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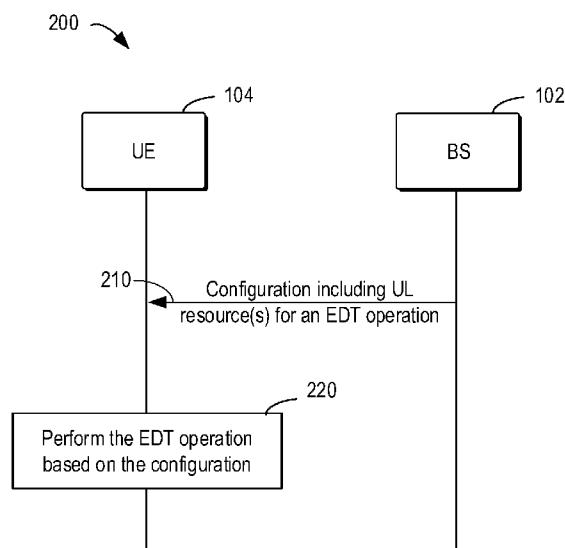


Fig. 2

(57) Abstract: Various aspects of the present disclosure relate to early data transmission. In one aspect, a UE receives a configuration for an early data transmission operation. The configuration includes at least one uplink resource or at least one downlink resource for the early data transmission operation. Then, the UE the EDT operation based on the configuration. In this way, early data transmission, for example, in a non-terrestrial network can be enhanced, thereby improving communication performance in early data transmission.

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EARLY DATA TRANSMISSION

TECHNICAL FIELD

[0001] The present disclosure relates to wireless communications, and more specifically to a user equipment (UE), a base station, and methods for enhanced early data transmission (EDT).

BACKGROUND

[0002] A wireless communications system may include one or multiple network communication devices, such as base stations, which may be otherwise known as an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. Each network communication devices, such as a base station may support wireless communications for one or multiple user communication devices, which may be otherwise known as 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] The wireless communication system may comprise one or more satellites which may relay signals or act as base stations, such as in non-terrestrial network (NTN). The satellite in the NTN can be a geostationary earth orbiting (GEO) satellite with a fixed location to the Earth, or a low earth orbiting (LEO) satellite orbiting around the Earth. In the NTN, considering the need of supporting massive capacity in terms of number and types of UEs, there is a need to optimize uplink transmission and downlink transmission between the satellite and the UE.

SUMMARY

[0004] The present disclosure relates to a UE, a base station, and methods for a solution of EDT. With the UE, base station and methods, the uplink and downlink signalling for EDT can be reduced, for example, thereby enhancing EDT in the NTN.

[0005] In a first aspect, some implementations of a UE described herein may include a processor; and a transceiver coupled to the processor, wherein the processor is configured to: receive, via the transceiver and from a base station, a configuration for an early data transmission (EDT) operation, wherein the configuration includes at least one uplink (UL) resource or at least one downlink (DL) resource for the EDT operation; and perform the EDT operation based on the configuration.

[0006] In some implementations, the processor is configured to perform the EDT operation by transmitting a message 3 (Msg3) without transmission of a Msg1 and reception of a Msg2.

[0007] In some implementations, the at least one uplink (UL) resource comprises at least one of the following: at least one UL resource shared by a plurality of UEs in a group; at least one UL resource shared by UEs in a cell; or at least one UL resource dedicated for the UE.

[0008] In some implementations, the configuration further includes an identity associated to the UL resource, and the identity comprises at least one of the following: a first group identity indicating a group of UEs that are allowed to use the at least one UL resource for the EDT operation; a first UE identity indicating a specific UE in a group that is allowed to use the at least one UL resource for the EDT operation; or a second UE identity indicating a specific UE in a cell that is allowed to use the at least one UL resource for the EDT operation.

[0009] In some implementations, the processor is configured to perform the EDT operation based on the configuration by: determining a UL resource among the at least one UL resource based on one or more of the first group identity, the first UE identity, or the second UE identity; and transmitting a Msg3 using the determined UL resource without transmission of a Msg1 and reception of a Msg2.

[0010] In some implementations, the Msg3 includes the one or more of the first group identity, the first UE identity, or the second UE identity.

[0011] In some implementations, the processor is configured to determine the UL resource by: determining, based on the first UE identity, a UL resource shared by UEs in the group; determining, based on the second UE identity, a UL resource shared by UEs in the cell; or determining a UL resource shared by UEs in the group or the cell randomly.

[0012] In some implementations, a serial number of the shared UL resource is determined based on a UE identity and a resource size of the shared UL resource.

[0013] In some implementations, the processor is configured to transmit the Msg 3 by: in a case that one or both of the first group identity and the first UE identity are configured, transmitting the Msg3 using the UL resource shared by UEs in the group; or in a case that the second UE identity is configured, transmitting the Msg3 using the UL resource shared by UEs in the cell.

[0014] In some implementations, the processor is configured to perform the EDT operation based on the configuration by: transmitting, to the base station, a Msg3 using the UL resource dedicated for the UE.

[0015] In some implementations, the configuration includes a threshold configured for the EDT operation, and the configured threshold includes at least one of the following: a signal strength threshold for the EDT operation; a signal quality threshold for the EDT operation; a latency threshold for the EDT operation; a distance threshold for the EDT operation; or a time point for the EDT operation.

[0016] In some implementations, the processor is configured to perform the EDT operation based on the configuration by: in a case that a non-access stratum (NAS) layer of the UE requests for mobile originated early data transmission (MO-EDT) and an uplink data size is less than a data size threshold, and at least one predetermined condition is fulfilled, initiating the EDT operation.

[0017] In some implementations, the at least one predetermined condition comprises at least one of the following: the configured threshold is the signal strength threshold, and the strength of a signal received by the UE is equal to or above the configured threshold; the configured threshold is the signal quality threshold, and the quality of a signal received by the UE is equal to or above the configured threshold; the configured threshold is the latency threshold, and a timing advance or a round-trip time of the UE is equal to or less than the configured threshold; the configured threshold is the distance threshold, and a distance from the UE to the base station or an antenna unit or a reference point of a serving cell is equal to or less than the configured threshold; the configured threshold is the time point, and the current time at which the MO-EDT is requested is prior to the time point; or a cell stop serving time or a feeder link switch time out of the configuration is obtained,

the current time at which the MO-EDT is requested is prior to the cell stop serving time or the feeder link switch time.

[0018] In some implementations, the processor is further configured to: prior to performing the EDT operation, calculate a timing advance to be pre-compensated for UL synchronization of the UE to a cell provided by the base station.

[0019] In some implementations, the timing advance is calculated based on valid information including an ephemeris of a serving cell and a position of the UE.

[0020] In some implementations, the processor is further configured to: in a case that the valid information is not obtained, delay the performing of the EDT operation to acquire the valid information.

[0021] In some implementations, in a case that the valid information is not obtained, the timing advance is calculated based on current information for an ephemeris of a serving cell and a position of the UE.

[0022] In some implementations, the processor is further configured to: in a case that the calculation of the timing advance fails, determine that the EDT operation is unsuccessful.

[0023] In some implementations, the processor is further configured to: in a case that the EDT operation is determined as unsuccessful, perform a fallback operation.

[0024] In some implementations, the fallback operation comprises at least one of the following: in a case that a contention indication from the base station is received or in a case that a timer of the UE for contention resolution expires, suspending the EDT operation for a time duration; in a case that a contention indication or a fallback indication from the base station is received or in a case that the timer of the UE for contention resolution expires, performing an EDT operation configured with a random access preamble or a random access response; or in a case that the contention indication or a fallback indication from the base station is received or in a case that the timer of the UE for contention resolution expires, performing a connection establishment to transition to a connected state.

[0025] In some implementations, the timer for the contention resolution is separate from a timer used for contention resolution of the EDT configured with the random access preamble or the random access response.

[0026] In some implementations, the timer for contention resolution is a timer specific for a non-terrestrial network, and a start of the timer is offset by the UE to a round trip time of the base station.

[0027] In some implementations, the at least one DL resource comprises at least one of the following: at least one DL resource shared by a plurality of UEs in a group; at least one DL resource shared by UEs in a cell; or at least one DL resource dedicated for the UE.

[0028] In some implementations, the configuration further includes an identity associated to reception of a message 4 (Msg4), and the identity comprises at least one of the following: a second group identity indicating a group of UEs that are allowed to receive a Msg4 associated to the group; a third UE identity indicating a specific UE in a group that is allowed to receive a Msg4 associated to the group; or a fourth UE identity indicating a specific UE in a cell that is allowed to receive a Msg4 associated to the cell.

[0029] In some implementations, the Msg4 includes at least one of the following as a common part: zero information or data from the NAS layer; empty information or data from the NAS layer; a common wait time for a delay tolerant service; a common cell reselection configuration including a frequency priority; common redirection information; a common cause indication or value for connection release; a common chaining count for a next hop; a common robust header compression (EOHC) configuration for a data radio bearer (DRB); a flag indication indicating successful reception of uplink EDT data; or at least one identity that indicates successful reception or no reception of uplink EDT data from an indicated UE.

[0030] In some implementations, the common part is received via multicast or broadcast using the at least one DL resource shared by the plurality of UEs in the group or shared by the UEs in the cell.

[0031] In some implementations, the Msg4 includes at least one of the following as a dedicated part: non-zero information or data from the NAS layer; a UE-specific wait time for a delay tolerant service; a UE-specific cell reselection configuration including a frequency priority; UE-specific redirection information; a UE-specific identity for connection resume; UE-specific downlink data; a flag indication indicating successful reception of uplink EDT data; a physical layer acknowledgement indication; or a media access control (MAC) layer acknowledgement indication.

[0032] In some implementations, the dedicated part is received via unicast using the at least one DL resource dedicated for the UE.

[0033] In some implementations, the processor is further configured to: receive the Msg4 from the base station and based on at least one of the second group identity, the third UE identity, and the fourth UE identity.

[0034] In some implementations, the processor is further configured to: prior to the reception of the Msg4, and in a case that a remaining validity duration of at least one of the ephemeris of the serving cell or the position of the UE is less than a threshold, delay global navigation satellite system (GNSS) position fix or ephemeris acquiring.

[0035] In some implementations, an unavailable duration or an expected duration for the reception of the Msg4 is indicated in a Msg 3.

[0036] In some implementations, a remaining validity duration of information for UL synchronization is indicated in a Msg 3.

[0037] In some implementations, the processor is configured to receive the Msg4 by: prior to the reception of the Msg4, in a case that a remaining validity duration of at least one of a cell stop serving time or a feeder link switch time is less than a threshold, receive, from the base station, the Msg4 in another cell which is reselected and synchronized to the another cell.

[0038] In some implementations, the processor is configured to receive the Msg4 by: prior to the reception of the Msg4, in a case that a remaining validity duration of at least one of a cell stop serving time or a feeder link switch time is less than a threshold, receive, from another base station, the Msg4 in another cell which is synchronized to the another base station.

[0039] In some implementations, the UE and the base station is in a non-terrestrial network (NTN).

[0040] In a second aspect, some implementations of a base station described herein may include a processor; and a transceiver coupled to the processor, wherein the processor is configured to: transmit, via the transceiver and to a user equipment (UE), a configuration for an early data transmission (EDT) operation, wherein the configuration includes at least one uplink (UL) resource or at least one downlink (DL) resource for the EDT operation.

[0041] In some implementations, the at least one UL resource comprises at least one of the following: at least one UL resource shared by a plurality of UEs in a group; at least one UL resource shared by UEs in a cell; or at least one UL resource dedicated for the UE.

