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(71) Applicants (for CN only): NOKIA SHANGHAI BELL

CO., LTD. [CN/CN]; No. 388, Ningqiao Road, Pudong Jin-qiao, Shanghai 201206 (CN). NOKIA SOLUTIONS AND NETWORKS OY [FI/FI]; Karaportti 3, 02610 Espoo (FI).

(71) Applicant (for all designated States except CN): NOKIA

TECHNOLOGIES OY [FI/FI]; Karaportti 3, 02610 Espoo (FI).

(72) Inventor: LI, Haitao; Nokia Solutions and Networks Sys-

tem Technology (Beijing) Co., Ltd., No.1 Wangjing East Road, Chaoyang District, Beijing 100020 (CN).

(74) Agent: KING & WOOD MALLESONS; 20th Floor,

East Tower, World Financial Centre, No.1 Dongsanhuan Zhonglu, Chaoyang District, Beijing 100020 (CN).

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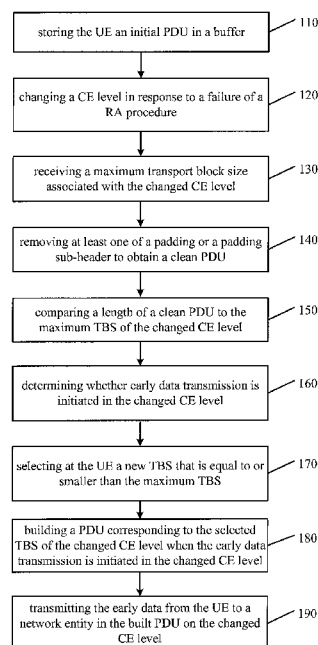


Figure 1

(57) **Abstract:** Various communication systems may benefit from improved random access procedures. For example, it may be helpful to improve random access procedure when changing a coverage enhancement level. A method, according to certain embodiments, may include changing a coverage enhancement level in response to a failure of a random access procedure. The method may also include determining whether early data transmission may be initiated in the changed coverage enhancement level. In addition, the method may include building at a user equipment a protocol data unit corresponding to the changed coverage enhancement level when the early data transmission is initiated in the changed coverage enhancement level. Further, the method may include transmitting the early data from the user equipment to a network entity in the built packet data unit on the changed coverage enhanced level.

CREATING PROTOCOL DATA UNIT FOR EARLY DATA TRANSMISSION

BACKGROUND:

5 **Field:**

[0001] Various communication systems may benefit from improved random access procedures. For example, it may be helpful to improve random access procedures when changing a coverage enhancement level.

10 **Description of the Related Art:**

[0002] Third Generation Partnership Project (3GPP) technology, such as Internet of Things (IoT), has been developed to allow for the exchange of small data transmissions between a massive network of physical device, vehicles, home appliances, and other items. In particular, the IoT network allows for items embedded
15 with electronics, sensors, and/or actuators to communicate with each another, and with other existing 3GPP technologies, such as Long Term Evolution (LTE) or LTE-Advanced (LTE-A). Narrowband IoT (NB-IoT) is a cellular technology that has been developed to provide wide-area coverage for IoT. NB-IoT provides for deployment flexibility, low device complexity, long battery lifetime, support of
20 massive number of devices in a cell, and/or significant coverage extension beyond existing cellular technologies.

[0003] One of the goals of NB-IoT is to reduce the amount of signaling needed for transmission of uplink or downlink small data. To do so, support for early data transmission on a dedicated resource during a random access procedure is allowed.
25 The early data transmission allows for transmission of downlink and/or uplink data after transmission of a narrowband physical resource access channel and before the radio resource connection (RRC) is complete. The user equipment can therefore

initiate early data transmission as part of a message 3 (Msg3) in the random access procedure towards the network without first establishing the RRC connection.

[0004] For NB-IoT technology, random access procedures allow a user equipment to try increase coverage levels. Four coverage enhancement (CE) levels correspond to different coverage may be provided, and the user equipment can determine a CE level, for example, based on the serving cell's Reference Signal Received Power (RSRP) measurement and broadcasted RSRP threshold for different CE levels. Each of the CE levels has associated time and frequency resources to be used by the user equipment for random access preamble transmissions. When the user equipment fails random access after one or more attempts in a given CE level, the user equipment may consider itself to be in the next CE level and reattempts random access procedures until the user equipment reaches a maximum number of allowed attempts or successfully established the RRC.

