

DEVICES AND METHODS OF COMMUNICATION

TECHNICAL FIELD

[0001] The present disclosure relates to wireless communications, and more specifically to devices and methods of communication for ambient Internet of things (A-IoT).

BACKGROUND

[0002] A wireless communications system may include one or multiple network communication devices, such as base stations, which may be otherwise known as an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. Each network communication devices, such as a base station may support wireless communications for one or multiple user communication devices, which may be otherwise known as user equipment (UE), or other suitable terminology. The wireless communications system may support wireless communications 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). Additionally, the wireless communications system may support wireless communications across various radio access technologies including third generation (3G) radio access technology, fourth generation (4G) radio access technology, fifth generation (5G) radio access technology, among other suitable radio access technologies beyond 5G (e.g., sixth generation (6G)).

[0003] A-IoT is an Internet of things (IoT) technology of supporting battery-less devices with no energy storage capability or devices with energy storage that do not need to be replaced or recharged manually. Recently, it is proposed to design a compact protocol stack and corresponding procedures for A-IoT, e.g., paging, random access, data transmission, etc.

SUMMARY

[0004] The present disclosure relates to methods, devices, and systems that support a paging for an A-IoT device. By responding to at least part of messages for paging an A-IoT device from different entities, an A-IoT device may handle a paging scenario.

[0005] In one aspect, some implementations of the method and devices described herein may comprise: receiving, from a set of second devices, a set of messages for paging the first device; and in accordance with a determination that a subset of messages in the set of messages fulfils a condition, responding to the subset of messages.

[0006] In some implementations of the method and devices described herein, the condition may comprise at least one of the following: a message in the subset of messages indicates identification information of the first device; the message indicates an area in which the first device is located; the message is transmitted by a second device in a configured list of second devices; or the message indicates a resource available for the first device to respond to the message.

[0007] In some implementations of the method and devices described herein, the subset of messages may comprise a plurality of messages, and responding to the subset of messages may comprise: selecting a message from the plurality of messages; and responding to the message.

[0008] In some implementations of the method and devices described herein, selecting the message may comprise: selecting the message based on at least one of the following: energy harvesting efficiency of the message; a priority of a cause of the message; reception time of the message; response time of the message; a priority of a second device in the set of second devices; a priority of a response to the message; an access control configuration from a second device in the set of second devices; or a random selection.

[0009] In some implementations of the method and devices described herein, responding to the subset of messages may comprise: receiving, from the set of second devices, a set of control signaling for the set of messages; selecting a control signaling in the set of control signaling; and in accordance with a determination that a message corresponding to the control signaling fulfills the condition, responding to the message.

[0010] In some implementations of the method and devices described herein, selecting the control signaling may comprise: selecting the control signaling based on at least one of the following: reception time of the control signaling; a priority of a second device in the set of second devices; a priority of a response to the control signaling; a payload size of the control signaling; or a random selection.

[0011] In some implementations of the method and devices described herein, responding to the subset of messages may comprise: receiving, from the set of second devices via the transceiver, a set of control signaling for the set of messages; decoding the set of messages for the set of control signaling; selecting a message in the set of messages that fulfills the condition; and responding to the message.

[0012] Some implementations of the method and devices described herein may further comprise: in accordance with a determination that no response to an initial transmission of a message in the subset of messages is made, making no response to a set of repeated transmissions of the message; or in accordance with a determination that a response to a message in the set of messages is failed, responding to one or more messages in the set of messages.

[0013] In some implementations of the method and devices described herein, the subset of messages may comprise a plurality of messages, and responding to the subset of messages may comprise: responding to the plurality of messages in parallel based on at least one of the following: the plurality of messages indicate different causes; the plurality of messages indicate non-conflicted resources for response; or the plurality of messages indicate different service identities.

[0014] Some implementations of the method and devices described herein may further comprise: in accordance with a determination that an ongoing procedure between the first device and a second device is maintained while the set of messages for paging the first device are received, making no response to the set of messages.

[0015] Some implementations of the method and devices described herein may further comprise: in accordance with a determination that an ongoing procedure between the first device and a second device is maintained while the set of messages for paging the first device are received, responding to a message in the set of messages that indicates at least one of the following: a cause requiring no uplink transmission; a resource for a response to the message that does not conflict with the ongoing procedure; or a service identity different from a service identity of the ongoing procedure.

[0016] In some implementations of the method and devices described herein, responding to the message may comprise: in accordance with a determination that the service identity of the message indicates a service having a priority higher than a

priority of a service of the ongoing procedure and the resource does not conflict with the ongoing procedure, responding to the message.

[0017] Some implementations of the method and devices described herein may further comprise: in accordance with a determination that the resource conflicts with the ongoing procedure, aborting the ongoing procedure.

[0018] In some implementations of the method and devices described herein, in accordance with a determination that a message from a second device is responded, setting a status of the first device as inventoried; or in accordance with a determination that an ongoing procedure is maintained, setting the status of the first device as active.

[0019] In some implementations of the method and devices described herein, the first device is an A-IoT device, and the second device is a base station or a communication node between the base station and the A-IoT device.

[0020] In another aspect, some implementations of the method and devices described herein may comprise: transmitting a message for paging a first device; receiving, from the first device, a response to the message; and transmitting information of the first device to a third device.

[0021] In some implementations of the method and devices described herein, the information of the first device may comprise at least one of the following: an identity of the first device; an identity of an ongoing service of the first device; or a status of the first device.

[0022] Some implementations of the method and devices described herein may further comprise: in accordance with a determination that the response to the message is received, set a status of the first device as inventoried; or in accordance with a determination that an ongoing procedure between the first device and the second device is maintained, set the status of the first device as active.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] FIG. 1 illustrates an example of a wireless communications system that supports a paging for an A-IoT device in accordance with aspects of the present disclosure.

[0024] FIG. 2 illustrates an example of a process that supports a paging for an A-IoT device in accordance with aspects of the present disclosure.

[0025] FIG. 3 illustrates an example of a device that supports a paging for an A-IoT device in accordance with aspects of the present disclosure.

[0026] FIG. 4 illustrates an example of a processor that supports a paging for an A-IoT device in accordance with aspects of the present disclosure.

[0027] FIG. 5 illustrates a flowchart of a method that supports a paging for an A-IoT device in accordance with aspects of the present disclosure.

[0028] FIG. 6 illustrates a flowchart of another method that supports a paging for an A-IoT device in accordance with aspects of the present disclosure.

DETAILED DESCRIPTION

[0029] Principles of the present disclosure will now be described with reference to some embodiments. It is to be understood that these embodiments are described only for the purpose of illustration and help those skilled in the art to understand and implement the present disclosure, without suggesting any limitation as to the scope of the disclosure. The disclosure described herein may be implemented in various manners other than the ones described below.

[0030] In the following description and claims, unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skills in the art to which this disclosure belongs.

[0031] References in the present disclosure to “one embodiment,” “an example embodiment,” “an embodiment,” “some embodiments,” and the like indicate that the embodiment(s) described may include a particular feature, structure, or characteristic, but it is not necessary that every embodiment includes the particular feature, structure, or characteristic. Moreover, such phrases do not necessarily refer to the same embodiment(s). Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to affect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described. The term “embodiment” may be interchangeably used with “implementation”.

[0032] It shall be understood that although the terms “first” and “second” or the like may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another element. For example, a first element could also be termed as a second element, and similarly, a second element could also be termed as a first element, without departing from the scope of implementations. As used herein, the term “and/or” includes any and all combinations of one or more of the listed terms.

[0033] The terminology used herein is for the purpose of describing particular implementations only and is not intended to be limiting of example implementations. As used herein, the singular forms “a”, “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises”, “comprising”, “has”, “having”, “includes” and/or “including”, when used herein, specify the presence of stated features, elements, and/or components etc., but do not preclude the presence or addition of one or more other features, elements, components and/ or combinations thereof.