[0042] In some implementations, the configuration further includes an identity associated to the UL resource, and the identity comprises at least one of the following: a first group identity indicating a group of UEs that are allowed to use the at least one UL resource for the EDT operation; a first UE identity indicating a specific UE in a group that is allowed to use the at least one UL resource for the EDT operation; or a second UE identity indicating a specific UE in a cell that is allowed to use the at least one UL resource for the EDT operation.

[0043] In some implementations, the processor is further configured to: identify the EDT operation based on one of the following: the first group identity; the first UE identity; the second UE identity; or the UL resource is dedicated for the UE.

[0044] In some implementations, the processor is further configured to: receive, from the UE, a Msg 3 transmitted based on the EDT operation.

[0045] In some implementations, the Msg 3 includes the one or more of the first group identity and the first and second UE identities.

[0046] In some implementations, the configuration includes a threshold configured for the EDT operation, and the configured threshold includes at least one of the following: a signal strength threshold for the EDT operation; a signal quality threshold for the EDT operation; a latency threshold for the EDT operation; a distance threshold for the EDT operation; or a time point for the EDT operation.

[0047] In some implementations, the processor is further configured to: transmit, via the transceiver and to the UE, one of the following: a contention indication for the EDT operation; a fallback indication for indicating the UE to fall back to perform an EDT configured with a random access preamble or a random access response; or a fallback indication for indicating the UE to fall back to perform a connection establishment to transition to a connected state.

[0048] In some implementations, the at least one DL resource comprises at least one of the following: at least one DL resource shared by a plurality of UEs in a group; at least

one DL resource shared by UEs in a cell; or at least one DL resource dedicated for the UE.

[0049] In some implementations, the configuration further includes an identity associated to reception of a message 4 (Msg4), and the identity comprises at least one of the following: a second group identity indicating a group of UEs that are allowed to receive a Msg4 associated to the group; a third UE identity indicating a specific UE in a group that is allowed to receive a Msg4 associated to the group; or a fourth UE identity indicating a specific UE in a cell that is allowed to receive a Msg4 associated to the cell.

[0050] In some implementations, the Msg4 includes at least one of the following as a common part: zero information or data from the NAS layer; empty information or data from the NAS layer; a common wait time for a delay tolerant service; a common cell reselection configuration including a frequency priority; common redirection information; a common cause indication or value for connection release; a common chaining count for a next hop; a common robust header compression (ROHC) configuration for a data radio bearer (DRB); a flag indication indicating successful reception of uplink EDT data; or at least one identity that indicates successful reception or no reception of uplink EDT data from an indicated UE.

[0051] In some implementations, the common part is transmitted via multicast or broadcast using the at least one DL resource shared by the plurality of UEs in the group or shared by the UEs in the cell.

[0052] In some implementations, the Msg4 includes at least one of the following as a dedicated part: non-zero information or data from the NAS layer; a UE-specific wait time for a delay tolerant service; a UE-specific cell reselection configuration including a frequency priority; UE-specific redirection information; a UE-specific identity for connection resume; UE-specific downlink data; a flag indication indicating successful reception of uplink EDT data; a physical layer acknowledgement indication; or a media access control (MAC) layer acknowledgement indication.

[0053] In some implementations, the dedicated part is transmitted via unicast using the at least one DL resource dedicated for the UE.

[0054] In some implementations, the processor is further configured to: transmit, to the UE, the Msg4.

[0055] In some implementations, the processor is further configured to: prior to the transmission of the Msg4, and in a case that at least one of a cell stop serving time or a feeder link switch time is to be reached, transmit, to another base station, a Msg 3 received from the UE.

[0056] In some implementations, the processor is further configured to: prior to the transmission of the Msg4, and in a case that at least one of a cell stop serving time or a feeder link switch time is to be reached, transmit, to another base station, a Msg4 generated based on reception of a Msg 3 received from the UE.

[0057] In a third aspect, some implementations of a method described herein may include: receiving, via the transceiver and from a base station, a configuration for an early data transmission (EDT) operation, wherein the configuration includes at least one uplink (UL) resource or at least one downlink (DL) resource for the EDT operation; and performing the EDT operation based on the configuration.

[0058] In a fourth aspect, some implementations of a processor described herein may include at least one memory and a controller coupled with the at least one memory and configured to cause the controller to: receive, via the transceiver and from a base station, a configuration for an early data transmission (EDT) operation, wherein the configuration includes at least one uplink (UL) resource or at least one downlink (DL) resource for the EDT operation; and perform the EDT operation based on the configuration.

[0059] In a fifth aspect, some implementations of a method described herein may include: transmitting, via the transceiver and to a user equipment (UE), a configuration for an early data transmission (EDT) operation, wherein the configuration includes at least one uplink (UL) resource or at least one downlink (DL) resource for the EDT operation.

[0060] It is to be understood that the summary section is not intended to identify key or essential features of embodiments of the present disclosure, nor is it intended to be used to limit the scope of the present disclosure. Other features of the present disclosure will become easily comprehensible through the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0061] Fig. 1 illustrates an example of a wireless communications system for enhanced EDT in accordance with aspects of the present disclosure.

[0062] Fig. 2 illustrates a signaling chart of an example process for enhanced EDT in accordance with some aspects of the present disclosure.

[0063] Fig. 3 illustrates a signaling chart of an example process for enhanced EDT in accordance with some aspects of the present disclosure.

[0064] Fig. 4A illustrates a signaling chart of a part of an example process for enhanced EDT in accordance with aspects of the present disclosure.

[0065] Fig. 4B illustrates a signaling chart of another part of the example process of Fig. 4A in accordance with aspects of the present disclosure.

[0066] Fig. 5 illustrates an example of a device for enhanced EDT in accordance with some aspects of the present disclosure.

[0067] Fig. 6 illustrates an example of a processor for enhanced EDT in accordance with aspects of the present disclosure.

[0068] Fig. 7 illustrate a flowchart of a method for enhanced EDT in accordance with aspects of the present disclosure.

[0069] Fig. 8 illustrate a flowchart of a method for enhanced EDT in accordance with aspects of the present disclosure.

DETAILED DESCRIPTION

[0070] 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.

[0071] 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.

[0072] References in the present disclosure to “one implementation,” “an example implementation,” “an implementation,” “some implementations,” and the like indicate that the implementation(s) described may include a particular feature, structure, or

characteristic, but it is not necessary that every implementation includes the particular feature, structure, or characteristic. Moreover, such phrases do not necessarily refer to the same implementation(s). Further, when a particular feature, structure, or characteristic is described in connection with an implementation, 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 implementations whether or not explicitly described.

[0073] It shall be understood that although the terms “first” and “second” or the like may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another element. For example, a first element could also be termed as a second element, and similarly, a second element could also be termed as a first element, without departing from the scope of implementations. As used herein, the term “and/or” includes any and all combinations of one or more of the listed terms. In some examples, values, procedures, or apparatuses are referred to as “best,” “lowest,” “highest,” “minimum,” “maximum,” or the like. It will be appreciated that such descriptions are intended to indicate that a selection among many used functional alternatives can be made, and such selections need not be better, smaller, higher, or otherwise preferable to other selections.

[0074] 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. For example, the term “includes” and its variants are to be read as open terms that mean “includes, but is not limited to.” The term “based on” is to be read as “based at least in part on.” The term “one implementation” and “an implementation” are to be read as “at least one implementation.” The term “another implementation” is to be read as “at least one other implementation.” The use of an expression such as “A and/or B” can mean either “only A” or “only B” or “both A and B.” Other definitions, explicit and implicit, may be included below.

[0075] Aspects of the present disclosure are described in the context of a wireless communications system.

[0076] Fig. 1 illustrates an example of a wireless communications system 100 for enhanced EDT 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 (NE)), one or more terminal devices or 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.

[0077] 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 (BS), a network element, a radio access network (RAN) node, 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.

[0078] In NTN scenarios, a network entity 102 may be implemented as a satellite. A network entity 102 in form of a satellite can directly communicate to UE 104 using LTE/NR Uu interface. The satellite may be a transparent satellite or a regenerative satellite. For NTN with a transparent satellite, a base station on earth may communicate with a UE via the satellite. For example, a communication link 110 between the satellite

and the UE 104, a communication link 110 between the satellite and a base station on earth, and a communication link 116 between the base station on earth and core network 106 may be used for the NTN transparent mode. For NTN with a regenerative satellite, the base station may be on board and directly communicate with the UE. For example, a communication link 110 between the satellite and the UE 104, and a communication link 116 between the satellite (with full or part of an eNB/gNB on board) and core network 106 may be used for the NTN regenerative mode.

[0079] 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.

[0080] 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.

[0081] The one or more UEs 104 may be devices in different forms or having different capabilities. Some examples of UEs 104 are illustrated in Fig. 1. A UE 104 may be capable of communicating with various types of devices, such as the network entities 102, other UEs 104, or network equipment (e.g., the core network 106, the packet data network 108, a relay device, an integrated access and backhaul (IAB) node, or another network equipment), as shown in Fig. 1. Additionally, or alternatively, a UE 104 may support communication with other network entities 102 or UEs 104, which may act as relays in the wireless communications system 100.

[0082] 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.

[0083] 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).

[0084] 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 radio access network (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.

[0085] 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)).

[0086] Split of functionality between a CU, a DU, and an RU may be flexible and may support different functionalities depending upon which functions (e.g., network layer functions, protocol layer functions, baseband functions, radio frequency functions, and any combinations thereof) are performed at a CU, a DU, or an RU. For example, a functional split of a protocol stack may be employed between a CU and a DU such that the CU may support one or more layers of the protocol stack and the DU may support one or more different layers of the protocol stack. In some implementations, the CU may host upper protocol layer (e.g., a layer 3 (L3), a layer 2 (L2)) functionality and signaling (e.g., radio resource control (RRC), service data adaptation protocol (SDAP), packet data convergence protocol (PDCP)). The CU may be connected to one or more DUs or RUs, and the one or more DUs or RUs may host lower protocol layers, such as a layer 1 (L1) (e.g., physical (PHY) layer) or an L2 (e.g., radio link control (RLC) layer, medium access control (MAC) layer) functionality and signaling, and may each be at least partially controlled by the CU.

[0087] 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).

[0088] 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.

[0089] 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.

[0090] 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, N3, 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).

[0091] 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.

[0092] 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.

[0093] 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.

[0094] 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.

[0095] 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.

[0096] 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.

[0097] The NTN refers to a network or a segment of the network using radio frequency (RF) resources on board a satellite. 3GPP Rel-17 specifications have provided basic support of NTN features and in Rel-18 further provided optimization. EDT is a feature supported in LTE protocols to allow UE data transmission and reception without entering CONNECTED state so as to reduce UE power consumption. The EDT can be characterized into mobile originated early data transmission (MO-EDT) and mobile terminated early data transmission (MT-EDT).

[0098] The MO-EDT allows one uplink data transmission optionally followed by one downlink data transmission during a random access procedure, and it is triggered when the upper layers have requested the establishment or resumption of the radio resource control (RRC) connection for mobile originated data and the uplink data size is less than or equal to a size threshold indicated in system information.

[0099] The MT-EDT is intended for a single downlink data transmission during a random access procedure, and it is initiated by a mobility management entity (MME) if the UE and the network support the MT-EDT and there is a single DL data transmission for the UE.

[0100] In general, an EDT scheme includes Msg1(preamble) transmission, Msg2(RAR) reception, Msg3 transmission, and Msg4 reception in an entire random access procedure. In particular, the above mentioned EDT only supports operations with random access and unicast delivery of message 4 (Msg4). For Rel-19 NTN enhancements, considering the need of supporting massive capacity in terms of number and types of UEs, an identification mechanism to reduce the required uplink and downlink signaling is desirable. Satellite operators and vendors have proposed to optimize the EDT/preconfigured uplink resource (PUR) mechanisms.

