003] An article "a" before an element is unrestricted and understood to refer to "at least one" of those elements or "one or more" of those elements. The terms "a," "at least one," "one or more," and "at least one of one or more" may be interchangeable. As used herein, including in the claims, "or" as used in a list of items (e.g., a list of items prefaced by a phrase such as "at least one of" or "one or more of" or "one or both of") indicates an inclusive list such that, for example, a list of at least one of A, B, or C means A or B or C or AB or AC or BC or ABC (i.e., A and B and C). Also, as used herein, the phrase "based on" shall not be construed as a reference to a closed set of conditions. For example, an example step that is described as "based on condition A" may be based on both a condition A and a condition B without departing from the scope of the present disclosure. In other words, as used herein, the phrase "based on" shall be construed in the same manner as the phrase "based at least in part on." Further, as used herein, including in the claims, a "set", a "group" or a "list" may include one or more elements.

[0004] Some embodiments of the present disclosure provide a first device. The first device may include at least one memory; and at least one processor coupled with the at least one memory and configured to cause the first device to: transmit, to a group of second devices, a first state indication signal indicating each second device of the group of second devices to switch to a first state; determine, at a first time instance, that at least a percentage of second devices within the group of second devices have received the first state indication signal; and transmit, to the group of second devices, signaling for ambient IoT communication.

[0005] In some embodiments, the first state indication signal is transmitted repeatedly or periodically until the first time instance.

[0006] In some embodiments, the first time instance is determined based on at least one of a number of second devices within the group of second devices, radio frequency (RF) energy harvesting efficiency of the second devices, charging and discharging times of the second devices, capacitor sizes of the second devices, or storage sizes of the second devices.

[0007] In some embodiments, the first state indication signal is a low voltage signal, a high voltage signal, a pre-known first sequence, a pre-known ON-OFF pattern, or carried in a physical channel.

[0008] In some embodiments, the physical channel includes at least one of a first indicator indicating the first state or a second indicator indicating one of: a time period during which the second device does not monitor the first state indication signal and the signaling for ambient IoT communication, and after which the second device monitors the signaling for ambient IoT communication; a time period during which the second device does not monitor the first state indication signal and the signaling for ambient IoT communication, and after which the second device monitors the first state indication signal and the signaling for ambient IoT communication; a time period during which the second device does not monitor the first state indication signal and a second state indication signal, and after which the second device monitors the second state indication signal or both the first state indication signal and the second state indication signal; and a time period during which the second device does not monitor the first state indication signal and one or more of a third state indication signal and a fourth state indication signal, and after which the second device monitors the first state indication signal and the one or more of the third state indication signal and the fourth state indication signal.

[0009] In some embodiments, the first state indication signal indicates each second device in the group of second devices to switch to an active state to monitor the signaling for ambient IoT communication. In some embodiments, the first state indication signal indicates each second device in the group of second devices to switch to an inactive state for a first time period during which the second device monitors the first state indication signal and the signaling for IoT communication is transmitted after the first time period. In some embodiments, the first state indication signal indicates each second device in the group of second devices to switch to the inactive state.

[0010] In some embodiments, the at least one processor is configured to cause the first device to: transmit, to the group of second devices, a second state indication signal indicating each second device of the group of second devices to switch to an active state to monitor the signaling for ambient IoT communication; transmit, to first type second devices in the group of second devices, a third state indication signal indicating each first type second device in the group of second devices to switch to the active state to monitor the signaling for ambient IoT communication; or transmit, to second type second devices in the group of second devices, the third state indication signal indicating each second type second device in the group of second devices to switch to the inactive state.

[0011] In some embodiments, the second state indication signal is transmitted repeatedly or periodically until a second time instance.

[0012] In some embodiments, the at least one processor is configured to cause the first device to: determine that at least a percentage of second devices within the group of second devices have received the second state indication signal at the second time instance; and transmit the signaling for ambient IoT communication after the second time instance.

[0013] In some embodiments, the second time instance is determined based on at least one of a number of second devices within the group of second devices, RF energy harvesting efficiency of the second devices, charging and discharging times of the second devices, capacitor sizes of the second devices, or storage sizes of the second devices.

[0014] In some embodiments, the second state indication signal is a high voltage signal, a low voltage signal, a pre-known second sequence, a pre-known ON-OFF pattern, or carried in a physical channel.

[0015] In some embodiments, the physical channel includes at least one of a first indicator indicating the active state or a second indicator indicating a time period during which the second device does not monitor the first state indication signal and the second state indication signal, and after which the second device monitors the first state indication signal and the second state indication signal.

[0016] In some embodiments, the third state indication signal is transmitted repeatedly or periodically until a third time instance.

[0017] In some embodiments, the at least one processor is configured to cause the first device to: determine that at least a percentage of first type second devices within the group of second devices have received the third state indication signal at the third time instance; and transmit the signaling for ambient IoT communication to the first type second devices in the group of second devices after the third time instance.

[0018] In some embodiments, the third time instance is determined based on at least one of a number of first type second devices within the group of second devices, RF energy harvesting efficiency of the first type second devices, charging and discharging times of the first type second devices, capacitor sizes of the first type second devices, or storage sizes of the first type second devices.

[0019] In some embodiments, the third state indication signal is a high voltage signal, a low voltage signal, a pre-known third sequence, a pre-known ON-OFF pattern, or carried in a physical channel.

[0020] In some embodiments, the physical channel includes at least one of: a first indicator indicating the active state for the first type second device, the inactive state for the second type second device, or both; or a second indicator indicating a time period during which the first type second device does not monitor the first state indication signal and the third state indication signal, and after which the first type second device monitors the first state indication signal and the third state indication signal.

[0021] In some embodiments, the at least one processor is configured to cause the first device to: in response to transmitting the third state indication signal, transmit, to second type second devices in the group of second devices, a fourth state indication signal indicating each second type second device in the group of second devices to switch to the active state to monitor the signaling for ambient IoT communication.

[0022] In some embodiments, the fourth state indication signal is transmitted repeatedly or periodically until a fourth time instance.

[0023] In some embodiments, the at least one processor is configured to cause the first device to: determine that at least a percentage of second type second devices within the group of second devices have received the fourth state indication signal at the fourth time instance; and transmit the signaling for ambient IoT communication to the second type second devices in the group of second devices after the fourth time instance.

[0024] In some embodiments, the fourth time instance is determined based on at least one of a number of second type second devices within the group of second devices, RF energy harvesting efficiency of the second type second devices, charging and discharging times of the second type second devices, capacitor sizes of the second type second devices, or storage sizes of the second type second devices.

[0025] In some embodiments, the fourth state indication signal is a low voltage signal, a high voltage signal, a pre-known fourth sequence, a pre-known ON-OFF pattern, or carried in a physical channel.

[0026] In some embodiments, the physical channel includes at least one of a first indicator indicating the active state for the second type second device or a second indicator indicating a time period during which the second type second device does not monitor the first state indication signal and one or more of the third state indication signal and the fourth state indication signal, and after which the second type second device monitors the first state indication signal and the one or more of the third state indication signal and the fourth state indication signal.

[0027] In some embodiments, the first type second devices in the group of second devices include one or more devices having a first sustainable operation time and the second type second devices in the group of second devices include one or more devices having a second sustainable operation time or a third sustainable operation time. In some embodiments, the first type second devices in the group of second devices include one or more devices having the first sustainable operation time or the second sustainable operation time and the second type second devices in the group of second devices include one or more devices having the third sustainable operation time.

[0028] Some embodiments of the present disclosure provide a second device. The second device may include at least one memory; and at least one processor coupled with the at least one memory and configured to cause the second device to: receive, from a first device, a first state indication signal; switch to a first state in response to receiving the first state indication signal; and receive, from the first device, signaling for ambient IoT communication.

[0029] In some embodiments, the first state indication signal is a low voltage signal, a high voltage signal, a pre-known first sequence, a pre-known ON-OFF pattern, or carried in a physical channel.

[0030] In some embodiments, the physical channel includes at least one of a first indicator indicating the first state or a second indicator indicating one of: a time period during which the second device does not monitor the first state indication signal and the signaling for ambient IoT communication, and after which the second device monitors the signaling for ambient IoT communication; a time period during which the second device does not monitor the first state indication signal and the signaling for ambient IoT communication, and after which the second device monitors the first state indication signal and the signaling for ambient IoT communication; a time period during which the second device does not monitor the first state indication signal and a second state indication signal, and after which the second device monitors the second state indication signal or both the first state indication signal and the second state indication signal; and a time period during which the second device does not monitor the first state indication signal and one or more of a third state indication signal and a fourth state indication signal, and after which the second device monitors the first state indication signal and the one or more of the third state indication signal and the fourth state indication signal.

[0031] In some embodiments, the first state indication signal indicates the second device to switch to an active state to monitor the signaling for ambient IoT communication. In some embodiments, the first state indication signal indicates the second device to switch to an inactive state for a first time period and the at least one processor is configured to cause the second device to monitor the first state indication signal and switch to the active state to monitor the signaling for IoT communication in response to not detecting the first state indication signal during the first time period. In some embodiments, the first state indication signal indicates the second device to switch to the inactive state.

[0032] In some embodiments, the at least one processor is configured to cause the second device to: receive a second state indication signal indicating the second device to switch to an active state to monitor the signaling for ambient IoT communication; in response to the second device being a first type second device, receive a third state indication signal indicating the second device to switch to the active state to monitor the signaling for ambient IoT communication; in response to the second device being a second type second device, receive the third state indication signal indicating the second device to switch to the inactive state; or in response to the second device being the second type second device, receive a fourth state indication signal indicating the second device to switch to the active state to monitor the signaling for ambient IoT communication.

[0033] In some embodiments, the second state indication signal is a high voltage signal, a low voltage signal, a pre-known second sequence, a pre-known ON-OFF pattern, or carried in a physical channel.

[0034] In some embodiments, the physical channel includes at least one of a first indicator indicating the active state or a second indicator indicating a time period during which the second device does not monitor the first state indication signal and the second state indication signal, and after which the second device monitors the first state indication signal and the second state indication signal.

[0035] In some embodiments, the third state indication signal is a high voltage signal, a low voltage signal, a pre-known third sequence, a pre-known ON-OFF pattern, or carried in a physical channel.

[0036] In some embodiments, the physical channel includes at least one of: a first indicator indicating the active state for the first type second device, the inactive state for the second type second device, or both; or a second indicator indicating a time period during which the first type second device does not monitor the first state indication signal and the third state indication signal, and after which the first type second device monitors the first state indication signal and the third state indication signal.

[0037] In some embodiments, the fourth state indication signal is a low voltage signal, a high voltage signal, a pre-known fourth sequence, a pre-known ON-OFF pattern, or carried in a physical channel.

[0038] In some embodiments, the physical channel includes at least one of a first indicator indicating the active state for the second type second device or a second indicator indicating a time period during which the second type second device does not monitor the first state indication signal and one or more of the third state indication signal and the fourth state indication signal, and after which the second type second device monitors the first state indication signal and the one or more of the third state indication signal and the fourth state indication signal.

[0039] In some embodiments, the first type second device has a first sustainable operation time and the second type second device has a second sustainable operation time or a third sustainable operation time. In some embodiments, the first type second device has the first sustainable operation time or the second sustainable operation time and the second type second device has the third sustainable operation time.

[0040] Some embodiments of the present disclosure provide a processor. The processor may include at least one controller coupled with at least one memory and configured to cause the processor to: transmit, to a group of second devices, a first state indication signal indicating each second device of the group of second devices to switch to a first state; determine, at a first time instance, that at least a percentage of second devices within the group of second devices have received the first state indication signal; and transmit, to the group of second devices, signaling for ambient IoT communication.

[0041] Some embodiments of the present disclosure provide a processor. The processor may include at least one controller coupled with at least one memory and configured to cause the processor to: receive, from a first device, a first state indication signal; switch to a first state in response to receiving the first state indication signal; and receive, from the first device, signaling for ambient IoT communication.

[0042] Some embodiments of the present disclosure provide a method for wireless communication. The method may include: transmitting, to a group of second devices, a first state indication signal indicating each second device of the group of second devices to switch to a first state; determining, at a first time instance, that at least a percentage of second devices within the group of second devices have received the first state indication signal; and transmitting, to the group of second devices, signaling for ambient IoT communication.

[0043] Some embodiments of the present disclosure provide a method for wireless communication. The method may include: receiving, from a first device, a first state indication signal; switching to a first state in response to receiving the first state indication signal; and receiving, from the first device, signaling for ambient IoT communication.

[0044] Some embodiments of the present disclosure provide an apparatus. According to some embodiments of the present disclosure, the apparatus may include: at least one non-transitory computer-readable medium having stored thereon computer-executable instructions; at least one receiving circuitry; at least one transmitting circuitry; and at least one processor coupled to the at least one non-transitory computer-readable medium, the at least one receiving circuitry and the at least one transmitting circuitry, wherein the at least one non-transitory computer-readable medium and the computer executable instructions may be configured to, with the at least one processor, cause the apparatus to perform a method according to some embodiments of the present disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0045] In order to describe the manner in which the advantages and features of the disclosure can be obtained, a description of the disclosure is rendered by reference to specific embodiments thereof, which are illustrated in the appended drawings. These drawings depict only exemplary embodiments of the disclosure and are not therefore to be considered limiting of its scope.

[0046] FIG. 1 illustrates a schematic diagram of a wireless communication system in accordance with some embodiments of the present disclosure;

[0047] FIGs. 2A-2E illustrate exemplary topologies for IoT networks and devices in accordance with some embodiments of the present disclosure;

[0048] FIGs. 3 and 4 illustrate flowcharts of wireless communication methods in accordance with some embodiments of the present disclosure;

[0049] FIG. 5 illustrates an example of a UE in accordance with some embodiments of the present disclosure;

[0050] FIG. 6 illustrates an example of a processor in accordance with some embodiments of the present disclosure; and

[0051] FIG. 7 illustrates an example of a network equipment (NE) in accordance with some embodiments of the present disclosure; and

[0052] FIG. 8 illustrates a block diagram of exemplary apparatus in accordance with some embodiments of the present disclosure.

DETAILED DESCRIPTION

[0053] The detailed description of the appended drawings is intended as a description of the preferred embodiments of the present disclosure and is not intended to represent the only form in which the present disclosure may be practiced. It should be understood that the same or equivalent functions may be accomplished by different embodiments that are intended to be encompassed within the spirit and scope of the present disclosure.

[0054] Reference will now be made in detail to some embodiments of the present disclosure, examples of which are illustrated in the accompanying drawings. To facilitate understanding, embodiments are provided under a specific network architecture(s) and new service scenarios, such as the 3rd generation partnership project (3GPP) 5G NR or 6G, 3GPP LTE, and so on. It is contemplated that along with the developments of network architectures and new service scenarios, all embodiments in the present disclosure are also applicable to similar technical problems; and moreover, the terminologies recited in the present disclosure may change, which should not affect the principles of the present disclosure.

[0055] In recent years, IoT has attracted much attention in the wireless communication world. It is expected that further reductions of size, complexity, and power consumption of IoT devices can enable the deployment of tens or even hundreds of billions of IoT devices for various applications and provide added value across the entire value chain. However, existing technologies cannot meet all the requirements of target use cases.

[0056] The present disclosure provides various methods and apparatuses for ambient IoT communication. The proposed solutions can address use cases and scenarios that cannot otherwise be fulfilled based on existing 3GPP technologies and can achieve ultra-low complexity and ultra-low power consumption for ambient IoT. For example, when a reader attempts to perform IoT communication with IoT devices, errors may occur due to the limited sustainable time of the IoT devices. Embodiments of the present disclosure provide solutions for increasing the sustainable operation time of an IoT device. Proposed solutions in this disclosure can address at least the above issues in the ambient IoT communication while achieve ultra-low complexity and ultra-low power consumption for ambient IoT.

[0057] FIG. 1 illustrates a schematic diagram of wireless communication system 100 in accordance with some embodiments of the present disclosure.

[0058] The wireless communication system 100 may include one or more NEs 102 (e.g., one or more BSs), one or more UEs 104, and a core network (CN) 106. The wireless communication system 100 may support various radio access technologies. In some implementations, the wireless communication system 100 may be a 4G network, such as an LTE network or an LTE-Advanced (LTE-A) network. In some other implementations, the wireless communication system 100 may be a NR network, such as a 5G network, a 5G-Advanced (5G-A) network, or a 5G ultra-wideband (5G-UWB) network. In other implementations, the wireless communication system 100 may be a combination of a 4G network and a 5G network, or other suitable radio access technology including Institute of Electrical and Electronics Engineers (IEEE) 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), and IEEE 802.20. The wireless communication system 100 may support radio access technologies beyond 5G, for example, 6G. Additionally, the wireless communication system 100 may support technologies, such as time division multiple access (TDMA), frequency division multiple access (FDMA), or code division multiple access (CDMA), etc.

[0059] The one or more NEs 102 may be dispersed throughout a geographic region to form the wireless communication system 100. One or more of the NEs 102 described herein may be or include or may be referred to as a network node, a base station, a network element, a network function, a network entity, a radio access network (RAN), a NodeB, an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. An NE 102 and a UE 104 may communicate via a communication link, which may be a wireless or wired connection. For example, an NE 102 and a UE 104 may perform wireless communication (e.g., receive signaling, transmit signaling) over a Uu interface.

[0060] An NE 102 may provide a geographic coverage area for which the NE 102 may support services for one or more UEs 104 within the geographic coverage area. For example, an NE 102 and a UE 104 may support wireless communication of signals related to services (e.g., voice, video, packet data, messaging, broadcast, etc.) according to one or multiple radio access technologies. In some implementations, an NE 102 may be moveable, for example, a satellite associated with a non-terrestrial network (NTN). In some implementations, different geographic coverage areas 112 associated with the same or different radio access technologies may overlap, but the different geographic coverage areas may be associated with a different NE 102.

[0061] The one or more UEs 104 may be dispersed throughout a geographic region of the wireless communication system 100. A UE 104 may include or may be referred to as a remote unit, a mobile device, a wireless device, a remote device, a subscriber device, a transmitter device, a receiver device, or some other suitable terminology. In some implementations, the UE 104 may be referred to as a unit, a station, a terminal, or a client, among other examples. Additionally, or alternatively, the UE 104 may be referred to as an Internet-of-Things (IoT) device, an Internet-of-Everything (IoE) device, or machine-type communication (MTC) device, among other examples.

[0062] A UE 104 may be able to support wireless communication directly with other UEs 104 over a communication link. For example, a UE 104 may support wireless communication directly with another UE 104 over a device-to-device (D2D) communication link. In some implementations, such as vehicle-to-vehicle (V2V) deployments, vehicle-to-everything (V2X) deployments, or cellular-V2X deployments, the communication link 114 may be referred to as a sidelink. For example, a UE 104 may support wireless communication directly with another UE 104 over a PC5 interface.

[0063] An NE 102 may support communication with the CN 106, or with another NE 102, or both. For example, an NE 102 may interface with another NE 102 or the CN 106 through one or more backhaul links (e.g., S1, N2, N3 or another network interface). In some implementations, the NE 102 may communicate with each other directly. In some other implementations, the NE 102 may communicate with each other or indirectly (e.g., via the CN 106). In some implementations, one or more NEs 102 may include subcomponents, such as an access network entity, which may be an example of an access node controller (ANC). An ANC may communicate with the one or more

UEs 104 through one or more other access network transmission entities, which may be referred to as radio heads, smart radio heads, or transmission-reception points (TRPs).