[0034] In some scenarios, an A-IoT device may receive multiple paging messages from different entities (e.g., a base station, a communication node between a base station and the A-IoT device, etc.). In this case, A-IoT device's behaviors to handle or respond to the different paging messages need to be defined.

[0035] Embodiments of the present disclosure provide a solution of a paging for an A-IoT device. In one aspect, a first device (i.e., A-IoT device) may receive a set of messages for paging the first device from a set of second devices. If a subset of messages in the set of messages fulfils a condition, the first device may respond to the subset of messages. In this way, by only responding to a message fulfilling a condition, a paging for an A-IoT device may be carried out in an efficient way and thus communication efficiency may be improved. Further, energy consumption at the A-IoT device may be reduced.

[0036] In another aspect, a second device may transmit a message for paging a first device, and receive a response to the message from the first device. The second device may transmit information of the first device to a third device. In this way, management of a paging for an A-IoT device may be optimized.

[0037] In the context of the present disclosure, the term “first device” may refer to a battery-less device with no energy storage capability or a device with energy storage that do not need to be replaced or recharged manually. The term “first device” may be interchangeably used with “A-IoT device” or “A-IoT UE”. The term “A-IoT” may be interchangeably used with “passive IoT”.

[0038] In the context of the present disclosure, the term “second device” refers to a node communicating with an A-IoT device. For example, the node may be a base station or a communication node between the base station and the A-IoT device. For example, the communication node may be a relay, integrated access and backhaul (IAB) node, UE, repeater, etc. which is capable of A-IoT. In some embodiments, the second device may be a node providing excitation signal or energy to the A-IoT device. In some embodiments, the second device may be a node transmitting a command to the A-IoT device to implement a selection, inventory or access (e.g., read and write) to the A-IoT device.

[0039] Aspects of the present disclosure are described in the context of a wireless communications system.

[0040] FIG. 1 illustrates an example of a wireless communications system 100 that supports a paging for an A-IoT device in accordance with aspects of the present disclosure. The wireless communications system 100 may include one or more network entities (also referred to as network equipment (NE)). For convenience, network entities 102-1, 102-2 and 102-3 are shown and are collectively referred to as one or more network entities 102 hereinafter. The wireless communications system 100 may further include one or more A-IoT devices 101, one or more UEs 104, a core network (CN) 106, and a packet data network 108. The wireless communications system 100 may support various radio access technologies. In some implementations, the wireless communications 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 communications system 100 may be a 5G network, such as an NR network. In other implementations, the wireless communications 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), IEEE 802.20. The wireless communications system 100 may support radio

access technologies beyond 5G. Additionally, the wireless communications system 100 may support technologies, such as time division multiple access (TDMA), frequency division multiple access (FDMA), or code division multiple access (CDMA), etc.

[0041] The one or more A-IoT devices 101 may be dispersed throughout a geographic region of the wireless communications system 100. An A-IoT device 101 may be a battery-less device with no energy storage capability or a device with energy storage that do not need to be replaced or recharged manually. The A-IoT device 101 may comprise an energy harvesting module and a backscattering module. The A-IoT device 101 may receive an energy supply signal or command via the energy harvesting module and backscatter a signal via the backscattering module.

[0042] The one or more network entities 102 may be dispersed throughout a geographic region to form the wireless communications system 100. One or more of the network entities 102 described herein may be or include or may be referred to as a network node, a base station, a network element, a radio access network (RAN), a base transceiver station, an access point, a NodeB, an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. A network entity 102 and a UE 104 may communicate via a communication link 110, which may be a wireless or wired connection. For example, a network entity 102 and a UE 104 may perform wireless communication (e.g., receive signaling, transmit signaling) over a Uu interface.

[0043] A network entity 102 may provide a geographic coverage area 112 for which the network entity 102 may support services (e.g., voice, video, packet data, messaging, broadcast, etc.) for one or more UEs 104 within the geographic coverage area 112. For example, a network entity 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, a network entity 102 may be moveable, for example, a satellite associated with a non-terrestrial network. 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 112 may be associated with different network entities 102. Information and signals described herein may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced

throughout the description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

[0044] The one or more UEs 104 may be dispersed throughout a geographic region of the wireless communications system 100. A UE 104 may include or may be referred to as a mobile device, a wireless device, a remote device, a remote unit, a handheld device, or a subscriber 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. In some implementations, a UE 104 may be stationary in the wireless communications system 100. In some other implementations, a UE 104 may be mobile in the wireless communications system 100.

[0045] The one or more UEs 104 may be devices in different forms or having different capabilities. Some examples of UEs 104 are illustrated in FIG. 1. A UE 104 may be capable of communicating with various types of devices, such as the network entities 102, other UEs 104, or network equipment (e.g., the core network 106, the packet data network 108, a relay device, an IAB node, or another network equipment), as shown in FIG. 1. Additionally, or alternatively, a UE 104 may support communication with other network entities 102 or UEs 104, which may act as relays in the wireless communications system 100.

[0046] A UE 104 may also be able to support wireless communication directly with other UEs 104 over a communication link 114. 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.

[0047] A network entity 102 may support communications with the core network 106, or with another network entity 102, or both. For example, a network entity 102 may interface with the core network 106 through one or more backhaul links 116 (e.g.,

via an S1, N2, N2, or another network interface). The network entities 102 may communicate with each other over the backhaul links 116 (e.g., via an X2, Xn, or another network interface). In some implementations, the network entities 102 may communicate with each other directly (e.g., between the network entities 102). In some other implementations, the network entities 102 may communicate with each other or indirectly (e.g., via the core network 106). In some implementations, one or more network entities 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 a radio heads, smart radio heads, or transmission-reception points (TRPs).

[0048] In some implementations, a network entity 102 may be configured in a disaggregated architecture, which may be configured to utilize a protocol stack physically or logically distributed among two or more network entities 102, such as an IAB network, an open RAN (O-RAN) (e.g., a network configuration sponsored by the O-RAN Alliance), or a virtualized RAN (vRAN) (e.g., a cloud RAN (C-RAN)). For example, a network entity 102 may include one or more of a central unit (CU), a distributed unit (DU), a radio unit (RU), a RAN Intelligent Controller (RIC) (e.g., a Near-Real Time RIC (Near-RT RIC), a Non-Real Time RIC (Non-RT RIC)), a Service Management and Orchestration (SMO) system, or any combination thereof.

[0049] An RU may also be referred to as a radio head, a smart radio head, a remote radio head (RRH), a remote radio unit (RRU), or a transmission reception point (TRP). One or more components of the network entities 102 in a disaggregated RAN architecture may be co-located, or one or more components of the network entities 102 may be located in distributed locations (e.g., separate physical locations). In some implementations, one or more network entities 102 of a disaggregated RAN architecture may be implemented as virtual units (e.g., a virtual CU (VCU), a virtual DU (VDU), a virtual RU (VRU)).

[0050] Split of functionality between a CU, a DU, and an RU may be flexible and may support different functionalities depending upon which functions (e.g., network layer functions, protocol layer functions, baseband functions, radio frequency functions, and any combinations thereof) are performed at a CU, a DU, or an RU. For example, a

functional split of a protocol stack may be employed between a CU and a DU such that the CU may support one or more layers of the protocol stack and the DU may support one or more different layers of the protocol stack. In some implementations, the CU may host upper protocol layer (e.g., a layer 3 (L3), a layer 2 (L2)) functionality and signaling (e.g., Radio Resource Control (RRC), service data adaptation protocol (SDAP), Packet Data Convergence Protocol (PDCP)). The CU may be connected to one or more DUs or RUs, and the one or more DUs or RUs may host lower protocol layers, such as a layer 1 (L1) (e.g., physical (PHY) layer) or an L2 (e.g., radio link control (RLC) layer, medium access control (MAC) layer) functionality and signaling, and may each be at least partially controlled by the CU 160.

