

SYNCHRONIZATION FOR A-IOT DEVICE

TECHNICAL FIELD

[0001] The present disclosure relates to wireless communications, and more specifically to synchronization for an ambient internet of things (A-IoT) device.

BACKGROUND

[0002] A wireless communications system may include one or multiple network communication devices, such as base stations (BSs), 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 wireless communication system may include an A-IoT device, which has a lower capability in terms of complexity and power consumption. Multiple topologies, for example, topologies 1 to 4, are supported for the A-IoT device. In topology 1, the A-IoT device directly and bidirectionally communicates with a BS. In topology 2, the A-IoT device communicates bidirectionally with an intermediate node between the A-IoT device and a BS. In topology 3, the A-IoT device communicates unidirectionally with a BS, and communicates unidirectionally with an assisting node. In topology 4, the A-IoT device communicates bidirectionally with a UE. However, transmission enhancements in this wireless communication system, especially, enhancements on synchronization for the A-IoT device considering the above multiple topologies, are still needed.

SUMMARY

[0004] The present disclosure relates to methods, apparatuses, and systems that support synchronization for an A-IoT device. With the apparatuses and methods, it is possible to improve the flexibility and efficiency of the synchronization procedure of the device, such as the A-IoT device.

[0005] In some implementations, there is provided a first device. The first device comprises at least one memory; and at least one processor coupled with the at least one memory and configured to cause the first device to: receive, from a second device, a configuration for providing a synchronization service for a third device; determine, based on the configuration, a resource for transmitting a plurality of signals for synchronization of the third device; and transmit, to the third device, the plurality of signals on the resource.

[0006] In some implementations, there is provided a second device. The second device comprises at least one memory; and at least one processor coupled with the at least one memory and configured to cause the second device to: determine a configuration for a first device to provide a synchronization service for a third device; and transmit the configuration to the first device.

[0007] In some implementations, there is provided a third device. The third device comprises at least one memory; and at least one processor coupled with the at least one memory and configured to cause the third device to: receive, from a first device and/or a second device, a plurality of signals and system information, the system information a first field associated with an identifier of a cell of the second device and a second field associated with an identifier of the first device; and perform synchronization based on the plurality of signals and the system information.

[0008] In some implementations, there is provided a method performed by the first device. The method comprises: receiving, from a second device, a configuration for providing a synchronization service for a third device; determining, based on the configuration, a resource for transmitting a plurality of signals for synchronization of the third device; and transmitting, to the third device, the plurality of signals on the resource.

[0009] In some implementations, there is provided a method performed by the second device. The method comprises: determining a configuration for a first device to provide a synchronization service for a third device; and transmitting the configuration to the first device.

[0010] In some implementations, there is provided a method performed by the third device. The method comprises: receiving, from a first device and/or a second device, a plurality of signals and system information, the system information a first field associated with an identifier of a cell of the second device and a second field associated with an identifier of the first device; and perform synchronization based on the plurality of signals and the system information.

[0011] In some implementations, there is provided a processor for wireless communication. The processor comprises at least one controller coupled with at least one memory and configured to cause the processor to: receive, from a second device, a configuration for providing a synchronization service for a third device; determine, based on the configuration, a resource for transmitting a plurality of signals for synchronization of the third device; and transmit, to the third device, the plurality of signals on the resource.

[0012] In some implementations, there is provided a processor for wireless communication. The processor comprises at least one controller coupled with at least one memory and configured to cause the processor to: determine a configuration for a first device to provide a synchronization service for a third device; and transmit the configuration to the first device.

[0013] In some implementations, there is provided a processor for wireless communication. The processor comprises at least one controller coupled with at least one memory and configured to cause the processor to: receive, from a first device and/or a second device, a plurality of signals and system information, the system information a first field associated with an identifier of a cell of the second device and a second field associated with an identifier of the first device; and perform synchronization based on the plurality of signals and the system information.

[0014] Some implementations of the method and the first device described herein may further include transmitting, to the second device, one or more of the following: capability information associated with a capability of providing the synchronization service; or an identifier of the first device. In some implementations of the method and the first device described herein, the capability information may comprise one of the following: a type of the first device; or an indication of the capability of providing the synchronization service.

[0015] Some implementations of the method and the first device described herein may further include receiving, from the second device, an indication to provide the synchronization service for the third device. In some implementations of the method and the first device described herein, one of the indication or the configuration may be received during a connection establishment process between the first device and the second device, or after the connection establishment process is established.

[0016] Some implementations of the method and the first device described herein may further include transmitting, to the second device, a request to provide the synchronization service for the third device.

[0017] In some implementations of the method and the first device described herein, the configuration may comprise one or more of the following: time domain resource information for the plurality of signals; system information for synchronization of the third device; or information on generation of the plurality of signals. In some implementations of the method and the first device described herein, determining the resource for transmitting the plurality of signals based on the configuration may comprises determining a first plurality of occasions for transmitting the plurality of signals based on the time domain resource information.

[0018] In some implementations of the method and the first device described herein, the first plurality of occasions may be part of a second plurality of occasions for the second device to transmit a plurality of signals for synchronization of the third device. Some implementations of the method and the first device described herein may further include performing synchronization with the second device based on one or more occasions in the second plurality of occasions that are not overlapped with the first plurality of occasions. In some implementations of the method and the first device described herein, the first plurality of occasions may be the same as a third plurality of occasions for the fourth device to transmit a plurality of signals for synchronization of the third device.

[0019] In some implementations of the method and the first device described herein, the first plurality of occasions may not be overlapped with a second plurality of occasions for the second device to transmit a plurality of signals for synchronization of the third device. In some implementations of the method and the first device described herein, the first plurality of occasions may be the same as a third plurality of occasions for the fourth

device to transmit a plurality of signals for synchronization of the third device. Some implementations of the method and the first device described herein may further include performing synchronization with the second device based the second plurality of occasions.

[0020] In some implementations of the method and the first device described herein, the first plurality of occasions may not be overlapped with a third plurality of occasions for the fourth device to transmit a plurality of signals for synchronization of the third device, and the first plurality of occasions and the third plurality of occasions may be part of a second plurality of occasions for the second device to transmit a plurality of signals for synchronization of the third device.

[0021] In some implementations of the method and the first device described herein, the first plurality of occasions may not be overlapped with a third plurality of occasions for the fourth device to transmit a plurality of signals for synchronization of the third device, and the first plurality of occasions and the third plurality of occasions may not be overlapped with a second plurality of occasions for the second device to transmit a plurality of signals for synchronization of the third device. Some implementations of the method and the first device described herein may further include performing synchronization with the second device based the second plurality of occasions.

[0022] In some implementations of the method and the first device described herein, the time domain resource information may comprise one or more of: an index of a first time unit (TU) within a second TU, or an index of a third TU within the first TU, and wherein the second TU comprises a plurality of first TUs, and the first TU comprises a plurality of third TUs. In some implementations of the method and the first device described herein, a number of the plurality of first TUs within the second TU may be associated with a transmission period of the system information.

[0023] Some implementations of the method and the first device described herein may further include transmitting, to the third device, system information on the resource, the system information comprises one or more of the following: a first field indicating an identifier of a cell of the second device; or a second field indicating an identifier of the first device.

[0024] In some implementations of the method and the first device described herein, the first device may comprise a network device or a terminal device, the second device

may comprise a base station, and the third device may comprise an internet of things (IoT) device.