[0064] The CN 106 may support user authentication, access authorization, tracking, connectivity, and other access, routing, or mobility functions. The CN 106 may be an evolved packet core (EPC), or a 5G core (5GC), which may include a control plane entity that manages access and mobility (e.g., a mobility management entity (MME), an access and mobility management (AMF)) functions and a user plane entity that routes packets or interconnects to external networks (e.g., a serving gateway (S-GW), a Packet Data Network (PDN) gateway (P-GW), or a user plane function (UPF)). In some implementations, the control plane entity may manage non-access stratum (NAS) functions, such as mobility, authentication, and bearer management (e.g., data bearers, signal bearers, etc.) for the one or more UEs 104 served by the one or more NEs 102 associated with the CN 106.

[0065] The CN 106 may communicate with a packet data network over one or more backhaul links (e.g., via an S1, N2, N3, or another network interface). The packet data network may include an application server. In some implementations, one or more UEs 104 may communicate with the application server. A UE 104 may establish a session (e.g., a protocol data unit (PDU) session, or the like) with the CN 106 via an NE 102. The CN 106 may route traffic (e.g., control information, data, and the like) between the UE 104 and the application server using the established session (e.g., the established PDU session). The PDU session may be an example of a logical connection between the UE 104 and the CN 106 (e.g., one or more network functions of the CN 106).

[0066] In the wireless communication system 100, the NEs 102 and the UEs 104 may use resources of the wireless communication system 100 (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers)) to perform various operations (e.g., wireless communication). In some implementations, the NEs 102 and the UEs 104 may support different resource structures. For example, the NEs 102 and the UEs 104 may support different frame structures. In some implementations, such as in 4G, the NEs 102 and the UEs 104 may support a single frame structure. In some other implementations, such as in 5G and among other suitable radio access technologies, the NEs 102 and the UEs 104 may support various frame structures (i.e., multiple frame structures). The NEs 102 and the UEs 104 may support various frame structures based on one or more numerologies.

[0067] In some embodiments, the NEs 102 may include one or more relay nodes, integrated access and backhaul (IAB) nodes or wireless access backhaul (WAB) nodes which can provide wireless access services for UEs 104. A relay node (or an IAB node or a WAB node) can directly connect to a BS or hop through one or more relay nodes (or one or more IAB or WAB nodes) before reaching the BS.

[0068] One or more numerologies may be supported in the wireless communication system 100, and a numerology may include a subcarrier spacing and a cyclic prefix. A first numerology (e.g., μ=0) may be associated with a first subcarrier spacing (e.g., 15 kHz) and a normal cyclic prefix. In some implementations, the first numerology (e.g., μ=0) associated with the first subcarrier spacing (e.g., 15 kHz) may utilize one slot per subframe. A second numerology (e.g., μ=1) may be associated with a second subcarrier spacing (e.g., 30 kHz) and a normal cyclic prefix. A third numerology (e.g., μ=2) may be associated with a third subcarrier spacing (e.g., 60 kHz) and a normal cyclic prefix or an extended cyclic prefix. A fourth numerology (e.g., μ=3) may be associated with a fourth subcarrier spacing (e.g., 120 kHz) and a normal cyclic prefix. A fifth numerology (e.g., μ=4) may be associated with a fifth subcarrier spacing (e.g., 240 kHz) and a normal cyclic prefix. A sixth numerology (e.g., μ=5) may be associated with a sixth subcarrier spacing (e.g., 480 kHz) and a normal cyclic prefix. A seventh numerology (e.g., μ=6) may be associated with a seventh subcarrier spacing (e.g., 960 kHz) and a normal cyclic prefix. For ambient IoT communication, additional numerologies (e.g., μ=-1 or μ =-2) may be introduced corresponding to 7.5 kHz or 3.75 kHz respectively.

[0069] A time interval of a resource (e.g., a communication resource) may be organized according to frames (also referred to as radio frames). Each frame may have a duration, for example, a 10 millisecond (ms) duration. In some implementations, each frame may include multiple subframes. For example, each frame may include 10 subframes, and each subframe may have a duration, for example, a 1 ms duration. In some implementations, each frame may have the same duration. In some implementations, each subframe of a frame may have the same duration.

[0070] Additionally or alternatively, a time interval of a resource (e.g., a communication resource) may be organized according to slots. For example, a subframe may include a number (e.g., quantity) of slots. The number of slots in each subframe may also depend on the one or more numerologies supported in the wireless communication system 100. For instance, the first, second, third, fourth, and fifth numerologies (i.e., μ=0, μ=1, μ=2, μ=3, μ=4) associated with respective subcarrier spacings (SCSs) of 15 kHz, 30 kHz, 60 kHz, 120 kHz, and 240 kHz may utilize a single slot per subframe, two slots per subframe, four slots per subframe, eight slots per subframe, and 16 slots per subframe, respectively. Each slot may include a number (e.g., quantity) of symbols (e.g., orthogonal frequency-division multiplexing (OFDM) symbols). In some implementations, the number (e.g., quantity) of slots for a subframe may depend on a numerology. For a normal cyclic prefix, a slot may include 14 symbols. For an extended cyclic prefix (e.g., applicable for 60 kHz subcarrier spacing), a slot may include 12 symbols. The relationship between the number of symbols per slot, the number of slots per subframe, and the number of slots per frame for a normal cyclic prefix and an extended cyclic prefix may depend on a numerology. It should be understood that reference to a first numerology (e.g., μ=0) associated with a first subcarrier spacing (e.g., 15 kHz) may be used interchangeably between subframes and slots.

[0071] In the wireless communication system 100, an electromagnetic (EM) spectrum may be split, based on frequency or wavelength, into various classes, frequency bands, frequency channels, etc. By way of example, the wireless communication system 100 may support one or multiple operating frequency bands, such as frequency range designations FR1 (410 MHz – 7.125 GHz), FR2 (24.25 GHz – 52.6 GHz), FR3 (7.125 GHz – 24.25 GHz), FR4 (52.6 GHz – 114.25 GHz), FR4a or FR4-1 (52.6 GHz – 71 GHz), and FR5 (114.25 GHz – 300 GHz). In some implementations, the NEs 102 and the UEs 104 may perform wireless communication over one or more of the operating frequency bands. In some implementations, FR1 may be used by the NEs 102 and the UEs 104, among other equipment or devices for cellular communication traffic (e.g., control information, data). In some implementations, FR2 may be used by the NEs

102 and the UEs 104, among other equipment or devices for short-range, high data rate capabilities.

[0072] FR1 may be associated with one or multiple numerologies (e.g., at least three numerologies). For example, FR1 may be associated with a first numerology (e.g., μ=0), which includes 15 kHz subcarrier spacing; a second numerology (e.g., μ=1), which includes 30 kHz subcarrier spacing; and a third numerology (e.g., μ=2), which includes 60 kHz subcarrier spacing. FR2 may be associated with one or multiple numerologies (e.g., at least 2 numerologies). For example, FR2 may be associated with a third numerology (e.g., μ=2), which includes 60 kHz subcarrier spacing; and a fourth numerology (e.g., μ=3), which includes 120 kHz subcarrier spacing.

[0073] A UE 104 may include computing devices, such as desktop computers, laptop computers, personal digital assistants (PDAs), tablet computers, smart televisions (e.g., televisions connected to the Internet), set-top boxes, game consoles, security systems (including security cameras), vehicle on-board computers, network devices (e.g., routers, switches, and modems), or the like. According to some embodiments of the present disclosure, a UE 104 may include a portable wireless communication device, a smart phone, a cellular telephone, a flip phone, a device having a subscriber identity module, a personal computer, a selective call receiver, or any other device that is capable of sending and receiving communication signals on a wireless network. In some embodiments of the present disclosure, a UE 104 includes wearable devices, such as smart watches, fitness bands, optical head-mounted displays, or the like. Moreover, a UE 104 may be referred to as a subscriber unit, a mobile, a mobile station, a user, a terminal, a mobile terminal, a wireless terminal, a fixed terminal, a subscriber station, a user terminal, or a device, or described using other terminology used in the art. A UE 104 may communicate with an NE 102 (e.g., a BS) via uplink (UL) communication signals. An NE 102 may communicate with a UE 104 via downlink (DL) communication signals.

[0074] In some embodiments of the present disclosure, an NE 102 and a UE 104 may communicate over licensed spectrums, whereas in some other embodiments, an NE 102 and a UE 104 may communicate over unlicensed spectrums. The present disclosure is not intended to be limited to the implementation of any particular wireless communication system architecture or protocol. Persons skilled in the art should understand that as technology develops and advances, the terminologies described in the present disclosure may change, but should not affect or limit the principles and spirit of the present disclosure.

[0075] In recent years, IoT has attracted much attention in the wireless communication world. More "things" are expected to be interconnected to improve productivity efficiency and increasing comforts of life. It is expected that further reductions of size, complexity, and power consumption of IoT devices can enable the deployment of tens or even hundreds of billions of IoT devices for various applications and provide added value across the entire value chain. However, it is impossible to power all IoT devices by batteries that need to be replaced or recharged manually, which leads to high maintenance costs, serious environmental issues, and even safety hazards in some use cases (for example, wireless sensors in the electric power and petroleum industries).

[0076] Most existing wireless communication devices are powered by batteries that need to be replaced or recharged manually. The automation and digitalization of various industries will open up numerous new markets requiring new IoT technologies supporting battery-less devices with no energy storage capability or devices with energy storage that do not need to be replaced or recharged manually. The form factors of such devices must be reasonably small to bring about the validity of target use cases. In some embodiments of the present disclosure, as will be described later, it is proposed that a capacitor may be used to support limited energy storage capability, and that the energy of such IoT devices is provided by the harvesting of radio waves, light, motion, heat, and/or any other power source(s) that may be deemed suitable.

[0077] Considering the limited size and complexity required by practical applications for battery-less devices with no energy storage capability or devices with limited energy storage that do not need to be replaced or recharged manually, the output power of an energy harvester may be typically from 1 μW to a few hundreds μW. Existing cellular devices may not work well with energy harvesting due to their peak power consumption of higher than 10 mW.

[0078] An example type of application is asset identification, which presently has to resort mainly to barcodes and RFID in most industries. The main advantage of these two technologies is their ultra-low complexity and small form factor of such tags. However, the limited reading range of a few meters usually requires handheld scanning which leads to labor intensive and time-consuming operations, or requires RFID portals/gates which leads to costly deployments. Moreover, the lack of an interference management scheme results in severe interference between RFID readers and capacity problems, especially in case of dense deployment. It is hard to support a large-scale network with seamless coverage of RFID.

[0079] Since existing technologies cannot meet all the requirements of target use cases, the present disclosure provides a new IoT technology to open up new markets within, for example, 3GPP systems, whose number of connections and/or device density can be orders of magnitude higher than existing IoT technologies. The new IoT technology can provide complexity and power consumption orders of magnitude lower than the existing 3GPP low power wide area (LPWA) technologies (e.g., Narrow-Band IoT (NB-IoT) and enhanced machine type communication (eMTC)), and can address use cases and scenarios that cannot otherwise be fulfilled based on existing 3GPP LPWA IoT technologies.

[0080] As used herein, the term "ambient IoT device", "AIoT device" or “AIoT tag” can refer to a device without batteries or with limited energy storage capabilities. For an ambient IoT device, energy can be provided by harvesting radio waves, light, motion, heat, or any other suitable source. An ambient IoT device can also be called a zero-power terminal, a near-zero power terminal, a passive IoT device, an ambient backscatter communication (AmBC) device, tag, etc. Compared with low-power and wide-coverage services, such as narrow band (NB) IoT, enhanced machine type communication (eMTC), ambient IoT is to be designed with ultra-low complexity and ultra-low power consumption, and is orders of magnitude lower than the existing 3GPP technologies. Hence, it is suitable for more application scenarios.

[0081] For convenience, some embodiments of the present disclosure may be described with respect to ambient IoT or ambient IoT devices (e.g., an ambient IoT tag), and it should be appreciated by persons skilled in the art that these embodiments can also be applied to other IoT communication or other IoT devices.

[0082] FIGs. 2A-2E illustrate exemplary topologies for IoT networks and devices in accordance with some embodiments of the present disclosure. In these exemplary topologies, the ambient IoT device may be provided with a carrier wave from another node(s) either inside or outside the topology. The links in each topology may be bidirectional or unidirectional.

[0083] Although elements in each topology such as the BS, UE, assisting node, or intermediate node are described in the singular, the plural is also contemplated. The mixture of indoor and outdoor placements of such nodes is regarded as a network implementation choice. Consideration would need to be taken of potential impact on device or node complexity. In some connectivity topologies, this does not imply the existence of multi-hop assisting or intermediate nodes.

[0084] For the sake of convenience, in the context of the present disclosure, the BS, intermediate node (e.g., an IAB node, a WAB node, a relay node, a UE, or a repeater), assisting node (e.g., an IAB node, a WAB node, a relay node, a UE, or a repeater), or UE-type reader which an IoT device (e.g., a tag) connects with can be referred to as an IoT reader or a reader. In addition, for the sake of convenience, in the context of the present disclosure, the transmission from an IoT reader to an IoT device can be called R2D (reader to device) transmission; and the transmission from an IoT device (e.g., a tag) to an IoT reader can be called D2R (device to reader) transmission. In some embodiments, the channel which carries R2D transmission can be referred to as physical reader-to-device channel (PRDCH) and the channel which carries D2R transmission can be referred to as physical device-to-reader channel (PDRCH). Persons skilled in the art understand that other terminologies can also apply, without affect or limit the principles and scope of the present disclosure.

[0085] It should be noted that in this disclosure, encoded bits for ambient IoT communication may also be referred to as chips, symbols, or other terminologies, and the encoding method may be referred to a modulation method, a waveform generation method or some of combinations of the encoding method, the waveform generation method, and the modulation method.

[0086] In FIG. 2A, an ambient IoT device can directly and bidirectionally communicate with a BS. The communication between the BS and the ambient IoT device includes ambient IoT data and/or signaling. This topology includes the possibility that the BS transmitting to the ambient IoT device is different than the BS receiving from the ambient IoT device.

[0087] In FIG. 2B, an ambient IoT device can communicate bidirectionally with an intermediate node between the IoT device and a BS. The intermediate node can be a relay, an IAB node, a WAB node, a UE, a repeater, a UE-type reader, etc. which is capable of ambient IoT. The intermediate node may transfer ambient IoT data and/or signaling between the BS and the ambient IoT device.

[0088] For example, the intermediate node in FIG. 2B may be a UE, which can communicate with the BS via a Uu link and communicate with the ambient IoT device by R2D transmission and D2R transmission. In some embodiments, for the topology shown in FIG. 2B, there is no difference in physical layer design from the topology shown in FIG. 2A. For example, from the perspective of the BS, the UE is deemed as a normal UE. From the perspective of the ambient IoT device, the UE is transparent and deemed as an ambient IoT reader which is not differentiated from a BS.

[0089] In FIG. 2C, an ambient IoT device can transmit data/signaling to a BS and can receive data/signaling from an assisting node (i.e., for DL assistance). The assisting node may receive the data/signaling from the BS. In this topology, the assisting node can be a relay, an IAB node, a WAB node, a UE, a repeater, a UE-type reader, etc. which is capable of ambient IoT.

[0090] In FIG. 2D, an ambient IoT device can receive data/signaling from a BS and can transmit data/signaling to the assisting node (i.e., for UL assistance). The assisting node may transmit the data/signaling to the BS. In this topology, the assisting node can be a relay, an IAB node, a WAB node, a UE, a repeater, a UE-type reader, etc. which is capable of ambient IoT.

[0091] In FIG. 2E, an ambient IoT device can communicate bidirectionally with a UE. The communication between the UE and the ambient IoT device includes ambient IoT data and/or signaling.

[0092] In some embodiments, FR1 licensed spectrum in frequency division duplexing

(FDD) is considered for ambient IoT communication. For example, a UE, as an intermediate node in the topology shown in FIG. 2B, may transmit R2D signals/channels in FDD UL band and receive D2R signals/channel in FDD UL band. In other examples, the UE may transmit R2D signals/channels in FDD DL band and receive D2R signals/channel in FDD UL band, or transmit R2D signals/channels in FDD DL band and receive D2R signals/channel in FDD DL band. The UE can transmit UL signals/channel to a BS in FDD UL band and receive DL signals/channel from the BS in FDD DL band.

[0093] In the present disclosure, the ambient IoT communication may include, but not limited to, a command procedure between a reader and a group of IoT devices (e.g., tags), an inventory procedure between a reader and a group of IoT devices (e.g., tags), or both. For example, a reader may transmit a command related signaling (e.g., an indoor command) to a group of IoT devices. The applicable scenarios of such command may include, but not limited to, online modification of medical instruments status, device activation and deactivation, elderly health care, device permanent deactivation and electronic shelf label.

[0094] For example, a reader may transmit inventory related signaling (e.g., indoor inventory signaling) to a group of IoT devices and a response corresponding to the devices' responses (e.g., random numbers generated by the devices). The applicable scenarios of such signaling may include, but not limited to, automated warehousing, medical instruments inventory management and positioning, non-public network for logistics, automobile manufacturing, airport terminal/shipping port, smart laundry, automated supply chain distribution, fresh food supply chain, end-to-end logistics, and flower auction. The reader may receive a response (e.g., the devices' random numbers) to the inventory related signaling and a device ID (e.g., electronic product code (EPC) ID) from one or more of the plurality of devices. For example, a reader may transmit a Query command or the like to IoT devices to trigger an inventory round. In response to receiving the Query command, an IoT device may generate a random backoff counter in the range of $[0, 2^Q-1]$ (where Q is the slot-count parameter) and transmit a response to the Query command when the random backoff counter is counted down to zero.

[0095] Embodiments of the present disclosure provides various methods for ambient

IoT communication. For example, embodiments of the present disclosure provide solutions for increasing the sustainable operation time of an IoT device. For example, the sustainable operation time of an IoT device may be affected by several factors, including for example, RF energy harvesting efficiency, device charging and discharging time, device's capacitor size, device's storage size, and so on. Different RF energy harvesting efficiency, different device charging and discharging time, different device's capacitor size, and/or different device's storage size may result in different device sustainable operation times.

[0096] For example, in some embodiments, an IoT device may start monitoring R2D transmissions, signals or channels as long as its harvested energy is above a predefined threshold, and may start harvesting energy as long as its stored energy is below another predefined threshold. The sustainable time of the IoT device may be calculated from the time instance when the IoT device starts to monitor R2D transmission to the time instance when the device starts to harvest energy. Since there is a single antenna on the IoT device, the IoT device cannot transmit or receive signals during the energy harvesting process. Such device behavior is not controllable because the IoT device is designed with ultra-low complexity and ultra-low power consumption. The charging time may be tens of seconds due to the relatively low RF energy harvesting efficiency.

[0097] In some embodiments, when a reader attempts to perform IoT communication with IoT devices, errors may occur due to the limited sustainable time of the IoT devices. For example, when a reader triggers an inventory to a group of IoT devices, it would be too optimistic to assume that every IoT device has sufficient energy to maintain reception of the Query command from the reader and transmission of a response to the reader within the entire inventory round. In some cases, the R2D signal may be missed by an IoT device and/or the D2R signal may be dropped when the IoT device is harvesting energy. Further, a reader is not aware of the sustainable operation time of an IoT device, so that the reader cannot determine whether an IoT device is available to receive the R2D signal and/or transmit the corresponding D2R signal. It is important to ensure that the group of devices to be inventoried is available to receive the R2D signal and/or transmit the corresponding D2R signal within the inventory round. Otherwise, the inventory process cannot be performed properly.