[0051] Additionally, or alternatively, a functional split of the protocol stack may be employed between a DU and an RU such that the DU may support one or more layers of the protocol stack and the RU may support one or more different layers of the protocol stack. The DU may support one or multiple different cells (e.g., via one or more RUs). In some implementations, a functional split between a CU and a DU, or between a DU and an RU may be within a protocol layer (e.g., some functions for a protocol layer may be performed by one of a CU, a DU, or an RU, while other functions of the protocol layer are performed by a different one of the CU, the DU, or the RU).

[0052] A CU may be functionally split further into CU control plane (CU-CP) and CU user plane (CU-UP) functions. A CU may be connected to one or more DUs via a midhaul communication link (e.g., F1, F1-c, F1-u), and a DU may be connected to one or more RUs via a fronthaul communication link (e.g., open fronthaul (FH) interface). In some implementations, a midhaul communication link or a fronthaul communication link may be implemented in accordance with an interface (e.g., a channel) between layers of a protocol stack supported by respective network entities 102 that are in communication via such communication links.

[0053] The core network 106 may support user authentication, access authorization, tracking, connectivity, and other access, routing, or mobility functions. The core network 106 may be an evolved packet core (EPC), or a 5G core (5GC), which may include one or more core network elements 103. A core network element 103 may be a control plane entity that manages access and mobility (e.g., a mobility management entity (MME), an access and mobility management functions (AMF)) or 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 network entities 102 associated with the core network 106.

[0054] The core network 106 may communicate with the packet data network 108 over one or more backhaul links 116 (e.g., via an S1, N2, N2, or another network interface). The packet data network 108 may include an application server 118. In some implementations, one or more UEs 104 may communicate with the application server 118. A UE 104 may establish a session (e.g., a protocol data unit (PDU) session, or the like) with the core network 106 via a network entity 102. The core network 106 may route traffic (e.g., control information, data, and the like) between the UE 104 and the application server 118 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 core network 106 (e.g., one or more network functions of the core network 106).

[0055] In the wireless communications system 100, the network entities 102 and the UEs 104 may use resources of the wireless communications 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 communications). In some implementations, the network entities 102 and the UEs 104 may support different resource structures. For example, the network entities 102 and the UEs 104 may support different frame structures. In some implementations, such as in 4G, the network entities 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 network entities 102 and the UEs 104 may support various frame structures (i.e., multiple frame structures). The network entities 102 and the UEs 104 may support various frame structures based on one or more numerologies.

[0056] One or more numerologies may be supported in the wireless communications system 100, and a numerology may include a subcarrier spacing and a cyclic prefix. A first numerology (e.g., $\mu=0$) 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., $\mu=0$) associated with the first subcarrier spacing (e.g., 15 kHz) may utilize one slot per subframe. A second numerology (e.g., $\mu=1$) may be associated with a second subcarrier spacing (e.g., 30 kHz) and a normal cyclic prefix. A third numerology (e.g., $\mu=2$) 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., $\mu=3$) may be associated with a fourth subcarrier spacing (e.g., 120 kHz) and a normal cyclic prefix. A fifth numerology (e.g., $\mu=4$) may be associated with a fifth subcarrier spacing (e.g., 240 kHz) and a normal cyclic prefix.

[0057] 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.

[0058] 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 communications system 100. For instance, the first, second, third, fourth, and fifth numerologies (i.e., $\mu=0$, $\mu=1$, $\mu=2$, $\mu=3$, $\mu=4$) associated with respective subcarrier spacings 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., 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., $\mu=0$) associated with a first subcarrier spacing (e.g., 15 kHz) may be used interchangeably between subframes and slots.

[0059] In the wireless communications 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 communications 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 network entities 102 and the UEs 104 may perform wireless communications over one or more of the operating frequency bands. In some implementations, FR1 may be used by the network entities 102 and the UEs 104, among other equipment or devices for cellular communications traffic (e.g., control information, data). In some implementations, FR2 may be used by the network entities 102 and the UEs 104, among other equipment or devices for short-range, high data rate capabilities.

[0060] 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., $\mu=0$), which includes 15 kHz subcarrier spacing; a second numerology (e.g., $\mu=1$), which includes 30 kHz subcarrier spacing; and a third numerology (e.g., $\mu=2$), 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., $\mu=2$), which includes 60 kHz subcarrier spacing; and a fourth numerology (e.g., $\mu=3$), which includes 120 kHz subcarrier spacing.

[0061] In some scenarios, the A-IoT device 101 may directly and bidirectionally communicate with the network entity 102. The communication between the A-IoT device 101 and the network entity 102 includes A-IoT data and/or signaling. These scenarios may be called as Topology 1.

[0062] In some scenarios, the A-IoT device 101 may communicate bidirectionally with an intermediate node between the A-IoT device 101 and the network entity 102. The intermediate node may be the UE 104, a relay, a IAB node, a repeater, etc. which is capable of A-IoT. The intermediate node may transfer A-IoT data and/or signaling between the A-IoT device 101 and the network entity 102. These scenarios may be called as Topology 2.

[0063] In some scenarios, the A-IoT device 101 may transmit data/signaling to the network entity 102, and receive data/signaling from an assisting node; or the A-IoT device 101 may receive data/signaling from the network entity 102, and transmit data/signaling to the assisting node. The assisting node may be the UE 104, a relay, an IAB node, a repeater, etc. which is capable of A-IoT. These scenarios may be called as Topology 3.

[0064] In some scenarios, the A-IoT device 101 may communicate bidirectionally with the UE 104. The communication between the A-IoT device 101 and the UE 104 includes A-IoT data and/or signaling. These scenarios may be called as Topology 4.

[0065] According to a general scope defined for A-IoT, there is no radio resource control (RRC) state, no mobility (i.e., at least no cell selection/re-selection like function), no hybrid automatic repeat request (HARQ) and no automatic repeat request (ARQ) in some topologies of A-IoT. In the case that an A-IoT device receives multiple messages for paging the A-IoT device from different entities (e.g., base station, intermediate node, etc.), how to handle or respond to the multiple messages needs to be defined.

[0066] Embodiments of the present disclosure provide a solution of a paging for an A-IoT device. In the solution, A-IoT device's behaviors to handle or respond to multiple messages for paging the A-IoT device may be defined by considering one or more of the following aspects: indicated contents with or within each message; A-IoT device's status upon reception of the message (e.g., just activated/non-activated, or involved in other procedures); or A-IoT device's capability to handle multiple paging procedures or multiple session-like procedures with a same entity or with different entities. The solution will be described in connection with FIG. 2 below.

[0067] FIG. 2 illustrates an example of a process 200 that supports a paging for an A-IoT device in accordance with aspects of the present disclosure. For purpose of discussion, the process 200 will be described in connection with FIG. 1. The process 200 may involve a first device, a set of second devices (i.e., one or more second devices) and a third device. The first device may be an A-IoT device, the second device may be a base station or a communication node between the base station and the A-IoT device, and the third device may be another second device or a core network element. For illustration, the following description will be given by assuming that the first device is the A-IoT device 101, the set of second devices is the network entities 102-1 and 102-2,

and the third device is the core network element 103. It is to be understood that the steps and the order of the steps in FIG. 2 are merely for illustration, and not for limitation. For convenience, the term 'paging message' may be used hereinafter to refer to a message for paging an A-IoT device.

[0068] As shown in FIG. 2, the A-IoT device 101 may receive 210 a set of messages for paging the A-IoT device 101. For example, the A-IoT device 101 may receive 211, from the network entity 102-1, a message (for convenience, also referred to as a first paging message herein) for paging the A-IoT device 101. The A-IoT device 101 may receive 212, from the network entity 102-2, a message (for convenience, also referred to as a second paging message herein) for paging the A-IoT device 101. It is to be understood that more or less paging messages may also be feasible.