[0025] Some implementations of the method and the second device described herein may further include receiving, from the first device, one or more of the following: capability information associated with a capability of providing the synchronization service; or an identifier of the first device. In some implementations of the method and the second device described herein, the capability information may comprise one of the following: a type of the first device; or an indication of the capability of providing the synchronization service.

[0026] Some implementations of the method and the second device described herein may further include transmitting, to the first device, an indication to provide the synchronization service for the third device. In some implementations of the method and the second device described herein, one of the indication or the configuration is transmitted during a connection establishment process between the first device and the second device, or after the connection establishment process is established.

[0027] Some implementations of the method and the second device described herein may further include receiving, from the first device, a request to provide the synchronization service for the third device.

[0028] In some implementations of the method and the second device described herein, the configuration comprises one or more of the following: time domain resource information for a plurality of signals for synchronization of the third device; system information for synchronization of the third device; or information on generation of the plurality of signals. In some implementations of the method and the second device described herein, the time domain resource information comprises one or more of: an index of a first time unit (TU) within a second TU, or an index of a third TU within the first TU, and wherein the second TU comprises a plurality of first TUs, and the first TU comprises a plurality of third TUs. In some implementations of the method and the second device described herein, a number of the plurality of first TUs within the second TU is associated with a transmission period of the system information. Some implementations of the method and the second device described herein may further include determining the time domain resource information based on an identifier of the first device.

[0029] Some implementations of the method and the second device described herein may further include determining a second plurality of occasions for transmitting a plurality of signals for synchronization of the third device; and transmitting, to the third device, the plurality of signals and system information on the second plurality of occasions, and in some implementations of the method and the second device described herein, the system information may comprise one or more of the following a first field indicating an identifier of a cell of the second device; or a second field associated with an identifier of the first device, wherein the second field comprises a default value.

[0030] In some implementations of the method and the second device described herein, a first plurality of occasions for the first device to transmit a plurality of signals for synchronization of the third device may be part of the second plurality of occasions. In some implementations of the method and the second device described herein, the first plurality of occasions may be the same as a third plurality of occasions for the fourth device to transmit a plurality of signals for synchronization of the third.

[0031] In some implementations of the method and the second device described herein, a first plurality of occasions for the first device to transmit a plurality of signals for synchronization of the third device may not be overlapped with the second plurality of occasions. In some implementations of the method and the second device described herein, the first plurality of occasions may be the same as a third plurality of occasions for the fourth device to transmit a plurality of signals for synchronization of the third device.

[0032] In some implementations of the method and the second device described herein, the first plurality of occasions may not be overlapped with a third plurality of occasions for the fourth device to transmit a plurality of signals for synchronization of the third device, and the first plurality of occasions and the third plurality of occasions are part of the second plurality of occasions.

[0033] In some implementations of the method and the second device described herein, the first plurality of occasions may not be overlapped with a third plurality of occasions for the fourth device to transmit a plurality of signals for synchronization of the third device, and the first plurality of occasions and the third plurality of occasions are not overlapped with the second plurality of occasions.

[0034] In some implementations of the method and the second device described herein, the first device may comprise a network device or a terminal device, the second device may comprise a base station, and the third device may comprise an internet of things (IoT) device.

[0035] In some implementations of the method and the third device described herein, the plurality of signals may be received from the first device, the first field may comprise the identifier of the cell of the second device, and the second field may comprise the identifier of the first device.

[0036] In some implementations of the method and the third device described herein, the plurality of signals may be received from the second device, the first field may comprise the identifier of the cell of the second device, and the second field may comprise a default value.

[0037] In some implementations of the method and the third device described herein, the plurality of signals may be received from the second device, the first field may comprise a default value, and the second field may comprise the identifier of the first device.

[0038] In some implementations of the method and the third device described herein, the plurality of signals may comprise a first plurality of signals received from the first device on a plurality of occasions, and a second plurality of signals received from the second device on the plurality of occasions, and performing synchronization may comprise combining the first plurality of signals and the second plurality of signals; and performing synchronization based on a result of the combining.

[0039] In some implementations of the method and the third device described herein, the plurality of signals may comprise a first plurality of signals received from the first device on a plurality of occasions, and some implementations of the method and the third device described herein may further include receiving, from a fourth device, a third plurality of signals on the plurality of occasions; and performing synchronization comprises combining the first plurality of signals and the third plurality of signals; and performing synchronization based on a result of the combining. In some implementations of the method and the third device described herein, the plurality of signals may further comprises a second plurality of signals received from the second device on a further

plurality of occasions, and performing synchronization may comprise performing synchronization based on the result of the combining, and the second plurality of signals.

[0040] In some implementations of the method and the third device described herein, the plurality of signals may comprise a first plurality of signals received from the first device on a first plurality of occasions, and some implementations of the method and the third device described herein may further include receiving, from a fourth device, a third plurality of signals on a second plurality of occasions, and performing synchronization may comprise performing synchronization based on the first plurality of signals and the third plurality of signals. In some implementations of the method and the third device described herein, the plurality of signals further may comprise a second plurality of signals received from the second device on a third plurality of occasions, and performing synchronization may comprise performing synchronization based on the first plurality of signals, the second plurality of signals, and the third plurality of signals.

[0041] In some implementations of the method and the third device described herein, the first device may comprise a network device or a terminal device, the second device may comprise a base station, and the third device may comprise an internet of things (IoT) device.

BRIEF DESCRIPTION OF THE DRAWINGS

[0042] FIG. 1A illustrates an example of a wireless communications system that supports carrier wave node determination in accordance with aspects of the present disclosure;

[0043] FIG. 1B illustrates an example of topology 1 associated with aspects of the present disclosure;

[0044] FIG. 1C illustrates an example of topology 2 associated with aspects of the present disclosure;

[0045] FIG. 1D illustrates an example of topology 3 associated with aspects of the present disclosure;

[0046] FIG. 1E illustrates an example of topology 4 associated with aspects of the present disclosure;

[0047] FIGS. 2A to 2C illustrate example process flows in accordance with some example embodiments of the present disclosure;

[0048] FIG. 3A illustrates an example time-domain resource structure in accordance with some example embodiments of the present disclosure;

[0049] FIG. 3B illustrates a first example time-domain resource configuration in accordance with some example embodiments of the present disclosure;

[0050] FIG. 3C illustrates a second example time-domain resource configuration in accordance with some example embodiments of the present disclosure;

[0051] FIG. 3D illustrates a third example time-domain resource configuration in accordance with some example embodiments of the present disclosure;

[0052] FIG. 3E illustrates a fourth example time-domain resource configuration in accordance with some example embodiments of the present disclosure;

[0053] FIG. 4 illustrates an example of a device that supports synchronization for an A-IoT device in accordance with aspects of the present disclosure;

[0054] FIG. 5 illustrates an example of a processor that supports synchronization for an A-IoT device in accordance with aspects of the present disclosure; and

[0055] FIGS. 6 through 8 illustrate flowcharts of methods that support synchronization for an A-IoT device in accordance with aspects of the present disclosure.

[0056] Throughout the drawings, the same or similar reference numerals represent the same or similar elements.

DETAILED DESCRIPTION

[0057] 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.

[0058] 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.

[0059] 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.

[0060] 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 embodiments. As used herein, the term “and/or” includes any and all combinations of one or more of the listed terms.