[0101] In view of the forgoing, some embodiments of the disclosure focus on the enhancements to reduce the required uplink and downlink signaling for completing an EDT transaction, i.e., message 3 (Msg3) transmission without transmission/reception of

message 1 (Msg1)/message 2 (Msg2, random access response(RAR)), or efficient delivery (reduced overhead) of Msg4/RRCEarlyDataComplete. Specifically, some embodiments of the disclosure provide a mechanism on how to implement or support the enhancements of EDT in Rel-17 and Rel-18 IoT/NR NTN. In other words, the disclosure can develop the signaling and procedures to optimize EDT operations in NTN deployment with specific focuses on the two enhancements mentioned above for Rel-19 IoT NTN.

[0102] More specifically, regarding the enhancement of Msg3 transmission without Msg1 and Msg2, the embodiments of the disclosure may be provided based on the following considerations.

[0103] In an EDT scheme, the UE relies on transmission of an EDT-dedicated preamble to request for EDT, and the eNB can identify the request for EDT based on the use of EDT-dedicated preamble. If Msg1(preamble) transmission is omitted for EDT, a new scheme is needed for the UE to request for a EDT operation and for the eNB to identify the request for the EDT operations.

[0104] In the EDT scheme, there is no resource pre-configuration for the UE, and therefore the UE relies on reception of Msg2(RAR) to acquire the UL resource for the followed Msg3 transmission. If Msg2(RAR) is omitted for EDT, how to configure the UE with the corresponding resource for Msg3 transmission needs to be specified.

[0105] In the EDT scheme, the initiation of EDT only considers one metric of data size while the channel quality (e.g., signal strength) can be guaranteed by a random access mechanism (e.g., power ramping). If Msg1(preamble) is omitted for EDT, how to ensure that the channel quality is sufficient to transmit Msg3 is still desirable. Moreover, for the NTN deployed with LEO satellites, the timing of cell change (e.g., cell stop serving time or feeder link switch time) shall be considered as well.

[0106] In the Rel-17 and Rel-18 NTN, the UE needs to pre-compensate the timing advance between the UE and the network reference point for UL synchronization before initiating random access. For an EDT operation in such deployment, it is also required for the UE to calculate the pre-compensated timing advance, while a procedure to acquire ephemeris or a UE position may interrupt the initiation of EDT.

[0107] In the EDT scheme, the UE fallbacks to RRC connection establishment if the EDT operation is not successful. If Msg3 transmission without Msg1(preamble)/Msg2(RAR) is supported and not successful, the followed operation including possible backoff or fallback needs to be specified.

[0108] Herein, how to enable or configure an EDT operation without Msg1(preamble)/Msg2(RAR), i.e., configuration and execution of the EDT operation without Msg1(preamble)/Msg2(RAR), will be described with reference to Figs. 2 and 4 below.

[0109] Fig. 2 illustrates a signaling chart of an example process 200 for enhanced EDT in accordance with aspects of the present disclosure. Fig. 4A illustrates a signaling chart of a part of an example process 400 for enhanced EDT in accordance with aspects of the present disclosure. Fig. 4B illustrates a signaling chart of another part of the example process 400. For the purpose of discussion, the processes 200 and 400 may involve the UE 104 and the BS (e.g. eNB) 102. The processes 200 and 400 may be applied to the wireless communications system 100 with reference to Fig. 1. It would be appreciated that the processes 200 and 400 may be applied to other communication scenarios, which will not be described in detail.

[0110] As shown in Fig. 2, the UE 104 receives 210 a configuration for an EDT operation from the BS 102. The configuration includes at least one UL resource for the EDT operation. The UE 104 performs 220 the EDT operation based on the configuration, for example, by transmitting an Msg3 without transmission of an Msg1 and reception of an Msg2. In other words, the eNB 102 configures the UE 104 with UL resource(s) for an EDT operation without Msg1(preamble)/Msg2(RAR). In one embodiment #1, as shown in Fig. 4A, the eNB 102 configures 410 the UE 104 with the UL resource(s) for EDT operation without Msg1(preamble)/Msg2(RAR) in IDLE, and the UE 104 initiates an EDT operation without Msg1(preamble)/Msg2(RAR) using the configured UL resource(s).

[0111] In an implementation A1, the at least one UL resource may comprise at least one UL resource shared by a plurality of UEs in a group. The configuration may further comprise an identity associated to the UL resource. The identity may comprise one or both of a group identity and a UE identity. The group identity indicates a group of UEs that are allowed to use the at least one UL resource for the EDT operation, and the UE

identity indicates a specific UE in a group that is allowed to use the at least one UL resource for the EDT operation.

[0112] For example, in a multicast/group manner shared by a pack of UEs 104, a group identity is associated to each group of UEs 104 and the corresponding resource(s), e.g. an EDT-group-ID. In other words, the UL resource(s) is shared by UEs in the same group indicated by the group identity associated to it. A UE identity for a UE in the group may be needed to differentiate UEs 104 using the same resource(s), e.g. an EDT-RNTI. The UE 104 may either select a resource (e.g., the shared resource with a serial number) based on this UE identity, e.g. the EDT-RNTI for the UE in the group. The serial number of the shared UL resource may be determined based on this UE identity and a resource size of the shared UL resource by UEs in the group, for example, as UE identity mods resource size. Alternatively, the UE 104 may determine a UL resource shared by UEs in the group randomly. In other words, the UE 104 may determine a UL resource among the at least one UL resource based one or both of the group identity and a UE identity used to identify a UE in a group. Then, the UE 104 can transmit the Msg 3 using the determined UL resource, e.g. the UL resource shared by UEs in the group, without transmission of the Msg 1 and reception of the Msg 2. The Msg3 may include one or both of the group identity and the UE identity for the UE 104 in the group. On the other side of communication, the eNB 102 may receive the Msg3 and identify an EDT operation without Msg1(preamble)/Msg2(RAR) based on at least one of the used UL resource(s), the group identity, or the UE identity.

[0113] In another implementation A2, the at least one UL resource may comprise at least one UL resource shared by UEs 104 in a cell. The configuration may further comprise an identity associated to the UL resource. The identity may comprise another UE identity indicating a specific UE 104 in a cell that is allowed to use the at least one UL resource for the EDT operation.

[0114] For example, in a broadcast manner shared by all UEs 104 in the cell, the UL resource(s) is shared by all UEs 104 in the cell. A UE identity for a UE in a cell may be needed to differentiate UEs 104 using the same resource, e.g. EDT-RNTI. The UE 104 may either select a resource (e.g., the shared UL resource with a serial number) based on this UE identity, e.g. EDT-RNTI for the UE in the cell. The serial number of the shared UL resource may be determined based on this UE identity and a resource size of the

shared UL resource by UEs in the cell, for example, as UE identity mods resource size. Alternatively, the UE 104 may determine a UL resource shared by UEs in the cell randomly. In other words, the UE 104 may determine a UL resource among the at least one UL resource based on a UE identity used to identify a UE in a cell. Then, the UE 104 can transmit the Msg 3 using the determined UL resource, e.g. the UL resource shared by UEs in the cell, without transmission of the Msg 1 and reception of the Msg 2. The Msg3 may include the UE identity for the UE 104 in the cell. On the other side of communication, the eNB 102 may receive the Msg3 and identify an EDT operation without Msg1(preamble)/Msg2(RAR) based on at least one of the used UL resource or this UE identity.

[0115] In yet another implementation A3, the at least one UL resource may comprise at least one UL resource dedicated for the UE 104. For example, in a unicast manner dedicated for a UE, the UL resource(s) is dedicated for the UE 104. The UE 102 may transmit the Msg 3 using the UL resource dedicated for the UE. On the other side of communication, the eNB 102 may identify an EDT operation without Msg1(preamble)/Msg2(RAR) based on the used UL resource.

[0116] It should be understood that the above implementations can be modified in combination with each other and other implementations.

[0117] In the above implementations A1-A3, the eNB 102 can identify an EDT operation without Msg1(preamble)/Msg2(RAR) requested by the UE 104 via one of the following options. In option B1, in correspondence to A1, A2, and A3, if the UE 104 may use the dedicated resource for an EDT operation without Msg1(preamble)/Msg2(RAR), the eNB 102 can identify the dedicated resource. In option B2, in correspondence to A1 and A2, if the UE 104 may use the UE identity for EDT operation without Msg1(preamble)/Msg2(RAR), the eNB 102 can identify the UE identity. In option B3, in correspondence to A1, if the UE 104 may use the group identity for EDT operation without Msg1(preamble)/Msg2(RAR), the eNB 102 can identify the group identity. In option B4, the UE 104 explicitly indicates EDT transmission without Msg1(preamble)/Msg2(RAR).

[0118] As described above, the UE 104 may skip 420 the transmission of Msg1 and the reception of Msg2 when the configuration for EDT without Msg1 and Msg2 is configured. The UE may determine 430 to initiate the EDT without Msg1 and Msg2, as

shown in Fig. 4A. In some implementations, with respect of how to ensure that the channel quality is sufficient to transmit the Msg3, the configuration may include a threshold configured for the EDT operation.

[0119] Specifically, in addition to the data size metric, other metric of initiating an EDT operation without Msg1(preamble)/Msg2(RAR) (e.g. a RSRP/Distance/TA threshold) may be introduced. For example, in one embodiment #2, as shown in Fig. 4A, the eNB 102 may configure the UE 104 with a threshold other than the data size threshold for EDT operation without Msg1(preamble)/Msg2(RAR). If a non-access stratum (NAS) layer of the UE requests for mobile originated early data transmission (MO-EDT) and an uplink data size is less than a data size threshold, and at least one of the following conditions, the UE 104 may initiate the EDT operation.

[0120] Condition 1: the configured threshold is the signal strength threshold, and the strength of a signal received by the UE is equal to or above the configured threshold.

[0121] Condition 2: the configured threshold is the signal quality threshold, and the quality of a signal received by the UE is equal to or above the configured threshold.

[0122] Condition 3: the configured threshold is the latency threshold, and a timing advance or a round-trip time of the UE is equal to or less than the configured threshold.

[0123] Condition 4: the configured threshold is the distance threshold, and a distance from the UE to the base station or an antenna unit or a reference point of a serving cell is equal to or less than the configured threshold.

[0124] Condition 5: the configured threshold is the time point, and the current time at which the MO-EDT is requested is prior to the time point.

[0125] Condition 6: a cell stop serving time or a feeder link switch time out of the configuration is obtained, the current time at which the MO-EDT is requested is prior to the cell stop serving time or the feeder link switch time, or the remaining time before the cell stop serving time and/or the feeder link switch time.

[0126] In some implementations, UL synchronization is required for guaranteeing for the above EDT operation without Msg1(preamble)/Msg2(RAR). Initiation of an EDT operation without Msg1(preamble)/Msg2(RAR) may trigger UE calculation for a timing advance to be pre-compensated, for example, using the newly acquired or already stored GNSS position or ephemeris. For example, prior to performing the EDT operation, the

UE 104 may calculate a timing advance to be pre-compensated for UL synchronization of the UE to a cell provided by the base station. In one embodiment #3, as shown in Fig. 4A, when the UE 104 decides to initiate an EDT operation without Msg1(preamble)/Msg2(RAR), the UE 104 may trigger and perform 440 calculation for a timing advance to be pre-compensated for UL synchronization to an NTN cell. The timing advance may be calculated based on valid information including an ephemeris of a serving cell and a position of the UE 104.