SUMMARY

[0005] According to certain embodiments, an apparatus may include at least one memory including computer program code, and at least one processor. The at least one memory and the computer program code may be configured, with the at least one processor, to cause the apparatus at least to change a coverage enhancement level in response to a failure of a radio access procedure. The at least one memory and the computer program code may also be configured, with the at least one processor, to cause the apparatus at least to determine whether early data transmission may be initiated in the changed coverage enhancement level. In addition, the at least one memory and the computer program code may be configured, with the at least one processor, to cause the apparatus at least to build a protocol data unit corresponding to the changed coverage enhancement level when the early data transmission is initiated in the changed coverage enhancement level. Further, the at least one

memory and the computer program code may also be configured, with the at least one processor, to cause the apparatus at least to transmit the early data to a network entity in the built packet data unit on the changed coverage enhanced level.

[0006] A method, according to certain embodiments, may include changing a coverage enhancement level in response to a failure of a random access procedure. The method may also include determining whether early data transmission may be initiated in the changed coverage enhancement level. In addition, the method may include building at a user equipment a protocol data unit corresponding to the changed coverage enhancement level when the early data transmission is initiated in the changed coverage enhancement level. Further, the method may include transmitting the early data from the user equipment to a network entity in the built packet data unit on the changed coverage enhanced level.

[0007] An apparatus, in certain embodiments, may include means for changing a coverage enhancement level in response to a failure of a random access procedure. The apparatus may also include means for determining whether early data transmission may be initiated in the changed coverage enhancement level. In addition, the apparatus may include building a protocol data unit corresponding to the changed coverage enhancement level when the early data transmission is initiated in the changed coverage enhancement level. Further, the apparatus may include means for transmitting the early data to a network entity in the built packet data unit on the changed coverage enhanced level.

[0008] According to certain embodiments, a non-transitory computer-readable medium encoding instructions that, when executed in hardware, perform a process. The process may include changing a coverage enhancement level in response to a failure of a random access procedure. The process may also include determining whether early data transmission may be initiated in the changed coverage enhancement level. In addition, the process may include building at a user

equipment a protocol data unit corresponding to the changed coverage enhancement level when the early data transmission is initiated in the changed coverage enhancement level. Further, the process may include transmitting the early data from the user equipment to a network entity in the built packet data unit on the
5 changed coverage enhanced level.

[0009] According to certain other embodiments, a computer program product may encode instructions for performing a process. The process may include changing a coverage enhancement level in response to a failure of a random access procedure. The process may also include determining whether early data transmission may be
10 initiated in the changed coverage enhancement level. In addition, the process may include building at a user equipment a protocol data unit corresponding to the changed coverage enhancement level when the early data transmission is initiated in the changed coverage enhancement level. Further, the process may include transmitting the early data from the user equipment to a network entity in the built
15 packet data unit on the changed coverage enhanced level.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] For proper understanding of the invention, reference should be made to the accompanying drawings, wherein:

20 [0011] Figure 1 illustrates an example of a flow diagram according to certain embodiments.

[0012] Figure 2 illustrates an example of a system according to certain embodiments.

DETAILED DESCRIPTION

25 [0013] In certain embodiments, a failed random access procedure may be re-attempted one or more times. The failure, for example, may be caused by a failure to receive a Random Access Response (RAR) or a contention resolution failure. When a random

access failure occurs, data included in a Msg3 as part of an early data transmission may not be successfully transmitted. The user equipment may then perform a new preamble transmission, also known as message 1 (Msg1), and attempt to retransmit Msg3 from a buffer at the user equipment. The buffer may include or store a Msg3
5 protocol data unit (PDU) that includes data meant for early transmission. In some embodiments, however, the user equipment may be unable to retransmit the stored Msg3 PDU. In particular, changing the CE level may change the uplink grant to the user equipment, thereby causing the stored Msg3 PDU to no longer fit within the Msg3 uplink grant corresponding to the changed CE level.