[0061] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of example embodiments. 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.

[0062] As used herein, the term “communication network” refers to a network following any suitable communication standards, such as, 5G new radio (NR), LTE, LTE-Advanced (LTE-A), Wideband Code Division Multiple Access (WCDMA), High-Speed Packet Access (HSPA), Narrow Band Internet of Things (NB-IoT), and so on. Further, the communications between a UE and a network device in the communication network

may be performed according to any suitable generation communication protocols, including but not limited to, the first generation (1G), the second generation (2G), 2.5G, 2.75G, the third generation (3G), the 4G, 4.5G, the 5G communication protocols, and/or any other protocols either currently known or to be developed in the future. Embodiments of the present disclosure may be applied in various communication systems. Given the rapid development in communications, there will also be future type communication technologies and systems in which the present disclosure may be embodied. It should not be seen as limiting the scope of the present disclosure to only the aforementioned systems.

[0063] As used herein, the term “network device” generally refers to a node in a communication network via which a UE can access the communication network and receive services therefrom. The network device may refer to a base station (BS) or an access point (AP), for example, a node B (NodeB or NB), a radio access network (RAN) node, an evolved NodeB (eNodeB or eNB), a NR NB (also referred to as a gNB), a Remote Radio Unit (RRU), a radio header (RH), an infrastructure device for a vehicle-to-everything (V2X) communication, a transmission and reception point (TRP), a reception point (RP), a remote radio head (RRH), a relay, an integrated access and backhaul (IAB) node, a low power node such as a femto a base station (BS), a pico BS, and so forth, depending on the applied terminology and technology. The network device may further refer to a network function (NF) in the core network, for example, a service management function (SMF), an access and mobility management function (AMF), a policy control function (PCF), a user plane function (UPF) or devices with same function in future network architectures, and so forth.

[0064] As used herein, the term “UE” generally refers to any end device that may be capable of wireless communications. By way of example rather than a limitation, a UE may also be referred to as a communication device, a terminal device, an end user device, a subscriber station (SS), an unmanned aerial vehicle (UAV), a portable subscriber station, a mobile station (MS), or an access terminal (AT). The UE may include, but is not limited to, a mobile phone, a cellular phone, a smart phone, a voice over IP (VoIP) phone, a wireless local loop phone, a tablet, a wearable UE, a personal digital assistant (PDA), a portable computer, a desktop computer, an image capture UE such as a digital camera, a gaming UE, a music storage and playback appliance, a vehicle-mounted wireless UE, a wireless endpoint, a mobile station, laptop-embedded equipment (LEE), laptop-mounted equipment (LME), a USB dongle, a smart device, wireless customer-premises equipment

(CPE), an Internet of Things (IoT) device, a watch or other wearable, a head-mounted display (HMD), a vehicle, a drone, a medical device (for example, a remote surgery device), an industrial device (for example, a robot and/or other wireless devices operating in an industrial and/or an automated processing chain contexts), a consumer electronics device, a device operating on commercial and/or industrial wireless networks, and the like. In the following description, the terms: “UE,” “communication device,” “terminal,” and “UE,” may be used interchangeably.

[0065] As used herein, the term “A-IoT device” refers to a device without batteries or with limited energy storage capabilities. For the A-IoT device, energy is provided by harvesting radio waves, light, motion, heat, or any other suitable source. A-IoT device can also be called zero-power terminals, near-zero power terminals, passive IoT device, ambient backscatter communication (AmBC) device, tag, etc. Compared with low-power and wide-coverage services, such as narrow band (NB) IoT, enhance machine type communication (eMTC), A-IoT has lower complexity and lower power consumption, and is suitable for more application scenarios.

[0066] Principles and implementations of embodiments of the present disclosure will be described in detail below with reference to the figures.

[0067] FIG. 1A illustrates an example of a wireless communications system (or referred to as communication network) 100 that supports carrier wave node determination in accordance with aspects of the present disclosure. The wireless communications system 100 may include one or more network entities 102 (also referred to as network equipment), one or more UEs 104, a core network 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.

[0068] 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.

[0069] 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.

[0070] 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.

[0071] 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. 1A. 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 integrated access and backhaul (IAB) node, or another network equipment), as shown in FIG. 1A. 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.

[0072] 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.

[0073] 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).

[0074] 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 integrated access backhaul (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.

[0075] 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)).

[0076] 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, MAC layer) functionality and signaling, and may each be at least partially controlled by the CU.

[0077] 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).

[0078] 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.

[0079] 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 a control plane entity that manages access and mobility (e.g., a mobility management entity (MME), an access and mobility management functions (AMF)) and a user plane entity that routes packets or interconnects to external networks (e.g., a serving gateway (S-GW), a Packet Data Network (PDN) gateway (P-GW), or a user plane function (UPF)). In some implementations, the control plane entity may manage non-access stratum (NAS) functions, such as mobility, authentication, and bearer management (e.g., data bearers, signal bearers, etc.) for the one or more UEs 104 served by the one or more network entities 102 associated with the core network 106.

[0080] 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).

[0081] 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.

[0082] 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.

[0083] 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.

[0084] 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.

[0085] 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.

[0086] 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.

[0087] Reference is made to FIGS. 1B to 1E to give example illustrations of the above topologies 1 to 4. Reference is first made to FIG. 1B, which illustrates an example of topology 1 associated with aspects of the present disclosure. As shown in FIG. 1B, in topology 1, an A-IoT device 121 communicates with a BS 122 directly and bi-directionally. The communication between the BS 122 and the A-IoT device 121 includes A-IoT data and/or signalling. This topology includes a possibility of a transmission from the BS 122 to the A-IoT device 121 and a different possibility of a transmission from the A-IoT device 121 to the BS 122.

[0088] FIG. 1C illustrates an example of topology 2 associated with aspects of the present disclosure. As shown in FIG. 1C, in topology 2, an A-IoT device 131 communicates bidirectionally with an intermediate node 132 between the A-IoT device 131 and base station 133. In this topology, the intermediate node 132 may be a relay node, an IAB node, a UE, a repeater, etc., which is capable of A-IoT. The intermediate node 132 transfers A-IoT data and/or signalling between the BS 133 and the A-IoT device 131.

[0089] Topology 3 may comprise two topology types, i.e., a topology 3A and a topology 3B. FIG. 1D illustrates an example of topology 3 with a topology type of 3B associated with aspects of the present disclosure. In topology 3B, an A-IoT device 141 receives data/signalling from a BS 142 and transmits data/signalling to an assisting node 143. In this topology, the assisting node 143 may be a relay, IAB, UE, repeater, etc. which is capable of A-IoT. For topology 3A, the example illustration of FIG. 1D also applies, only with the difference that it has the opposite direction of the ambient IoT

data/signaling. In topology 3A, an A-IoT device 141 transmits data/signalling to a BS 142, and receives data/signalling from an assisting node 143.

[0090] FIG. 1E illustrates an example of topology 4 associated with aspects of the present disclosure. As shown in FIG. 1E, in topology 4, an A-IoT device 151 communicates bidirectionally with a UE 152. The communication between the UE 152 and the A-IoT device 151 includes A-IoT data and/or signalling.