[0098] The present disclosure provides various solutions for solve the above issues. For example, embodiments of the present disclosure provide methods and apparatus for increasing the sustainable operation time of an IoT device. Proposed solutions in this disclosure can address at least the above issues in the ambient IoT communication while achieve ultra-low complexity and ultra-low power consumption for ambient IoT. More details on the embodiments of the present disclosure will be illustrated in the following text in combination with the appended drawings.

[0099] In some embodiments of present disclosure, an (ambient) IoT device may be implemented in various forms. For example, various types of IoT devices may have sustainable operation times. For example, at least the following three device types are supported in the present disclosure. Device 1 may have a shorter sustainable operation time than device 2a and device 2b and device 2a may have a shorter sustainable operation time than device 2b.

- **Device 1**: ~1 μW peak power consumption, has energy storage, initial sampling frequency offset (SFO) up to 10^X ppm, neither DL nor UL amplification in the device. The device's UL transmission is backscattered on a carrier wave provided externally.
- **Device 2a**: ≤ a few hundred μW peak power consumption, has energy storage, initial SFO up to 10^X ppm, both DL and/or UL amplification in the device. The device's UL transmission is backscattered on a carrier wave provided externally.
- **Device 2b**: ≤ a few hundred μW peak power consumption, has energy storage, initial SFO up to 10^X ppm, both DL and/or UL amplification in the device. The device's UL transmission is generated internally by the device.

[00100] In some embodiments of present disclosure, for ambient IoT between a reader (e.g., a BS in the topology shown in FIG. 2A, an intermediate node in the topology shown in FIG. 2B, an assisting node or a BS in the topology shown in FIGs. 2C and 2D or a UE in the topology shown in FIG. 2E) to an (ambient) IoT device, at least two states may be defined for the IoT device. For example, the at least two states may include an inactive state and an active state. During the inactive state, an IoT device can harvest and store energy including RF energy. The IoT device cannot transmit any signal during the inactive state. During the active state, the IoT device can at least

receive R2D signal and transmit D2R signal.

[00101] It should be noted that in the present disclosure, an inactive state can also be referred to as a sleep state, a silent state, a deactivated state or an OFF state, or other terminologies; and an active state can also be referred to as an activated state, a waked state, a Tx/Rx state, an ON state, or other terminologies, without affect or limit the principles and scope of the present disclosure.

[00102] Two state indication signals (denoted as signal #A1 and signal #A2 for clarity) may be employed to indicate the IoT device to enter the inactive state or the active state. For example, signal #A1 can indicate an IoT device to enter the inactive state and signal #A2 can indicate an IoT device to enter the active state. During the inactive state, an IoT device may monitor signal #A1 for inactive state indication and signal #A2 for active state indication. Alternatively, the IoT device in an inactive state may only monitor signal #A2. During the active state, an IoT device may monitor the signaling for ambient IoT communication. For example, the IoT device may monitor a Query command from the reader for triggering an inventory round. The IoT device in an active state may also monitor signal #A1, signal #A2 or both.

[00103] In some embodiments, a reader may transmit signal #A1 multiple times to a group of IoT devices for indicating each IoT device in the group to enter the inactive state. For example, signal #A1 can be repeatedly transmitted so that it can be received by as many IoT devices within a group of IoT devices as possible. For example, signal #A1 can be periodically transmitted by the reader to save the energy of the reader. In some embodiments, the periodicity may be smaller than the minimum sustainable operation time of the IoT devices within the group so that signal #A1 can be received at least once by each IoT device within the group.

[00104] In some embodiments, the reader may stop transmitting signal #A1 when a certain stop criterion is satisfied. For example, the reader may stop transmitting signal #A1 when it determines (e.g., assumes) that at least a specific percentage of IoT devices within the group of IoT devices have received signal #A1 and/or entered the inactive state. The specific percentage may be 100% or lower. The specific percentage may be predefined in a standard(s), implemented by the reader, or configured by radio resource control (RRC) signaling (e.g., in the case that the reader is a UE).

[00105] In some embodiments, the reader may have its own policy for determining (e.g., assuming) when the stop criterion is satisfied. For example, the reader can determine the time instance when at least the specific percentage of IoT devices within the group of IoT devices have received signal #A1 and/or entered the inactive state based on various factors. For example, these factors may include at least one of: a number of IoT devices within the group of IoT devices, RF energy harvesting efficiency of the IoT devices, charging and discharging times of the IoT devices, capacitor sizes of the IoT devices, or storage sizes of the IoT devices.

[00106] Signal #A1 can be implemented in various forms. The following are some examples. Persons skilled in the art can conceive of other forms that are also within the scope of the present disclosure.

[00107] In some embodiments, signal #A1 may be a low voltage signal, which may require a minimum detection power consumption. The low voltage signal may be more suitable for an IoT device with lower peak power consumption (e.g., device 1 with about 1 μW peak power consumption) than for an IoT device with higher peak power consumption (e.g., device 2a and device 2b with several hundred μW peak power consumption).

[00108] In some embodiments, signal #A1 may be a high voltage signal, which may require a minimum detection power consumption. The high voltage signal can provide RF energy for devices to harvest energy during an inactive state. The high voltage signal may be more suitable for an IoT device with lower peak power consumption (e.g., device 1 with about 1 μW peak power consumption) than for an IoT device with higher peak power consumption (e.g., device 2a and device 2b with several hundred μW peak power consumption).

[00109] In some embodiments, signal #A1 may be a sequence (e.g., "101010…10") and encoded with high voltage signal and low voltage signal alternatively, which may require a low detection power consumption for various types of IoT devices (e.g., device 1, device 2a and device 2b). The sequence may be pre-known to the IoT devices and the reader. For example, the sequence may be predefined in a standard(s), preconfigured.

[00110] In some embodiments, signal #A1 may be a pre-known ON-OFF pattern (e.g., a high-low or low-high voltage signal pattern), which may require a low detection power consumption for various types of IoT devices (e.g., device 1, device 2a and device 2b).

[00111] In some embodiments, signal #A1 may be carried by a physical channel (i.e., a physical R2D channel). The physical channel may include at least one of a state indicator or a time period indicator. For example, the physical channel may include at least one bit for indicating the state of an IoT device. For example, 1 bit of "0" may indicate signal #A1, i.e., indicating the device to enter or switch to an inactive state, while 1 bit of "1" indicating signal #A2, i.e., indicating the device to enter or switch to an active state; or vice versa. For example, the physical channel may include one or more bits for indicating a time period, during which an IoT device does not need to monitor signal #A1 and signal #A2, thereby further reducing power consumption of the IoT device. After the indicated time period (in other words, in response to the expiry of the indicated time period), the IoT device may start to monitor signal #A2 or both signal #A1 and signal #A2.

[00112] In some examples, the time period indicator may indicate the time period from a set of values, which may be in units of absolute time (e.g., milliseconds), chip duration (e.g., a chip length), or symbol duration (e.g., a symbol length) or other time units that can be conceived of by persons skilled in the art. For example, the set of values may be {10ms, 20ms, 40ms, 80ms …}. The set of values may be predefined in a standard(s) or preconfigured.

[00113] In some embodiments, a reader may transmit signal #A2 multiple times to the group of IoT devices for indicating each IoT device in the group to enter the active state. For example, signal #A2 can activate an IoT device that receives it to prepare for IoT communication (e.g., receiving of a Query command from the reader and/or transmitting of a response signal to the reader). For example, signal #A2 can be repeatedly transmitted so that it can be received by as many IoT devices within the group of IoT devices as possible. For example, signal #A2 can be periodically transmitted by the reader to save the energy of the reader. In some embodiments, the periodicity may be smaller than the minimum sustainable operation time of the IoT

devices within the group so that signal #A2 can be received at least once by each IoT device within the group.

[00114] In some embodiments, the reader may stop transmitting signal #A2 when a certain stop criterion is satisfied. For example, the reader may stop transmitting signal #A2 when it determines (e.g., assumes) that at least a specific percentage of IoT devices within the group of IoT devices have received signal #A2 and/or entered the active state. The specific percentage may be 100% or lower. The specific percentage may be predefined in a standard(s), implemented by the reader, or configured by RRC signaling (e.g., in the case that the reader is a UE).

[00115] In some embodiments, the reader may have its own policy for determining (e.g., assuming) when the stop criterion is satisfied. For example, the reader can determine the time instance when at least the specific percentage of IoT devices within the group of IoT devices have received signal #A2 and/or entered the active state based on various factors. For example, these factors may include at least one of: a number of IoT devices within the group of IoT devices, RF energy harvesting efficiency of the IoT devices, charging and discharging times of the IoT devices, capacitor sizes of the IoT devices, or storage sizes of the IoT devices.

[00116] Signal #A2 can be implemented in various forms. The following are some examples. Persons skilled in the art can conceive of other forms that are also within the scope of the present disclosure.

[00117] In some embodiments, signal #A2 may be a high voltage signal, which can activate an IoT device to prepare for IoT communication (e.g., receiving a Query command from the reader and/or transmitting a response signal to the reader). The high voltage signal may require a minimum detection power consumption. The high voltage signal may be more suitable for an IoT device with lower peak power consumption (e.g., device 1 with about 1 μW peak power consumption) than for an IoT device with higher peak power consumption (e.g., device 2a and device 2b with several hundred μW peak power consumption). Since signal #A1 and signal #A2 are different, when signal #A2 is a high voltage signal, signal #A1 may be a low voltage signal.

[00118] In some embodiments, signal #A2 may be a low voltage signal, which can

activate an IoT device to prepare for IoT communication (e.g., receiving a Query command from the reader and/or transmitting a response signal to the reader). The low voltage signal may require a minimum detection power consumption. The low voltage signal may be more suitable for an IoT device with lower peak power consumption (e.g., device 1 with about 1 μW peak power consumption) than for an IoT device with higher peak power consumption (e.g., device 2a and device 2b with several hundred μW peak power consumption). Since signal #A1 and signal #A2 are different, when signal #A2 is a low voltage signal, signal #A1 may be a high voltage signal.

[00119] In some embodiments, signal #A2 may be a sequence (e.g., "0101010…1") and encoded with low voltage signal and high voltage signal alternatively, which may require a low detection power consumption for various types of IoT devices (e.g., device 1, device 2a and device 2b). The sequence may be pre-known to the IoT devices and the reader. For example, the sequence may be predefined in a standard(s), preconfigured. Since signal #A1 and signal #A2 are different, the sequence that represents signal #A2 is different from the one that represents signal #A1.

[00120] In some embodiments, signal #A2 may be a pre-known ON-OFF pattern (e.g., a high-low or low-high voltage signal pattern), which may require a low detection power consumption for various types of IoT devices (e.g., device 1, device 2a and device 2b). Since signal #A1 and signal #A2 are different, different ON-OFF patterns may be used for signal #A2 and signal #A1.

[00121] In some embodiments, signal #A2 may be carried by a physical channel (i.e., a physical R2D channel). The physical channel may include at least one of a state indicator or a time period indicator. For example, the physical channel may include at least one bit for indicating the state of an IoT device. For example, 1 bit of "0" may indicate signal #A1, i.e., indicating the device to enter or switch to an inactive state, while 1 bit of "1" indicating signal #A2, i.e., indicating the device to enter or switch to an active state; or vice versa. For example, the physical channel may include one or more bits for indicating a time period, during which an IoT device does not need to monitor signal #A1 and signal #A2, thereby further reducing power consumption of the IoT device. After the indicated time period (in other words, in response to the expiry of the indicated time period), the IoT device may start to monitor signal #A1 or both

signal #A1 and signal #A2.

[00122] In some examples, the time period indicator may indicate the time period from a set of values, which may be in units of absolute time (e.g., milliseconds), chip duration (e.g., a chip length), or symbol duration (e.g., a symbol length) or other time units that can be conceived of by persons skilled in the art. For example, the set of values may be {10ms, 20ms, 40ms, 80ms …}. The set of values may be predefined in a standard(s) or preconfigured.

[00123] From the perspective of a reader, before it starts an IoT communication with a group of devices (e.g., triggering an inventory round), the reader may transmit signal #A1 to the group of devices. In some examples, signal #A1 may be transmitted multiple times until a corresponding stop criterion is satisfied. For example, the reader may determine whether a certain percentage of devices in the group have received signal #A1 and/or entered the inactive state. Then, the reader may transmit signal #A2 to the group of devices. For example, signal #A2 may be transmitted when a start criterion is satisfied. For example, the reader may determine whether all devices in the group have received signal #A1 and/or entered the inactive state. For example, after the stop of signal #A1, the reader may wait for a certain time before transmitting signal #A2. In some examples, signal #A2 may be transmitted multiple times until a corresponding stop criterion is satisfied. For example, the reader may determine whether a certain percentage of devices in the group have received signal #A2 and/or entered the active state. Then, the reader may transmit an R2D transmission to the group of devices. In some examples, the R2D transmission may carry a Query command to the group of devices to trigger an inventory round.

[00124] From the perspective of an IoT device, after it harvests enough energy, it may start to monitor the signals and channels from the reader. In response to the reception of signal #A1, the IoT device may act accordingly as described above. For example, the IoT device may switch to or enter the inactive state and may further monitor signal #A2 or both signal #A1 and signal #A2. In response to the reception of signal #A2, the IoT device may act accordingly as described above. For example, the IoT device may switch to or enter the active state and prepare to receive R2D signals and transmit D2R signals (e.g., monitoring the signaling for ambient IoT communication). For

example, in response to the reception of the R2D transmissions carrying a Query command, the IoT device may start an inventory round. For example, the IoT device may generate a random backoff counter in the range of [0, 2^Q-1] and transmit a response when the random backoff counter is counted down to zero. An IoT device may receive signal #A1 and/or signal #A2 multiple times and may act in accordance with each received signal.

[00125] In some embodiments of present disclosure, for ambient IoT between a reader (e.g., a BS in the topology shown in FIG. 2A, an intermediate node in the topology shown in FIG. 2B, an assisting node or a BS in the topology shown in FIGs. 2C and 2D or a UE in the topology shown in FIG. 2E) to an (ambient) IoT device, at least two states may be defined for the IoT device. For example, the at least two states may include an inactive state and an active state. During the inactive state, an IoT device can harvest and store energy including RF energy. The IoT device cannot transmit any signal during the inactive state. During the active state, the IoT device can at least receive R2D signal and transmit D2R signal.

[00126] At least three state indication signals (denoted as signal #B1, signal #B2 and signal #B3 for clarity) may be employed to indicate the states of IoT devices. For example, signal #B1 can indicate an IoT device to enter the inactive state. For example, all types of IoT devices may enter the inactive state in response to receiving signal #B1. Signal #B2 can indicate a certain type of IoT device (denoted as type #1 device) to enter the active state. Signal #B3 can indicate other type(s) of IoT devices (denoted as type #2 device) to enter the active state. For example, type #1 device may include the IoT device with a relatively shorter sustainable operation time and type #2 device may include the IoT device with a relatively longer sustainable operation time. For example, type #1 device may be device 1 while type #2 device may be device 2a or device 2b. For example, type #1 device may be device 1 or device 2a while type #2 device may be device 2b.

[00127] In some examples, signal #B2 may further indicate that type #2 device to enter the inactive state. In these examples, type #2 device may need to monitor signal #B1, signal #B2 and signal #B3. For example, during the inactive state, type #1 device may monitor signal #B1 for inactive state indication and signal #B2 for active state

indication; and during the inactive state, type #2 device may monitor signal #B1 for inactive state indication, signal #B2 for active state indication and signal #B3 for active state indication. During the active state, both type #1 device and type #2 device may monitor the signaling for ambient IoT communication. For example, an IoT device may monitor a Query command from the reader for triggering an inventory round. Type #1 device in an active state may also monitor signal #B1, signal #B2 or both. Type #2 device in an active state may also monitor any one of signal #B1, signal #B2 and signal #B3.

[00128] In some examples, signal #B2 may only be designed for type #1 device. For example, signal #B2 only indicates type #1 device to enter the active state. Type #2 device may not be able to or may not need to detect signal #B2. For example, during the inactive state, type #1 device may monitor signal #B1 and signal #B2; and during the inactive state, type #2 device may monitor signal #B1 and signal #B3. During the active state, both type #1 device and type #2 device may monitor the signaling for ambient IoT communication. For example, an IoT device may monitor a Query command from the reader for triggering an inventory round. Type #1 device in an active state may also monitor signal #B1, signal #B2 or both. Type #2 device in an active state may also monitor signal #B1, signal #B3 or both.

[00129] In some embodiments, a reader may transmit signal #B1 multiple times to a group of IoT devices for indicating each IoT device in the group to enter the inactive state. For example, signal #B1 can be repeatedly transmitted so that it can be received by as many IoT devices within a group of IoT devices as possible. For example, signal #B1 can be periodically transmitted by the reader to save the energy of the reader. In some embodiments, the periodicity may be smaller than the minimum sustainable operation time of the IoT devices within the group so that signal #B1 can be received at least once by each IoT device within the group.

[00130] In some embodiments, the reader may stop transmitting signal #B1 when a certain stop criterion is satisfied. For example, the reader may stop transmitting signal #B1 when it determines (e.g., assumes) that at least a specific percentage of IoT devices within the group of IoT devices have received signal #B1 and/or entered the inactive state. The specific percentage may be 100% or lower. The specific percentage may

be predefined in a standard(s), implemented by the reader, or configured by RRC signaling (e.g., in the case that the reader is a UE).

[00131] In some embodiments, the reader may have its own policy for determining (e.g., assuming) when the stop criterion is satisfied. For example, the reader can determine the time instance when at least the specific percentage of IoT devices within the group of IoT devices have received signal #B1 and/or entered the inactive state based on various factors. For example, these factors may include at least one of: a number of IoT devices within the group of IoT devices, RF energy harvesting efficiency of the IoT devices, charging and discharging times of the IoT devices, capacitor sizes of the IoT devices, or storage sizes of the IoT devices.

[00132] Signal #B1 can be implemented in various forms. The following are some examples. Persons skilled in the art can conceive of other forms that are also within the scope of the present disclosure.

[00133] In some embodiments, signal #B1 may be a low voltage signal, which may require a minimum detection power consumption. The low voltage signal may be more suitable for an IoT device with lower peak power consumption (e.g., device 1 with about 1 μW peak power consumption) than for an IoT device with higher peak power consumption (e.g., device 2a and device 2b with several hundred μW peak power consumption).

[00134] In some embodiments, signal #B1 may be a high voltage signal, which may require a minimum detection power consumption. The high voltage signal can provide RF energy for devices to harvest energy during an inactive state. The high voltage signal may be more suitable for an IoT device with lower peak power consumption (e.g., device 1 with about 1 μW peak power consumption) than for an IoT device with higher peak power consumption (e.g., device 2a and device 2b with several hundred μW peak power consumption).

[00135] In some embodiments, signal #B1 may be a sequence (e.g., "101010…10") and encoded with high voltage signal and low voltage signal alternatively, which may require a low detection power consumption for various types of IoT devices (e.g., device 1, device 2a and device 2b). The sequence may be pre-known to the IoT

devices and the reader. For example, the sequence may be predefined in a standard(s), preconfigured.