10 **[0014]** In legacy NB-IoT procedures, the network provides an uplink grant to the user equipment that is based on a Transport Block Size (TBS) of 88 bits. In some embodiments, 8 bits may equal 1 byte. For early data transmissions, however, which include the transmission of small data as part of the Msg3 transmission, the uplink grant may be larger than 88 bits. For example, the TBS may range from 320 bits to
15 1000 bits. A network entity may provide different maximum TBSs for different CE levels. In some embodiments, the different maximum TBSs may be included as part of a broadcasting signaling transmitted from the network entity. For purpose of reducing the number of padding bits, a user equipment (UE) may choose a smaller TBS than the granted maximum size broadcasted by the network entity.

20 **[0015]** When the UE changes the CE level when reattempting random access procedures, in certain embodiments the TBS may not be the same as the initial or original uplink TBS granted during the initial random access procedure attempt. Some embodiments, therefore, help to facilitate Msg3 retransmission when the stored PDU located at a buffer may no longer fit the newly selected UL grant associated with the
25 changed CE level.

[0016] Figure 1 illustrates an example of a flow diagram according to certain embodiments. In particular, Figure 1 illustrates an example of a method performed by

a UE, such as an IoT device. As part of a random access procedure, the UE may receive an initial uplink grant from the network entity. The uplink grant includes an initial PDU having a given TBS. For example, the PDU may be a medium access control (MAC) PDU. In step 110, the UE may store the initial PDU in a transmit
5 buffer. The buffer may be stored in either a removable or a non-removable memory of the UE. The initial PDU may be for transmission by the UE to the network entity. The storing of the initial PDU in a buffer may occur, for example, after the UE transmits a Msg3 that includes the initial PDU as part of a random access procedures. In some other embodiments, the UE may also store a service data unit (SDU) and/or a MAC
10 Control Element (CE) in addition to the initial PDU. The SDU may be located at a higher protocol layer than a PDU, and the SDU may be converted to a PDU using, for example, encapsulation.

[0017] In step 120, the UE may change a CE level in response to a failure of a random access procedure in a certain CE level. For example, a random access failure may
15 occur on a first CE level, at which point the UE may attempt to change the CE level to a second CE level and reattempt random access. The UE may be informed of the failure via the reception of a random access response from the network entity, or a lack thereof. In step 130, the UE may receive a maximum TBS associated with the changed CE level. The maximum TBS associated with the changed CE level may be
20 broadcasted from a network entity to one or more UEs. In some embodiments, the maximum TBS associated with the changed CE level, as shown in step 130, may be received before the changing of the CE level, as shown in step 120. In step 140, the UE may remove at least one of a padding or a padding sub-header from the stored initial PDU to obtain a clean PDU. Removing the padding may involve removing one
25 or more filler bits in the PDU, thereby reducing the size of the PDU. In certain embodiments, the clean PDU may be obtained by removing at least one of a padding or a padding sub-header of the initial PDU.

[0018] In step 150, the UE may compare a length of the clean PDU and the maximum TBS corresponding to the changed CE level, as received by the UE in step 130. In certain embodiments the UE may initiate the early data transmission when the clean PDU is smaller than or equal to the maximum TBS corresponding to the changed CE level. In other embodiments, the UE may transmit the PDU stored in the buffer after the random access procedure is complete when the clean PDU is larger than the maximum TBS corresponding to the changed CE level. In other words, in embodiments in which the clean PDU length is larger than the maximum TBS size, the UE may start random access procedures without utilizing early data transmissions.

10 On the other hand, when the clean PDU length is small than or equal to the maximum TBS size, the UE may reattempt random access procedures with early data transmissions.

[0019] In step 170, the UE may select a new TBS from a list of flexible TBSs allowed by the uplink grant provided by the network entity according to the clean PDU length.

15 The list of TBS allowed by the uplink grant may correspond to a given CE level, and may include one or more TBSs from which the UE may select. In other words, each CE level may be associated with a list of allowable TBSs.