[0091] In release 19 (Rel-19), a new study item (SID) on A-IoT was approved. As discussed in this SID, for A-IoT, synchronization and timing related issues need to be studied for accessing the network. Since A-IoT is required to provide complexity and power consumption orders-of-magnitude lower than existing 3rd generation partnership project (3GPP) low power wide area (LPWA) technologies such as narrowband internet of things (NB-IoT) and long-term evolution-machine type communication (LTE-MTC), a new solution of configurations and procedures is needed for A-IoT synchronization.

[0092] Moreover, as discussed above, multiple topologies (i.e., topologies 1 to 4) are supported for the A-IoT device. Inventors notice that considering the configurations and procedures for the A-IoT device to perform cell selection in different topologies, there is a need to introduce a unified solution for all topologies.

[0093] However, as of now, there is no effective way to perform synchronization for the A-IoT device. Therefore, there is a need for an improved solution for the synchronization procedure for the A-IoT device, especially, for the synchronization procedure for the A-IoT device with a consideration of a unified solution for multiple topologies.

[0094] Embodiments of the present disclosure provide a solution for synchronization for an A-IoT device. In one aspect of the solution of the present disclosure, a first device (for example, a network device or a terminal device acting as an intermediate node) receives, from a second device (for example, a base station), a configuration for providing a synchronization service for a third device (for example, an IoT device, such as an A-IoT device). The first device determines, based on the configuration, a resource for transmitting a plurality of signals for synchronization of the third device. Moreover, the first device transmits, to the third device, the plurality of signals on the resource.

[0095] By allowing the first device to provide the synchronization service for the third device, this solution can facilitate the synchronization procedure of the third device. In this way, it is possible to improve the flexibility and efficiency of the synchronization procedure of the third device.

[0096] FIGS. 2A to 2C illustrate example process flows 200A to 200C in accordance with some example embodiments of the present disclosure. Reference is first made to FIG. 2A. For the purpose of discussion, the process 200A will be described with reference to FIGS. 1C and 1D. The process 200A may involve a first device 201, a second device 202, and a third device 203. For example, the first device 201 may comprise the intermediate node 132 as shown in FIG. 1C or the assisting node 143 as shown in FIG. 1D with the topology type of 3B. For example, the second device 202 may comprise the BS 133 as shown in FIG. 1C or the BS 142 as shown in FIG. 1D with the topology type of 3B. For example, the third device 203 may comprise the A-IoT device 131 as shown in FIG. 1C, or the A-IoT device 141 as shown in FIG. 1D with the topology type of 3B. It is to be understood that the steps and the order of the steps in FIG. 2A are merely for illustration, and not for limitation. It is to be understood that the process 200A may further include additional blocks not shown and/or omit some shown blocks, and the scope of the present disclosure is not limited in this regard.

[0097] As shown in FIG. 2A, the second device 202 determines (205) a configuration for the first device 201 to provide a synchronization service for the third device 203. In other words, the second device 202 may configure the first device 201 to become a synchronization point for the third device 203. Then, the second device 202 transmits (210) the configuration to the first device 201.

[0098] Configuring the first device 201 as the synchronization point for the third device 203 may be triggered in a variety of ways.

[0099] In some embodiments, configuring the first device 201 as the synchronization point for the third device 203 may be determined (or in other words, may be triggered) by the second device 202. To configure the first device 201 to provide the synchronization service for the third device 203, the second device 202 may need to obtain capability information of the first device 201 to provide the synchronization service. For example, the first device 201 may transmit, to the second device 202, capability information associated with the capability of providing the synchronization

service. The capability information may comprise a type of the first device 201. In this case, the capability may be indicated by the type of the first device 201 implicitly. Alternatively or additionally, the capability information may comprise an indication of the capability of providing the synchronization service. In this case, the capability may be indicated by an explicit capability indicator. The first device 201 may transmit, to the second device 202, an identifier (ID) of the first device 201, for example, together with the capability information, to identify the first device 201. As an example, during a connection establishment between the first device 201 and the second device 202, the first device 201 may report to the second device 202 its capability of being a synchronization point for the third device 203 and its ID.

[0100] On the basis of the capability information of the first device 201, the second device 202 may determine to configure the first device 201 as the synchronization point for the third device 203. The second device 202 may transmit, to the first device 201, an indication to provide the synchronization service for the third device 203. In this case, the second device 202 may indicate the first device 201 to become a synchronization point explicitly and provide the configuration of synchronization to the first device 201 explicitly. In other words, in this case, configuring the first device 201 as a synchronization point for the third device 203 may be triggered by the explicit indication from the second device 202. Alternatively or additionally, the second device 202 may transmit, to the first device 201, the configuration to indicate implicitly to the first device 201 to provide the synchronization service for the third device 203. For example, the indication and/or the configuration may be transmitted during a connection establishment process between the first device 201 and the second device 202, or after the connection establishment process is established.

[0101] In some embodiments, configuring the first device 201 as the synchronization point for the third device 203 may be triggered by a request from the first device 201. In this case, the first device 201 may transmit, to the second device 202, a request to provide the synchronization service for the third device 203. For example, the first device 201 may transmit, to the second device, a request of becoming a synchronization point, in the case that a connection has been established between the first device 201 and the second device 202. Upon receiving the request from the first device 201, the second device 202 may determine to configure the first device 201 to become the synchronization point and provide the configuration of synchronization to the first device 201. Likewise, the second

device 202 may transmit, to the first device 201, an indication to provide the synchronization service for the third device 203 explicitly. Alternatively or additionally, the second device 202 may transmit, to the first device 201, the configuration of synchronization to indicate implicitly to the first device 201 to provide the synchronization service for the third device 203.

[0102] In some embodiments, the configuration may comprise time domain resource information for a plurality of signals for synchronization of the third device 203, also referred to as a plurality of synchronization signals, such as synchronization signals for A-IoT (SS-AIoT). The configuration may indicate time domain transmission occasions for the first device 201 to transmit the plurality of synchronization signals. Alternatively or additionally, the configuration may comprise system information for synchronization of the third device 203 (for example, a physical cell ID (PCI) of the second device 202). Alternatively or additionally, the configuration may comprise information on the generation of the plurality of synchronization signals, for example, the generation of SS-AIoT.

[0103] In some embodiments, the time-domain resources for the plurality of synchronization signals may be organized in periodic, where each hyper time unit (hyper-TU) may be repeated in the time domain. Each hyper-TU (also referred to as a second TU) may include a plurality of TUs (also referred to as first TUs). As an example, the first TU may be similar to a frame in an NR system. The number of the plurality of TUs within the hyper-TU may be determined based on (and thus associated with) the transmission period of the system information. Each TU may comprise a plurality of sub-TUs (also referred to as third TUs). As an example, the third TU may be similar to a sub-frame in an NR system. An example time-domain resource structure is illustrated in FIG. 3A. As shown in FIG. 3A, each hyper-TU includes N_1 TUs. The value of N_1 may be determined based on the transmission period of the system information. Each TU is further divided into N_2 sub-TUs.

[0104] Based on this time-domain resource structure, a plurality of synchronization signals may be carried by a plurality of sub-TUs within a TU. In other words, a plurality of occasions for transmitting the plurality of synchronization signals may be in terms of sub-TUs. To indicate the time-domain resources for the plurality of synchronization signals, the first TUs within each second TU and the third TUs within each first TU may

be indexed. For example, the time domain resource information may comprise one or more of: an index of a first TU within a second TU, or an index of a third TU within the first TU.