[00136] In some embodiments, signal #B1 may be a pre-known ON-OFF pattern (e.g., a high-low or low-high voltage signal pattern), which may require a low detection power consumption for various types of IoT devices (e.g., device 1, device 2a and device 2b).

[00137] In some embodiments, signal #B1 may be carried by a physical channel (i.e., a physical R2D channel). The physical channel may include at least one of a state indicator or a time period indicator.

[00138] For example, the physical channel may include at least one bit for indicating the state of an IoT device. For example, the state indicator may include one bit, wherein a first bit value (e.g., "0" or "1") may indicate signal #B1, i.e., indicating an IoT device (e.g., both type #1 device and type #2 device) to enter or switch to an inactive state, and a second bit value (e.g., "1" or "0") may indicate signal #B2, i.e., indicating a type #1 device to enter or switch to an active state. In some examples, the second bit value may indicate that a type #2 device is still in an inactive state. For example, the state indicator may include at least two bits, e.g., {b1, b2}. In some examples, signals #B1-#B3 may be indicated by different bit value combinations. For example, {0,0} may indicate signal #B1, {1,0} may indicate signal #B2, and {1,1} may indicate signal #B3. In some examples, different bits of the state indicator may correspond to different types of devices. For example, bit b1 may correspond to type #1 device and bit b2 may correspond to type #2 device. For example, {0,0} may indicate signal #B1; {1, x2} or {1,0} may indicate signal #B2, where x2 can be either "0" or "1"; and {x1,1} may indicate signal #B3, where x1 can be either "0" or "1".

[00139] For example, the physical channel may include one or more bits for indicating a time period, during which an IoT device does not need to monitor signal #B1 and one or more of signal #B2 and signal #B3, thereby further reducing power consumption of the IoT device. For example, during the indicated time period, an IoT device does not need to monitor signal #B1, signal #B2 and signal #B3. For example, if signal #B2 is specific for type #1 device, type #2 device always does not need to monitor signal #B2. For example, if signal #B2 can be applied to both type #1 device and type #2 device,

type #2 device does not need to monitor signal #B2 during the indicated time period. For example, signal #B3 is specific for type #2 device, and therefore type #1 device always does not need to monitor signal #B3. After the indicated time period (in other words, in response to the expiry of the indicated time period), the IoT device may start to monitor signal #B1 and one or more of signal #B2 and signal #B3.

[00140] In some examples, the time period indicator may indicate the time period from a set of values, which may be in units of absolute time (e.g., milliseconds), chip duration (e.g., a chip length), or symbol duration (e.g., a symbol length) or other time units that can be conceived of by persons skilled in the art. For example, the set of values may be {10ms, 20ms, 40ms, 80ms …}. The set of values may be predefined in a standard(s) or preconfigured.

[00141] In some embodiments, a reader may transmit signal #B2 multiple times to type #1 devices for indicating each type #1 device in the group to enter the active state. For example, signal #B2 can activate a type #1 device that receives it to prepare for IoT communication (e.g., receiving of a Query command from the reader and/or transmitting of a response signal to the reader). Type #2 devices in the group may still be in the inactive state. For example, signal #B2 can be repeatedly transmitted so that it can be received by as many type #1 devices within the group of IoT devices as possible. For example, signal #B2 can be periodically transmitted by the reader to save the energy of the reader. In some embodiments, the periodicity may be smaller than the minimum sustainable operation time of the type #1 devices within the group so that signal #B2 can be received at least once by each type #1 device within the group.

[00142] In some embodiments, the reader may stop transmitting signal #B2 when a certain stop criterion is satisfied. For example, the reader may stop transmitting signal #B2 when it determines (e.g., assumes) that at least a specific percentage of type #1 devices within the group of IoT devices have received signal #B2 and/or entered the active state. The specific percentage may be 100% or lower. The specific percentage may be predefined in a standard(s), implemented by the reader, or configured by RRC signaling (e.g., in the case that the reader is a UE).

[00143] In some embodiments, the reader may have its own policy for determining (e.g., assuming) when the stop criterion is satisfied. For example, the reader can

determine the time instance when at least the specific percentage of type #1 devices within the group of IoT devices have received signal #B2 and/or entered the active state based on various factors. For example, these factors may include at least one of: a number of type #1 devices within the group of IoT devices, RF energy harvesting efficiency of type #1 devices, charging and discharging times of type #1 devices, capacitor sizes of type #1 devices, or storage sizes of type #1 devices.

[00144] Signal #B2 can be implemented in various forms. The following are some examples. Persons skilled in the art can conceive of other forms that are also within the scope of the present disclosure.

[00145] In some embodiments, signal #B2 may be a high voltage signal, which can activate a type #1 device to prepare for IoT communication (e.g., receiving a Query command from the reader and/or transmitting a response signal to the reader). The high voltage signal may require a minimum detection power consumption. The high voltage signal may be more suitable for an IoT device with lower peak power consumption (e.g., device 1 with about 1 μW peak power consumption) than for an IoT device with higher peak power consumption (e.g., device 2a and device 2b with several hundred μW peak power consumption). Since signal #B1 and signal #B2 are different, when signal #B2 is a high voltage signal, signal #B1 may be a low voltage signal.

[00146] In some embodiments, signal #B2 may be a low voltage signal, which can activate a type #1 device to prepare for IoT communication (e.g., receiving a Query command from the reader and/or transmitting a response signal to the reader). The low voltage signal which may require a minimum detection power consumption. The low voltage signal may be more suitable for an IoT device with lower peak power consumption (e.g., device 1 with about 1 μW peak power consumption) than for an IoT device with higher peak power consumption (e.g., device 2a and device 2b with several hundred μW peak power consumption). Since signal #B1 and signal #B2 are different, when signal #B2 is a low voltage signal, signal #B1 may be a high voltage signal.

[00147] In some embodiments, signal #B2 may be a sequence (e.g., "0101010…1") and encoded with low voltage signal and high voltage signal alternatively, which may require a low detection power consumption for various types of IoT devices (e.g., device 1, device 2a and device 2b). The sequence may be pre-known to the IoT

devices and the reader. For example, the sequence may be predefined in a standard(s), preconfigured. Since signal #B1 and signal #B2 are different, the sequence that represents signal #B2 is different from the one that represents signal #B1.

[00148] In some embodiments, signal #B2 may be a pre-known ON-OFF pattern for type #1 device (e.g., a high-low or low-high voltage signal pattern), which may require a low detection power consumption for various types of IoT devices (e.g., device 1, device 2a and device 2b). Since signal #B1 and signal #B2 are different, different ON-OFF patterns may be used for signal #B2 and signal #B1.

[00149] In some embodiments, signal #B2 may be carried by a physical channel (i.e., a physical R2D channel). The physical channel may include at least one of a state indicator or a time period indicator.

[00150] For example, the physical channel may include at least one bit for indicating the state of an IoT device. For example, the state indicator may include one bit, wherein a first bit value (e.g., “0” or “1”) may indicate signal #B1, i.e., indicating an IoT device (e.g., both type #1 device and type #2 device) to enter or switch to an inactive state, and a second bit value (e.g., “1” or “0”) may indicate signal #B2, i.e., indicating a type #1 device to enter or switch to an active state. In some examples, the second bit value may indicate that a type #2 device is still in an inactive state. For example, the state indicator may include at least two bits, e.g., {b1, b2}. In some examples, signals #B1-#B3 may be indicated by different bit value combinations. In some examples, different bits of the state indicator may correspond to different types of devices.

[00151] For example, the physical channel may include one or more bits for indicating a time period, during which a type #1 device does not need to monitor signal #B1 and signal #B2, thereby further reducing power consumption of the device. After the indicated time period (in other words, in response to the expiry of the indicated time period), the type #1 device may start to monitor signal #B1 or both signal #B1 and signal #B2.

[00152] In some examples, the time period indicator may indicate the time period from a set of values, which may be in units of absolute time (e.g., milliseconds), chip duration

(e.g., a chip length), or symbol duration (e.g., a symbol length) or other time units that can be conceived of by persons skilled in the art. For example, the set of values may be {10ms, 20ms, 40ms, 80ms …}. The set of values may be predefined in a standard(s) or preconfigured.

[00153] In some embodiments, a reader may transmit signal #B3 multiple times to type #2 devices for indicating each type #2 device in the group to enter the active state. For example, signal #B3 can activate a type #2 device that receives it to prepare for IoT communication (e.g., receiving of a Query command from the reader and/or transmitting of a response signal to the reader). For example, signal #B3 can be repeatedly transmitted so that it can be received by as many type #2 devices within the group of IoT devices as possible. For example, signal #B3 can be periodically transmitted by the reader to save the energy of the reader. In some embodiments, the periodicity may be smaller than the minimum sustainable operation time of the type #2 devices within the group so that signal #B3 can be received at least once by each type #2 device within the group.

[00154] In some embodiments, the reader may stop transmitting signal #B3 when a certain stop criterion is satisfied. For example, the reader may stop transmitting signal #B3 when it determines (e.g., assumes) that at least a specific percentage of type #2 devices within the group of IoT devices have received signal #B3 and/or entered the active state. The specific percentage may be 100% or lower. The specific percentage may be predefined in a standard(s), implemented by the reader, or configured by RRC signaling (e.g., in the case that the reader is a UE).

[00155] In some embodiments, the reader may have its own policy for determining (e.g., assuming) when the stop criterion is satisfied. For example, the reader can determine the time instance when at least the specific percentage of type #2 devices within the group of IoT devices have received signal #B3 and/or entered the active state based on various factors. For example, these factors may include at least one of: a number of type #2 devices within the group of IoT devices, RF energy harvesting efficiency of type #2 devices, charging and discharging times of type #2 devices, capacitor sizes of type #2 devices, or storage sizes of type #2 devices.

[00156] Signal #B3 can be implemented in various forms. The following are some

examples. Persons skilled in the art can conceive of other forms that are also within the scope of the present disclosure. Signal #B3 is different from signal #B1 or different from both signal #B1 and signal #B2.

[00157] In some embodiments, signal #B3 may be a high voltage signal, which can activate a type #2 device to prepare for IoT communication (e.g., receiving a Query command from the reader and/or transmitting a response signal to the reader). The high voltage signal may require a minimum detection power consumption.

[00158] In some embodiments, signal #B3 may be a low voltage signal, which can activate a type #2 device to prepare for IoT communication (e.g., receiving a Query command from the reader and/or transmitting a response signal to the reader). The low voltage signal which may require a minimum detection power consumption.

[00159] In some embodiments, signal #B3 may be a sequence (e.g., “00110011…0011”) and encoded with low voltage signal and high voltage signal alternatively, which may require a low detection power consumption for various types of IoT devices (e.g., device 1, device 2a and device 2b). The sequence may be pre-known to the IoT devices and the reader. For example, the sequence may be predefined in a standard(s), preconfigured.

[00160] In some embodiments, signal #B3 may be a pre-known ON-OFF pattern for type #2 device (e.g., a high-low or low-high voltage signal pattern), which may require a low detection power consumption for various types of IoT devices (e.g., device 1, device 2a and device 2b).

[00161] In some embodiments, signal #B3 may be carried by a physical channel (i.e., a physical R2D channel). The physical channel may include at least one of a state indicator or a time period indicator.

[00162] For example, the physical channel may include at least one bit for indicating the state of an IoT device. For example, the state indicator may include one bit, wherein a first bit value (e.g., “0” or “1”) may indicate signal #B1, i.e., indicating an IoT device (e.g., both type #1 device and type #2 device) to enter or switch to an inactive state, and a second bit value (e.g., “1” or “0”) may indicate signal #B3, i.e., indicating

a type #2 device to enter or switch to an active state. For example, the state indicator may include at least two bits, e.g., {b1, b2}. In some examples, signals #B1-#B3 may be indicated by different bit value combinations. In some examples, different bits of the state indicator may correspond to different types of devices.

[00163] For example, the physical channel may include one or more bits for indicating a time period, during which a type #2 device does not need to monitor signal #B1 and one or more of signal #B2 and signal #B3, thereby further reducing power consumption of the device. After the indicated time period (in other words, in response to the expiry of the indicated time period), the type #2 device may start to monitor signal #B1 and one or more of signal #B2 and signal #B3.

[00164] In some examples, the time period indicator may indicate the time period from a set of values, which may be in units of absolute time (e.g., milliseconds), chip duration (e.g., a chip length), or symbol duration (e.g., a symbol length) or other time units that can be conceived of by persons skilled in the art. For example, the set of values may be {10ms, 20ms, 40ms, 80ms …}. The set of values may be predefined in a standard(s) or preconfigured.

[00165] From the perspective of a reader, before it starts an IoT communication with a group of devices (e.g., triggering an inventory round), the reader may transmit signal #B1 to the group of devices. In some examples, signal #B1 may be transmitted multiple times until a corresponding stop criterion is satisfied. For example, the reader may determine whether a certain percentage of devices in the group have received signal #B1 and/or entered the inactive state.

[00166] Then, the reader may transmit signal #B2 to the group of devices or to type #1 devices in the group. For example, signal #B2 may be transmitted when a start criterion is satisfied. For example, the reader may determine whether all devices in the group have received signal #B1 and/or entered the inactive state. For example, after the stop of signal #B1, the reader may wait for a certain time before transmitting signal #B2. In some examples, signal #B2 may be transmitted multiple times until a corresponding stop criterion is satisfied. For example, the reader may determine whether a certain percentage of type #1 devices in the group have received signal #B2 and/or entered the active state. Then, the reader may transmit an R2D transmission to

the group of devices or to type #1 devices in the group. In some examples, the R2D transmission may carry a Query command to trigger an inventory round for type #1 devices.

[00167] Then, the reader may transmit signal #B3 to the group of devices or to type #2 devices in the group. For example, signal #B3 may be transmitted when a start criterion is satisfied. For example, the reader may determine whether a certain percentage of type #1 devices in the group have complete the inventory round. For example, after triggering the inventory round for type #1 devices, the reader may wait for a certain time before transmitting signal #B3. In some examples, signal #B3 may be transmitted multiple times until a corresponding stop criterion is satisfied. For example, the reader may determine whether a certain percentage of type #2 devices in the group have received signal #B3 and/or entered the active state. Then, the reader may transmit an R2D transmission to the group of devices or to type #2 devices in the group. In some examples, the R2D transmission may carry a Query command to trigger an inventory round for type #2 devices.

[00168] From the perspective of an IoT device, after it harvests enough energy, it may start to monitor the signals and channels from the reader. In response to the reception of signal #B1, the IoT device may act accordingly as described above. For example, the IoT device may switch to or enter the inactive state and may further monitor signal #B1 and one or more of signal #B2 and signal #B3. In response to the reception of signal #B2, a type #1 device may act accordingly as described above. For example, the type #1 device may switch to or enter the active state and prepare to receive R2D signals and transmit D2R signals (e.g., monitoring the signaling for ambient IoT communication). In response to the reception of signal #B2, a type #2 device may stay in an inactive state. In response to the reception of signal #B3, a type #2 device may act accordingly as described above. For example, the type #2 device may switch to or enter the active state and prepare to receive R2D signals and transmit D2R signals (e.g., monitoring the signaling for ambient IoT communication). In response to the reception of the R2D transmissions carrying a Query command, an IoT device (e.g., either type #1 or type #2 device) may start an inventory round. For example, the IoT device may generate a random backoff counter in the range of [0, 2^Q-1] and transmit a response when the random backoff counter is counted down to zero. An IoT device

may receive signal #B1, signal #B2 and/or signal #B3 multiple times and may act in accordance with each received signal.

[00169] Considering that type #1 devices have a shorter sustainable operation time than type #2 devices, it is beneficial to initiate the IoT communication (e.g., an inventory) for type #1 devices earlier than for type #2 devices. In some embodiments, the IoT communication (e.g., an inventory) for type #1 devices and the IoT communication (e.g., an inventory) for type #2 devices can be separately and independently performed in different sessions (e.g., different inventory sessions). In some embodiments, the IoT communication (e.g., an inventory) for type #1 devices and the IoT communication (e.g., an inventory) for type #2 devices can be performed in the same session. For example, after completing the inventory round of all type #1 devices or a percentage of type #1 devices within the group of devices, the reader starts to transmit signal #B3 and corresponding Query command to trigger the inventory round of type #2 devices.

[00170] In some embodiments of present disclosure, for ambient IoT between a reader (e.g., a BS in the topology shown in FIG. 2A, an intermediate node in the topology shown in FIG. 2B, an assisting node or a BS in the topology shown in FIGs. 2C and 2D or a UE in the topology shown in FIG. 2E) to an (ambient) IoT device, at least two states may be defined for the IoT device. For example, the at least two states may include an inactive state and an active state. During the inactive state, an IoT device can harvest and store energy including RF energy. The IoT device cannot transmit any signal during the inactive state. During the active state, the IoT device can at least receive R2D signal and transmit D2R signal.

[00171] A plurality of state indication signals may be employed to indicate the states of IoT devices, wherein one state indication signal (denoted as signal #C1) is used to indicate the inactive state and each of the remaining state indications (including for example signal #C2, signal #C3 and signal #C4) corresponds to a type of IoT device. For example, all types of IoT devices may enter the inactive state in response to receiving signal #C1. Signal #C2 can indicate a type of IoT device (denoted as type #1' device) to enter the active state; signal #C3 can indicate another type of IoT device (denoted as type #2' device) to enter the active state; and signal #C4 can indicate yet another type of IoT device (denoted as type #3' device) to enter the active state. For

example, type #1' device may include device 1, type #2' device may include device 2a and type #3' device may include device 2b. The descriptions with respect to signal #B1 may be similar applied to signal #C1 and the descriptions with respect to signals #B2 and #B3 may be similar applied to signals #C2-C4.

[00172] From the perspective of a reader, before it starts an IoT communication with a group of devices (e.g., triggering an inventory round), the reader may transmit signal #C1 to the group of devices. In some examples, signal #C1 may be transmitted multiple times until a corresponding stop criterion is satisfied. Then, the reader may transmit signal #C2 to the group of devices or to type #1' devices in the group. For example, signal #C2 may be transmitted when a start criterion is satisfied. In some examples, signal #C2 may be transmitted multiple times until a corresponding stop criterion is satisfied. Then, the reader may transmit an R2D transmission to the group of devices or to type #1' devices in the group. In some examples, the R2D transmission may carry a Query command to trigger an inventory round for type #1' devices. Then, the reader may transmit signal #C3 to the group of devices or to type #2' devices in the group. For example, signal #C3 may be transmitted when a start criterion is satisfied. In some examples, signal #C3 may be transmitted multiple times until a corresponding stop criterion is satisfied. Then, the reader may transmit an R2D transmission to the group of devices or to type #2' devices in the group. In some examples, the R2D transmission may carry a Query command to trigger an inventory round for type #2' devices. Then, the reader may transmit signal #C4 to the group of devices or to type #3' devices in the group. For example, signal #C4 may be transmitted when a start criterion is satisfied. In some examples, signal #C4 may be transmitted multiple times until a corresponding stop criterion is satisfied. Then, the reader may transmit an R2D transmission to the group of devices or to type #3' devices in the group. In some examples, the R2D transmission may carry a Query command to trigger an inventory round for type #3' devices.