[0020] In some embodiments, the UE may select a new TBS for early data transmission that is equal to or small than the maximum transport block size corresponding to the changed CE level, and that is larger than or equal to the clean PDU, as shown in step 170. In other words, the amount of early data transmitted may be smaller than the selected TBS. Among the flexible TBS, for example, the UE may select a TBS size that is larger than the clean PDU length, but is the smallest possible TBS size that fits the PDU length. Choosing the smallest possible TBS size may allow

20 for the minimization of padding. For example, if the amount of user data to be transmitted as the early data, as part of a Msg3, is 600 bits, and the list of possible TBSs corresponding to the CE level includes 320, 550, 750, and 1000 bits, the UE

25

may select a TBS size of 750 bits. The selection of 750 bits may represent the smallest possible TBS size that fits the clean PDU length. In step 180, the UE may build a PDU corresponding to selected TBS of the changed CE level when the early data transmission is initiated in the changed CE level. The determination to initiate the building of the PDU, for example, may comprise adding one or more bytes to the clean PDU for padding or padding subheader.

[0021] In some other embodiments, the user equipment may store an initial SDU and corresponding control elements in a transmit buffer. The initial SDU and the corresponding control elements may be transmitted by the UE to the network entity. The building of the PDU, as shown in step 180, for example, may include adding one or more bytes to the initial SDU and the corresponding control elements for padding or padding subheader. In step 190, the UE may transmit the early data to a network entity in the built PDU on the changed CE level. The transmitting of the early data may be a retransmission.

[0022] In certain embodiments, when the selected TBS size is equal to the clean PDU length, no padding or padding header may be added. In other words, when the clean MAC PDU length is equal to the size of the selected TBS, no padding and padding headers may be added. In some other embodiments, in which padding of one or two bytes may be required, the built PDU may be created by placing one or two MAC subheaders for padding in the beginning and/or the end of the clean PDU. For example, when the selected TBS is larger than the clean MAC PDU length by one byte or two bytes, certain embodiment may add one or two padding subheaders, without adding padding bits. The building of the PDU may therefore include adding one or two bytes as headers or subheaders for padding. In other embodiments in which more than two bytes for padding are used, the UE may add padding and padding related MAC subheaders as part of the built PDU.

[0023] One example of the embodiments shown in Figure 1 may be a UE undergoing

early data transmissions in a CE level-1. The maximum TBS broadcasted for the current CE level-1 may be 1000 bits, while the list of allowed flexible TBS may be 320, 550, 750, and 1000 bits. When the user data transmitted during early data transmission is 600 bits, the UE may select the flexible TBS size of 750 bits in the uplink grant to build or create the PDU for Msg3 transmissions. The 750 bit PDU may be stored in a buffer of the UE. The Msg3 may be transmitted, at which point the random access procedures fail, for example, due to contention resolution failure. After a few random access failures in the CE level-1, the UE may move to CE level-2 for further random access attempts.

- 10 **[0024]** The broadcasted maximum TBS size for CE level-2 may be 700 bits, which is smaller than the 1000 bit maximum of CE level-1. The list of allowed flexible TBS for CE level-2 may be 320, 450, 550, and 700. The UE may select the 700 bits TBS, and attempt to transmit early state transmissions for 600 bits of user data using the uplink grant of 700 bits. The initial PDU, however, that is stored in the Msg3 buffer has a size of 750 bits, meaning that the initial PDU can no longer be transmitted in the new uplink grant for CE level-2, which has a size of 700 bits. UE can therefore build or re-build a PDU that corresponds and fits to the changed CE level, specifically to the 700 bit uplink grant of the PDU. As discussed above, each time the UE transmits the Msg3 including the PDU, such as a MAC PDU, the UE may store the MAC PDU, the MAC SDU, or the MAC CEs in a buffer. When the UE does not change CE levels, the uplink grant in the random access response and the TBS size remain the same for Msg3 retransmission. In such embodiments, the UE may simply obtain the MAC PDU from the buffer for Msg3 retransmission. In other embodiments, however, in which the CE level is changed, the UE may obtain the stored initial SDU plus the MAC CEs or PDU, and use the SDU plus MAC CEs or PDU to re-build the PDU according to the TBS corresponding to the changed CE level.