[0105] After receiving the configuration, the first device 201 determines (215), based on the configuration, a resource for transmitting a plurality of signals for synchronization of the third device 203, and transmit (220), to the third device 203, the plurality of signals on the resource. For example, based on the time domain resource information obtained from the configuration, the first device 201 may determine a plurality of occasions (also referred to as a first plurality of occasions) for transmitting the plurality of synchronization signals. As an example, system information may be transmitted along with the synchronization signals on the first plurality of occasions. Alternatively or additionally, one or more other intermediate nodes may transmit synchronization signals (for example, together with system information) on one or more occasions (or in other words, in one or more sub-TUs) to the third device 203.

[0106] In some implementations, in addition to the synchronization signals from the first device 201, synchronization signals from the second device 202 may also be transmitted to the third device 203. The second device 202 may determine a plurality of occasions (also referred to a second plurality of occasions) used by the second device 202 to transmit a plurality of signals for synchronization of the third device 203. Then, the second device 202 may transmit (225), to the third device 203, the plurality of signals on the second plurality of occasions. For example, system information may be transmitted along with the synchronization signals on the second plurality of occasions.

[0107] Thus, to provide a unified signaling for transmitting system information from the first device 201 (alternatively, one or more other intermediate nodes) and the second device 202, different fields to identify the cell of the second device 202 and the first device 201 respectively may be needed to be comprised in the system information. To identify the cell of the second device 202, the system information may comprise a field (also referred to as a first field) indicating an ID of the cell (For example, PCI) of the second device 202. To identify the first device 201, the system information may comprise another field (also referred to as a second field) indicating an ID of the first device 201.

[0108] In the case of the first device 201 transmitting the system information to the third device 203, the system information transmitted by the first device 201 may comprise

the first field indicating the ID of the cell of the second device 202 and/or the second field indicating the ID of the first device 201. Alternatively or additionally, for one of other intermediate nodes, the system information may comprise a second field indicating its ID likewise.

[0109] In the case of the second device 202 transmitting the system information to the third device 203, the system information transmitted by the second device 202 may comprise the first field indicating the ID of the cell of the second device 202. Alternatively or additionally, considering that there is no intermediate node ID transmitted, the second field in the system information may comprise a default value. For example, the second field may be set to all-ones or all-zero.

[0110] After receiving the plurality of signals from the first device 201 and/or the second device 202, the third device 203 performs (230) synchronization. The third device 203 may perform synchronization based on the the plurality of signals from the first device 201 and/or the second device 202 and the system information. For example, if the third device 230 needs to connect to the network, it may perform a cell selection procedure. For example, the third device 203 may search for synchronization signals to identify the presence of a cell (for example, an A-IoT cell), for example, with a consideration of the satisfaction of a condition. For example, the condition may be that the reference signal received power (RSRP) of the synchronization signals is above a predefined threshold.

[0111] As an example, the third device 203 may identify the device from which the synchronization signals are received based on the first field and the second field within the system information, and combine the received synchronization signals from different devices, such as the first device, the second device, and alternatively, one or more other intermediate nodes, which will be described respectively in the following when discussing different time-domain resource configurations for synchronization of the third device 203. Then, the third device 203 may synchronize in the time and frequency based on a result of the combining to identify the carrier frequency and the sub-TU structure within a TU.

[0112] The synchronization procedure at the third device 203 may be different according to different time-domain resource configurations for synchronization signals. Thus, there is a need to discuss some example time-domain resource configurations. For example, a set of occasions for the second device 202 to transmit synchronization signals

may be denoted by S , and a set of occasions for the intermediate node(s) (for example, the first device 201) to transmit synchronization signals may be denoted by $S_i, i \in [1..I_{max}]$, $I_{max} \geq 1$, where I_{max} represents the number of candidate sets of transmission occasions for synchronization signals. As described above, each element in S or S_1 may be expressed as the index of the TU and/or the index of the sub-TU.

[0113] As an example, the first plurality of occasions for the first device 201 to transmit the plurality of synchronization signals may be part of the second plurality of occasions for the second device 202 to transmit a plurality of synchronization signals for synchronization of the third device 203. In other words, the first device 201 may be configured to transmit synchronization signals on a subset of synchronization signal transmission occasions of the second device 202, i.e., $S_1 \subseteq S$ and $I_{max} = 1$. The synchronization signal transmission occasions of the first device 201 may be adjusted dynamically by the second device 202.

[0114] FIG. 3B illustrates a first example time-domain resource configuration in accordance with some example embodiments of the present disclosure. FIG. 3B illustrates the example time-domain resource configuration of the first 4 TUs. As shown in FIG. 3B, sub-TUs 2 and 7 within each TU (i.e. each of TU #m to TU #m+3) are configured as SS-AIoT transmission occasions for the second device 202 (i.e. for the gNB as shown). Sub-TUs 2 and 7 within TU #m+1 and TU #m+3 are configured as SS-AIoT transmission occasions for the first device 201 (i.e. for the intermediate node as shown).

[0115] With this time-domain resource configuration, the third device 203 may combine synchronization signals in S_1 received from the first device 201 and the second device 202, and perform synchronization based on a result of the combining. Alternatively or additionally, the set of transmission occasions for transmitting synchronization signals may be identical for different intermediate nodes (for example, comprising the first device 201 and one or more other intermediate nodes), i.e., $S_i, i \in [1..I_{max}]$, $I_{max} = 1$. In other words, the identical transmission occasion set, that is, S_1 , may be used for these different intermediate nodes to transmit synchronization signals. In this case, the third device 203 may combine synchronization signals received from the intermediate nodes and the second device 202, and perform synchronization based on a result of the combining.

[0116] Moreover, in this case, the first device 201 may perform synchronization with the second device 202 based on one or more occasions in the second plurality of occasions that are not overlapped with the first plurality of occasions. In other words, the difference of occasions between S and S_1 , i.e., $S - S_1$, may be used for the first device 201 to perform synchronization with the second device 202.

[0117] As another example, the first plurality of occasions for the first device 201 to transmit the plurality of synchronization signals may not be overlapped with the second plurality of occasions for the second device 202 to transmit a plurality of synchronization signals. In other words, the first device 201 may be configured to transmit synchronization signals on a different set of synchronization signal transmission occasions from that of the second device 202, i.e., $S_1 \cap S = \emptyset$ and $I_{max} = 1$, where $\emptyset$ represents an empty set.

[0118] FIG. 3C illustrates a second example time-domain resource configuration in accordance with some example embodiments of the present disclosure. FIG. 3C illustrates the example time-domain resource configuration of the first 4 TUs. As shown in FIG. 3C, sub-TUs 2 and 7 within TU #m and TU #m+2 are configured as SS-AIoT transmission occasions for the second device 202 (i.e. for the gNB as shown). Sub-TUs 2 and 7 within TU #m+1 and TU #m+3 are configured as SS-AIoT transmission occasions for the first device 201 (i.e. for the intermediate node as shown).

[0119] For example, the set of transmission occasions for transmitting synchronization signals may be identical for different intermediate nodes (for example, comprising the first device 201 and one or more other intermediate nodes), i.e., $S_i, i \in [1..I_{max}]$, $I_{max} = 1$. In other words, the identical transmission occasion set, that is, S_1 , may be used for these different intermediate nodes to transmit synchronization signals. In this case, the third device 203 may combine synchronization signals received from the intermediate nodes, and perform synchronization based on a result of the combining. For example, an indoor third device 203 may combine synchronization signals received from multiple intermediate nodes in proximity, for example, indoor or outdoor intermediate nodes, such as an outdoor BS and an indoor UE.