[00173] From the perspective of an IoT device, after it harvests enough energy, it may start to monitor the signals and channels from the reader. In response to the reception of signal #C1, the IoT device may act accordingly as described above. For example, the IoT device may switch to or enter the inactive state and may further monitor signal #C1 and one or more of signals #C2-#C4. In response to the reception of signal #C2,

a type #1' device may act accordingly as described above. For example, the type #1' device may switch to or enter the active state and prepare to receive R2D signals and transmit D2R signals (e.g., monitoring the signaling for ambient IoT communication). In response to the reception of signal #C3, a type #2' device may act accordingly as described above. For example, the type #2' device may switch to or enter the active state and prepare to receive R2D signals and transmit D2R signals (e.g., monitoring the signaling for ambient IoT communication). In response to the reception of signal #C4, a type #3' device may act accordingly as described above. For example, the type #3' device may switch to or enter the active state and prepare to receive R2D signals and transmit D2R signals (e.g., monitoring the signaling for ambient IoT communication). In response to the reception of the R2D transmissions carrying a Query command, an IoT device may start an inventory round. For example, the IoT device may generate a random backoff counter in the range of [0, 2^Q-1] and transmit a response when the random backoff counter is counted down to zero. An IoT device may receive any of signals #C1-#C4 multiple times and may act in accordance with each received signal.

[00174] In some embodiments, the IoT communications (e.g., inventories) for different types of devices can be performed separately and independently in respective sessions (e.g., different inventory sessions) or in the same session.

[00175] In some embodiments of present disclosure, for ambient IoT between a reader (e.g., a BS in the topology shown in FIG. 2A, an intermediate node in the topology shown in FIG. 2B, an assisting node or a BS in the topology shown in FIGs. 2C and 2D or a UE in the topology shown in FIG. 2E) to an (ambient) IoT device, at least two states may be defined for the IoT device. For example, the at least two states may include an inactive state and an active state. During the inactive state, an IoT device can harvest and store energy including RF energy. The IoT device cannot transmit any signal during the inactive state. During the active state, the IoT device can at least receive R2D signal and transmit D2R signal.

[00176] An active state indication signal (denoted as signal #D1 for clarity) may be employed to indicate the IoT device to enter the active state. During the inactive state, an IoT device may monitor signal #D1 for active state indication. During the active state, an IoT device may monitor the signaling for ambient IoT communication. For

example, the IoT device may monitor a Query command from the reader for triggering an inventory round. In some examples, before detecting signal #D1, the IoT device may stay in the inactive state.

[00177] In some embodiments, a reader may transmit signal #D1 multiple times to a group of IoT devices for indicating each IoT device in the group to enter the active state. For example, signal #D1 can be repeatedly transmitted so that it can be received by as many IoT devices within a group of IoT devices as possible. For example, signal #D1 can be periodically transmitted by the reader to save the energy of the reader. In some embodiments, the periodicity may be smaller than the minimum sustainable operation time of the IoT devices within the group so that signal #D1 can be received at least once by each IoT device within the group.

[00178] In some embodiments, the reader may stop transmitting signal #D1 when a certain stop criterion is satisfied. For example, the reader may stop transmitting signal #D1 when it determines (e.g., assumes) that at least a specific percentage of IoT devices within the group of IoT devices have received signal #D1 and/or entered the active state. The specific percentage may be 100% or lower. The specific percentage may be predefined in a standard(s), implemented by the reader, or configured by RRC signaling (e.g., in the case that the reader is a UE).

[00179] In some embodiments, the reader may have its own policy for determining (e.g., assuming) when the stop criterion is satisfied. For example, the reader can determine the time instance when at least the specific percentage of IoT devices within the group of IoT devices have received signal #D1 and/or entered the active state based on various factors. For example, these factors may include at least one of: a number of IoT devices within the group of IoT devices, RF energy harvesting efficiency of the IoT devices, charging and discharging times of the IoT devices, capacitor sizes of the IoT devices, or storage sizes of the IoT devices.

[00180] Signal #D1 can be implemented in various forms. The following are some examples. Persons skilled in the art can conceive of other forms that are also within the scope of the present disclosure.

[00181] In some embodiments, signal #D1 may be a low voltage signal, which can

activate an IoT device to prepare for IoT communication (e.g., receiving a Query command from the reader and/or transmitting a response signal to the reader). The low voltage signal may require a minimum detection power consumption. The low voltage signal may be more suitable for an IoT device with lower peak power consumption (e.g., device 1 with about 1 μW peak power consumption) than for an IoT device with higher peak power consumption (e.g., device 2a and device 2b with several hundred μW peak power consumption).

[00182] In some embodiments, signal #D1 may be a high voltage signal, which can activate an IoT device to prepare for IoT communication (e.g., receiving a Query command from the reader and/or transmitting a response signal to the reader). The high voltage signal may require a minimum detection power consumption. The high voltage signal may be more suitable for an IoT device with lower peak power consumption (e.g., device 1 with about 1 μW peak power consumption) than for an IoT device with higher peak power consumption (e.g., device 2a and device 2b with several hundred μW peak power consumption).

[00183] In some embodiments, signal #D1 may be a sequence (e.g., “101010…10”) and encoded with high voltage signal and low voltage signal alternatively, which may require a low detection power consumption for various types of IoT devices (e.g., device 1, device 2a and device 2b). The sequence may be pre-known to the IoT devices and the reader. For example, the sequence may be predefined in a standard(s), preconfigured.

[00184] In some embodiments, signal #D1 may be a pre-known ON-OFF pattern (e.g., a high-low or low-high voltage signal pattern), which may require a low detection power consumption for various types of IoT devices (e.g., device 1, device 2a and device 2b).

[00185] In some embodiments, signal #D1 may be carried by a physical channel (i.e., a physical R2D channel). The physical channel may include at least one of a state indicator or a time period indicator. For example, the physical channel may include at least one bit for indicating the state of an IoT device. For example, 1 bit of “1” may indicate signal #D1, i.e., indicating the device to enter or switch to an active state, while 1 bit of “0” may indicate the device to enter or switch to an inactive state or may be

reserved; or vice versa. For example, the physical channel may include one or more bits for indicating a time period, during which an IoT device does not need to monitor signal #D1 and the signaling for IoT communication (e.g., the Query command), thereby further reducing power consumption of the IoT device. After the indicated time period (in other words, in response to the expiry of the indicated time period), the IoT device may start to monitor the signaling for IoT communication (e.g., the Query command).

[00186] In some examples, the time period indicator may indicate the time period from a set of values, which may be in units of absolute time (e.g., milliseconds), chip duration (e.g., a chip length), or symbol duration (e.g., a symbol length) or other time units that can be conceived of by persons skilled in the art. For example, the set of values may be {10ms, 20ms, 40ms, 80ms …}. The set of values may be predefined in a standard(s) or preconfigured.

[00187] From the perspective of a reader, before it starts an IoT communication with a group of devices (e.g., triggering an inventory round), the reader may transmit signal #D1 to the group of devices. In some examples, signal #D1 may be transmitted multiple times until a corresponding stop criterion is satisfied. For example, the reader may determine whether a certain percentage of devices in the group have received signal #D1 and/or entered the active state. Then, the reader may transmit an R2D transmission to the group of devices. In some examples, the R2D transmission may be transmitted when a start criterion is satisfied. For example, the reader may determine whether all devices in the group have received signal #D1 and/or entered the active state. For example, after the stop of signal #D1, the reader may wait for a certain time before transmitting the R2D transmission. In some examples, the R2D transmission may carry a Query command to the group of devices to trigger an inventory round.

[00188] From the perspective of an IoT device, after it harvests enough energy, it may start to monitor the signals and channels from the reader. For example, an IoT device may monitor signal #D1. In response to the reception of signal #D1, the IoT device may act accordingly as described above. For example, the IoT device may switch to or enter the active state and may further monitor the signaling for ambient IoT

communication. For example, the IoT device may prepare to receive R2D signals and transmit D2R signals. For example, in response to the reception of the R2D transmissions carrying a Query command, the IoT device may start an inventory round. For example, the IoT device may generate a random backoff counter in the range of [0, 2^Q-1] and transmit a response when the random backoff counter is counted down to zero. An IoT device may receive signal #D1 multiple times and may act in accordance with each received signal #D1.

[00189] In some embodiments of present disclosure, for ambient IoT between a reader (e.g., a BS in the topology shown in FIG. 2A, an intermediate node in the topology shown in FIG. 2B, an assisting node or a BS in the topology shown in FIGs. 2C and 2D or a UE in the topology shown in FIG. 2E) to an (ambient) IoT device, at least two states may be defined for the IoT device. For example, the at least two states may include an inactive state and an active state. During the inactive state, an IoT device can harvest and store energy including RF energy. The IoT device cannot transmit any signal during the inactive state. During the active state, the IoT device can at least receive R2D signal and transmit D2R signal.

[00190] An inactive state indication signal (denoted as signal #E1 for clarity) may be employed to indicate the IoT device to enter the inactive state. During the inactive state, an IoT device may monitor signal #E1 for active state indication. During the inactive state, an IoT device may monitor signal #E1. Within a duration (denoted as duration #E for clarity) the IoT device does not detect signal #E1, the IoT device may switch to an active state. Duration #E n may be predefined in standards or preconfigured during manufacturing. During the active state, an IoT device may monitor signal #E1 and the signaling for ambient IoT communication. For example, the IoT device may monitor a Query command from the reader for triggering an inventory round. In response to the reception signal #E1, the IoT device may switch to the inactive state and continue to monitor signal #E1.

[00191] In some embodiments, a reader may transmit signal #E1 multiple times to a group of IoT devices for indicating each IoT device in the group to enter the inactive state. For example, signal #E1 can be repeatedly transmitted so that it can be received by as many IoT devices within a group of IoT devices as possible. For example, signal

#E1 can be periodically transmitted by the reader to save the energy of the reader. In some embodiments, the periodicity may be smaller than the minimum sustainable operation time of the IoT devices within the group so that signal #E1 can be received at least once by each IoT device within the group.

[00192] In some embodiments, the reader may stop transmitting signal #E1 when a certain stop criterion is satisfied. For example, the reader may stop transmitting signal #E1 when it determines (e.g., assumes) that at least a specific percentage of IoT devices within the group of IoT devices have received signal #E1 and/or entered the inactive state. The specific percentage may be 100% or lower. The specific percentage may be predefined in a standard(s), implemented by the reader, or configured by RRC signaling (e.g., in the case that the reader is a UE).

[00193] In some embodiments, the reader may have its own policy for determining (e.g., assuming) when the stop criterion is satisfied. For example, the reader can determine the time instance when at least the specific percentage of IoT devices within the group of IoT devices have received signal #E1 and/or entered the inactive state based on various factors. For example, these factors may include at least one of: a number of IoT devices within the group of IoT devices, RF energy harvesting efficiency of the IoT devices, charging and discharging times of the IoT devices, capacitor sizes of the IoT devices, or storage sizes of the IoT devices.

[00194] Signal #E1 can be implemented in various forms. The following are some examples. Persons skilled in the art can conceive of other forms that are also within the scope of the present disclosure.

[00195] In some embodiments, signal #E1 may be a low voltage signal, which may require a minimum detection power consumption. The low voltage signal may be more suitable for an IoT device with lower peak power consumption (e.g., device 1 with about 1 μW peak power consumption) than for an IoT device with higher peak power consumption (e.g., device 2a and device 2b with several hundred μW peak power consumption).

[00196] In some embodiments, signal #E1 may be a high voltage signal, which may require a minimum detection power consumption. The high voltage signal may be

more suitable for an IoT device with lower peak power consumption (e.g., device 1 with about 1 μW peak power consumption) than for an IoT device with higher peak power consumption (e.g., device 2a and device 2b with several hundred μW peak power consumption).

[00197] In some embodiments, signal #E1 may be a sequence (e.g., "101010…10") and encoded with high voltage signal and low voltage signal alternatively, which may require a low detection power consumption for various types of IoT devices (e.g., device 1, device 2a and device 2b). The sequence may be pre-known to the IoT devices and the reader. For example, the sequence may be predefined in a standard(s), preconfigured.

[00198] In some embodiments, signal #E1 may be a pre-known ON-OFF pattern (e.g., a high-low or low-high voltage signal pattern), which may require a low detection power consumption for various types of IoT devices (e.g., device 1, device 2a and device 2b).

[00199] In some embodiments, signal #E1 may be carried by a physical channel (i.e., a physical R2D channel). The physical channel may include at least one of a state indicator or a time period indicator. For example, the physical channel may include at least one bit for indicating the state of an IoT device. For example, 1 bit of "0" may indicate signal #E1, i.e., indicating the device to enter or switch to an inactive state, while 1 bit of "1" may indicate the device to enter or switch to an active state or may be reserved; or vice versa. For example, the physical channel may include one or more bits for indicating a time period, during which an IoT device does not need to monitor signal #E1, thereby further reducing power consumption of the IoT device. After the indicated time period (in other words, in response to the expiry of the indicated time period), the IoT device may start to monitor signal #E1. If the inactive state indication signal is not detected after the expiry of the indicated time period, the IoT device may switch to the active state and may monitor the signaling for IoT communication (e.g., the Query command) from the reader.

[00200] In some examples, the time period indicator may indicate the time period from a set of values, which may be in units of absolute time (e.g., milliseconds), chip duration (e.g., a chip length), or symbol duration (e.g., a symbol length) or other time units that

can be conceived of by persons skilled in the art. For example, the set of values may be {10ms, 20ms, 40ms, 80ms …}. The set of values may be predefined in a standard(s) or preconfigured.

[00201] From the perspective of a reader, before it starts an IoT communication with a group of devices (e.g., triggering an inventory round), the reader may transmit signal #E1 to the group of devices. In some examples, signal #E1 may be transmitted multiple times until a corresponding stop criterion is satisfied. For example, the reader may determine whether a certain percentage of devices in the group have received signal #E1 and/or entered the inactive state. Then, the reader may transmit an R2D transmission to the group of devices. In some examples, the R2D transmission may be transmitted when a start criterion is satisfied. For example, after the stop of signal #E1, the reader may wait for a certain time before transmitting the R2D transmission. For example, the reader may wait for the devices to switch to the active state. In some examples, the R2D transmission may carry a Query command to the group of devices to trigger an inventory round.

[00202] From the perspective of an IoT device, after it harvests enough energy, it may start to monitor the signals and channels from the reader. For example, an IoT device may monitor signal #E1. In response to the reception of signal #E1, the IoT device may act accordingly as described above. For example, the IoT device may switch to or enter the inactive state, and after a certain duration the IoT device does not detect signal #E1, the IoT device may enter the active state and start to monitor the signaling for ambient IoT communication. For example, in response to the reception of the R2D transmissions carrying a Query command, the IoT device may start an inventory round. For example, the IoT device may generate a random backoff counter in the range of [0, 2^Q-1] and transmit a response when the random backoff counter is counted down to zero. An IoT device may receive signal #E1 multiple times and may act in accordance with each received signal #E1.

[00203] FIG. 3 illustrates a flowchart of method 300 for wireless communication in accordance with some embodiments of the present disclosure. Details described in all of the foregoing embodiments of the present disclosure are applicable for the embodiments shown in FIG. 3. In some examples, method 300 may be performed by

a reader such as a BS in the topology shown in FIG. 2A, an intermediate node in the topology shown in FIG. 2B, an assisting node or a BS in the topology shown in FIGs. 2C and 2D or a UE in the topology shown in FIG. 2E. In some embodiments, the reader may execute a set of instructions to control the functional elements of the reader to perform the described functions or operations. In some examples, a processor of the reader may cause the reader to perform method 300.

[00204] At 311, a first device may transmit, to a group of second devices, a first state indication signal indicating each second device of the group of second devices to switch to a first state. At 313, the first device may determine, at a first time instance, that at least a percentage of second devices within the group of second devices have received the first state indication signal. At 315, the first device may transmit, to the group of second devices, signaling for ambient IoT communication.

[00205] In some embodiments, the first state indication signal is transmitted repeatedly or periodically until the first time instance.

[00206] In some embodiments, the first time instance is determined based on at least one of a number of second devices within the group of second devices, radio frequency (RF) energy harvesting efficiency of the second devices, charging and discharging times of the second devices, capacitor sizes of the second devices, or storage sizes of the second devices.

[00207] In some embodiments, the first state indication signal is a low voltage signal, a high voltage signal, a pre-known first sequence, a pre-known ON-OFF pattern, or carried in a physical channel.

[00208] In some embodiments, the physical channel includes at least one of a first indicator indicating the first state or a second indicator indicating one of: a time period during which the second device does not monitor the first state indication signal and the signaling for ambient IoT communication, and after which the second device monitors the signaling for ambient IoT communication; a time period during which the second device does not monitor the first state indication signal and the signaling for ambient IoT communication, and after which the second device monitors the first state indication signal and the signaling for ambient IoT communication; a time period

during which the second device does not monitor the first state indication signal and a second state indication signal, and after which the second device monitors the second state indication signal or both the first state indication signal and the second state indication signal; and a time period during which the second device does not monitor the first state indication signal and one or more of a third state indication signal and a fourth state indication signal, and after which the second device monitors the first state indication signal and the one or more of the third state indication signal and the fourth state indication signal.

[00209] In some embodiments, the first state indication signal indicates each second device in the group of second devices to switch to an active state to monitor the signaling for ambient IoT communication. In some embodiments, the first state indication signal indicates each second device in the group of second devices to switch to an inactive state for a first time period during which the second device monitors the first state indication signal and the signaling for IoT communication is transmitted after the first time period. In some embodiments, the first state indication signal indicates each second device in the group of second devices to switch to the inactive state.

[00210] In some embodiments, the first device may: transmit, to the group of second devices, a second state indication signal indicating each second device of the group of second devices to switch to an active state to monitor the signaling for ambient IoT communication; transmit, to first type second devices in the group of second devices, a third state indication signal indicating each first type second device in the group of second devices to switch to the active state to monitor the signaling for ambient IoT communication; or transmit, to second type second devices in the group of second devices, the third state indication signal indicating each second type second device in the group of second devices to switch to the inactive state.

[00211] In some embodiments, the second state indication signal is transmitted repeatedly or periodically until a second time instance.

[00212] In some embodiments, the first device may: determine that at least a percentage of second devices within the group of second devices have received the second state indication signal at the second time instance; and transmit the signaling for ambient IoT communication after the second time instance.

[00213] In some embodiments, the second time instance is determined based on at least one of a number of second devices within the group of second devices, RF energy harvesting efficiency of the second devices, charging and discharging times of the second devices, capacitor sizes of the second devices, or storage sizes of the second devices.

[00214] In some embodiments, the second state indication signal is a high voltage signal, a low voltage signal, a pre-known second sequence, a pre-known ON-OFF pattern, or carried in a physical channel.

[00215] In some embodiments, the physical channel includes at least one of a first indicator indicating the active state or a second indicator indicating a time period during which the second device does not monitor the first state indication signal and the second state indication signal, and after which the second device monitors the first state indication signal and the second state indication signal.

[00216] In some embodiments, the third state indication signal is transmitted repeatedly or periodically until a third time instance.

[00217] In some embodiments, the first device may: determine that at least a percentage of first type second devices within the group of second devices have received the third state indication signal at the third time instance; and transmit the signaling for ambient IoT communication to the first type second devices in the group of second devices after the third time instance.

[00218] In some embodiments, the third time instance is determined based on at least one of a number of first type second devices within the group of second devices, RF energy harvesting efficiency of the first type second devices, charging and discharging times of the first type second devices, capacitor sizes of the first type second devices, or storage sizes of the first type second devices.