[0069] With reference to FIG. 2, the A-IoT device 101 may determine 220 that a subset of messages in the set of paging messages fulfills a condition. The subset of messages may comprise one or more paging messages. In some embodiments, the subset of messages may comprise the whole set of paging messages.

[0070] As shown in FIG. 2, the A-IoT device 101 may respond 230 to the subset of messages fulfilling the condition. In this example, it is assumed that the first message from the network entity 102-1 fulfils the condition.

[0071] In some embodiments, in the case that the A-IoT device 101 is in a non-activated or sleep state, the set of paging messages may be transmitted from different entities (i.e., second devices). For example, the core network 106 may indicate surrounding second devices to find one or multiple A-IoT devices (e.g., the A-IoT device 101). Alternatively, a second device may transmit a paging message to surrounding UEs periodically. In this case, the second device is an activator and transmits energy carrier to activate the A-IoT device 101 firstly, and the paging message may be transmitted dependent or independent with the energy carrier. If the paging message is transmitted independent with the energy carrier, the energy carrier may be transmitted firstly and then the A-IoT device 101 wakes up to receive the paging message. The A-IoT device 101 may perform backscatter transmission upon reception of enough energy from the activator.

[0072] In some embodiments, the condition may comprise that a paging message indicates identification (ID) information of the A-IoT device 101. In some

embodiments, the ID information of the A-IoT device 101 may be a device ID, e.g., complete or partial of a tag ID, an electronic product code (EPC) ID or other defined group or subgroup IDs. It is to be understood that any other suitable IDs may also be feasible. In some embodiments, the A-IoT device 101 may only respond to a paging message which indicates the ID information of the A-IoT device 101.

[0073] In some embodiments, the condition may comprise that a paging message indicates an area (also referred to as a paging area herein) in which the A-IoT device 101 is located. In some embodiments, the area may be a storage rack. It is to be understood that any other suitable pre-defined area information may also be feasible. In some embodiments, the A-IoT device 101 may only respond to a paging message which indicates the area in which the A-IoT device 101 is located (if the area is carried). In some embodiments, the A-IoT device 101 may have priori knowledge on specific area the A-IoT device 101 itself is located in. The specific area may be pre-defined in the A-IoT device 101 or pre-configured by the network entity.

[0074] In some embodiments, the condition may comprise that a paging message is transmitted by a second device in a configured list of second devices, i.e., transmitted by a specific entity. In some embodiments, the A-IoT device 110 may store information of second devices (e.g., base stations or intermediate nodes) accessed before. In some embodiments, the A-IoT device 110 may be configured with the information of second devices (e.g., base stations or intermediate nodes). In some embodiments, the A-IoT device 110 may only respond to a paging message from a specific entity (if the specific entity is configured).

[0075] In some embodiments, the condition may comprise that a paging message indicates a resource (e.g., time and/or frequency resource information) available for the A-IoT device 110 to respond to the message. In some embodiments, the A-IoT device 110 may only respond to a paging message which indicates available time/frequency resource information for response.

[0076] It is to be understood that any combination of the above conditions or any other suitable conditions may also be feasible.

[0077] In some embodiments, a paging message may be transmitted to the A-IoT device 101 directly without a control signaling for the paging message. In some embodiments, the A-IoT device 101 may receive and decode multiple paging messages.

Based on information carried in the paging messages, the A-IoT device 101 may select one or more paging messages fulfilling the above conditions and respond to the selected one or more paging messages.

[0078] In some embodiments, if a plurality of paging messages satisfy the conditions described in connection with the step 220, the A-IoT device 101 may select one paging message from a specific entity to response.

[0079] In some embodiments, the A-IoT device 101 may select one paging message based on energy harvesting efficiency of the paging message. In some embodiments, the A-IoT device 101 may respond to a paging message which provides most efficient energy harvesting, i.e., the most energy or the fastest to fully energy.

[0080] In some embodiments, the A-IoT device 101 may select one paging message based on a priority of a cause (also referred to as a paging cause herein) of the paging message. In some embodiments, the priority may be configured or pre-defined in the A-IoT device 101. For example, the paging cause may indicate inventory service and may have a higher priority than other causes.

[0081] In some embodiments, the A-IoT device 101 may select one paging message based on reception time of the paging message. In some embodiments, the A-IoT device 101 may respond to the earliest received paging message.

[0082] In some embodiments, the A-IoT device 101 may select one paging message based on response time of the paging message. In some embodiments, the response time may be indicated in the resource information or indicated with an additional response time window. In some embodiments, the A-IoT device 101 may respond to a paging message with the shortest response time. In some embodiments, the A-IoT device 101 may respond to a paging message with the longest response time.

[0083] In some embodiments, the A-IoT device 101 may select one paging message based on a priority of a second device in the set of second devices. The priority of the second device may be configured or pre-defined in the A-IoT device 101. For example, the A-IoT device 101 may respond to a paging message transmitted by a second device with a highest priority among the set of second devices.

[0084] In some embodiments, the A-IoT device 101 may select one paging message based on a priority of a response to the paging message. The priority of the response

may be configured or pre-defined in the A-IoT device 101. For example, the A-IoT device 101 may select a paging message with a highest priority of response among the received paging messages.

[0085] In some embodiments, the A-IoT device 101 may select one paging message based on an access control configuration. The access control configuration may be configured or pre-configured by the second device. For example, the A-IoT device 101 may respond to a paging message transmitted by a second device without access control configuration that has a higher priority than a second device with access control configuration. Alternatively, the A-IoT device 101 may respond to a paging message transmitted by a second device which permits or allows the A-IoT device 101 to access based on the provided access control configuration that has a higher priority than a second device which limits or does not allow the A-IoT device 101 to access based on the provided access control configuration.

[0086] In some embodiments, the A-IoT device 101 may select one paging message based on a random selection. That is, the A-IoT device 101 may respond one paging message randomly.

[0087] It is to be understood that the selection of the paging message may be made based on any combination of the above selection principles. The selection of the paging message may be made by UE implementation.

[0088] In some embodiments, a second device initiating a paging may transmit a paging message repeatedly to ensure reliability. In some embodiments, if no response to an initial transmission of a paging message is made, the A-IoT device 101 may not respond to a set of repeated transmissions of the paging message. In other words, for the repeated paging transmissions, if the A-IoT device 101 decides to discard or skip or not respond to the initial paging message from a specific entity, the A-IoT device 101 may also discard or skip or not respond to handle the repeated paging transmissions.

[0089] In some embodiments, a paging message may be transmitted to the A-IoT device 101 with a control signaling for the paging message. In some embodiments, the A-IoT device 101 may receive, from the set of second devices (e.g., the network entities 102-1 and 102-2), a set of control signaling for the set of paging messages. In this case, the A-IoT device 101 may decode a control signaling firstly and then decode a paging message based on information indicated in the control signaling.

[0090] In some embodiments, the A-IoT device 101 may receive different control signaling associated with different paging messages and differentiate the paging messages by the different control signaling.

[0091] In some embodiments, the A-IoT device 101 may select a control signaling in the set of control signaling. If a paging message corresponding to the control signaling fulfills the condition described in connection with the step 220, the A-IoT device 101 may respond to the paging message.

[0092] In some embodiments, the A-IoT device 101 may select the control signaling based on reception time of the control signaling. In some embodiments, the A-IoT device 101 may select the earliest received control signaling.

[0093] In some embodiments, the A-IoT device 101 may select the control signaling based on a priority of a second device in the set of second devices. The priority of the second devices may be configured or pre-defined in the A-IoT device 101. For example, the A-IoT device 101 may select a control signaling transmitted by a second device with a highest priority among the set of second devices.

[0094] In some embodiments, the A-IoT device 101 may select the control signaling based on a priority of a response to the control signaling. The priority of the response may be configured or pre-defined in the A-IoT device 101. For example, the A-IoT device 101 may select a control signaling with a highest priority of response.