[0127] In an implementation, if the UE 104 does not have the necessary valid information (including the ephemeris of the serving cell and the UE position) to calculate the timing advance, i.e., if the valid information is not obtained, the UE 104 may delay the performing of the EDT operation to acquire the valid information, or delay the initiation of the EDT operation and acquire the necessary valid information. For example, the initiation of the EDT operation without Msg1(preamble)/Msg2(RAR) is delayed when the UE 104 is acquiring a GNSS position or ephemeris (SIB31). Alternatively, the acquiring of GNSS position or ephemeris is suspended (no UL sync loss after validity duration) when an EDT operation without Msg1(preamble)/Msg2(RAR) is triggered.

[0128] In another implementation, if the valid information is not obtained, the timing advance is calculated based on current information for an ephemeris of a serving cell and a position of the UE. In other words, the UE 104 may calculate the timing advance using the current information without triggering UL synchronization loss and suspending the acquiring of the necessary valid information.

[0129] In yet another implementation, if the calculation of the timing advance fails, the UE 104 may determine that the EDT operation is unsuccessful. In other words, the UE 104 can consider the EDT operation as unsuccessful if the UE 104 fails to calculate the timing advance to be pre-compensated.

[0130] In some implementations, if the EDT operation is determined as unsuccessful, the UE 104 may perform a fallback operation. For example, in one embodiment #4, as shown in Fig. 4B, when the UE 104 may consider the above EDT operation as unsuccessful, a Fallback mechanism for EDT operation without Msg1(preamble)/Msg2(RAR) can be performed (450) as below.

[0131] In an implementation C1, if a contention indication from the base station is received or if a timer of the UE for contention resolution expires, the UE 104 may perform

the fallback operation by suspending the EDT operation for a time duration. In other words, the UE 104 may suspend the EDT operation without Msg1(preamble)/Msg2(RAR) and wait for a next attempt, e.g., when the UE 104 receives an indication of contention from the eNB 102 or when the UE 104 has a timer for contention resolution (Msg4 reception) expired. The UE 104 may back off for a time duration to use the next available resource.

[0132] In another implementation C2, if a contention indication or a fallback indication from the base station 102 is received or if the timer of the UE 104 for contention resolution expires, the UE 104 may perform the fallback operation by performing an EDT operation configured with a random access preamble or a random access response.

[0133] In other words, the UE 104 may fall back (460) to the EDT (with random access, or Msg1(preamble)/Msg2(RAR)), e.g., when the UE 104 receives an indication of contention or fallback from the eNB 102 or when the UE 104 has a timer for contention resolution (Msg4 reception) expired. For example, the UE 104 may fall back to connection establishment so as to transit to a CONNECTED state if the UE 104 receives an indication of contention or fallback from the eNB 102 or when the UE 104 has a timer for contention resolution (Msg4 reception) expired.

[0134] When the UE 104 decides to fall back (460) to the EDT (with random access, or Msg1(preamble)/Msg2(RAR)), the UE 104 may determine 461 to initial normal EDT with Msg1 and Msg2. Then, the UE 104 can transmit 462 Msg1 (random access preamble) to the eNB 102, and the eNB 102 can transmit 463 Msg2 (random access response) to the UE 104. Next, the UE 104 may transmit 464 Msg3 (*RRCEarlyDataRequest* or *RRCCConnectionResumeRequest*) using UL resource(s) scheduled in Msg2, which includes *RRCEarlyDataRequest* (e.g. *(5G-)s-TMSI*, *establishmentCause*, *dedicatedInfoNAS*, and so on) and *RRCCConnectionResumeRequest* (e.g. *resumeID*, *resumeCause*, *UL data*, and so on).

[0135] In yet another implementation C3, if the contention indication or a fallback indication from the base station 102 is received or if the timer of the UE for contention resolution expires, the UE 104 may perform a connection establishment to transition to a connected state.

[0136] In other words, the UE 104 may directly fall back to connection establishment so as to transit to a CONNECTED state, e.g., when the UE 104 receives an indication of

contention or fallback from the eNB 102 or the UE 104 has a timer for contention resolution (Msg4 reception) expired. The timer for the contention resolution may be separate from a timer used for contention resolution of the EDT configured with the random access preamble or the random access response. Alternatively, the timer for contention resolution may a timer specific for a non-terrestrial network, and a start of the timer is offset by the UE 104 to a round trip time (RTT) of the base station 102. In other words, the timer for contention resolution (Msg4 reception) of the EDT operation without Msg1/Msg2 could be a timer different from that used for contention resolution of the EDT operation with Msg1/Msg2, e.g., *contentionResolutionTimerEDT*. The timer for contention resolution (Msg4 reception) of the EDT operation without Msg1/Msg2 could be a timer specific for the NTN, and its start is offsetted by the UE 104 to the BS RTT.

[0137] Regarding the enhancement of efficient delivery of Msg4 as mentioned above, some embodiments of the disclosure may be provided based on the following considerations.

[0138] In the EDT (with random access, or Msg1(preamble)/Msg2(RAR)), the delivery of Msg4(*RRCEarlyDataComplete*) is unicast via the dedicated signaling, and all its included fields (*dedicatedInfoNAS*, *extendedWaitTime*, *idleModeMobilityControlInfo*, *redirectedCarrierInfo*) are optional.

[0139] The contents of Msg4 are not all UE-specific. For example, at least the fields *extendedWaitTime*, *idleModeMobilityControlInfo*, and *redirectedCarrierInfo*, could be common for multiple or even all UEs in a cell. It is not necessary to always unicast these fields with the duplicated signalling overhead. When there is no corresponding DL data from the NAS, the Msg4 could be simplified, e.g., to a flag indication or a lower-layer indication, so as to reduce the signaling overhead.

[0140] As mentioned in the above description of Msg 3, due to the need of UL synchronization or the satellite movement, reception of Msg4 (*RRCEarlyDataComplete*) may also be interrupted by GNSS position fix or ephemeris acquiring, or by approaching the stop serving time (and possible cell change). In these cases, how to ensure the reception of Msg4 (*RRCEarlyDataComplete*) or how to handle the unsuccessful operation needs to be specified as well.

[0141] How to implement the efficient delivery of Msg4(*RRCEarlyDataComplete*), i.e., enhanced delivery of Msg4 for an EDT operation, will be described with reference

to Figs. 3 and 4. Fig. 3 illustrates a signaling chart of an example process 300 for enhanced EDT in accordance with aspects of the present disclosure. For the purpose of discussion, the process 300 may involve the UE 104 and the BS (e.g. eNB) 102 in the processes 200 and 400. The process 300 may be applied to the wireless communications system 100 with reference to Fig. 1. It would be appreciated that the process 300 may be applied to other communication scenarios, which will not be described in detail.

[0142] As shown in Fig. 3, the UE 104 receives 310 receive a configuration for an EDT operation from the base station 102. The configuration comprises at least one DLresource for the EDT operation. The at least one DL resource may comprise at least one DL resource shared by a plurality of UEs in a group. Additionally or alternatively, the at least one DL resource may comprise at least one DL resource shared by UEs in a cell. Additionally or alternatively, the at least one DL resource may comprise at least one DL resource dedicated for the UE.

[0143] In some implementations, the configuration may further include an identity associated to reception of an Msg4. This identity may comprise a group identity indicating a group of UEs that are allowed to receive a Msg4 associated to the group. Additionally or alternatively, this identity may comprise a UE identity indicating a specific UE in a group that is allowed to receive a Msg4 associated to the group. Additionally or alternatively, this identity may comprise another UE identity indicating a specific UE in a cell that is allowed to receive a Msg4 associated to the cell.

[0144] With respect of the enhancement to Msg4 content or format, in an implementation D1, the Msg4 may be divided into a common part and a dedicated (UE-specific) part.

[0145] In an example, for *RRCEarlyDataComplete* for CP-EDT, the common part may include at least one of the following: zero information or data from the NAS layer (e.g. *zero dedicatedInfoNAS*); empty information or data from the NAS layer (e.g. *empty dedicatedInfoNAS*); a common wait time for a delay tolerant service (e.g. *common extendedWaitTime*); a common cell reselection configuration including a frequency priority (e.g. *idleModeMobilityControlInfo*); common redirection information (e.g. *redirectedCarrierInfo*); a flag indication indicating successful reception of uplink EDT data, at least one UE identity that indicates successful reception or no reception of uplink EDT data from an indicated UE.

[0146] For *RRConnectionRelease* for UP-EDT, the common part may include at least one of the following: a common cause indication or value for connection release (e.g. *releaseCause*); a common chaining count for a next hop (e.g. *NextHopChainingCount*); a common robust header compression (EOHC) configuration for a data radio bearer (DRB) (e.g. *drb-ContinueROHC*); a flag indication indicating successful reception of uplink EDT data; or at least one identity that indicates successful reception or no reception of uplink EDT data from an indicated UE.

[0147] The common part may be delivered in a broadcast or multicast manner. That is, the common part may be transmitted from the base station 102 and received by the UE 104 via multicast or broadcast using the at least one DL resource shared by the plurality of UEs in the group or shared by the UEs in the cell. As an example, a group identity is introduced for the multicast manner, and can be the same as that used for the group-based configuration of the EDT operation without *Msg1*(preamble)/*Msg2*(RAR), i.e., the EDT-group-ID in the implementation A1.

[0148] Also, as shown in Fig. 4B, in one embodiment #5, the eNB 102 may transmit at least part of *Msg4* (*RRCEarlyDataComplete* for CP-EDT or *RRConnectionRelease* for UP-EDT) to UE in response to *Msg3* (*RRCEarlyDataRequest* for CP-EDT or *RRConnectionResumeRequest* for UP-EDT) using multicast or broadcast.

[0149] In an example, for *RRCEarlyDataComplete* for CP-EDT, the dedicated part may include at least one of the following: non-zero information or data from the NAS layer (e.g. non-zero *dedicatedInfoNAS*); a UE-specific wait time for a delay tolerant service (e.g. UE-specific *extendedWaitTime*); a UE-specific cell reselection configuration including a frequency priority (e.g. *idleModeMobilityControlInfo*); UE-specific redirection information (e.g. *redirectedCarrierInfo*); or a flag indication indicating successful reception of uplink EDT data.

[0150] For *RRConnectionRelease* for UP-EDT, the dedicated part may include at least one of the following: a UE-specific identity for connection resume (e.g. *resumeID*); UE-specific downlink data; a flag indication indicating successful reception of uplink EDT data; a physical layer acknowledgement indication; or a media access control (MAC) layer acknowledgement indication.

[0151] The dedicated part (if any) may be delivered in a unicast manner as a delta configuration. A timing advance command (TAC) may also be included to adjust the

UE's TA. Specifically, the dedicated part may be transmitted from the base station 102 and received from the UE 104 via unicast (dedicated signaling) using the at least one DL resource dedicated for the UE. Then, the UE may derive the complete Msg4 based on the received part of Msg4 via multicast or broadcast and the received other part of Msg4 via unicast.

[0152] In an implementation D2, the Msg4 is a non-RRC message as an ACK for Msg3 such as a Layer 1 ACK (optionally containing Time Advance Adjustment) or an MAC CE ACK (optionally containing Time Advance Command).

[0153] Next, the UE 104 performs 320 the EDT operation based on the configuration. For example, the UE 104 may receive the Msg4 transmitted from the base station 102 and based on at least one of the group identity, the UE identity for UEs in a group, and the UE identity for UEs in a cell.