[0120] Moreover, in this case, the first device 201 may perform synchronization with the second device 202 based on the second plurality of occasions. That is, S may be used for the first device 201 to synchronize with the second device.

[0121] As a further example, the first plurality of occasions for the first device 201 to transmit the plurality of synchronization signals may not be overlapped with a third plurality of occasions for a fourth device (for example, another intermediate node except the first device 201) to transmit a plurality of signals for synchronization of the third device 203, and the first plurality of occasions and the third plurality of occasions may be part of the second plurality of occasions used by the second device 202 to transmit a plurality of synchronization signals. In other words, in this case, different intermediate nodes may be configured with different sets of synchronization signal transmission occasions, i.e., $S_i \subseteq S$, $S_i \cap S_j = \emptyset$ where $i \in [1..I_{max}]$, $i \neq j$, and $I_{max} > 1$. In this way, it is beneficial to identify (or differentiate) intermediate nodes in proximity by their synchronization signal transmission occasions.

[0122] As an example, multiple candidate sets of synchronization signal transmission occasions may be pre-configured. The set of synchronization signal transmission occasions of an intermediate node (for example, the first device 201, or the fourth device), and thus the corresponding time domain resource information for the intermediate node, may be determined based on an ID of this intermediate node from the multiple candidate sets. As an implementation, for an intermediate node (for example, the first device 201, or the fourth device) with an ID denoted by ID_j where $j \in [1..J_{max}]$, a label (or an index) of the set of synchronization signal transmission occasions for this intermediate node with ID_j may be obtained by $L_j = ID_j \bmod I_{max}$.

[0123] FIG. 3D illustrates a third example time-domain resource configuration in accordance with some example embodiments of the present disclosure. FIG. 3D illustrates the example time-domain resource configuration of the first 4 TUs. As shown in FIG. 3D, sub-TUs 2 and 7 within each TU (i.e. each of TU #m to TU #m+3) are configured as SS-AIoT transmission occasions for the second device 202 (i.e. for the gNB as shown). Sub-TUs 2 and 7 within TU #m and TU #m+2 are configured as SS-AIoT transmission occasions for the first device 201 (i.e. for the first intermediate node as shown), and sub-TUs 2 and 7 within TU #m+1 and TU #m+3 are configured as SS-AIoT transmission occasions for another intermediate node (i.e. for the second intermediate node as shown).

[0124] Moreover, in this case, the first device 201 may perform synchronization with the second device 202 based on one or more occasions in the second plurality of occasions

that are not overlapped with the first plurality of occasions. In this case, the difference of occasions between S and S_1 , i.e., $S - S_1$, may be used for the first device 201 to perform synchronization with the second device 202.

[0125] As yet a further example, the first plurality of occasions for the first device 201 to transmit the plurality of synchronization signals may not be overlapped with occasions for a third plurality of occasions for a fourth device for example, another intermediate node except the first device 201)) to transmit a plurality of signals for synchronization of the third device 203. The first plurality of occasions and the third plurality of occasions may not be overlapped with the second plurality of occasions used by the second device 202 to transmit a plurality of synchronization signals. In other words, in this case, different intermediate nodes may be configured with different sets of synchronization signal transmission occasions, which are different from that of the second device 202, i.e., $S_i \cap S = \emptyset$, $S_i \cap S_j = \emptyset$ where $i \in [1..I_{max}]$, $i \neq j$, and $I_{max} > 1$. In this way, the intermediate nodes and the second device 202 may be distinguished by the corresponding synchronization transmission occasions.

[0126] Similarly, multiple candidate sets of synchronization signal transmission occasions may be pre-configured. The set of synchronization signal transmission occasions of an intermediate node (for example, the first device 201, or the fourth device), and thus the corresponding time domain resource information for the intermediate node, may be determined based on an ID of this intermediate node from the multiple candidate sets. As an implementation, for an intermediate node (for example, the first device 201, or the fourth device) with an ID denoted by ID_j where $j \in [1..J_{max}]$, and J_{max} represents the number of IDs, a label (or an index) of the set of synchronization signal transmission occasions for this intermediate node with ID_j may be obtained by $L_j = ID_j \bmod I_{max}$.

[0127] FIG. 3E illustrates a fourth example time-domain resource configuration in accordance with some example embodiments of the present disclosure. FIG. 3E illustrates the example time-domain resource configuration of the first 4 TUs. As shown in FIG. 3E, sub-TUs 2 and 7 within TU #m and TU #m+2 are configured as SS-AIoT transmission occasions for the second device 202 (i.e. for the gNB as shown). Sub-TUs 2 and 7 within TU #m+1 are configured as SS-AIoT transmission occasions for the first device 201 (i.e. for the first intermediate node as shown), and sub-TUs 2 and 7 within TU

#m+3 are configured as SS-AIoT transmission occasions for another intermediate node (i.e. for the second intermediate node as shown).

[0128] Moreover, in this case, the first device 201 may perform synchronization with the second device 202 based on the second plurality of occasions. That is, *S* may be used for the first device 201 to synchronize with the second device.

[0129] Reference now is made to FIG. 2B. For the purpose of discussion, the process 200B will be described with reference to FIGS. 1B and 1D. The process 200B may involve a second device 202, and a third device 203. For example, the second device 202 may comprise the BS 122 as shown in FIG. 1B or the BS 142 as shown in FIG. 1D with the topology type of 3A. For example, the third device 203 may comprise the A-IoT device 121 as shown in FIG. 1B, or the A-IoT device 141 as shown in FIG. 1D with the topology type of 3A. It is to be understood that the steps and the order of the steps in FIG. 2B are merely for illustration, and not for limitation. It is to be understood that the process 200B may further include additional blocks not shown and/or omit some shown blocks, and the scope of the present disclosure is not limited in this regard.

[0130] As shown in FIG. 2B, the second device 202 determines (235) a plurality of occasions for transmitting a plurality of signals for synchronization of the third device 203. Then, the second device 202 transmits (240), to the third device 203, the plurality of signals on the plurality of occasions. For example, system information may be transmitted along with the plurality of signals on the plurality of occasions. The system information may comprise the first field indicating an identifier of a cell of the second device 202, and/or the second field set to a default value. In this case, the second device 202 may be the only synchronization point for the third device 203. Then, the third device 203 performs (245) synchronization based on the the plurality of signals and the system information.

[0131] Some operations and features as described above with reference to FIGS. 2A are likewise applicable to the process 200B. Related details are omitted for brevity.

[0132] Reference is now made to FIG. 2C. For the purpose of discussion, the process 200C will be described with reference to FIG. 1E. The process 200C may involve a first device 201, and a third device 203. For example, the first device 201 may comprise the UE 152 as shown in FIG. 1E. For example, the third device 203 may comprise the A-IoT device 151 as shown in FIG. 1E. It is to be understood that the steps and the order of the

steps in FIG. 2C are merely for illustration, and not for limitation. It is to be understood that the process 200C may further include additional blocks not shown and/or omit some shown blocks, and the scope of the present disclosure is not limited in this regard.