25 **[0025]** Figure 2 illustrates a system according to certain embodiments. It should be

understood that each table, signal, or block in Figure 1 may be implemented by various means or their combinations, such as hardware, software, firmware, one or more processors and/or circuitry. In one embodiment, a system may include several devices, such as, for example, network entity 220 or UE 210. The system may
5 include more than one UE 210 and more than one network entity 220. Network entity 220 may be a base station, an access point, an access node, an enhanced NodeB (eNB), a 5G or New Radio NodeB, a server, a host, or any other network entity that may communicate with the UE.

[0026] Each of these devices may include at least one processor or control unit or
10 module, respectively indicated as 211 and 221. At least one memory may be provided in each device, and indicated as 212 and 222, respectively. The memory may include computer program instructions or computer code contained therein. One or more transceiver 213 and 223 may be provided, and each device may also include an antenna, respectively illustrated as 214 and 224. Although only one
15 antenna each is shown, many antennas and multiple antenna elements may be provided to each of the devices. Other configurations of these devices, for example, may be provided. For example, network entity 220 and UE 210 may be additionally configured for wired communication, in addition to wireless communication, and in such a case antennas 214 and 224 may illustrate any form of communication
20 hardware, without being limited to merely an antenna.

[0027] Transceivers 213 and 223 may each, independently, be a transmitter, a receiver, or both a transmitter and a receiver, or a unit or device that may be configured both for transmission and reception. The transmitter and/or receiver (as far as radio parts are concerned) may also be implemented as a remote radio head
25 which is not located in the device itself, but in a mast, for example. The operations and functionalities may be performed in different entities, such as nodes, hosts or servers, in a flexible manner. In other words, division of labor may vary case by

case. One possible use is to make a network entity deliver local content. One or more functionalities may also be implemented as virtual application(s) in software that can run on a server.

[0028] A user device or UE 210 may be a mobile station (MS), such as a mobile
5 phone or smart phone or multimedia device, an IoT cellular device, a computer, such as a tablet, provided with wireless communication capabilities, personal data or digital assistant (PDA) provided with wireless communication capabilities, portable media player, digital camera, pocket video camera, navigation unit provided with wireless communication capabilities or any combinations thereof. In
10 other embodiments, the user equipment may be replaced with a machine communication device that does not require any human interaction, such as a sensor, meter, or robot.

[0029] In some embodiments, an apparatus, such as a user equipment or a network entity, may include means for carrying out embodiments described above in relation
15 to Figure 1. In certain embodiments, at least one memory including computer program code can be configured to, with the at least one processor, cause the apparatus at least to perform any of the processes described herein.

[0030] Processors 211 and 221 may be embodied by any computational or data processing device, such as a central processing unit (CPU), digital signal processor
20 (DSP), application specific integrated circuit (ASIC), programmable logic devices (PLDs), field programmable gate arrays (FPGAs), digitally enhanced circuits, or comparable device or a combination thereof. The processors may be implemented as a single controller, or a plurality of controllers or processors.

[0031] For firmware or software, the implementation may include modules or unit
25 of at least one chip set (for example, procedures, functions, and so on). Memories 212 and 222 may independently be any suitable storage device, such as a non-transitory computer-readable medium. A hard disk drive (HDD), random

access memory (RAM), flash memory, or other suitable memory may be used. The memories may be combined on a single integrated circuit as the processor, or may be separate therefrom. Furthermore, the computer program instructions may be stored in the memory and which may be processed by the processors can be any
5 suitable form of computer program code, for example, a compiled or interpreted computer program written in any suitable programming language. The memory or data storage entity is typically internal but may also be external or a combination thereof, such as in the case when additional memory capacity is obtained from a service provider. The memory may be fixed or removable.

10 **[0032]** The memory and the computer program instructions may be configured, with the processor for the particular device, to cause a hardware apparatus such as network entity 220 or UE 210, to perform any of the processes described above (see, for example, Figure 1). Therefore, in certain embodiments, a non-transitory computer-readable medium may be encoded with computer instructions or one or
15 more computer program (such as added or updated software routine, applet or macro) that, when executed in hardware, may perform a process such as one of the processes described herein. Computer programs may be coded by a programming language, which may be a high-level programming language, such as objective-C, C, C++, C#, Java, etc., or a low-level programming language, such as a machine
20 language, or assembler. Alternatively, certain embodiments may be performed entirely in hardware.