[0095] In some embodiments, the A-IoT device 101 may select the control signaling based on a payload size of the control signaling. In some embodiments, the A-IoT device 101 may select the control signaling based on a random selection.

[0096] It is to be understood that the selection of the control signaling may be made based on any combination of the above selection principles. The selection of the control signaling may be made by UE implementation.

[0097] In some embodiments, if a paging message corresponding to the selected control signaling does not fulfill the condition described in connection with the step 220, the A-IoT device 101 may discard or skip or not respond to the paging message. The A-IoT device 101 may select a further control signaling to decode a paging message corresponding to the further control signaling until a paging message fulfilling the condition described in connection with the step 220 occurs.

[0098] In some embodiments, for a repeated transmission of paging, if the A-IoT device 101 decides to discard or skip or not respond to an initial paging message from a specific entity, the A-IoT device 101 may also discard or skip or not respond to handle the repeated transmission of paging by detecting the control signaling.

[0099] In some embodiments, the A-IoT device 101 may decode the set of paging messages for the set of control signaling. In other words, the A-IoT device 101 may decode each associated paging message for a received control signaling. Then the A-IoT device 101 may select one paging message fulfilling the condition described in connection with the step 220 based on information carried in the paging messages, and respond to the selected paging message.

[0100] In some embodiments, if a plurality of paging messages satisfy the condition described in connection with the step 220, the A-IoT device 101 may respond to the plurality of paging messages in parallel in some cases.

[0101] In some embodiments, if the plurality of paging messages indicate different causes, the A-IoT device 101 may respond to the plurality of paging messages in parallel. For example, the A-IoT device 101 may be allowed to handle the paging messages when the paging messages from different entities indicate different paging causes, e.g., for inventory or for command use cases respectively. That is, the A-IoT device 101 may only needs to respond to the paging indicating the inventory cause, and there is no random access needed for the paging indicating the command causes.

[0102] In some embodiments, if the plurality of paging messages indicate non-conflicted resources for response, the A-IoT device 101 may respond to the plurality of paging messages in parallel. For example, the A-IoT device 101 may be allowed to handle the paging messages when the paging messages from different entities indicates the non-conflicted resources for response. In some embodiments, the A-IoT device 101 may respond to a paging message by using the resource indicated in each paging message from different entities. In some embodiments, the A-IoT device 101 may perform collision handling (e.g., drop one of the transmissions, etc.) if collision from different entities occurred during subsequent random access or data transmission procedures.

[0103] In some embodiments, if the plurality of paging messages indicate different service identities, the A-IoT device 101 may respond to the plurality of paging messages

in parallel. For example, the A-IoT device 101 may be allowed to handle multiple paging messages when the paging messages indicate different task IDs or session IDs or service IDs which indicate that the paging from different entities target for different services or tasks or sessions.

[0104] In some embodiments, if a response to a paging message in the set of paging messages is failed, the A-IoT device 101 may respond to one or more paging messages in the set of paging messages. In other words, if the A-IoT device 101 responds to a specific paging message but is limited or not allowed to perform access during unified access control procedures or fails during a random access procedure with a specific entity transmitting the specific paging message, the A-IoT device 101 may be allowed to fallback to a response to different paging messages from other entities. Alternatively, the A-IoT device 101 may re-access the current entity based on defined rules for access control or random access failure.

[0105] In some embodiments, in the case that the A-IoT device 101 is activated and in an ongoing procedure, e.g., during a random access or data transmission with one or more specific entities (i.e., second devices), the set of paging messages may be transmitted from different entities (i.e., other second devices). In this case, it is to be defined whether the paging from different entities for the A-IoT device or for specific group of A-IoT devices including the A-IoT device is triggered or not. If triggered, how to respond to the paging is also to be defined.

[0106] In some embodiments, the A-IoT device 101 may only maintain ongoing procedures (e.g., paging, random access, data transmission, etc.) with one entity (i.e., second device) at the same time.

[0107] In some embodiments, if an ongoing procedure between the A-IoT device 101 and a second device (e.g., the network entity 102-3) is maintained while the set of paging messages for paging the A-IoT device 101 is received, the A-IoT device 101 may make no response to the set of paging messages. In other words, the A-IoT device 101 may discard or skip the set of paging messages. For example, if an associated control signaling indicates a message is for paging or the A-IoT device 101 decodes the message is for paging, or if the associated control signaling indicates the message is from a different entity or the A-IoT device 101 decodes the message is from a different entity, the A-IoT device 101 may discard or skip or not respond to the paging message.

[0108] In some embodiments, a second device may not transmit a paging message or initiate a paging procedure to A-IoT devices which have accessed to a specific entity (i.e., other second device) successfully. With reference to FIG. 2, if the A-IoT device 101 responds to a specific entity (e.g., the network entity 102-1) successfully during a paging procedure, the network entity 102-1 may indicate 240 information of the A-IoT device 101 to the core network element 103. Alternatively or additionally, the network entity 102-1 may indicate the information of the A-IoT device 101 to other network entities by Xn interface (not shown). In some embodiments, the information of the A-IoT device 101 may comprise at least one of the following: a device ID of the A-IoT device 101, an identity of an ongoing service of the A-IoT device 101, or a status of the A-IoT device 101. It is to be understood that any other suitable information is also feasible.

[0109] In some embodiments, the core network element 103 or other network entities may not transmit a paging message to the A-IoT device 101 that has been paged/inventoried already during this inventory period. In some embodiments, the core network element 103 or other network entities may not transmit a paging message to the A-IoT device 101 until the ongoing procedure with the current second device (e.g., the network entity 102-3) is ended. In some embodiments, the other network entities may also indicate its intermediate nodes (if any) not to page the A-IoT device 101.

[0110] With reference to FIG. 2, in some embodiments, if a paging message from a second device (e.g., the network entity 102-1) is responded, the A-IoT device 101 may set 250 a status of the A-IoT device 101 as inventoried. In some embodiments, if an ongoing procedure is maintained, the A-IoT device 101 may set the status of the A-IoT device 101 as active or acknowledged (ACK).

[0111] With reference to FIG. 2, in some embodiments, if a paging message from a second device (e.g., the network entity 102-1) is responded, the network entity 102-1 may set 260 a status of the A-IoT device 101 as inventoried. In some embodiments, if an ongoing procedure with the network entity 102-1 is maintained, the network entity 102-1 may set the status of the A-IoT device 101 as active or ACK.

[0112] In other words, for both A-IoT device side and network side, a specific status may be defined for A-IoT devices under different states. For example, when an A-IoT device has been paged and accessed to network, a status of the A-IoT device may be

defined as inventoried. No paging messages will be transmitted to the A-IoT device with inventoried status, or the A-IoT device in inventoried status will not respond to other paging messages.

[0113] When an A-IoT device has ongoing procedures (e.g., paging, random access, data transmission, etc.), the A-IoT device status may be defined as active or ACK. The A-IoT device may only maintain one procedure at the same time, and the A-IoT device with active or ACK status may not be allowed to access to other procedures. It is to be understood that any other suitable status definitions may also be feasible.

[0114] In some embodiments, the A-IoT device 101 may maintain multiple procedures with different entities and handle the procedures in parallel. In some embodiments, if the A-IoT device 101 receives the set of paging messages from different entities when the A-IoT device 101 has the ongoing procedures, the A-IoT device 101 may decode the paging messages or decodes the control signaling associated with the paging messages.

[0115] In some embodiments, the A-IoT device 101 may respond to a paging message in the set of paging messages that indicates a cause requiring no uplink transmission. In other words, if a paging message includes a paging cause and the paging cause does not require the A-IoT device 101 to perform an uplink transmission, e.g., command or status change, the A-IoT device 101 may receive the paging message and perform a command or action requested in the paging message.

[0116] In some embodiments, the A-IoT device 101 may respond to a paging message in the set of paging messages that indicates a resource for a response to the message that does not conflict with the ongoing procedure. In other words, if the paging message include a response resource and the response resource does not conflict with current transmission of the ongoing procedure, the A-IoT device 101 may respond to the paging message with the response resources.