[0133] As shown in FIG. 2C, the first device 201 determines (250), based on synchronization signal configuration, a plurality of occasions for transmitting a plurality of signals for synchronization of the third device 203. The first device 201 may obtain the synchronization signal configuration based on (pre-)configuration. Then, as shown in FIG. 2C, the first device 201 transmits (255), to the third device 203, the plurality of signals on the plurality of occasions. For example, system information may be transmitted along with the plurality of signals on the plurality of occasions. The system information may comprise the first field set to a default value, and/or the second field indicating an ID of the first device 201. Setting the first field to the default value may indicate that there is no presence of a BS. In this case, the first device 201 may be the only synchronization point for the third device 203. Then, the third device 203 performs (260) synchronization based on the the plurality of signals and the system information.

[0134] Some operations and features as described above with reference to FIGS. 2A are likewise applicable to the process 200C. Related details are omitted for brevity.

[0135] According to some embodiments with reference to FIGS. 2A to 3E, it is possible to improve the flexibility and efficiency of the synchronization procedure of the third device.

[0136] FIG. 4 illustrates an example of a device 400 that supports synchronization for an A-IoT device in accordance with aspects of the present disclosure. The device 400 may be an example of a first device 201, a second device 202 or a third device 203 as described herein. The device 400 may support wireless communication with one or more network entities 102, UEs 104, or any combination thereof. The device 400 may include components for bi-directional communications including components for transmitting and receiving communications, such as a processor 402, a memory 404, a transceiver 406, and, optionally, an I/O controller 408. 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).

[0137] The processor 402, the memory 404, the transceiver 406, 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 402, the memory 404, the transceiver 406, or various combinations or components thereof may support a method for performing one or more of the operations described herein.

[0138] In some implementations, the processor 402, the memory 404, the transceiver 406, 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 402 and the memory 404 coupled with the processor 402 may be configured to perform one or more of the functions described herein (e.g., executing, by the processor 402, instructions stored in the memory 404).

[0139] For example, the processor 402 may support wireless communication at the device 400 in accordance with examples as disclosed herein. The processor 402 may be configured to operable to support a means for receiving, from a second device, a configuration for providing a synchronization service for a third device; a means for determining, based on the configuration, a resource for transmitting a plurality of signals for synchronization of the third device; and a means for transmitting, to the third device, the plurality of signals on the resource. The processor 402 may be configured to operable to support a means for determining a configuration for a first device to provide a synchronization service for a third device; and a means for transmitting the configuration to the first device. The processor 402 may be configured to operable to support a means for receiving, from a first device and/or a second device, a plurality of signals and system information, the system information a first field associated with an identifier of a cell of the second device and a second field associated with an identifier of the first device; and a means for performing synchronization based on the plurality of signals and the system information.

[0140] The processor 402 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 402 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 402. The processor 402 may be configured to execute computer-readable instructions stored in a memory (e.g., the memory 404) to cause the device 400 to perform various functions of the present disclosure.

[0141] The memory 404 may include random access memory (RAM) and read-only memory (ROM). The memory 404 may store computer-readable, computer-executable code including instructions that, when executed by the processor 402 cause the device 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. In some implementations, the code may not be directly executable by the processor 402 but may cause a computer (e.g., when compiled and executed) to perform functions described herein. In some implementations, the memory 404 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.

[0142] The I/O controller 408 may manage input and output signals for the device 400. The I/O controller 408 may also manage peripherals not integrated into the device 400. In some implementations, the I/O controller 408 may represent a physical connection or port to an external peripheral. In some implementations, the I/O controller 408 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 408 may be implemented as part of a processor, such as the processor 406. In some implementations, a user may interact with the device 400 via the I/O controller 408 or via hardware components controlled by the I/O controller 408.

[0143] In some implementations, the device 400 may include a single antenna 410. However, in some other implementations, the device 400 may have more than one antenna 410 (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 406 may communicate bi-directionally, via the one or more antennas 410, wired, or wireless links as described herein. For example, the

transceiver 406 may represent a wireless transceiver and may communicate bi-directionally with another wireless transceiver. The transceiver 406 may also include a modem to modulate the packets, to provide the modulated packets to one or more antennas 410 for transmission, and to demodulate packets received from the one or more antennas 410. The transceiver 406 may include one or more transmit chains, one or more receive chains, or a combination thereof.

[0144] 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 410 for transmitting the amplified signal into the air or wireless medium.

[0145] 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 410 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.

[0146] FIG. 5 illustrates an example of a processor 500 that supports synchronization for an A-IoT device in accordance with aspects of the present disclosure. The processor 500 may be an example of a processor configured to perform various operations in accordance with examples as described herein. The processor 500 may include a controller 502 configured to perform various operations in accordance with examples as described herein. The processor 500 may optionally include at least one memory 504, such as L1/L2/L3 cache. Additionally, or alternatively, the processor 500 may optionally

include one or more arithmetic-logic units (ALUs) 500. 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).

[0147] The processor 500 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 500) 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).

[0148] The controller 502 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 500 to cause the processor 500 to support various operations in accordance with examples as described herein. For example, the controller 502 may operate as a control unit of the processor 500, generating control signals that manage the operation of various components of the processor 500. These control signals include enabling or disabling functional units, selecting data paths, initiating memory access, and coordinating timing of operations.

[0149] The controller 502 may be configured to fetch (e.g., obtain, retrieve, receive) instructions from the memory 504 and determine subsequent instruction(s) to be executed to cause the processor 500 to support various operations in accordance with examples as described herein. The controller 502 may be configured to track memory address of instructions associated with the memory 504. The controller 502 may be configured to decode instructions to determine the operation to be performed and the operands involved. For example, the controller 502 may be configured to interpret the instruction and determine control signals to be output to other components of the processor 500 to cause the processor 500 to support various operations in accordance with examples as described

herein. Additionally, or alternatively, the controller 502 may be configured to manage flow of data within the processor 500. The controller 502 may be configured to control transfer of data between registers, arithmetic logic units (ALUs), and other functional units of the processor 500.

[0150] The memory 504 may include one or more caches (e.g., memory local to or included in the processor 500 or other memory, such RAM, ROM, DRAM, SDRAM, SRAM, MRAM, flash memory, etc. In some implementations, the memory 504 may reside within or on a processor chipset (e.g., local to the processor 500). In some other implementations, the memory 504 may reside external to the processor chipset (e.g., remote to the processor 500).

[0151] The memory 504 may store computer-readable, computer-executable code including instructions that, when executed by the processor 500, cause the processor 500 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 502 and/or the processor 500 may be configured to execute computer-readable instructions stored in the memory 504 to cause the processor 500 to perform various functions. For example, the processor 500 and/or the controller 502 may be coupled with or to the memory 504, and the processor 500, the controller 502, and the memory 504 may be configured to perform various functions described herein. In some examples, the processor 500 may include multiple processors and the memory 504 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.

[0152] The one or more ALUs 500 may be configured to support various operations in accordance with examples as described herein. In some implementations, the one or more ALUs 500 may reside within or on a processor chipset (e.g., the processor 500). In some other implementations, the one or more ALUs 500 may reside external to the processor chipset (e.g., the processor 500). One or more ALUs 500 may perform one or more computations such as addition, subtraction, multiplication, and division on data. For example, one or more ALUs 500 may receive input operands and an operation code, which determines an operation to be executed. One or more ALUs 500 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 500 may support logical operations such as AND, OR, exclusive-OR (XOR), not-OR (NOR), and not-AND (NAND), enabling the one or more ALUs 500 to handle conditional operations, comparisons, and bitwise operations.