[0033] In certain embodiments, an apparatus may include circuitry configured to perform any of the processes or functions illustrated in Figures 1 and 2. Circuitry, in one example, may be hardware-only circuit implementations, such as analog and/or
25 digital circuitry. Circuitry, in another example, may be a combination of hardware circuits and software, such as a combination of analog and/or digital hardware circuit(s) with software or firmware, and/or any portions of hardware processor(s)

with software (including digital signal processor(s)), software, and at least one memory that work together to cause an apparatus to perform various processes or functions. In yet another example, circuitry may be hardware circuit(s) and or processor(s), such as a microprocessor(s) or a portion of a microprocessor(s), that
5 include software, such as firmware for operation. Software in circuitry may not be present when it is not needed for the operation of the hardware.

[0034] Furthermore, although Figure 2 illustrates a system including a network entity 220 and UE 210, certain embodiments may be applicable to other configurations, and configurations involving additional elements, as illustrated and
10 discussed herein. For example, multiple user equipment devices and multiple base stations may be present, or other nodes providing similar functionality, such as nodes that combine the functionality of a user equipment and a base station, such as a relay node. The UE 210 may likewise be provided with a variety of configurations for communication other than communicating with network entity 620. For
15 example, the UE 210 may be configured for device-to-device, machine-to-machine, or vehicle-to-vehicle communication.

[0035] The above embodiments provide for significant improvements to the functioning of a network and/or to the functioning of the network entities within the network, or the user equipment communicating with the network. For example,
20 certain embodiments help the UE to build a PDU corresponding to a changed CE level. The above embodiments may help to minimize the amount of padding for Msg3 retransmission. This can help to reduce the amount of power used by the UE to transmit early data transmissions, thereby reducing the amount of resources used by the network entity to process the early data transmissions. The reduction in the amount
25 of power used by the user equipment may help to preserve or extend the battery life of the user equipment. Certain embodiments may also help to build a MAC PDU that allows for the efficient exchange of early data transmission, even when the CE level

changes.

[0036] The features, structures, or characteristics of certain embodiments described throughout this specification may be combined in any suitable manner in one or more embodiments. For example, the usage of the phrases “certain embodiments,” “some
5 embodiments,” “other embodiments,” or other similar language, throughout this specification refers to the fact that a particular feature, structure, or characteristic described in connection with the embodiment may be included in at least one embodiment of the present invention. Thus, appearance of the phrases “in certain
10 embodiments,” “in some embodiments,” “in other embodiments,” or other similar language, throughout this specification does not necessarily refer to the same group of embodiments, and the described features, structures, or characteristics may be combined in any suitable manner in one or more embodiments.

[0037] One having ordinary skill in the art will readily understand that the invention as discussed above may be practiced with steps in a different order, and/or with
15 hardware elements in configurations which are different than those which are disclosed. Therefore, although the invention has been described based upon these preferred embodiments, it would be apparent to those of skill in the art that certain modifications, variations, and alternative constructions would be apparent, while remaining within the spirit and scope of the invention. Although the above
20 embodiments refer to further enhanced Machine Type Communication, the above embodiments may apply to any other 3GPP technology or non-3GPP technology, such as IoT technology, LTE, LTE-advanced, fourth generation (4G) technology, and/or fifth generation (5G) technology, New Radio technology, or Carrier Aggregation technology.

25 [0038] Partial Glossary

[0039] 3GPP Third Generation Partnership Project

[0040] LTE Long Term Evolution

	[0041]	LTE-A	Long Term Evolution Advanced
	[0042]	NB-IoT	Narrowband IoT
	[0043]	CE	Coverage Enhancement
	[0044]	RSRP	Reference Signal Received Power
5	[0045]	RAR	Random Access Response
	[0046]	Msg3	Message 3
	[0047]	PDU	Protocol Data Unit
	[0048]	MAC	Medium Access Control
	[0049]	SDU	Service Data Unit

WHAT IS CLAIMED IS:

1. A method comprising:

changing a coverage enhancement level in response to a failure of a random access procedure;

5 determining whether early data transmission is initiated in the changed coverage enhancement level;

building at a user equipment a protocol data unit corresponding to the changed coverage enhancement level when the early data transmission is initiated in the changed coverage enhancement level; and

10 transmitting the early data from the user equipment to a network entity in the built packet data unit on the changed coverage enhanced level.