[0117] In some embodiments, the A-IoT device 101 may respond to a paging message in the set of paging messages that indicates a service ID different from a service ID of the ongoing procedure. It is to be understood that a session ID or process ID or task ID may also be feasible. In some embodiments, for both A-IoT device side and network side, if a session ID or process ID or service ID or task ID is included in a paging message, and the A-IoT device 101 has been involved in a specific procedure

with the same session ID or process ID or service ID or task ID, the A-IoT device 101 may discard or skip or not respond to the paging message with the same session ID or process ID or service ID or task ID from a different entity.

[0118] In some embodiments, if the A-IoT device 101 receives a paging message which includes a different session ID or process ID or service ID or task ID, the A-IoT device 101 may decode the paging message. The A-IoT device 101 may respond to the paging message if the paging message fulfills the condition described in connection with the step 220.

[0119] In some embodiments, if a service ID of a paging message indicates a service having a priority higher than a priority of a service of the ongoing procedure and a resource indicated in the paging message does not conflict with the ongoing procedure, the A-IoT device 101 may respond to the paging message. In some embodiments, if a task ID of a paging message indicates a task having a priority higher than a priority of a task of the ongoing procedure and a resource indicated in the paging message does not conflict with the ongoing procedure, the A-IoT device 101 may respond to the paging message. In some embodiments, if a session ID of a paging message indicates a session having a priority higher than a priority of a session of the ongoing procedure and a resource indicated in the paging message does not conflict with the ongoing procedure, the A-IoT device 101 may respond to the paging message.

[0120] In other words, if a priority of a service/task/session is configured and a paging message indicates a service/task/session with higher priority, the A-IoT device 101 may be allowed to respond to the paging message if no confliction on transmission resource with current transmission of the ongoing procedure.

[0121] In some embodiments, if the indicated resource in the paging message conflicts with the ongoing procedure, the A-IoT device 101 may abort the ongoing procedure. That is, if confliction occurs, the high-priority service may be prioritized and the ongoing procedure may be aborted. The aborted procedure for the ongoing procedure may be handled by random access or data transmission procedures.

[0122] In some embodiments, the above criteria defined for an A-IoT device may be pre-defined in the A-IoT device. In some embodiments, the above criteria defined for an A-IoT device may be pre-configured in system information that the A-IoT device receives after waking up by an energy carrier. In some embodiments, the above criteria

defined for an A-IoT device may be configured by network if the A-IoT device has connected to network. In some embodiments, the above criteria defined for an A-IoT device may be updated based on network configuration.

[0123] So far, a solution of a paging for an A-IoT device is described. With the process 200, by only responding to a message fulfilling a condition, a paging for an A-IoT device may be carried out in an efficient way and thus communication efficiency may be improved. Further, energy consumption at the A-IoT device may be reduced.

[0124] FIG. 3 illustrates an example of a device 300 that supports a paging for an A-IoT device in accordance with aspects of the present disclosure. The device 300 may be an example of a first device (e.g., the A-IoT device 101) or a second device (e.g., the network entity 102 or the UE 104) or a third device (e.g., the network entity 102 or the UE 104 or the core network element 103) as described herein. The device 300 may support wireless communication with one or more network entities 102, UEs 104, the core network element 103, or any combination thereof. The device 300 may include components for bi-directional communications including components for transmitting and receiving communications, such as a processor 302, a memory 304, a transceiver 306, and, optionally, an I/O controller 308. 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).

[0125] The processor 302, the memory 304, the transceiver 306, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. For example, the processor 302, the memory 304, the transceiver 306, or various combinations or components thereof may support a method for performing one or more of the operations described herein.

[0126] In some implementations, the processor 302, the memory 304, the transceiver 306, or various combinations or components thereof may be implemented in hardware (e.g., in communications management circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA) or other programmable logic device, a discrete gate or transistor logic, discrete hardware components, or any combination thereof configured as or otherwise supporting a means for performing the functions

described in the present disclosure. In some implementations, the processor 302 and the memory 304 coupled with the processor 302 may be configured to perform one or more of the functions described herein (e.g., executing, by the processor 302, instructions stored in the memory 304).

[0127] For example, the processor 302 may support wireless communication at the device 300 in accordance with examples as disclosed herein. In some embodiments where the device 300 is implemented as a first device, the processor 302 may be configured to operable to support a means for: receiving a set of messages for paging the first device; and in accordance with a determination that a subset of messages in the set of messages fulfils a condition, responding to the subset of messages. In some embodiments where the device 300 is implemented as a second device, the processor 302 may be configured to operable to support a means for: transmitting a message for paging a first device; receiving, from the first device, a response to the message; and transmitting, to a third device, information of the first device.

[0128] The processor 302 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, a microcontroller, an ASIC, an FPGA, a programmable logic device, a discrete gate or transistor logic component, a discrete hardware component, or any combination thereof). In some implementations, the processor 302 may be configured to operate a memory array using a memory controller. In some other implementations, a memory controller may be integrated into the processor 302. The processor 302 may be configured to execute computer-readable instructions stored in a memory (e.g., the memory 304) to cause the device 300 to perform various functions of the present disclosure.

[0129] The memory 304 may include random access memory (RAM) and read-only memory (ROM). The memory 304 may store computer-readable, computer-executable code including instructions that, when executed by the processor 302 cause the device 300 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. In some implementations, the code may not be directly executable by the processor 302 but may cause a computer (e.g., when compiled and executed) to perform functions described herein. In some implementations, the memory 304 may include,

among other things, a basic I/O system (BIOS) which may control basic hardware or software operation such as the interaction with peripheral components or devices.

[0130] The I/O controller 308 may manage input and output signals for the device 300. The I/O controller 308 may also manage peripherals not integrated into the device 300. In some implementations, the I/O controller 308 may represent a physical connection or port to an external peripheral. In some implementations, the I/O controller 308 may utilize an operating system such as iOS®, ANDROID®, MS-WINDOWS®, OS/2®, UNIX®, LINUX®, or another known operating system. In some implementations, the I/O controller 308 may be implemented as part of a processor, such as the processor 306. In some implementations, a user may interact with the device 300 via the I/O controller 308 or via hardware components controlled by the I/O controller 308.

[0131] In some implementations, the device 300 may include a single antenna 310. However, in some other implementations, the device 300 may have more than one antenna 310 (i.e., multiple antennas), including multiple antenna panels or antenna arrays, which may be capable of concurrently transmitting or receiving multiple wireless transmissions. The transceiver 306 may communicate bi-directionally, via the one or more antennas 310, wired, or wireless links as described herein. For example, the transceiver 306 may represent a wireless transceiver and may communicate bi-directionally with another wireless transceiver. The transceiver 306 may also include a modem to modulate the packets, to provide the modulated packets to one or more antennas 310 for transmission, and to demodulate packets received from the one or more antennas 310. The transceiver 306 may include one or more transmit chains, one or more receive chains, or a combination thereof.

[0132] A transmit chain may be configured to generate and transmit signals (e.g., control information, data, packets). The transmit chain 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 transmit chain 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 transmit chain may also include one or more antennas 310 for transmitting the amplified signal into the air or wireless medium.

[0133] A receive chain may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receive chain may include one or more antennas 310 for receive the signal over the air or wireless medium. The receive chain may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receive chain 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 receive chain may include at least one decoder for decoding the processing the demodulated signal to receive the transmitted data.

[0134] FIG. 4 illustrates an example of a processor 400 that supports a paging for an A-IoT device in accordance with aspects of the present disclosure. The processor 400 may be an example of a processor configured to perform various operations in accordance with examples as described herein. The processor 400 may include a controller 402 configured to perform various operations in accordance with examples as described herein. The processor 400 may optionally include at least one memory 404, such as L1/L2/L3 cache. Additionally, or alternatively, the processor 400 may optionally include one or more arithmetic-logic units (ALUs) 406. 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).