[0154] In some implementations, UL synchronization regarding reception of Msg4 is required to be performed or ensured. For example, the reception of Msg4 may be interrupted by the global navigation satellite system (GNSS) position fix or ephemeris acquiring. In an implementation E1, for possible reception interruption brought by the GNSS position fix or ephemeris acquiring, the UE 104 may indicate the unavailable or expected duration of reception of Msg4. That is, an unavailable duration or an expected duration for the reception of Msg4 is indicated in Msg 3.

[0155] Alternatively, for example, in one embodiment #6, the UE 104 may decide to transmit Msg3 for an EDT operation and expect to receive Msg4 as its response, while at least one of the necessary information for UL synchronization, including the ephemeris of the serving cell and the UE position, is before its end of validity duration. In this case, for possible reception interruption brought by the GNSS position fix or ephemeris acquiring, the UE 104 may indicate the remaining validity duration of the necessary information (e.g. GNSS/ephemeris) for UL synchronization in Msg3. That is, a remaining validity duration of information for UL synchronization is indicated in Msg 3.

[0156] In an implementation E2, for possible reception interruption brought by the GNSS position fix or ephemeris acquiring, the GNSS position fix or ephemeris acquiring may be delayed without triggering UL synchronization loss after Msg3 transmission. For example, prior to the reception of the Msg4, and if a remaining validity duration of at

least one of the ephemeris of the serving cell or the position of the UE is less than a threshold, the UE 104 may delay GNSS position fix or ephemeris acquiring.

[0157] In some implementations, the reception of Msg4 may be interrupted due to the approaching of cell stop serving time or feeder link switch time. For example, in one embodiment #7, the UE 104 may decide to transmit Msg3 for EDT operation and expect to receive Msg4 as its response, while at least one of the cell stop serving time or the feeder link switch time is approaching.

[0158] In these implementations, the reception of Msg4 may be interrupted in a cell changed case or a cell unchanged case. In the cell changed case, the UE 104 may perform 480 the continuity of Msg 4 reception and continue to receive the Msg4 in the next cell after cell reselection if the UE 104 can guarantee UL synchronization in the next or reselected cell. The network can ensure delivery via X2/S1 interface signalling between eNBs. For example, prior to the reception of the Msg4, if a remaining validity duration of at least one of the cell stop serving time or the feeder link switch time is less than a threshold, the UE 104 may receive, from the base station 102, the Msg4 in another cell which is reselected and synchronized to the another cell.

[0159] In the cell unchanged case, the UE 104 may perform 480 the continuity of Msg 4 reception and continue to receive the Msg4 in the next cell after satellite switch with re-synchronization if the UE 104 can guarantee UL synchronization in the switched cell. For example, prior to the reception of the Msg4, if a remaining validity duration of at least one of the cell stop serving time or the feeder link switch time is less than a threshold, the UE 104 may receive, from another base station 102, the Msg4 in another cell which is synchronized to the another base station.

[0160] Fig. 5 illustrates an example of a device 500 for enhanced early data transmission in accordance with aspects of the present disclosure. The device 500 may be an example of a network entity 102 or a UE 104 as described herein. The device 500 may support wireless communication with one or more network entities 102, UEs 104, or any combination thereof. The device 500 may include components for bi-directional communications including components for transmitting and receiving communications, such as a processor 502, a memory 504, a transceiver 506, and, optionally, an I/O controller 508. 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).

[0161] The processor 502, the memory 504, the transceiver 506, 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 502, the memory 504, the transceiver 506, or various combinations or components thereof may support a method for performing one or more of the operations described herein.

[0162] In some implementations, the processor 502, the memory 504, the transceiver 506, 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 502 and the memory 504 coupled with the processor 502 may be configured to perform one or more of the functions described herein (e.g., executing, by the processor 502, instructions stored in the memory 504).

[0163] For example, the processor 502 may support wireless communication at the device 500 in accordance with examples as disclosed herein. The processor 502 may be configured to or operable to support: a means for receiving a configuration for an early data transmission operation, wherein the configuration includes at least one uplink resource or at least one downlink resource for the early data transmission operation; and a means for performing the early data transmission operation based on the configuration. In addition, the processor 502 may be configured to or operable to support means for performing various other operations of a UE as described above in connection with Figs. 1 to 4.

[0164] Alternatively, in some implementations, the processor 502 may be configured to or operable to support: a means for transmitting a configuration for an early data transmission operation, wherein the configuration includes at least one uplink resource or at least one downlink resource for the early data transmission operation. In addition, the

processor 502 may be configured to or operable to support means for performing various other operations of a base station as described above in connection with Figs. 1 to 4.

[0165] The processor 502 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 502 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 502. The processor 502 may be configured to execute computer-readable instructions stored in a memory (e.g., the memory 504) to cause the device 500 to perform various functions of the present disclosure.

[0166] The memory 504 may include random access memory (RAM) and read-only memory (ROM). The memory 504 may store computer-readable, computer-executable code including instructions that, when executed by the processor 502 cause the device 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. In some implementations, the code may not be directly executable by the processor 502 but may cause a computer (e.g., when compiled and executed) to perform functions described herein. In some implementations, the memory 504 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.

[0167] The I/O controller 508 may manage input and output signals for the device 500. The I/O controller 508 may also manage peripherals not integrated into the device 500. In some implementations, the I/O controller 508 may represent a physical connection or port to an external peripheral. In some implementations, the I/O controller 508 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 508 may be implemented as part of a processor, such as the processor 506. In some implementations, a user may interact with the device 500 via the I/O controller 508 or via hardware components controlled by the I/O controller 508.

[0168] In some implementations, the device 500 may include a single antenna 510. However, in some other implementations, the device 500 may have more than one antenna 510 (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 506 may communicate bi-directionally, via the one or more antennas 510, wired, or wireless links as described herein. For example, the transceiver 506 may represent a wireless transceiver and may communicate bi-directionally with another wireless transceiver. The transceiver 506 may also include a modem to modulate the packets, to provide the modulated packets to one or more antennas 510 for transmission, and to demodulate packets received from the one or more antennas 510. The transceiver 506 may include one or more transmit chains, one or more receive chains, or a combination thereof.

[0169] 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 510 for transmitting the amplified signal into the air or wireless medium.

[0170] 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 510 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.

[0171] Fig. 6 illustrates an example of a processor 600 for enhanced EDT in accordance with aspects of the present disclosure. The processor 600 may be an example of a processor configured to perform various operations in accordance with examples as described herein. The processor 600 may include a controller 602 configured to perform various operations in accordance with examples as described herein. The processor 600 may optionally include at least one memory 604, such as L1/L2/L3 cache. Additionally, or alternatively, the processor 600 may optionally include one or more arithmetic-logic units (ALUs) 606. One or more of these components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g., buses).

[0172] The processor 600 may be a processor chipset and include a protocol stack (e.g., a software stack) executed by the processor chipset to perform various operations (e.g., receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) in accordance with examples as described herein. The processor chipset may include one or more cores, one or more caches (e.g., memory local to or included in the processor chipset (e.g., the processor 600) or other memory (e.g., random access memory (RAM), read-only memory (ROM), dynamic RAM (DRAM), synchronous dynamic RAM (SDRAM), static RAM (SRAM), ferroelectric RAM (FeRAM), magnetic RAM (MRAM), resistive RAM (RRAM), flash memory, phase change memory (PCM), and others).

[0173] The controller 602 may be configured to manage and coordinate various operations (e.g., signaling, receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) of the processor 600 to cause the processor 600 to support various operations in accordance with examples as described herein. For example, the controller 602 may operate as a control unit of the processor 600, generating control signals that manage the operation of various components of the processor 600. These control signals include enabling or disabling functional units, selecting data paths, initiating memory access, and coordinating timing of operations.

[0174] The controller 602 may be configured to fetch (e.g., obtain, retrieve, receive) instructions from the memory 604 and determine subsequent instruction(s) to be executed to cause the processor 600 to support various operations in accordance with examples as

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

[0175] The memory 604 may include one or more caches (e.g., memory local to or included in the processor 600 or other memory, such as RAM, ROM, DRAM, SDRAM, SRAM, MRAM, flash memory, etc. In some implementation, the memory 604 may reside within or on a processor chipset (e.g., local to the processor 600). In some other implementations, the memory 604 may reside external to the processor chipset (e.g., remote to the processor 600).

[0176] The memory 604 may store computer-readable, computer-executable code including instructions that, when executed by the processor 600, cause the processor 600 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. The controller 602 and/or the processor 600 may be configured to execute computer-readable instructions stored in the memory 604 to cause the processor 600 to perform various functions. For example, the processor 600 and/or the controller 602 may be coupled with or to the memory 604, the processor 600, the controller 602, and the memory 604 may be configured to perform various functions described herein. In some examples, the processor 600 may include multiple processors and the memory 604 may include multiple memories. One or more of the multiple processors may be coupled with one or more of the multiple memories, which may, individually or collectively, be configured to perform various functions herein.

[0177] The one or more ALUs 606 may be configured to support various operations in accordance with examples as described herein. In some implementation, the one or more ALUs 606 may reside within or on a processor chipset (e.g., the processor 600). In

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

[0178] The processor 600 may support wireless communication in accordance with examples as disclosed herein. The processor 600 may be configured to or operable to support: a means for receiving a configuration for an early data transmission operation, wherein the configuration includes at least one uplink resource or at least one downlink resource for the early data transmission operation; and a means for performing the early data transmission operation based on the configuration. In addition, the processor 600 may be configured to or operable to support means for performing various other operations of a UE as described above in connection with Figs. 1 to 4.

[0179] Alternatively, in some implementations, the processor 600 may be configured to or operable to support: a means for transmitting a configuration for an early data transmission operation, wherein the configuration includes at least one uplink resource or at least one downlink resource for the early data transmission operation. In addition, the processor 600 may be configured to or operable to support means for performing various other operations of a base station as described above in connection with Figs. 1 to 4.

[0180] Fig. 7 illustrates a flowchart of a method 700 for enhanced EDT 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 the UE 104 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.

[0181] At 710, the method may include receiving a configuration for an EDT operation, wherein the configuration includes at least one UL resource or at least one DL resource for the EDT operation. 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 device as described with reference to Fig. 1.

[0182] At 720, the method may include performing the EDT operation based on the configuration. 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 device as described with reference to Fig. 1.

[0183] Fig. 8 illustrates a flowchart of a method 800 for enhanced EDT 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 the base station 102 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.

[0184] At 810, the method may include transmitting a configuration for an EDT operation, wherein the configuration includes at least one UL resource or at least one DL resource for the EDT operation. 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 device as described with reference to Fig. 1.

[0185] It shall be noted that implementations of the present disclosure which have been described with reference to Figs. 1 to 4 are also applicable to the device 500, the processor 600 and the methods 700, 800.

[0186] It should be noted that the methods described herein describes possible implementations, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible. Further, aspects from two or more of the methods may be combined.

[0187] 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).

[0188] 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.

[0189] 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.

[0190] 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.

[0191] 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.