[00219] In some embodiments, the third state indication signal is a high voltage signal, a low voltage signal, a pre-known third sequence, a pre-known ON-OFF pattern, or carried in a physical channel.

[00220] In some embodiments, the physical channel includes at least one of: a first indicator indicating the active state for the first type second device, the inactive state for the second type second device, or both; or a second indicator indicating a time period during which the first type second device does not monitor the first state indication signal and the third state indication signal, and after which the first type second device monitors the first state indication signal and the third state indication signal.

[00221] In some embodiments, the first device may: in response to transmitting the third state indication signal, transmit, to second type second devices in the group of second devices, a fourth state indication signal indicating each second type second device in the group of second devices to switch to the active state to monitor the signaling for ambient IoT communication.

[00222] In some embodiments, the fourth state indication signal is transmitted repeatedly or periodically until a fourth time instance.

[00223] In some embodiments, the first device may: determine that at least a percentage of second type second devices within the group of second devices have received the fourth state indication signal at the fourth time instance; and transmit the signaling for ambient IoT communication to the second type second devices in the group of second devices after the fourth time instance.

[00224] In some embodiments, the fourth time instance is determined based on at least one of a number of second type second devices within the group of second devices, RF energy harvesting efficiency of the second type second devices, charging and discharging times of the second type second devices, capacitor sizes of the second type second devices, or storage sizes of the second type second devices.

[00225] In some embodiments, the fourth state indication signal is a low voltage signal, a high voltage signal, a pre-known fourth sequence, a pre-known ON-OFF pattern, or carried in a physical channel.

[00226] In some embodiments, the physical channel includes at least one of a first indicator indicating the active state for the second type second device or a second indicator indicating a time period during which the second type second device does not

monitor the first state indication signal and one or more of the third state indication signal and the fourth state indication signal, and after which the second type second device monitors the first state indication signal and the one or more of the third state indication signal and the fourth state indication signal.

[00227] In some embodiments, the first type second devices in the group of second devices include one or more devices having a first sustainable operation time and the second type second devices in the group of second devices include one or more devices having a second sustainable operation time or a third sustainable operation time. In some embodiments, the first type second devices in the group of second devices include one or more devices having the first sustainable operation time or the second sustainable operation time and the second type second devices in the group of second devices include one or more devices having the third sustainable operation time.

[00228] It should be appreciated by persons skilled in the art that the sequence of the operations in exemplary method 300 may be changed and some of the operations in exemplary method 300 may be eliminated or modified, without departing from the spirit and scope of the disclosure.

[00229] FIG. 4 illustrates a flowchart of method 400 for wireless communication in accordance with some embodiments of the present disclosure. Details described in all of the foregoing embodiments of the present disclosure are applicable for the embodiments shown in FIG. 4. In some examples, method 400 may be performed by an IoT device. In some embodiments, the IoT device may execute a set of instructions to control the functional elements of the IoT device to perform the described functions or operations. In some examples, a processor of the IoT device may cause the IoT device to perform method 400.

[00230] At 411, a second device may receive, from a first device, a first state indication signal. At 413, the second device may switch to a first state in response to receiving the first state indication signal. At 415, the second device may receive, from the first device, signaling for ambient IoT communication.

[00231] In some embodiments, the first state indication signal is a low voltage signal, a high voltage signal, a pre-known first sequence, a pre-known ON-OFF pattern, or

carried in a physical channel.

[00232] In some embodiments, the physical channel includes at least one of a first indicator indicating the first state or a second indicator indicating one of: a time period during which the second device does not monitor the first state indication signal and the signaling for ambient IoT communication, and after which the second device monitors the signaling for ambient IoT communication; a time period during which the second device does not monitor the first state indication signal and the signaling for ambient IoT communication, and after which the second device monitors the first state indication signal and the signaling for ambient IoT communication; a time period during which the second device does not monitor the first state indication signal and a second state indication signal, and after which the second device monitors the second state indication signal or both the first state indication signal and the second state indication signal; and a time period during which the second device does not monitor the first state indication signal and one or more of a third state indication signal and a fourth state indication signal, and after which the second device monitors the first state indication signal and the one or more of the third state indication signal and the fourth state indication signal.

[00233] In some embodiments, the first state indication signal indicates the second device to switch to an active state to monitor the signaling for ambient IoT communication. In some embodiments, the first state indication signal indicates the second device to switch to an inactive state for a first time period. The second device may: monitor the first state indication signal and switch to the active state to monitor the signaling for IoT communication in response to not detecting the first state indication signal during the first time period. In some embodiments, the first state indication signal indicates the second device to switch to the inactive state.

[00234] In some embodiments, the second device may: receive a second state indication signal indicating the second device to switch to an active state to monitor the signaling for ambient IoT communication; in response to the second device being a first type second device, receive a third state indication signal indicating the second device to switch to the active state to monitor the signaling for ambient IoT communication; in response to the second device being a second type second device, receive the third

state indication signal indicating the second device to switch to the inactive state; or in response to the second device being the second type second device, receive a fourth state indication signal indicating the second device to switch to the active state to monitor the signaling for ambient IoT communication.

[00235] In some embodiments, the second state indication signal is a high voltage signal, a low voltage signal, a pre-known second sequence, a pre-known ON-OFF pattern, or carried in a physical channel.

[00236] In some embodiments, the physical channel includes at least one of a first indicator indicating the active state or a second indicator indicating a time period during which the second device does not monitor the first state indication signal and the second state indication signal, and after which the second device monitors the first state indication signal and the second state indication signal.

[00237] In some embodiments, the third state indication signal is a high voltage signal, a low voltage signal, a pre-known third sequence, a pre-known ON-OFF pattern, or carried in a physical channel.

[00238] In some embodiments, the physical channel includes at least one of: a first indicator indicating the active state for the first type second device, the inactive state for the second type second device, or both; or a second indicator indicating a time period during which the first type second device does not monitor the first state indication signal and the third state indication signal, and after which the first type second device monitors the first state indication signal and the third state indication signal.

[00239] In some embodiments, the fourth state indication signal is a low voltage signal, a high voltage signal, a pre-known fourth sequence, a pre-known ON-OFF pattern, or carried in a physical channel.

[00240] In some embodiments, the physical channel includes at least one of a first indicator indicating the active state for the second type second device or a second indicator indicating a time period during which the second type second device does not monitor the first state indication signal and one or more of the third state indication signal and the fourth state indication signal, and after which the second type second

device monitors the first state indication signal and the one or more of the third state indication signal and the fourth state indication signal.

[00241] In some embodiments, the first type second device has a first sustainable operation time and the second type second device has a second sustainable operation time or a third sustainable operation time. In some embodiments, the first type second device has the first sustainable operation time or the second sustainable operation time and the second type second device has the third sustainable operation time.

[00242] It should be appreciated by persons skilled in the art that the sequence of the operations in exemplary method 400 may be changed and some of the operations in exemplary method 400 may be eliminated or modified, without departing from the spirit and scope of the disclosure.

[00243] FIG. 5 illustrates an example of a UE 500 in accordance with aspects of the present disclosure. The UE 500 may include a processor 502, a memory 504, a controller 506, and a transceiver 508. The processor 502, the memory 504, the controller 506, or the transceiver 508, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. These components may be coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces.

[00244] The processor 502, the memory 504, the controller 506, or the transceiver 508, or various combinations or components thereof may be implemented in hardware (e.g., circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), or other programmable logic device, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure.

[00245] The processor 502 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, an ASIC, an FPGA, or any combination thereof). In some implementations, the processor 502 may be configured to operate the memory 504. In some other implementations, the memory 504 may be integrated into the processor 502. The processor 502 may be configured to execute computer-readable

instructions stored in the memory 504 to cause the UE 500 to perform various functions of the present disclosure.

[00246] The memory 504 may include volatile or non-volatile memory. The memory 504 may store computer-readable, computer-executable code including instructions when executed by the processor 502 cause the UE 500 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as the memory 504 or another type of memory. Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that may be accessed by a general-purpose or special-purpose computer.

[00247] In some implementations, the processor 502 and the memory 504 coupled with the processor 502 may be configured to cause the UE 500 to perform one or more of the functions described herein (e.g., executing, by the processor 502, instructions stored in the memory 504). For example, the processor 502 may support wireless communication at the UE 500 in accordance with examples as disclosed herein. For example, the UE 500 may be configured to support means for performing the operations as described with respect to FIGs. 1-3.

[00248] For example, the UE 500 may be configured to support: a means for transmitting, to a group of second devices, a first state indication signal indicating each second device of the group of second devices to switch to a first state; a means for determining, at a first time instance, that at least a percentage of second devices within the group of second devices have received the first state indication signal; and a means for transmitting, to the group of second devices, signaling for ambient IoT communication.

[00249] The controller 506 may manage input and output signals for the UE 500. The controller 506 may also manage peripherals not integrated into the UE 500. In some implementations, the controller 506 may utilize an operating system such as iOS®, ANDROID®, WINDOWS®, or other operating systems. In some implementations, the controller 506 may be implemented as part of the processor 502.

[00250] In some implementations, the UE 500 may include at least one transceiver 508. In some other implementations, the UE 500 may have more than one transceiver 508. The transceiver 508 may represent a wireless transceiver. The transceiver 508 may include one or more receiver chains 510, one or more transmitter chains 512, or a combination thereof.

[00251] A receiver chain 510 may be configured to receive signals (e.g., control information, data, or packets) over a wireless medium. For example, the receiver chain 510 may include one or more antennas for receive the signal over the air or wireless medium. The receiver chain 510 may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receiver chain 510 may include at least one demodulator configured to demodulate the receive signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receiver chain 510 may include at least one decoder for decoding the processing the demodulated signal to receive the transmitted data.

[00252] A transmitter chain 512 may be configured to generate and transmit signals (e.g., control information, data, or packets). The transmitter chain 512 may include at least one modulator for modulating data onto a carrier signal, preparing the signal for transmission over a wireless medium. The at least one modulator may be configured to support one or more techniques such as amplitude modulation (AM), frequency modulation (FM), or digital modulation schemes like phase-shift keying (PSK) or quadrature amplitude modulation (QAM). The transmitter chain 512 may also include at least one power amplifier configured to amplify the modulated signal to an appropriate power level suitable for transmission over the wireless medium. The transmitter chain 512 may also include one or more antennas for transmitting the amplified signal into the air or wireless medium.

[00253] It should be appreciated by persons skilled in the art that the components in exemplary UE 500 may be changed, for example, some of the components in exemplary UE 500 may be omitted or modified or a new component(s) may be added to exemplary UE 500, without departing from the spirit and scope of the disclosure. For example, in some embodiments, the UE 500 may not include the controller 506.

[00254] FIG. 6 illustrates an example of a processor 600 in accordance with aspects of the present disclosure. The processor 600 may be an example of a processor configured to perform various operations in accordance with examples as described herein. The processor 600 may include a controller 602 configured to perform various operations in accordance with examples as described herein. The processor 600 may optionally include at least one memory 604, which may be, for example, an L1/L2/L3 cache. Additionally, or alternatively, the processor 600 may optionally include one or more arithmetic-logic units (ALUs) 606. One or more of these components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g., buses).

[00255] The processor 600 may be a processor chipset and include a protocol stack (e.g., a software stack) executed by the processor chipset to perform various operations (e.g., receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) in accordance with examples as described herein. The processor chipset may include one or more cores, one or more caches (e.g., memory local to or included in the processor chipset (e.g., the processor 600) or other memory (e.g., random access memory (RAM), read-only memory (ROM), dynamic RAM (DRAM), synchronous dynamic RAM (SDRAM), static RAM (SRAM), ferroelectric RAM (FeRAM), magnetic RAM (MRAM), resistive RAM (RRAM), flash memory, phase change memory (PCM), and others).

[00256] The controller 602 may be configured to manage and coordinate various operations (e.g., signaling, receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) of the processor 600 to cause the processor 600 to support various operations in accordance with examples as described herein. For example, the controller 602 may operate as a control unit of the processor 600, generating control signals that manage the operation of various components of the processor 600. These control signals include enabling or disabling functional units, selecting data paths, initiating memory access, and coordinating timing of operations.

[00257] The controller 602 may be configured to fetch (e.g., obtain, retrieve, receive) instructions from the memory 604 and determine a subsequent instruction(s) to be

executed to cause the processor 600 to support various operations in accordance with examples as described herein. The controller 602 may be configured to track memory address of instructions associated with the memory 604. The controller 602 may be configured to decode instructions to determine the operation to be performed and the operands involved. For example, the controller 602 may be configured to interpret the instruction and determine control signals to be output to other components of the processor 600 to cause the processor 600 to support various operations in accordance with examples as described herein. Additionally, or alternatively, the controller 602 may be configured to manage flow of data within the processor 600. The controller 602 may be configured to control transfer of data between registers, ALUs, and other functional units of the processor 600.

[00258] The memory 604 may include one or more caches (e.g., memory local to or included in the processor 600 or other memory, such RAM, ROM, DRAM, SDRAM, SRAM, MRAM, flash memory, etc. In some implementations, the memory 604 may reside within or on a processor chipset (e.g., local to the processor 600). In some other implementations, the memory 604 may reside external to the processor chipset (e.g., remote to the processor 600).

[00259] The memory 604 may store computer-readable, computer-executable code including instructions that, when executed by the processor 600, cause the processor 600 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. The controller 602 and/or the processor 600 may be configured to execute computer-readable instructions stored in the memory 604 to cause the processor 600 to perform various functions. For example, the processor 600 and/or the controller 602 may be coupled with or to the memory 604, the processor 600, the controller 602, and the memory 604 may be configured to perform various functions described herein. In some examples, the processor 600 may include multiple processors and the memory 604 may include multiple memories. One or more of the multiple processors may be coupled with one or more of the multiple memories, which may, individually or collectively, be configured to perform various functions herein.

[00260] The one or more ALUs 606 may be configured to support various operations

in accordance with examples as described herein. In some implementations, the one or more ALUs 606 may reside within or on a processor chipset (e.g., the processor 600). In some other implementations, the one or more ALUs 606 may reside external to the processor chipset (e.g., the processor 600). One or more ALUs 606 may perform one or more computations such as addition, subtraction, multiplication, and division on data. For example, one or more ALUs 606 may receive input operands and an operation code, which determines an operation to be executed. One or more ALUs 606 be configured with a variety of logical and arithmetic circuits, including adders, subtractors, shifters, and logic gates, to process and manipulate the data according to the operation. Additionally, or alternatively, the one or more ALUs 606 may support logical operations such as AND, OR, exclusive-OR (XOR), not-OR (NOR), and not-AND (NAND), enabling the one or more ALUs 606 to handle conditional operations, comparisons, and bitwise operations.

[00261] The processor 600 may support wireless communication in accordance with examples as disclosed herein. For example, the processor 600 may be configured to support means for performing the operations as described with respect to FIGs. 1-4.

[00262] For example, the processor 600 may be configured to support means for performing the operations as described with respect to FIG. 3. For example, the processor 600 may be configured to or operable to support: a means for transmitting, to a group of second devices, a first state indication signal indicating each second device of the group of second devices to switch to a first state; a means for determining, at a first time instance, that at least a percentage of second devices within the group of second devices have received the first state indication signal; and a means for transmitting, to the group of second devices, signaling for ambient IoT communication.

[00263] For example, the processor 600 may be configured to support means for performing the operations as described with respect to FIG. 4. For example, the processor 600 may be configured to or operable to support: a means for receiving, from a first device, a first state indication signal; a means for switching to a first state in response to receiving the first state indication signal; and a means for receiving, from the first device, signaling for ambient IoT communication.

[00264] It should be appreciated by persons skilled in the art that the components in

exemplary processor 600 may be changed, for example, some of the components in exemplary processor 600 may be omitted or modified or a new component(s) may be added to exemplary processor 600, without departing from the spirit and scope of the disclosure. For example, in some embodiments, the processor 600 may not include the ALUs 606.

[00265] FIG. 7 illustrates an example of an NE 700 in accordance with aspects of the present disclosure. The NE 700 may include a processor 702, a memory 704, a controller 706, and a transceiver 708. The processor 702, the memory 704, the controller 706, or the transceiver 708, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. These components may be coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces.

[00266] The processor 702, the memory 704, the controller 706, or the transceiver 708, or various combinations or components thereof may be implemented in hardware (e.g., circuitry). The hardware may include a processor, a DSP, an ASIC, or other programmable logic device, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure.

[00267] The processor 702 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, an ASIC, an FPGA, or any combination thereof). In some implementations, the processor 702 may be configured to operate the memory 704. In some other implementations, the memory 704 may be integrated into the processor 702. The processor 702 may be configured to execute computer-readable instructions stored in the memory 704 to cause the NE 700 to perform various functions of the present disclosure.

[00268] The memory 704 may include volatile or non-volatile memory. The memory 704 may store computer-readable, computer-executable code including instructions when executed by the processor 702 cause the NE 700 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as the memory 704 or another type of memory. Computer-readable media includes both non-transitory computer storage media and communication media

including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that may be accessed by a general-purpose or special-purpose computer.

[00269] In some implementations, the processor 702 and the memory 704 coupled with the processor 702 may be configured to cause the NE 700 to perform one or more of the functions described herein (e.g., executing, by the processor 702, instructions stored in the memory 704). For example, the processor 702 may support wireless communication at the NE 700 in accordance with examples as disclosed herein. For example, the NE 700 may be configured to support means for performing the operations as described with respect to FIGs. 1-3.

[00270] For example, the NE 700 may be configured to support: a means for transmitting, to a group of second devices, a first state indication signal indicating each second device of the group of second devices to switch to a first state; a means for determining, at a first time instance, that at least a percentage of second devices within the group of second devices have received the first state indication signal; and a means for transmitting, to the group of second devices, signaling for ambient IoT communication.

[00271] The controller 706 may manage input and output signals for the NE 700. The controller 706 may also manage peripherals not integrated into the NE 700. In some implementations, the controller 706 may utilize an operating system such as iOS®, ANDROID®, WINDOWS®, or other operating systems. In some implementations, the controller 706 may be implemented as part of the processor 702.

[00272] In some implementations, the NE 700 may include at least one transceiver 708. In some other implementations, the NE 700 may have more than one transceiver 708. The transceiver 708 may represent a wireless transceiver. The transceiver 708 may include one or more receiver chains 710, one or more transmitter chains 712, or a combination thereof.

[00273] A receiver chain 710 may be configured to receive signals (e.g., control information, data, or packets) over a wireless medium. For example, the receiver chain 710 may include one or more antennas for receive the signal over the air or

wireless medium. The receiver chain 710 may include at least one amplifier (e.g., an LNA) configured to amplify the received signal. The receiver chain 710 may include at least one demodulator configured to demodulate the receive signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receiver chain 710 may include at least one decoder for decoding the processing the demodulated signal to receive the transmitted data.

[00274] A transmitter chain 712 may be configured to generate and transmit signals (e.g., control information, data, or packets). The transmitter chain 712may include at least one modulator for modulating data onto a carrier signal, preparing the signal for transmission over a wireless medium. The at least one modulator may be configured to support one or more techniques such as AM, FM, or digital modulation schemes like PSK or QAM. The transmitter chain 712 may also include at least one power amplifier configured to amplify the modulated signal to an appropriate power level suitable for transmission over the wireless medium. The transmitter chain 712 may also include one or more antennas for transmitting the amplified signal into the air or wireless medium.