[0135] The processor 400 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 400) 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).

[0136] The controller 402 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 400 to cause the processor 400 to support various operations in accordance with examples as described herein. For example, the controller 402 may operate as a control unit of the processor 400, generating control signals that manage the operation of various components of the processor 400. These control signals include enabling or disabling functional units, selecting data paths, initiating memory access, and coordinating timing of operations.

[0137] The controller 402 may be configured to fetch (e.g., obtain, retrieve, receive) instructions from the memory 404 and determine subsequent instruction(s) to be executed to cause the processor 400 to support various operations in accordance with examples as described herein. The controller 402 may be configured to track memory address of instructions associated with the memory 404. The controller 402 may be configured to decode instructions to determine the operation to be performed and the operands involved. For example, the controller 402 may be configured to interpret the instruction and determine control signals to be output to other components of the processor 400 to cause the processor 400 to support various operations in accordance with examples as described herein. Additionally, or alternatively, the controller 402 may be configured to manage flow of data within the processor 400. The controller 402 may be configured to control transfer of data between registers, arithmetic logic units (ALUs), and other functional units of the processor 400.

[0138] The memory 404 may include one or more caches (e.g., memory local to or included in the processor 400 or other memory, such RAM, ROM, DRAM, SDRAM, SRAM, MRAM, flash memory, etc. In some implementation, the memory 404 may reside within or on a processor chipset (e.g., local to the processor 400). In some other implementations, the memory 404 may reside external to the processor chipset (e.g., remote to the processor 400).

[0139] The memory 404 may store computer-readable, computer-executable code including instructions that, when executed by the processor 400, cause the processor

400 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 402 and/or the processor 400 may be configured to execute computer-readable instructions stored in the memory 404 to cause the processor 400 to perform various functions. For example, the processor 400 and/or the controller 402 may be coupled with or to the memory 404, and the processor 400, the controller 402, and the memory 404 may be configured to perform various functions described herein. In some examples, the processor 400 may include multiple processors and the memory 404 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.

[0140] The one or more ALUs 406 may be configured to support various operations in accordance with examples as described herein. In some implementation, the one or more ALUs 406 may reside within or on a processor chipset (e.g., the processor 400). In some other implementations, the one or more ALUs 406 may reside external to the processor chipset (e.g., the processor 400). One or more ALUs 406 may perform one or more computations such as addition, subtraction, multiplication, and division on data. For example, one or more ALUs 406 may receive input operands and an operation code, which determines an operation to be executed. One or more ALUs 406 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 406 may support logical operations such as AND, OR, exclusive-OR (XOR), not-OR (NOR), and not-AND (NAND), enabling the one or more ALUs 406 to handle conditional operations, comparisons, and bitwise operations.

[0141] The processor 400 may support wireless communication in accordance with examples as disclosed herein. In some embodiments where the processor 400 is implemented at a first device, the processor 400 may be configured to or operable to support a means for: receiving a set of messages for paging the first device; and in accordance with a determination that a subset of messages in the set of messages fulfils a condition, responding to the subset of messages. In some embodiments where the processor 400 is implemented at a second device, the processor 400 may be configured to or operable to support a means for: transmitting a message for paging a first device;

receiving, from the first device, a response to the message; and transmitting, to a third device, information of the first device.

[0142] FIG. 5 illustrates a flowchart of a method 500 that supports a paging for an A-IoT device in accordance with aspects of the present disclosure. The operations of the method 500 may be implemented by a device or its components as described herein. For example, the operations of the method 500 may be performed by a first device as described herein. In some implementations, the device may execute a set of instructions to control the function elements of the device to perform the described functions. Additionally, or alternatively, the device may perform aspects of the described functions using special-purpose hardware.

[0143] At block 510, the method 500 may comprise receiving, from a set of second devices, a set of messages for paging the first device. The operations of 510 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 510 may be performed by a device as described with reference to FIG. 1.

[0144] In some embodiments, the first device may be an A-IoT device, and the second device may be a base station or a communication node between the base station and the A-IoT device.

[0145] At block 520, the method 500 may comprise determining that a subset of messages in the set of messages fulfils a condition. The operations of 520 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 520 may be performed by a device as described with reference to FIG. 1.

[0146] In some embodiments, the condition may comprise at least one of the following: a message in the subset of messages indicates identification information of the first device; the message indicates an area in which the first device is located; the message is transmitted by a second device in a configured list of second devices; or the message indicates a resource available for the first device to respond to the message.

[0147] At block 530, the method 500 may comprise responding to the subset of messages. The operations of 530 may be performed in accordance with examples as

described herein. In some implementations, aspects of the operations of 530 may be performed by a device as described with reference to FIG. 1.

[0148] In some embodiments where the subset of messages comprises a plurality of messages, responding to the subset of messages may comprise: selecting a message from the plurality of messages; and responding to the message.

[0149] In some embodiments, selecting the message may comprise: selecting the message based on at least one of the following: energy harvesting efficiency of the message; a priority of a cause of the message; reception time of the message; response time of the message; a priority of a second device in the set of second devices; a priority of a response to the message; an access control configuration from a second device in the set of second devices; or a random selection.

[0150] In some embodiments, responding to the subset of messages may comprise: receiving, from the set of second devices, a set of control signaling for the set of messages; selecting a control signaling in the set of control signaling; and in accordance with a determination that a message corresponding to the control signaling fulfills the condition, responding to the message.

[0151] In some embodiments, selecting the control signaling may comprise: selecting the control signaling based on at least one of the following: reception time of the control signaling; a priority of a second device in the set of second devices; a priority of a response to the control signaling; a payload size of the control signaling; or a random selection.

[0152] In some embodiments, responding to the subset of messages may comprise: receiving, from the set of second devices via the transceiver, a set of control signaling for the set of messages; decoding the set of messages for the set of control signaling; selecting a message in the set of messages that fulfills the condition; and responding to the message.

[0153] In some embodiments, the method 500 may further comprise: in accordance with a determination that no response to an initial transmission of a message in the subset of messages is made, making no response to a set of repeated transmissions of the message; or in accordance with a determination that a response to a message in the set of messages is failed, responding to one or more messages in the set of messages.

[0154] In some embodiments where the subset of messages comprises a plurality of messages, responding to the subset of messages may comprise: responding to the plurality of messages in parallel based on at least one of the following: the plurality of messages indicate different causes; the plurality of messages indicate non-conflicted resources for response; or the plurality of messages indicate different service identities.

[0155] In some embodiments, the method 500 may further comprise: in accordance with a determination that an ongoing procedure between the first device and a second device is maintained while the set of messages for paging the first device is received, making no response to the set of messages.

[0156] In some embodiments, the method 500 may further comprise: in accordance with a determination that an ongoing procedure between the first device and a second device is maintained while the set of messages for paging the first device are received, responding to a message in the set of messages that indicates at least one of the following: a cause requiring no uplink transmission; a resource for a response to the message that does not conflict with the ongoing procedure; or a service identity different from a service identity of the ongoing procedure.

[0157] In some embodiments, responding to the message may comprise: in accordance with a determination that the service identity of the message indicates a service having a priority higher than a priority of a service of the ongoing procedure and the resource does not conflict with the ongoing procedure, responding to the message.

[0158] In some embodiments, the method 500 may further comprise: in accordance with a determination that the resource conflicts with the ongoing procedure, aborting the ongoing procedure.

[0159] In some embodiments, the method 500 may further comprise: in accordance with a determination that a message from a second device is responded, setting a status of the first device as inventoried; or in accordance with a determination that an ongoing procedure is maintained, setting the status of the first device as active.

[0160] FIG. 6 illustrates a flowchart of another method 600 that supports a paging for an A-IoT device in accordance with aspects of the present disclosure. The operations of the method 600 may be implemented by a device or its components as described herein. For example, the operations of the method 600 may be performed by a second

device as described herein. In some implementations, the device may execute a set of instructions to control the function elements of the device to perform the described functions. Additionally, or alternatively, the device may perform aspects of the described functions using special-purpose hardware.