[0153] The processor 500 may support wireless communication in accordance with examples as disclosed herein. The processor 500 may be configured to or operable to support a means for receiving, from a second device, a configuration for providing a synchronization service for a third device; a means for determining, based on the configuration, a resource for transmitting a plurality of signals for synchronization of the third device; and a means for transmitting, to the third device, the plurality of signals on the resource. The processor 500 may be configured to or operable to support a means for determining a configuration for a first device to provide a synchronization service for a third device; and a means for transmitting the configuration to the first device. The processor 500 may be configured to or operable to support a means for receiving, from a first device and/or a second device, a plurality of signals and system information, the system information a first field associated with an identifier of a cell of the second device and a second field associated with an identifier of the first device; and a means for performing synchronization based on the plurality of signals and the system information.

[0154] FIG. 6 illustrates a flowchart of a method 600 that supports synchronization 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 first device 201 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.

[0155] At 610, the method may include receiving, from a second device, a configuration for providing a synchronization service for a third 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 first device 201 as described with reference to FIG. 2.

[0156] At 620, the method may include determining, based on the configuration, a resource for transmitting a plurality of signals for synchronization of the third device. 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 first device 201 as described with reference to FIG. 2A.

[0157] At 630, the method may include transmitting, to the third device, the plurality of signals on the resource. 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 first device 201 as described with reference to FIG. 2A.

[0158] FIG. 7 illustrates a flowchart of a method 700 that supports synchronization for an A-IoT device in accordance with aspects of the present disclosure. The operations of the method 700 may be implemented by a device or its components as described herein. For example, the operations of the method 700 may be performed by a second device 202 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.

[0159] At 710, the method may include determining a configuration for a first device to provide a synchronization service for a third device. The operations of 710 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 710 may be performed by a second device 202 as described with reference to FIG. 2A.

[0160] At 720, the method may include transmitting the configuration to the first device. The operations of 720 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 720 may be performed by a second device 202 as described with reference to FIG. 2A.

[0161] FIG. 8 illustrates a flowchart of a method 800 that supports synchronization for an A-IoT device in accordance with aspects of the present disclosure. The operations of the method 800 may be implemented by a device or its components as described herein. For example, the operations of the method 800 may be performed by a third device 203 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.

[0162] At 810, the method may include receiving, from a first device and/or a second device, a plurality of signals and system information, the system information a first field associated with an identifier of a cell of the second device and a second field associated with an identifier of the first device. The operations of 810 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 810 may be performed by a third device 203 as described with reference to FIG. 2A.

[0163] At 820, the method may include performing synchronization based on the plurality of signals and the system information. The operations of 820 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 820 may be performed by a third device 203 as described with reference to FIG. 2A.

[0164] It should be noted that the methods described herein describe 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.

[0165] 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).

[0166] 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.

[0167] 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.

[0168] 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.

[0169] 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

What is claimed is:

1. A first device comprising:
at least one memory; and
at least one processor coupled with the at least one memory and configured to cause the first device to:
receive, from a second device, a configuration for providing a synchronization service for a third device;
determine, based on the configuration, a resource for transmitting a plurality of signals for synchronization of the third device; and
transmit, to the third device, the plurality of signals on the resource.
2. The first device of claim 1, wherein the at least one processor is further configured to cause the first device to:
transmit, to the second device, one or more of the following:
capability information associated with a capability of providing the synchronization service; or
an identifier of the first device.
3. The first device of claim 1, wherein the at least one processor is further configured to cause the first device to:
receive, from the second device, an indication to provide the synchronization service for the third device.
4. The first device of claim 1, wherein the configuration comprises one or more of the following:
time domain resource information for the plurality of signals;
system information for synchronization of the third device; or
information on generation of the plurality of signals.
5. The first device of claim 4, wherein determining the resource for transmitting the plurality of signals based on the configuration comprises:
determining a first plurality of occasions for transmitting the plurality of signals

based on the time domain resource information.

6. The first device of claim 5, wherein the first plurality of occasions are part of a second plurality of occasions for the second device to transmit a plurality of signals for synchronization of the third device.

7. The first device of claim 5, wherein the first plurality of occasions are not overlapped with a second plurality of occasions for the second device to transmit a plurality of signals for synchronization of the third device.

8. The first device of claim 5, wherein the first plurality of occasions are not overlapped with a third plurality of occasions for the fourth device to transmit a plurality of signals for synchronization of the third device, and the first plurality of occasions and the third plurality of occasions are part of a second plurality of occasions for the second device to transmit a plurality of signals for synchronization of the third device.

9. The first device of claim 4, wherein the time domain resource information comprises one or more of: an index of a first time unit (TU) within a second TU, or an index of a third TU within the first TU, and wherein the second TU comprises a plurality of first TUs, and the first TU comprises a plurality of third TUs.

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

transmit, to the third device, system information on the resource, the system information comprises one or more of the following:

- a first field indicating an identifier of a cell of the second device; or
- a second field indicating an identifier of the first device.

11. The first device of claim 1, wherein the first device comprises a network device or a terminal device, the second device comprises a base station, and the third device comprises an internet of things (IoT) device.

12. A second device comprising:

at least one memory; and
at least one processor coupled with the at least one memory and configured to cause the second device to:
determine a configuration for a first device to provide a synchronization service for a third device; and
transmit the configuration to the first device.

13. The second device of claim 12, wherein the at least one processor is further configured to cause the second device to:

receive, from the first device, one or more of the following:
capability information associated with a capability of providing the synchronization service; or
an identifier of the first device.

14. The second device of claim 12, wherein the at least one processor is further configured to cause the second device to:

transmit, to the first device, an indication to provide the synchronization service for the third device.

15. The second device of claim 12, wherein the configuration comprises one or more of the following:

time domain resource information for a plurality of signals for synchronization of the third device;
system information for synchronization of the third device; or
information on generation of the plurality of signals.

16. The second device of claim 15, wherein the time domain resource information comprises one or more of: an index of a first time unit (TU) within a second TU, or an index of a third TU within the first TU, and wherein the second TU comprises a plurality of first TUs, and the first TU comprises a plurality of third TUs.

17. The second device of claim 12, wherein the at least one processor is further configured to cause the second device to:

determine a second plurality of occasions for transmitting a plurality of signals for synchronization of the third device; and

transmit, to the third device, the plurality of signals and system information on the second plurality of occasions, and

wherein the system information comprises one or more of the following:

a first field indicating an identifier of a cell of the second device; or

a second field associated with an identifier of the first device, wherein the second field comprises a default value.

18. The second device of claim 17, wherein the first plurality of occasions are not overlapped with a third plurality of occasions for the fourth device to transmit a plurality of signals for synchronization of the third device, and the first plurality of occasions and the third plurality of occasions are not overlapped with the second plurality of occasions.

19. A processor for wireless communication, comprising:

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

receive, from a second device, a configuration for providing a synchronization service for a third device;

determine, based on the configuration, a resource for transmitting a plurality of signals for synchronization of the third device; and

transmit, to the third device, the plurality of signals on the resource.

20. A processor for wireless communication, comprising:

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

determine a configuration for a first device to provide a synchronization service for a third device; and

transmit the configuration to the first device.