[00275] It should be appreciated by persons skilled in the art that the components in exemplary NE 700 may be changed, for example, some of the components in exemplary NE 700 may be omitted or modified or a new component(s) may be added to exemplary NE 700, without departing from the spirit and scope of the disclosure. For example, in some embodiments, the NE 700 may not include the controller 706.

[00276] FIG. 8 illustrates a block diagram of exemplary apparatus 800 according to some embodiments of the present disclosure. As shown in FIG. 8, the apparatus 800 may include at least one processor 806 and at least one transceiver 802 coupled to the processor 806. The apparatus 800 may be an IoT device (e.g., an ambient IoT tag).

[00277] Although in this figure, elements such as the at least one transceiver 802 and processor 806 are described in the singular, the plural is contemplated unless a limitation to the singular is explicitly stated. In some embodiments of the present disclosure, the transceiver 802 may be divided into two devices, such as a receiving circuitry and a transmitting circuitry. In some embodiments of the present disclosure, the apparatus 800 may further include an input device, a memory, and/or other

components.

[00278] In some embodiments of the present disclosure, the transceiver 802 and the processor 806 may interact with each other so as to perform the operations with respect to the IoT device or the second device described in the foregoing embodiments such as FIGs. 1-4.

[00279] In some embodiments of the present disclosure, the apparatus 800 may further include at least one non-transitory computer-readable medium. For example, in some embodiments of the present disclosure, the non-transitory computer-readable medium may have stored thereon computer-executable instructions to cause the processor 806 to implement the method with respect to the IoT device or the second device as described above. For example, the computer-executable instructions, when executed, cause the processor 806 interacting with transceiver 802 to perform the operations with respect to the second device described in FIGs. 3 and 4.

[00280] Those having ordinary skill in the art would understand that the operations or steps of the methods described in connection with the aspects disclosed herein may be embodied directly in hardware, in a software module executed by a processor, or in a combination of the two. A software module may reside in RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, a hard disk, a removable disk, a CD-ROM, or any other form of storage medium known in the art. Additionally, in some aspects, the operations or steps of the methods may reside as one or any combination or set of codes and/or instructions on a non-transitory computer-readable medium, which may be incorporated into a computer program product.

[00281] While this disclosure has been described with specific embodiments thereof, it is evident that many alternatives, modifications, and variations may be apparent to those skilled in the art. The disclosure is not limited to the examples and designs described herein but is to be accorded with the broadest scope consistent with the principles and novel features disclosed herein. For example, various components of the embodiments may be interchanged, added, or substituted in other embodiments. Also, all of the elements of each figure are not necessary for the operation of the disclosed embodiments. For example, one of ordinary skill in the art of the disclosed embodiments would be enabled to make and use the teachings of the disclosure by

simply employing the elements of the independent claims. Accordingly, embodiments of the disclosure as set forth herein are intended to be illustrative, not limiting. Various changes may be made without departing from the spirit and scope of the disclosure.

[00282] In this document, the terms "includes," "including," or any other variation thereof, are intended to cover a non-exclusive inclusion, such that a process, method, article, or apparatus that includes a list of elements does not include only those elements but may include other elements not expressly listed or inherent to such process, method, article, or apparatus. An element proceeded by "a," "an," or the like does not, without more constraints, preclude the existence of additional identical elements in the process, method, article, or apparatus that includes the element. Also, the term "another" is defined as at least a second or more. The term "having" or the like, as used herein, is defined as "including." Expressions such as "A and/or B" or "at least one of A and B" may include any and all combinations of words enumerated along with the expression. For instance, the expression "A and/or B" or "at least one of A and B" may include A, B, or both A and B. The wording "the first," "the second" or the like is only used to clearly illustrate the embodiments of the present disclosure, but is not used to limit the substance of the present disclosure.

WHAT IS CLAIMED:

1. A first device, comprising:

at least one memory; and

at least one processor coupled with the at least one memory and configured to cause the first device to:

transmit, to a group of second devices, a first state indication signal indicating each second device of the group of second devices to switch to a first state;

determine, at a first time instance, that at least a percentage of second devices within the group of second devices have received the first state indication signal; and

transmit, to the group of second devices, signaling for ambient internet of things (IoT) communication.

2. The first device of claim 1, wherein the first state indication signal is a low voltage signal, a high voltage signal, a pre-known first sequence, a pre-known ON-OFF pattern, or carried in a physical channel; and.

wherein the physical channel comprises at least one of a first indicator indicating the first state or a second indicator indicating one of:

a time period during which the second device does not monitor the first state indication signal and the signaling for ambient IoT communication, and after which the second device monitors the signaling for ambient IoT communication;

a time period during which the second device does not monitor the first state indication signal and the signaling for ambient IoT communication, and after which the second device monitors the first state indication signal and the signaling for ambient IoT communication;

a time period during which the second device does not monitor the first state indication signal and a second state indication signal, and after which the second device monitors the second state indication signal or both the first state indication signal and the second state indication signal; and a time period during which the second device does not monitor the first state indication signal and one or more of a third state indication signal and a fourth state indication signal, and after which the second device monitors the first state indication signal and the one or more of the third state indication signal and the fourth state indication signal.

3. The first device of claim 1, wherein the first state indication signal indicates each second device in the group of second devices to switch to an active state to monitor the signaling for ambient IoT communication; or

wherein the first state indication signal indicates each second device in the group of second devices to switch to an inactive state for a first time period during which the second device monitors the first state indication signal and the signaling for IoT communication is transmitted after the first time period; or

wherein the first state indication signal indicates each second device in the group of second devices to switch to the inactive state.

4. The first device of claim 1, wherein the at least one processor is configured to cause the first device to:

transmit, to the group of second devices, a second state indication signal indicating each second device of the group of second devices to switch to an active state to monitor the signaling for ambient IoT communication;

transmit, to first type second devices in the group of second devices, a third state indication signal indicating each first type second device in the group of second devices to switch to the active state to monitor the signaling for ambient IoT communication; or

transmit, to second type second devices in the group of second devices, the third state indication signal indicating each second type second device in the group of second devices to switch to the inactive state.

5. The first device of claim 4, wherein the second state indication signal is a high voltage signal, a low voltage signal, a pre-known second sequence, a pre-known ON-OFF pattern, or carried in a physical channel; and

wherein the physical channel comprises at least one of a first indicator indicating the active state or a second indicator indicating a time period during which the second device does not monitor the first state indication signal and the second state indication signal, and after which the second device monitors the first state indication signal and the second state indication signal.

6. The first device of claim 4, wherein the third state indication signal is a high voltage signal, a low voltage signal, a pre-known third sequence, a pre-known ON-OFF pattern, or carried in a physical channel; and

wherein the physical channel comprises at least one of:

a first indicator indicating the active state for the first type second device, the inactive state for the second type second device, or both; or

a second indicator indicating a time period during which the first type second device does not monitor the first state indication signal and the third state indication signal, and after which the first type second device monitors the first state indication signal and the third state indication signal.

7. The first device of claim 4, wherein the at least one processor is configured to cause the first device to:

in response to transmitting the third state indication signal, transmit, to second type second devices in the group of second devices, a fourth state indication signal indicating each second type second device in the group of second devices to switch to the active state to monitor the signaling for ambient IoT communication.

8. The first device of claim 7, wherein the fourth state indication signal is a low voltage signal, a high voltage signal, a pre-known fourth sequence, a pre-known ON-OFF pattern, or carried in a physical channel; and

wherein the physical channel comprises at least one of a first indicator indicating the active state for the second type second device or a second indicator indicating a time period during which the second type second device does not monitor the first state indication signal and one or more of the third state indication signal and the fourth state indication signal, and after which the second type second device monitors the first state indication signal and the one or more of the third state indication signal and the fourth state indication signal.

9. A second device, comprising:

at least one memory; and

at least one processor coupled with the at least one memory and configured to cause the second device to:

receive, from a first device, a first state indication signal;

switch to a first state in response to receiving the first state indication signal; and

receive, from the first device, signaling for ambient internet of things (IoT) communication.

10. The second device of claim 9, wherein the first state indication signal is a low voltage signal, a high voltage signal, a pre-known first sequence, a pre-known ON-OFF pattern, or carried in a physical channel.

11. The second device of claim 10, wherein the physical channel comprises at least one of a first indicator indicating the first state or a second indicator indicating one of:

a time period during which the second device does not monitor the first state indication signal and the signaling for ambient IoT communication, and after which the second device monitors the signaling for ambient IoT communication;

a time period during which the second device does not monitor the first state indication signal and the signaling for ambient IoT communication, and after which the second device monitors the first state indication signal and the signaling for ambient IoT communication;

a time period during which the second device does not monitor the first state indication signal and a second state indication signal, and after which the second device monitors the second state indication signal or both the first state indication signal and the second state indication signal; and

a time period during which the second device does not monitor the first state indication signal and one or more of a third state indication signal and a fourth state indication signal, and after which the second device monitors the first state indication signal and the one or more of the third state indication signal and the fourth state indication signal.

12. The second device of claim 9, wherein the first state indication signal indicates the second device to switch to an active state to monitor the signaling for ambient IoT communication;

wherein the first state indication signal indicates the second device to switch to an inactive state for a first time period and the at least one processor is configured to cause the second device to monitor the first state indication signal and switch to the active state to monitor the signaling for IoT communication in response to not detecting the first state indication signal during the first time period; or

wherein the first state indication signal indicates the second device to switch to the inactive state.

13. The second device of claim 9, wherein the at least one processor is configured to cause the second device to:

receive a second state indication signal indicating the second device to switch to an active state to monitor the signaling for ambient IoT communication;

in response to the second device being a first type second device, receive a third state indication signal indicating the second device to switch to the active state to monitor the signaling for ambient IoT communication;

in response to the second device being a second type second device, receive the third state indication signal indicating the second device to switch to the inactive state; or

in response to the second device being the second type second device, receive a fourth state indication signal indicating the second device to switch to the active state to monitor the signaling for ambient IoT communication.

14. The second device of claim 13, wherein the second state indication signal is a high voltage signal, a low voltage signal, a pre-known second sequence, a pre-known ON-OFF pattern, or carried in a physical channel; and

wherein the physical channel comprises at least one of a first indicator indicating the active state or a second indicator indicating a time period during which the second device does not monitor the first state indication signal and the second state indication signal, and after which the second device monitors the first state indication signal and the second state indication signal.

15. The second device of claim 13, wherein the third state indication signal is a high voltage signal, a low voltage signal, a pre-known third sequence, a pre-known ON-OFF pattern, or carried in a physical channel.

16. The second device of claim 15, wherein the physical channel comprises at least one of:

a first indicator indicating the active state for the first type second device, the inactive state for the second type second device, or both; or

a second indicator indicating a time period during which the first type second device does not monitor the first state indication signal and the third state indication signal, and after which the first type second device monitors the first state indication signal and the third state indication signal.

17. The second device of claim 13, wherein the fourth state indication signal is a low voltage signal, a high voltage signal, a pre-known fourth sequence, a pre-known ON-OFF pattern, or carried in a physical channel.

18. The second device of claim 17, wherein the physical channel comprises at least one of a first indicator indicating the active state for the second type second device or a second indicator indicating a time period during which the second type second device does not monitor the first state indication signal and one or more of the third state indication signal and the fourth state indication signal, and after which the second type second device monitors the first state indication signal and the one or more of the third state indication signal and the fourth state indication signal.

19. A processor, comprising:

at least one controller coupled with at least one memory and configured to cause the processor to:

transmit, to a group of second devices, a first state indication signal indicating each second device of the group of second devices to switch to a first state;

determine, at a first time instance, that at least a percentage of second devices within the group of second devices have received the first state indication signal; and

transmit, to the group of second devices, signaling for ambient internet of things (IoT) communication.

20. A method for wireless communication, comprising:

transmitting, to a group of second devices, a first state indication signal indicating each second device of the group of second devices to switch to a first state;

determining, at a first time instance, that at least a percentage of second devices within the group of second devices have received the first state indication signal; and

transmitting, to the group of second devices, signaling for ambient internet of things (IoT) communication.

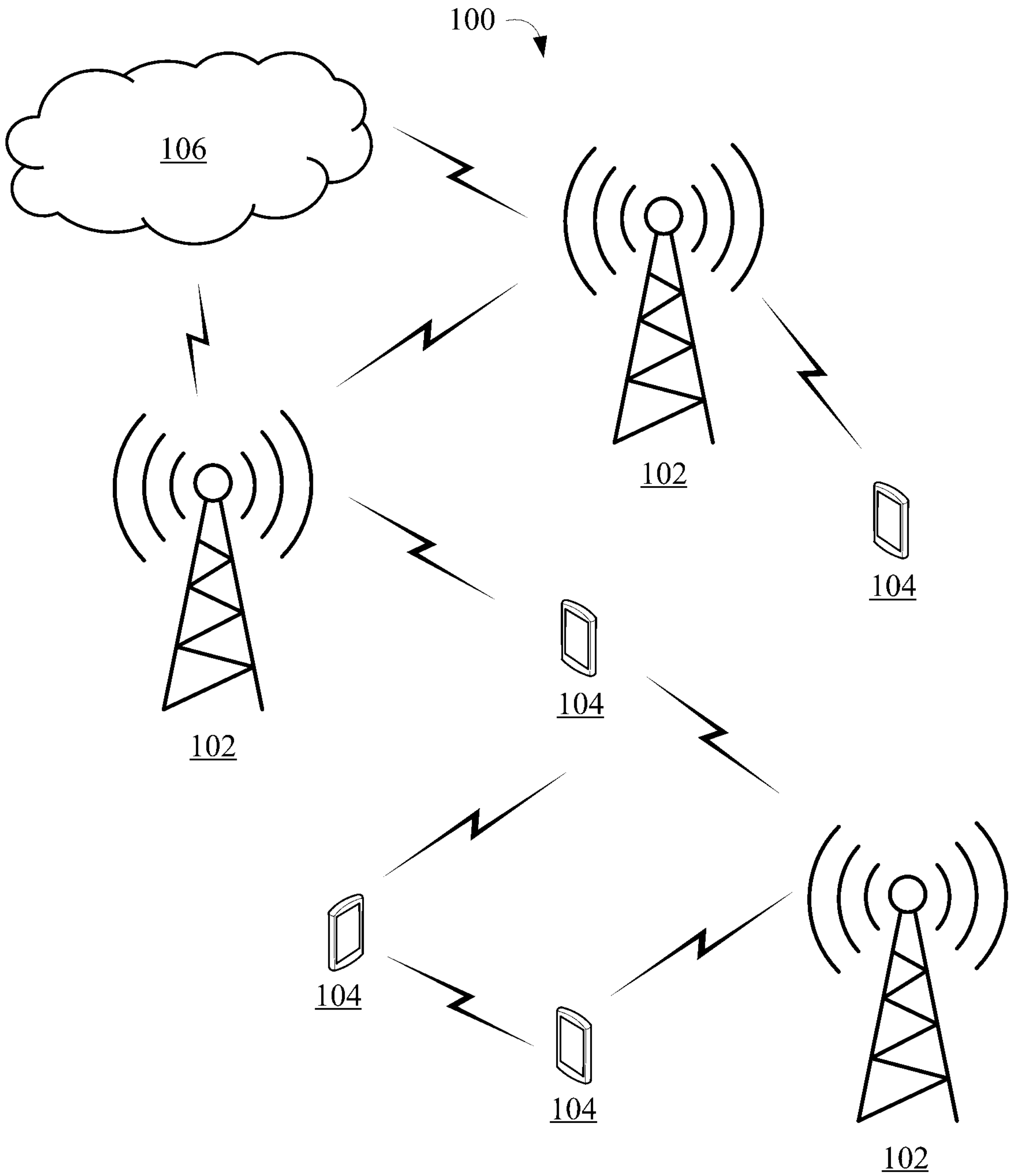

FIG. 1

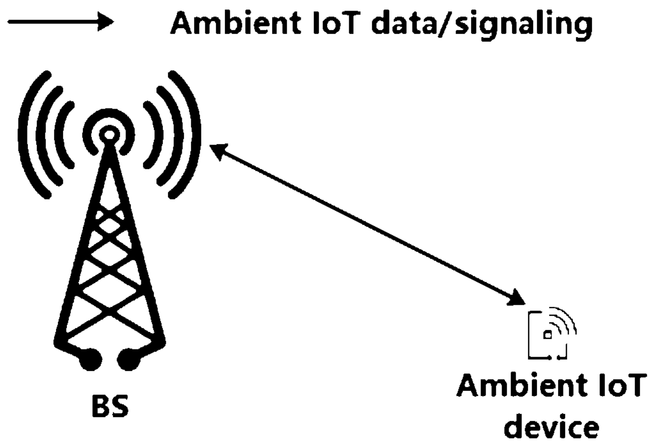

FIG. 2A

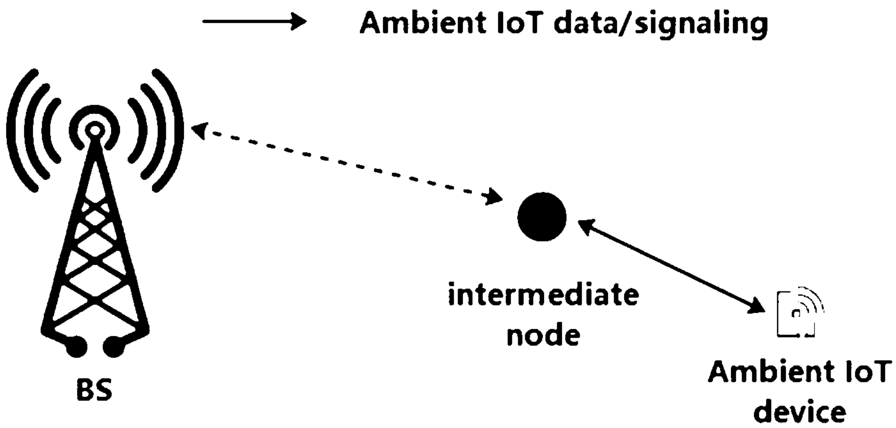

FIG. 2B

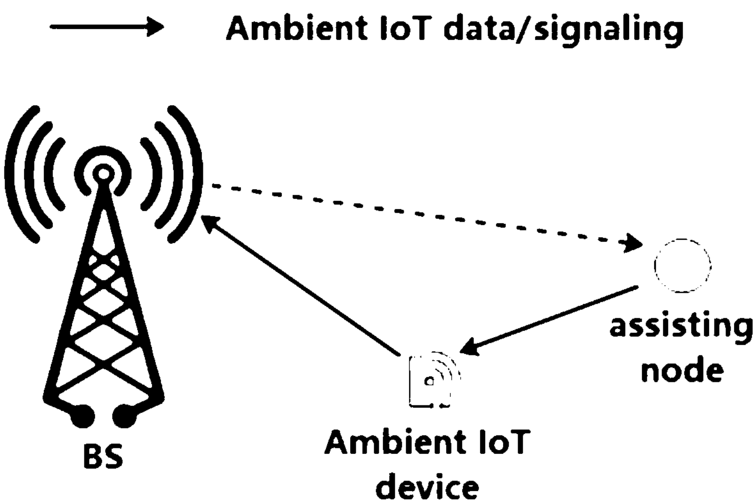

FIG. 2C

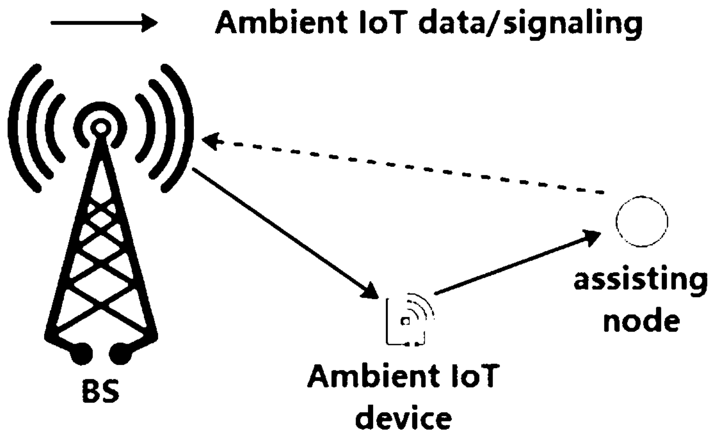
Ambient IoT data/signaling
BS
Ambient IoT device
assisting node