[0161] At block 610, the method 600 may comprise transmitting a message for paging a first device. The operations of 610 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 610 may be performed by a device as described with reference to FIG. 1.

[0162] At block 620, the method 600 may comprise receiving, from the first device, a response to the message. The operations of 620 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 620 may be performed by a device as described with reference to FIG. 1.

[0163] At block 630, the method 600 may comprise transmitting information of the first device to a third device. The operations of 630 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 630 may be performed by a device as described with reference to FIG. 1.

[0164] In some embodiments, the information of the first device comprises at least one of the following: an identity of the first device; an identity of an ongoing service of the first device; or a status of the first device.

[0165] In some embodiments, the method 600 may further comprise: in accordance with a determination that the response to the message is received, setting a status of the first device as inventoried; or in accordance with a determination that an ongoing procedure between the first device and the second device is maintained, setting the status of the first device as active.

[0166] In some embodiments, the first device may be an A-IoT device, the second device may be a base station or a communication node between the base station and the A-IoT device, and the third device may be another second device or a core network element.

[0167] It should be noted that the methods described herein describes possible implementations, and that the operations and the steps may be rearranged or otherwise

modified and that other implementations are possible. Further, aspects from two or more of the methods may be combined.

[0168] The various illustrative blocks and components described in connection with the disclosure herein may be implemented or performed with a general-purpose processor, a DSP, an ASIC, a CPU, an FPGA or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices (e.g., a combination of a DSP and a microprocessor, multiple microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration).

[0169] The functions described herein may be implemented in hardware, software executed by a processor, firmware, or any combination thereof. If implemented in software executed by a processor, the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium. Other examples and implementations are within the scope of the disclosure and appended claims. For example, due to the nature of software, functions described herein may be implemented using software executed by a processor, hardware, firmware, hardwiring, or combinations of any of these. Features implementing functions may also be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations.

[0170] 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. By way of example, non-transitory computer-readable media may include RAM, ROM, electrically erasable programmable ROM (EEPROM), flash memory, compact disk (CD) ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other non-transitory medium that may be used to carry or store desired program code means in the form of instructions or data structures and

that may be accessed by a general-purpose or special-purpose computer, or a general-purpose or special-purpose processor.

[0171] As used herein, including in the claims, 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” may include one or more elements.

[0172] The description herein is provided to enable a person having ordinary skill in the art to make or use the disclosure. Various modifications to the disclosure will be apparent to a person having ordinary skill in the art, and the generic principles defined herein may be applied to other variations without departing from the scope of the disclosure. Thus, the disclosure is not limited to the examples and designs described herein but is to be accorded the broadest scope consistent with the principles and novel features disclosed herein.

CLAIMS

1. A first device, comprising:
a processor; and
a transceiver coupled to the processor,
wherein the processor is configured to:
receive, from a set of second devices via the transceiver, a set of messages for paging the first device; and
in accordance with a determination that a subset of messages in the set of messages fulfils a condition, respond to the subset of messages.
2. The first device of claim 1, wherein the condition comprises at least one of the following:
a message in the subset of messages indicates identification information of the first device;
the message indicates an area in which the first device is located;
the message is transmitted by a second device in a configured list of second devices; or
the message indicates a resource available for the first device to respond to the message.
3. The first device of claim 1, wherein the subset of messages comprises a plurality of messages, and wherein the processor is configured to respond to the subset of messages by:
selecting a message from the plurality of messages; and
responding to the message.
4. The first device of claim 3, wherein the processor is configured to select the message by:
selecting the message based on at least one of the following:
energy harvesting efficiency of the message;
a priority of a cause of the message;
reception time of the message;

response time of the message;
a priority of a second device in the set of second devices;
a priority of a response to the message;
an access control configuration from a second device in the set of second devices; or
a random selection.

5. The first device of claim 1, wherein the processor is configured to respond to the subset of messages by:

receiving, from the set of second devices via the transceiver, a set of control signaling for the set of messages;
selecting a control signaling in the set of control signaling; and
in accordance with a determination that a message corresponding to the control signaling fulfills the condition, responding to the message.

6. The first device of claim 5, wherein the processor is configured to select the control signaling by:

selecting the control signaling based on at least one of the following:
reception time of the control signaling;
a priority of a second device in the set of second devices;
a priority of a response to the control signaling;
a payload size of the control signaling; or
a random selection.

7. The first device of claim 1, wherein the processor is configured to respond to the subset of messages by:

receiving, from the set of second devices via the transceiver, a set of control signaling for the set of messages;
decoding the set of messages for the set of control signaling;
selecting a message in the set of messages that fulfills the condition; and
responding to the message.

8. The first device of claim 1, wherein the processor is further configured to:

in accordance with a determination that no response to an initial transmission of a message in the subset of messages is made, make no response to a set of repeated transmissions of the message; or

in accordance with a determination that a response to a message in the set of messages is failed, respond to one or more messages in the set of messages.

9. The first device of claim 1, wherein the subset of messages comprises a plurality of messages, and wherein the processor is configured to respond to the subset of messages by:

responding to the plurality of messages in parallel based on at least one of the following:

the plurality of messages indicate different causes;

the plurality of messages indicate non-conflicted resources for response;

or

the plurality of messages indicate different service identities.

10. The first device of claim 1, wherein the processor is further configured to:

in accordance with a determination that an ongoing procedure between the first device and a second device is maintained while the set of messages for paging the first device is received, make no response to the set of messages.

11. The first device of claim 1, wherein the processor is further configured to:

in accordance with a determination that an ongoing procedure between the first device and a second device is maintained while the set of messages for paging the first device are received, respond to a message in the set of messages that indicates at least one of the following:

a cause requiring no uplink transmission;

a resource for a response to the message that does not conflict with the ongoing procedure; or

a service identity different from a service identity of the ongoing procedure.

12. The first device of claim 11, wherein the processor is configured to respond to the message by:

in accordance with a determination that the service identity of the message indicates a service having a priority higher than a priority of a service of the ongoing procedure and the resource does not conflict with the ongoing procedure, responding to the message.

13. The first device of claim 12, wherein the processor is further configured to:
in accordance with a determination that the resource conflicts with the ongoing procedure, abort the ongoing procedure.

14. The first device of claim 1, wherein the processor is further configured to:
in accordance with a determination that a message from a second device is responded, set a status of the first device as inventoried; or
in accordance with a determination that an ongoing procedure is maintained, set the status of the first device as active.

15. The first device of claim 1, wherein the first device is an ambient Internet of things (A-IoT) device, and the second device is a base station or a communication node between the base station and the A-IoT device.

16. A second device, comprising:
a processor; and
a transceiver coupled to the processor,
wherein the processor is configured to:
transmit, via the transceiver, a message for paging a first device;
receive, from the first device via the transceiver, a response to the message; and
transmit, to a third device via the transceiver, information of the first device.

17. The second device of claim 16, wherein the information of the first device comprises at least one of the following:

an identity of the first device;
an identity of an ongoing service of the first device; or
a status of the first device.

18. The second device of claim 16, wherein the processor is further configured to:

in accordance with a determination that the response to the message is received, set a status of the first device as inventoried; or

in accordance with a determination that an ongoing procedure between the first device and the second device is maintained, set the status of the first device as active.

19. A processor for wireless communication, comprising:

at least one memory; and

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

receive, from a set of second devices, a set of messages for paging the first device; and

in accordance with a determination that a subset of messages in the set of messages fulfils a condition, respond to the subset of messages.

20. A method performed by a first device, comprising:

receiving, from a set of second devices, a set of messages for paging the first device; and

in accordance with a determination that a subset of messages in the set of messages fulfils a condition, responding to the subset of messages.