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CLAIMS

WHAT IS CLAIMED IS:

1. A user equipment (UE), comprising:
a processor; and
a transceiver coupled to the processor,
wherein the processor is configured to:
 receive, via the transceiver and from a base station, a configuration for an early data transmission (EDT) operation, wherein the configuration includes at least one uplink (UL) resource or at least one downlink (DL) resource for the EDT operation; and
 perform the EDT operation based on the configuration.
2. The UE of claim 1, wherein the processor is configured to perform the EDT operation by:
 transmitting a message 3 (Msg3) without transmission of a Msg1 and reception of a Msg2.
3. The UE of claim 1, wherein the at least one uplink (UL) resource comprises at least one of the following:
 at least one UL resource shared by a plurality of UEs in a group;
 at least one UL resource shared by UEs in a cell; or
 at least one UL resource dedicated for the UE.
4. The UE of claim 3, wherein the configuration further includes an identity associated to the UL resource, and the identity comprises at least one of the following:
 a first group identity indicating a group of UEs that are allowed to use the at least one UL resource for the EDT operation;
 a first UE identity indicating a specific UE in a group that is allowed to use the at least one UL resource for the EDT operation; or
 a second UE identity indicating a specific UE in a cell that is allowed to use the at least one UL resource for the EDT operation.
5. The UE of claim 4, wherein the processor is configured to perform the EDT operation based on the configuration by:

determining a UL resource among the at least one UL resource based on one or more of the first group identity, the first UE identity, or the second UE identity; and

transmitting a Msg3 using the determined UL resource without transmission of a Msg1 and reception of a Msg2,

wherein the Msg3 includes the one or more of the first group identity, the first UE identity, or the second UE identity.

6. The UE of claim 1, wherein the configuration includes a threshold configured for the EDT operation, and the configured threshold includes at least one of the following:

a signal strength threshold for the EDT operation;

a signal quality threshold for the EDT operation;

a latency threshold for the EDT operation;

a distance threshold for the EDT operation; or

a time point for the EDT operation.

7. The UE of claim 6, wherein the processor is configured to perform the EDT operation based on the configuration by:

in a case that a non-access stratum (NAS) layer of the UE requests for mobile originated early data transmission (MO-EDT) and an uplink data size is less than a data size threshold, and at least one predetermined condition is fulfilled, initiating the EDT operation,

wherein the at least one predetermined condition comprises at least one of the following:

the configured threshold is the signal strength threshold, and the strength of a signal received by the UE is equal to or above the configured threshold;

the configured threshold is the signal quality threshold, and the quality of a signal received by the UE is equal to or above the configured threshold;

the configured threshold is the latency threshold, and a timing advance or a round-trip time of the UE is equal to or less than the configured threshold;

the configured threshold is the distance threshold, and a distance from the UE to the base station or an antenna unit or a reference point of a serving cell is equal to or less than the configured threshold;

the configured threshold is the time point, and the current time at which the MO-EDT is requested is prior to the time point; or

a cell stop serving time or a feeder link switch time out of the configuration is obtained, the current time at which the MO-EDT is requested is prior to the cell stop serving time or the feeder link switch time.

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

prior to performing the EDT operation, calculate a timing advance to be pre-compensated for UL synchronization of the UE to a cell provided by the base station; and

in a case that the calculation of the timing advance fails, determine that the EDT operation is unsuccessful.

9. The UE of claim 8, wherein the processor is further configured to:

in a case that the EDT operation is determined as unsuccessful, perform a fallback operation,

wherein the fallback operation comprises at least one of the following:

in a case that a contention indication from the base station is received or in a case that a timer of the UE for contention resolution expires, suspending the EDT operation for a time duration;

in a case that a contention indication or a fallback indication from the base station is received or in a case that the timer of the UE for contention resolution expires, performing an EDT operation configured with a random access preamble or a random access response; or

in a case that the contention indication or a fallback indication from the base station is received or in a case that the timer of the UE for contention resolution expires, performing a connection establishment to transition to a connected state.

10. The UE of claim 9, wherein the timer for contention resolution is a timer specific for a non-terrestrial network, and a start of the timer is offset by the UE to a round trip time of the base station.

11. The UE of any of claims 1-10, wherein the at least one DL resource comprises at least one of the following:

at least one DL resource shared by a plurality of UEs in a group;

at least one DL resource shared by UEs in a cell; or

at least one DL resource dedicated for the UE.

12. The UE of claim 11, wherein the configuration further includes an identity associated to reception of a message 4 (Msg4), and the identity comprises at least one of the following:

- a second group identity indicating a group of UEs that are allowed to receive a Msg4 associated to the group;

- a third UE identity indicating a specific UE in a group that is allowed to receive a Msg4 associated to the group; or

- a fourth UE identity indicating a specific UE in a cell that is allowed to receive a Msg4 associated to the cell.

13. The UE of claim 12, wherein the Msg4 includes at least one of the following as a common part:

- zero information or data from the NAS layer;

- empty information or data from the NAS layer;

- a common wait time for a delay tolerant service;

- a common cell reselection configuration including a frequency priority;

- common redirection information;

- a common cause indication or value for connection release;

- a common chaining count for a next hop;

- a common robust header compression (EOHC) configuration for a data radio bearer (DRB);

- a flag indication indicating successful reception of uplink EDT data; or

- at least one identity that indicates successful reception or no reception of uplink EDT data from an indicated UE.

14. A base station, comprising:

- a processor; and

- a transceiver coupled to the processor,

- wherein the processor is configured to:

- transmit, via the transceiver and to a user equipment (UE), a configuration for an early data transmission (EDT) operation, wherein the configuration includes at least one uplink (UL) resource or at least one downlink (DL) resource for the EDT operation.

15. The base station of claim 14, wherein the at least one UL resource comprises at least one of the following:

- at least one UL resource shared by a plurality of UEs in a group;
- at least one UL resource shared by UEs in a cell; or
- at least one UL resource dedicated for the UE.

16. The base station of claim 15, wherein the configuration further includes an identity associated to the UL resource, and the identity comprises at least one of the following:

- a first group identity indicating a group of UEs that are allowed to use the at least one UL resource for the EDT operation;
- a first UE identity indicating a specific UE in a group that is allowed to use the at least one UL resource for the EDT operation; or
- a second UE identity indicating a specific UE in a cell that is allowed to use the at least one UL resource for the EDT operation.

17. The base station of claim 14, wherein the configuration includes a threshold configured for the EDT operation, and the configured threshold includes at least one of the following:

- a signal strength threshold for the EDT operation;
- a signal quality threshold for the EDT operation;
- a latency threshold for the EDT operation;
- a distance threshold for the EDT operation; or
- a time point for the EDT operation.

18. The base station of any of claims 14-17, wherein the at least one DL resource comprises at least one of the following:

- at least one DL resource shared by a plurality of UEs in a group;
- at least one DL resource shared by UEs in a cell; or
- at least one DL resource dedicated for the UE.

19. The base station of claim 18, wherein the configuration further includes an identity associated to reception of a message 4 (Msg4), and the identity comprises at least one of the following:

a second group identity indicating a group of UEs that are allowed to receive a Msg4 associated to the group;

a third UE identity indicating a specific UE in a group that is allowed to receive a Msg4 associated to the group; or

a fourth UE identity indicating a specific UE in a cell that is allowed to receive a Msg4 associated to the cell.

20. The base station of claim 19, wherein the Msg4 includes at least one of the following as a common part:

zero information or data from the NAS layer;

empty information or data from the NAS layer;

a common wait time for a delay tolerant service;

a common cell reselection configuration including a frequency priority;

common redirection information;

a common cause indication or value for connection release;

a common chaining count for a next hop;

a common robust header compression (EOHC) configuration for a data radio bearer (DRB);

a flag indication indicating successful reception of uplink EDT data; or

at least one identity that indicates successful reception or no reception of uplink EDT data from an indicated UE.