FIG. 2D

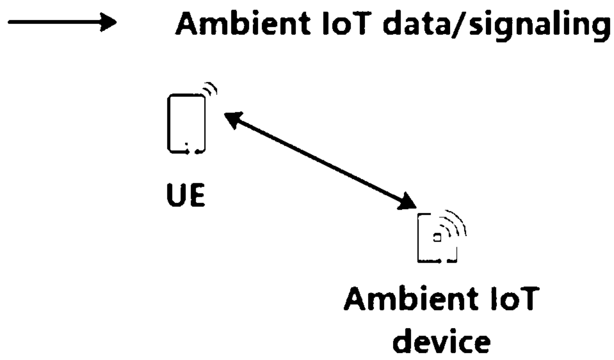
Ambient IoT data/signaling
UE
Ambient IoT device

FIG. 2E

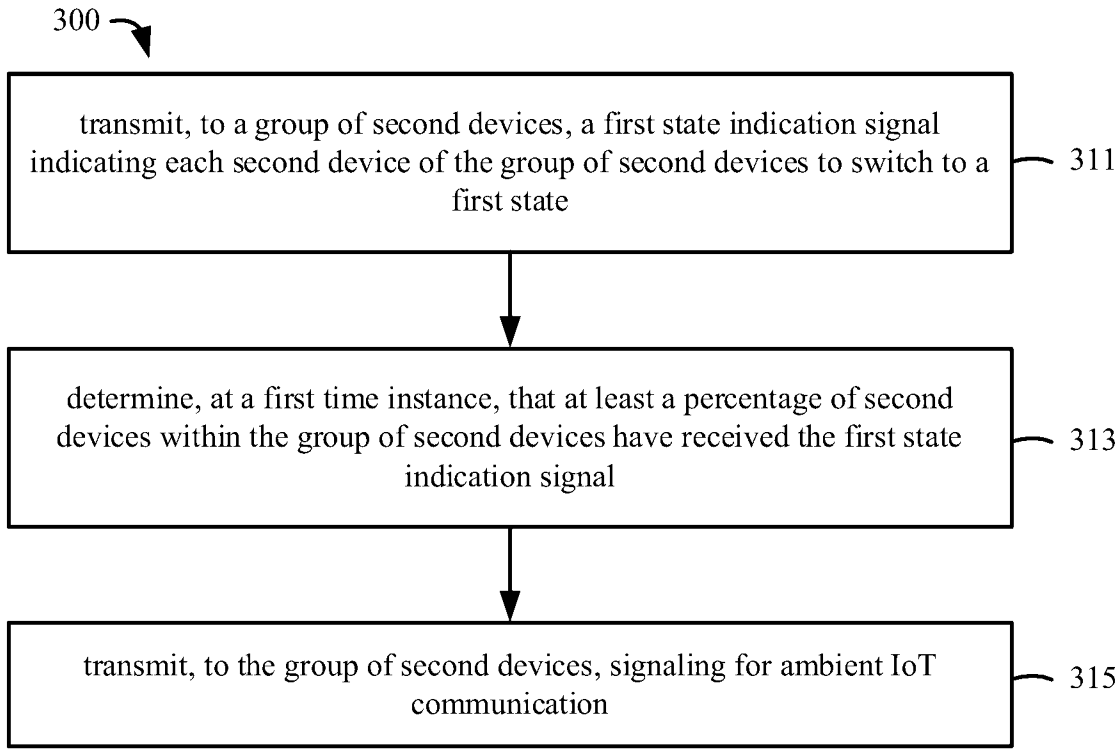
300
transmit, to a group of second devices, a first state indication signal indicating each second device of the group of second devices to switch to a first state
311
determine, at a first time instance, that at least a percentage of second devices within the group of second devices have received the first state indication signal
313
transmit, to the group of second devices, signaling for ambient IoT communication
315

FIG. 3

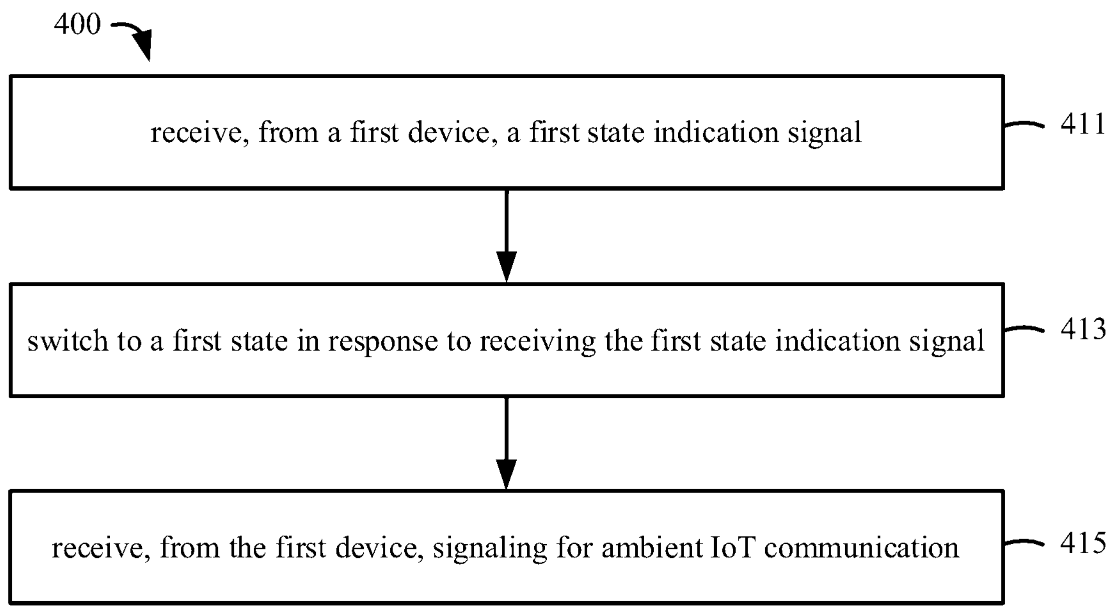
400
receive, from a first device, a first state indication signal
411
switch to a first state in response to receiving the first state indication signal
413
receive, from the first device, signaling for ambient IoT communication
415

FIG. 4

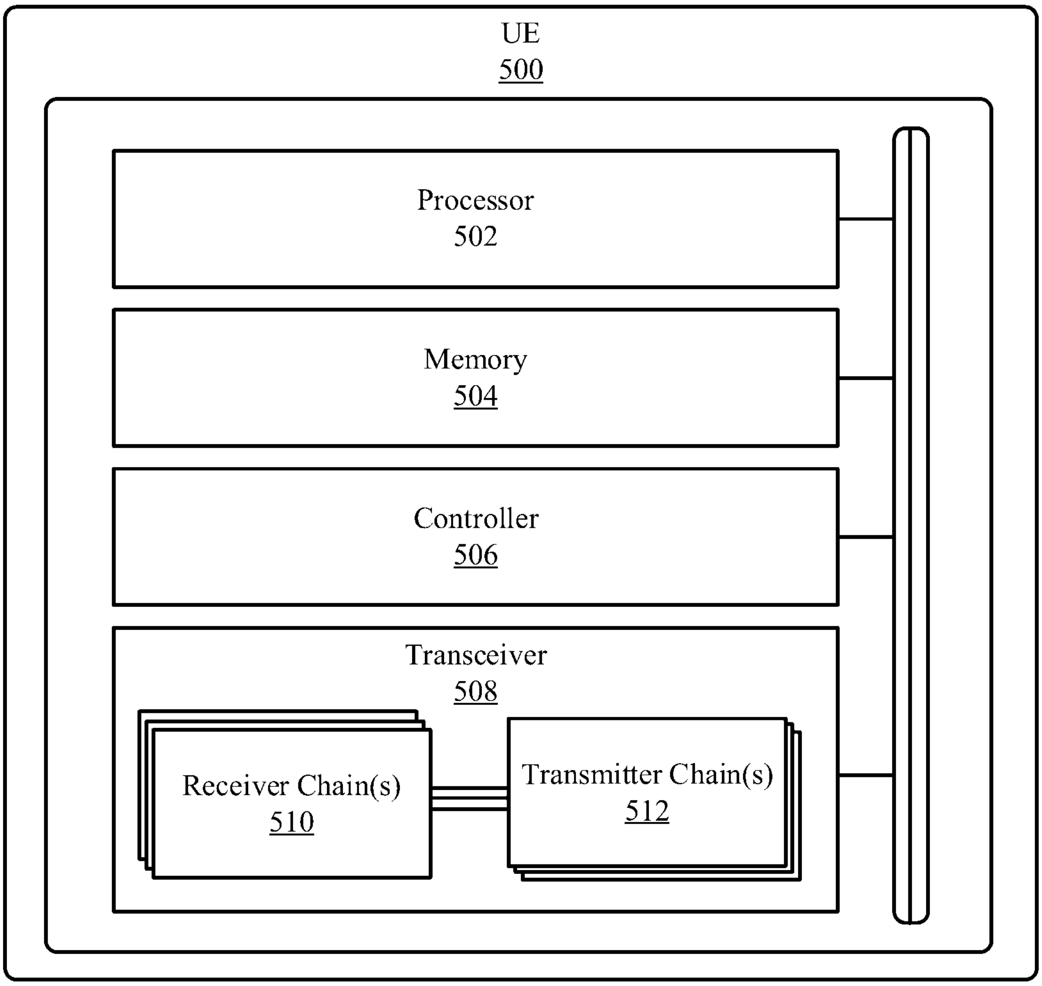
UE
500
Processor
502
Memory
504
Controller
506
Transceiver
508
Receiver Chain(s)
510
Transmitter Chain(s)
512

FIG. 5

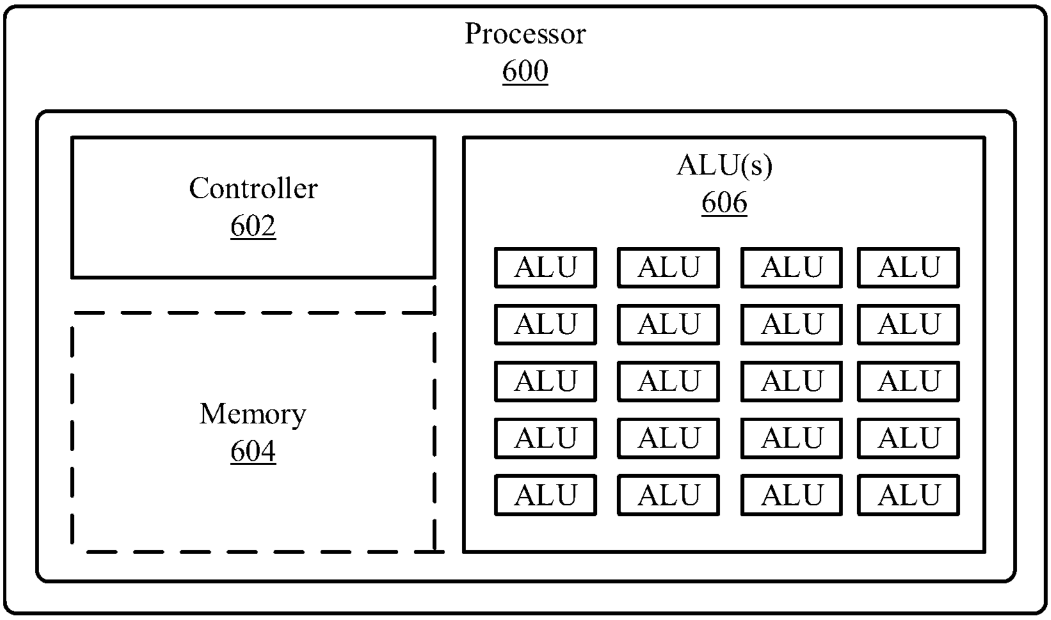
Processor
600
Controller
602
Memory
604
ALU(s)
606
ALU

FIG. 6

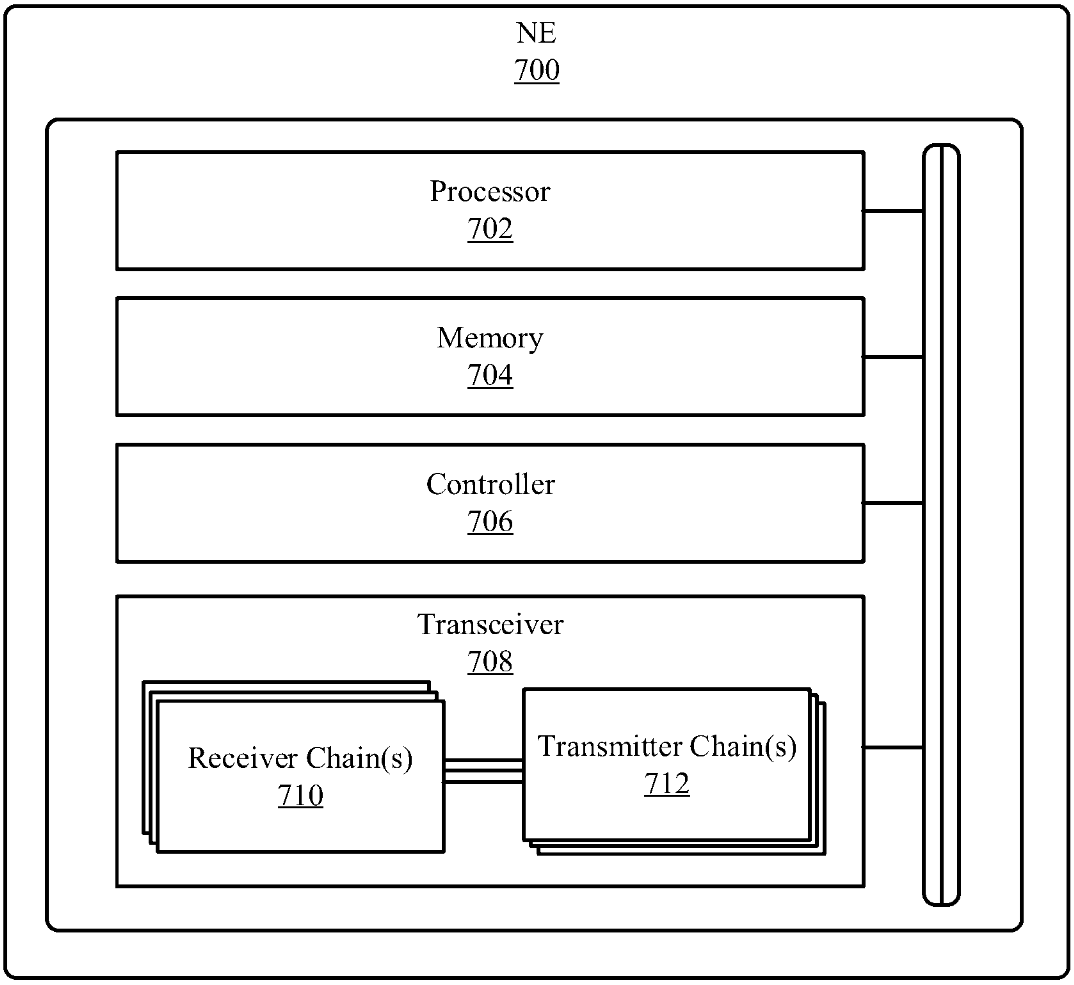
NE
700
Processor
702
Memory
704
Controller
706
Transceiver
708
Receiver Chain(s)
710
Transmitter Chain(s)
712

FIG. 7

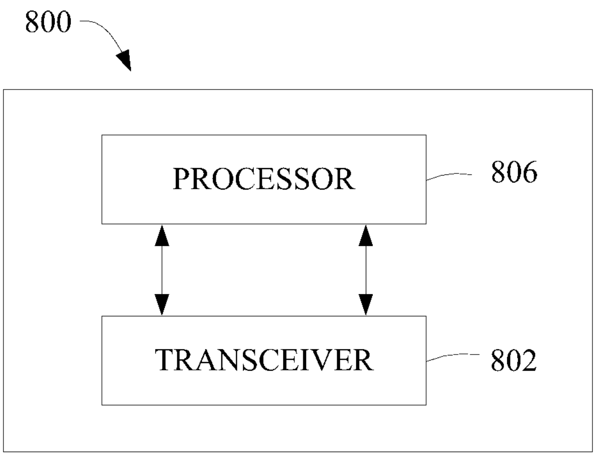
800
PROCESSOR
806
TRANSCEIVER
802

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2024/111241

A. CLASSIFICATION OF SUBJECT MATTER

H04W 8/14(2009.01)i

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)

IPC:H04W H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNTXT, ENTXT, WPABS, DWPI, VCN, CNKI, 3GPP: Internet of Things, IoT, AIoT, activate, wake, tag, each, switch, every, receive, deactivate, sleep, silent, off, low voltage, high voltage, sequence

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 117973421 A (BOE TECHNOLOGY GROUP CO., LTD.) 03 May 2024 (2024-05-03) description paragraphs 0103-0190,0243, figure 3	9-18
Y	CN 117973421 A (BOE TECHNOLOGY GROUP CO., LTD.) 03 May 2024 (2024-05-03) description paragraphs 0103-0190,0243, figure 3	1-8,19-20
Y	CN 117527006 A (BEIJING UNIVERSITY OF POSTS AND TELECOMMUNICATIONS) 06 February 2024 (2024-02-06) description paragraphs 0067-0073	1-8,19-20
X	CN 111712727 A (HUAWEI TECHNOLOGIES CO., LTD.) 25 September 2020 (2020-09-25) description paragraphs 0085-0124	9-18
A	CN 116502655 A (HUAWEI TECHNOLOGIES CO., LTD. et al.) 28 July 2023 (2023-07-28) the whole document	1-20
A	KR 20180131818 A (DEP SOLUTION CO., LTD.) 11 December 2018 (2018-12-11) the whole document	1-20

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"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	Date of mailing of the international search report
25 April 2025	**06 May 2025**

Name and mailing address of the ISA/CN	Authorized officer
CHINA NATIONAL INTELLECTUAL PROPERTY ADMINISTRATION **6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088, China**	**LIU,WenWen** Telephone No. **(+86) 010-53961662**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2024/111241

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	117973421	A	03 May 2024	None			
CN	117527006	A	06 February 2024	None			
CN	111712727	A	25 September 2020	WO	2019158187	A1	22 August 2019
CN	116502655	A	28 July 2023	WO	2023138409	A1	27 July 2023
KR	20180131818	A	11 December 2018	KR	101984224	B1	30 May 2019