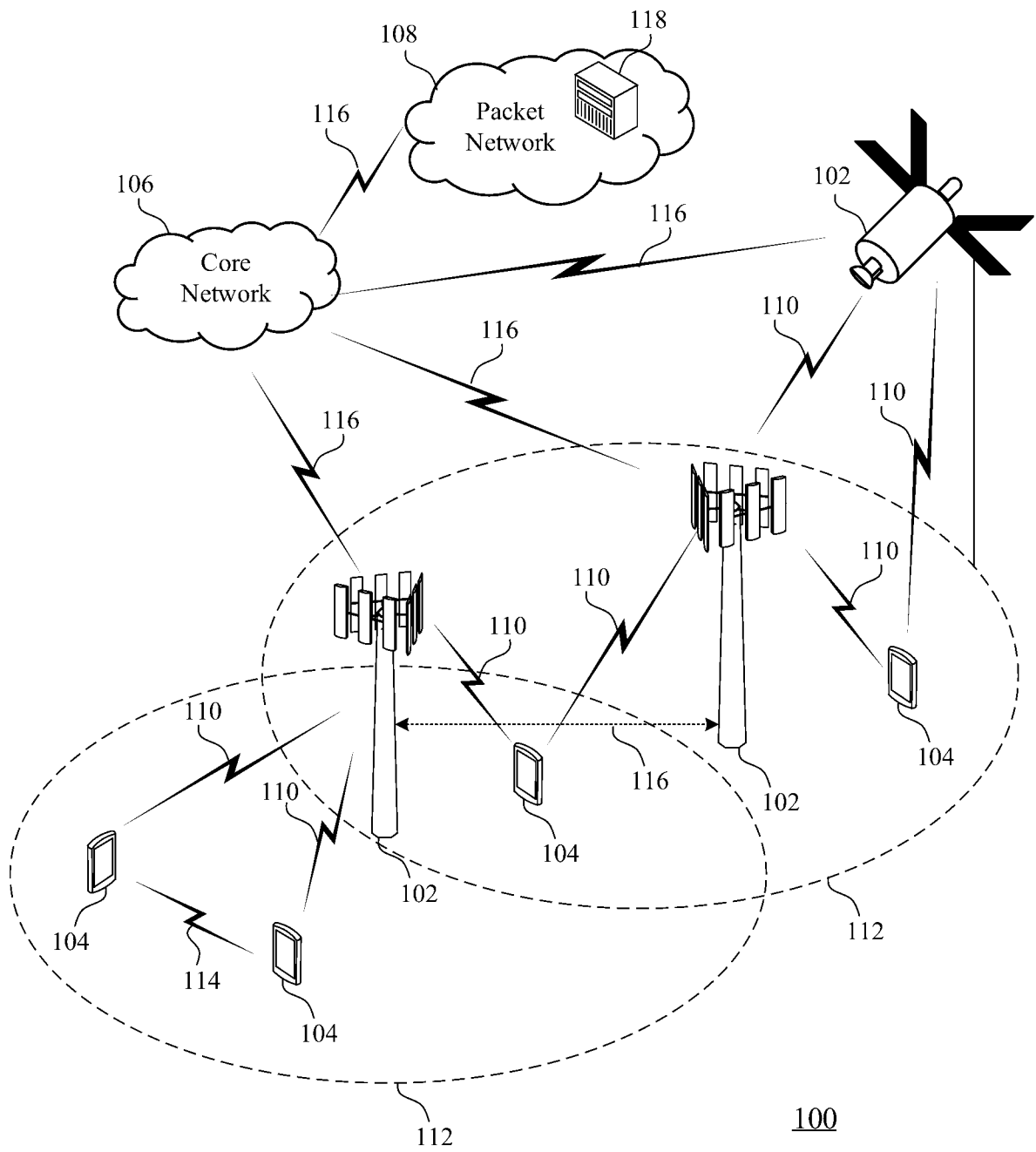


Fig. 1

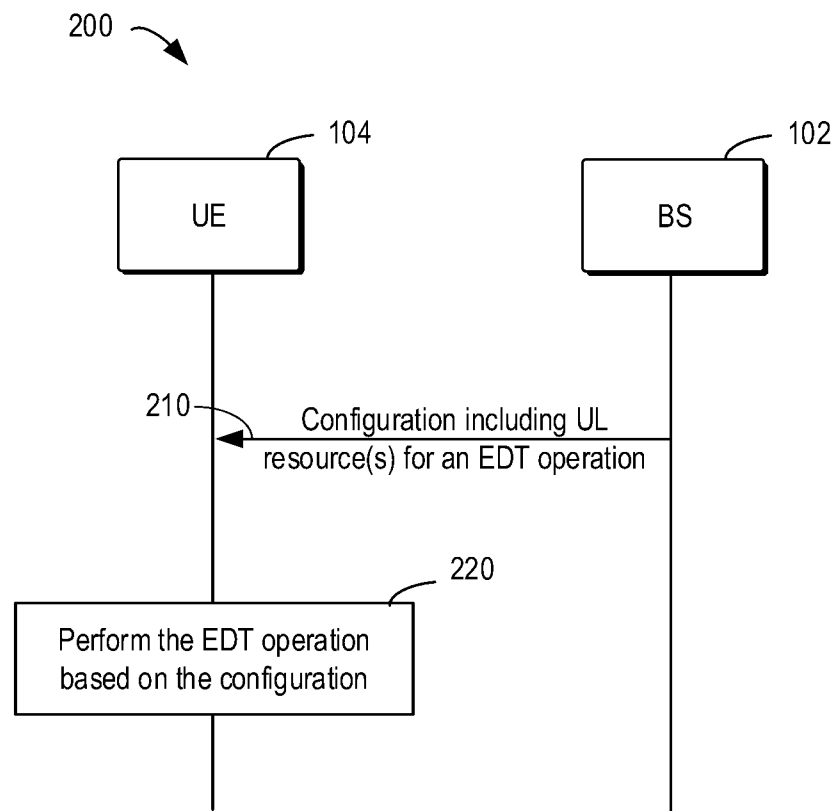
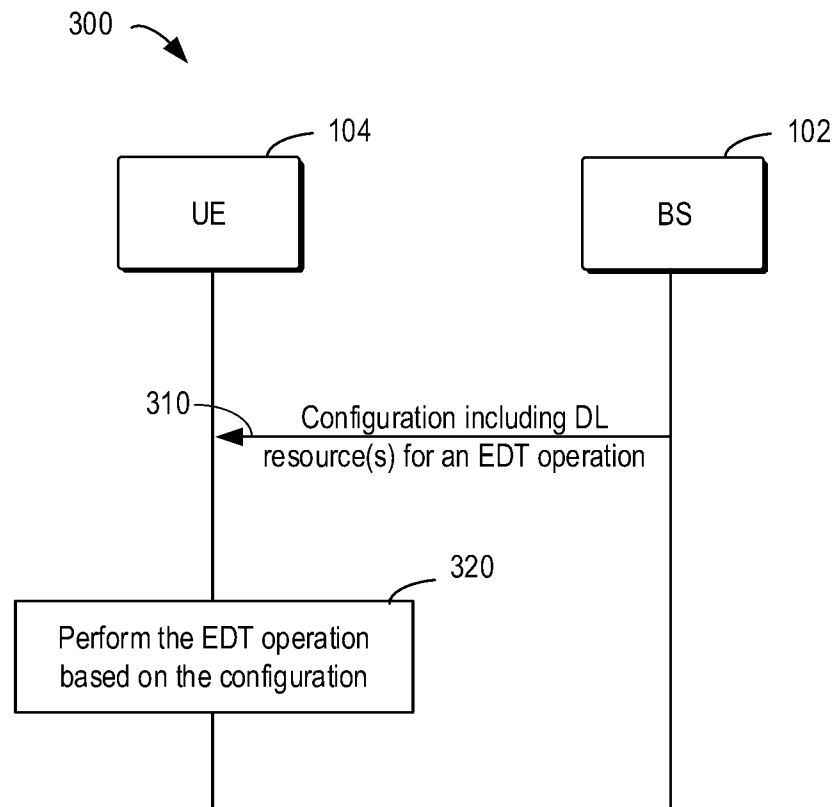


Fig. 2

**Fig. 3**

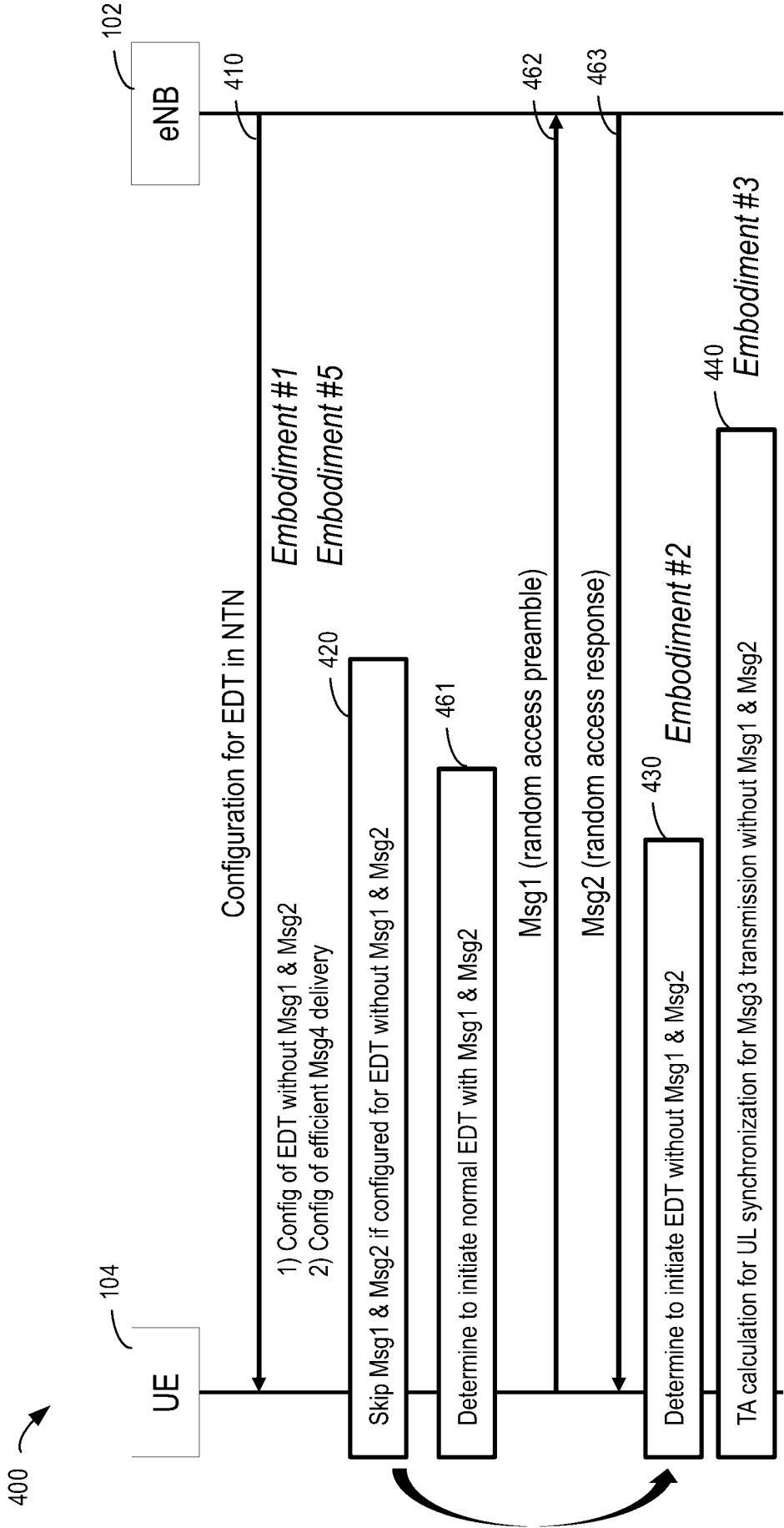


Fig. 4A

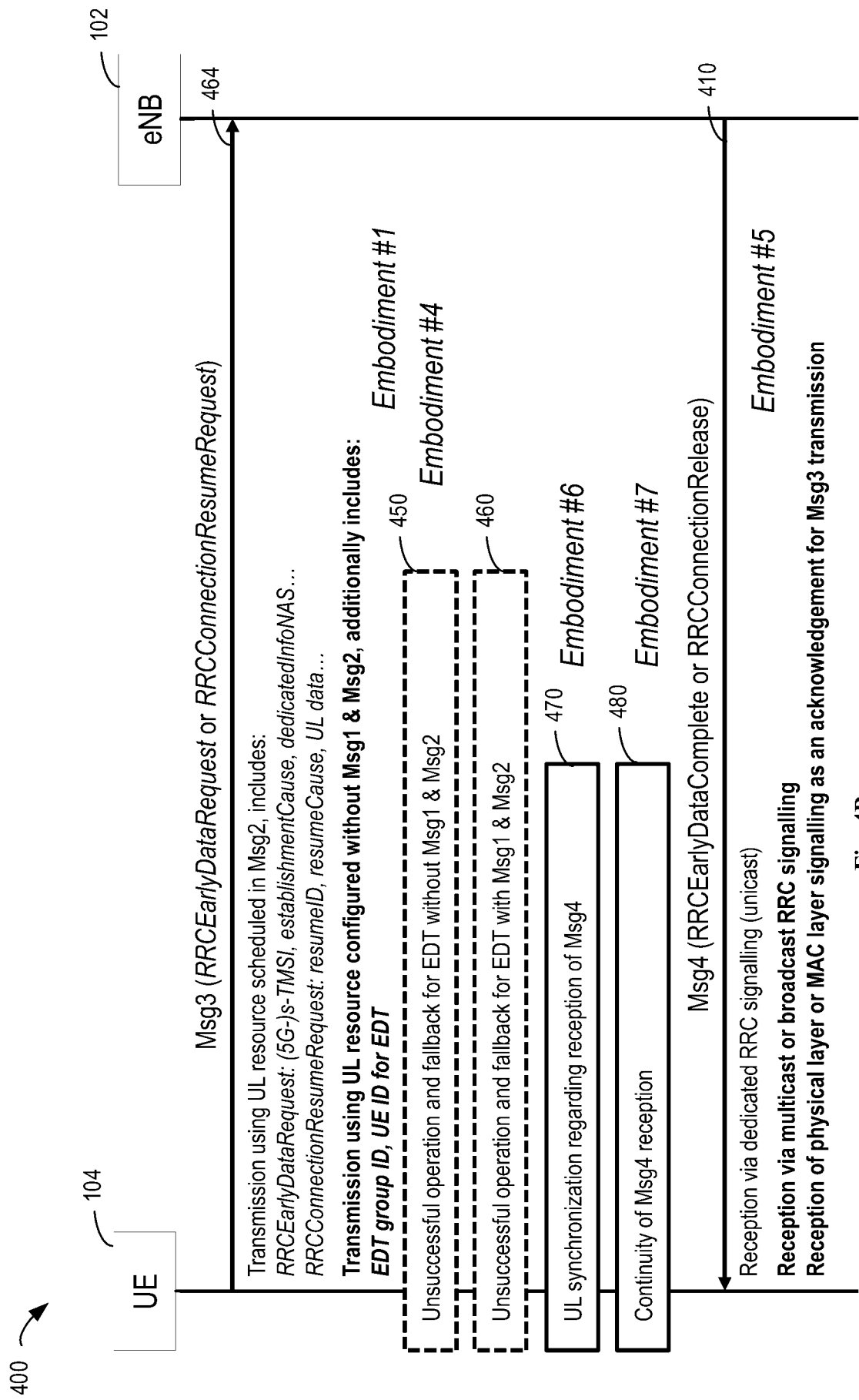


Fig. 4B

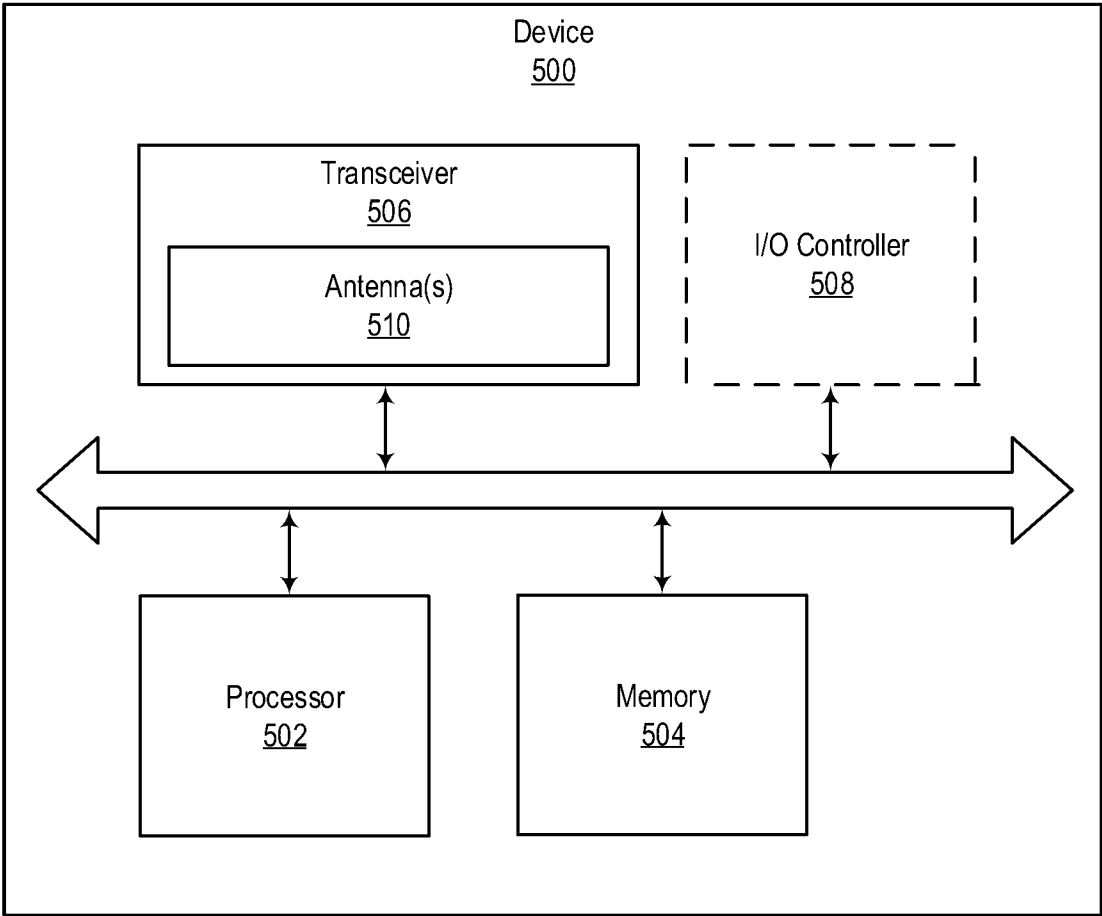


Fig. 5

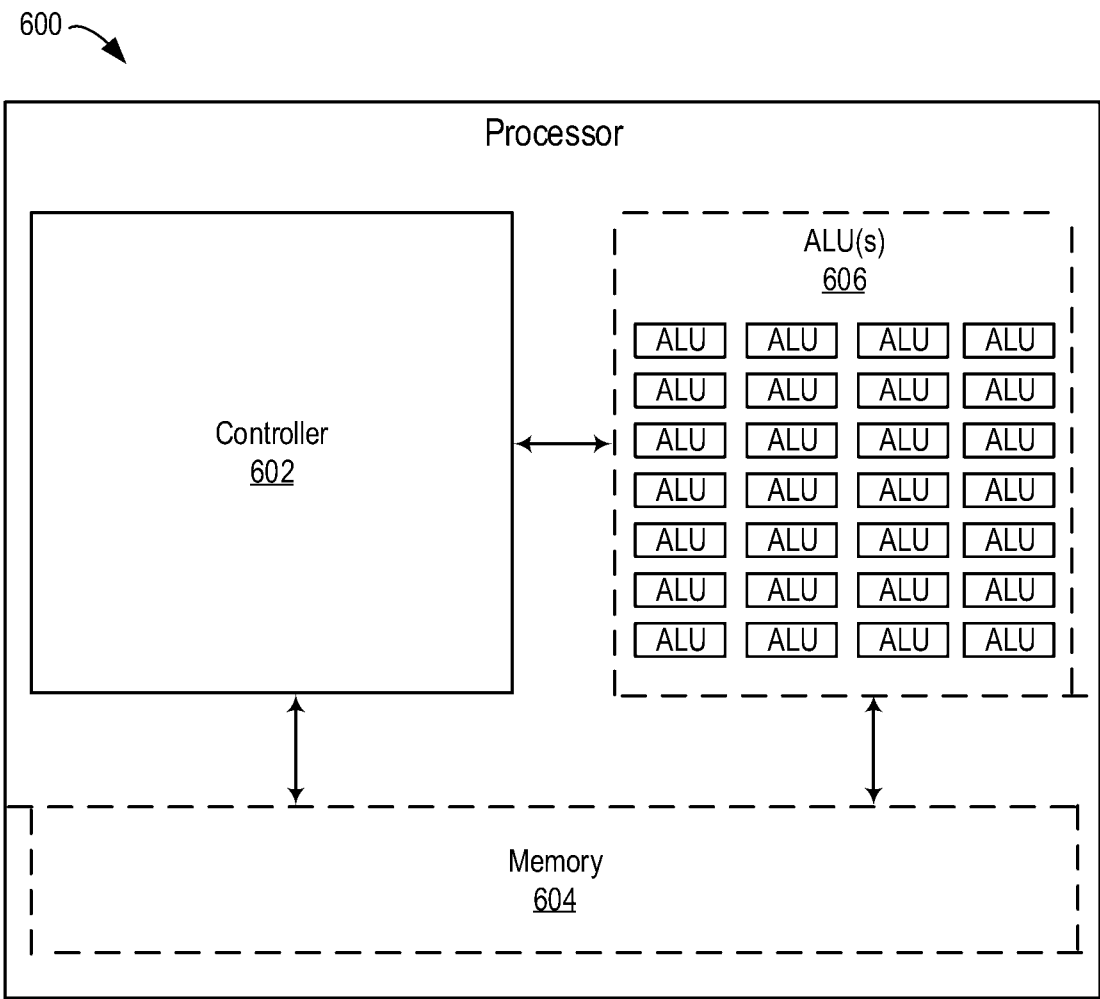
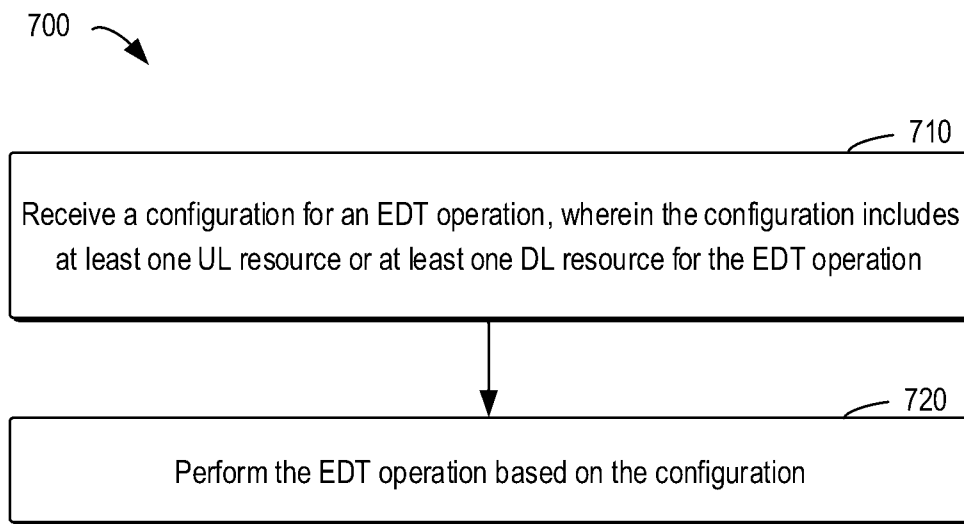
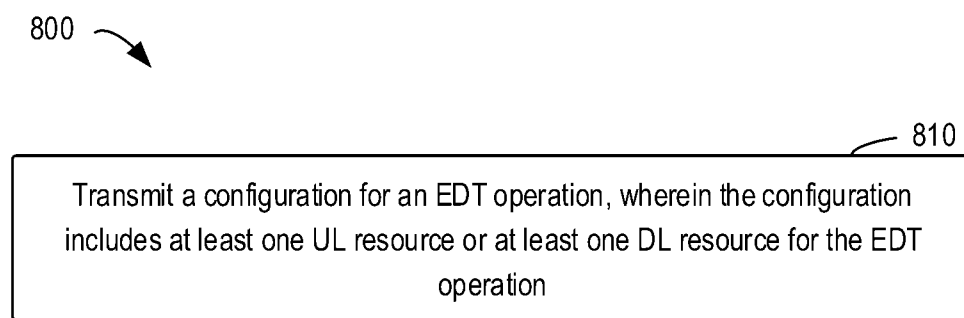


Fig. 6

**Fig. 7****Fig. 8**

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2024/085647

A. CLASSIFICATION OF SUBJECT MATTER H04W72/04(2023.01)i According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) IPC: H04W H04L Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) CNTXT, ENTXT, CNKI, 3GPP: EDT, resource, config+, UE, UEs, group, shar+, without, msg1, msg2, RAR		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2020056639 A1 (NOKIA SHANGHAI BELL CO., LTD. et al.) 26 March 2020 (2020-03-26) description, paragraphs 3-11, 37-97	1, 3-20
Y	WO 2020056639 A1 (NOKIA SHANGHAI BELL CO., LTD. et al.) 26 March 2020 (2020-03-26) description, paragraphs 3-11, 37-97	2
Y	DEUTSCHE TELEKOM (MODERATOR, RAN VC). "RP-234077, New WID: Non-Terrestrial Networks (NTN) for Internet of Things (IoT) Phase 3" 3GPP TSG RAN Meeting #102, 15 December 2023 (2023-12-15), sections 3, 4.1	2
A	CN 112400356 A (INTEL CORPORATION) 23 February 2021 (2021-02-23) the whole document	1-20
A	US 2023199617 A1 (TELEFONAKTIEBOLAGET LM ERICSSON (PUBL)) 22 June 2023 (2023-06-22) the whole document	1-20
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents: “A” document defining the general state of the art which is not considered to be of particular relevance “D” document cited by the applicant in the international application “E” earlier application or patent but published on or after the international filing date “L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) “O” document referring to an oral disclosure, use, exhibition or other means “P” document published prior to the international filing date but later than the priority date claimed “T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention “X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone “Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art “&” document member of the same patent family		
Date of the actual completion of the international search 13 December 2024		Date of mailing of the international search report 23 December 2024
Name and mailing address of the ISA/CN CHINA NATIONAL INTELLECTUAL PROPERTY ADMINISTRATION 6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088, China		Authorized officer LI,PuXin Telephone No. (+86) 010-53961653

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2024/085647

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
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CN	112400356	A	23 February 2021	EP	3858064	A1	04 August 2021
				EP	3858064	A4	22 June 2022
				WO	2020069103	A1	02 April 2020
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				PH	12020550813	A1	10 May 2021
				AR	114806	A1	21 October 2020
				EP	3701760	A1	02 September 2020