2. The method according to claim 1, wherein the transmitting of the early data is a retransmission.

15

3. The method according to claim 1 or 2, further comprising:

receiving at the user equipment a maximum transport block size associated with the changed coverage enhancement level.

20 4. The method according to any of claims 1-3, further comprising:

storing at the user equipment an initial protocol data unit in a transmit buffer,

wherein the initial protocol data unit is for transmission by the user equipment to the network entity.

5. The method according to any of claims 1-4, further comprising:

5 removing at least one of a padding or a padding sub-header from the stored initial protocol data unit to obtain a clean protocol data unit.

6. The method according to any of claims 1-5, further comprising:

storing at the user equipment an initial service data unit and corresponding
10 control elements in a transmit buffer, wherein the initial service data unit and the corresponding control elements are for transmission by the user equipment to the network entity, and wherein the building of the protocol data unit comprises adding one or more bytes to the initial service data unit and the corresponding control elements for padding or padding subheader.

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7. The method according to any of claims claim 1-6, further comprising:

comparing a length of the clean protocol data unit and the maximum transport block size corresponding to the changed coverage enhancement level; and

initiating the early data transmission when the clean protocol data unit is
20 smaller than or equal to the maximum transport block size corresponding to the

changed coverage enhancement level.

8. The method according to any of claims 1-7, further comprising:

transmitting the protocol data unit stored in the buffer after the random
5 access procedure is complete when the clean protocol data unit is larger than the
maximum transport block size corresponding to the changed coverage enhancement
level.

9. The method according to any of claims 1-8, further comprising:

10 selecting at the user equipment a new transport block size for early data
transmission that is equal to or smaller than the maximum transport block size
corresponding to the changed coverage enhancement level, and that is larger than or
equal to the clean protocol data unit.

15 10. The method according to any of claims 1-9, wherein the transmitted early
data is comprised in a message 3 transmission of the random access procedure.

11. The method according to any of claims 1-10, wherein the building of the
protocol data unit comprises adding one or more bytes to the clean protocol data
20 unit for padding or padding subheader.

12. An apparatus, comprising:

at least one memory comprising computer program code;

at least one processor, wherein the at least one memory and the computer
5 program code are configured, with the at least one processor, to cause the apparatus
at least to:

change a coverage enhancement level in response to a failure of a random
access procedure;

determine whether early data transmission is initiated in the changed
10 coverage enhancement level;

build a protocol data unit corresponding to the changed coverage
enhancement level when the early data transmission is initiated in the changed
coverage enhancement level; and

transmit the early data to a network entity in the built packet data unit on the
15 changed coverage enhanced level.

13. The apparatus according to claim 12, wherein the transmitting of the
early data is a retransmission.

20 14. The apparatus according to claim 12 or 13, wherein the at least one

memory and the computer program code are configured, with the at least one processor, to cause the apparatus at least to:

receive a maximum transport block size associated with the changed coverage enhancement level.

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15. The apparatus according to any of claims 12-14, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus at least to:

store an initial protocol data unit in a transmit buffer, wherein the initial
10 protocol data unit is for transmission by the user equipment to the network entity.

16. The apparatus according to any of claims 12-15, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus at least to:

15 remove at least one of a padding or a padding sub-header from the stored initial protocol data unit to obtain a clean protocol data unit.

17. The apparatus according to any of claims 12-16, wherein the at least one memory and the computer program code are configured, with the at least one
20 processor, to cause the apparatus at least to:

store an initial service data unit and corresponding control elements in a transmit buffer, wherein the initial service data unit and the corresponding control elements are for transmission to the network entity, and wherein the building of the protocol data unit comprises adding one or more bytes to the initial service data unit
5 and the corresponding control elements for padding or padding subheader.

18. The apparatus according to any of claims 12-17, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus at least to:

10 compare a length of the clean protocol data unit and the maximum transport block size corresponding to the changed coverage enhancement level; and

initiate the early data transmission when the clean protocol data unit is smaller than or equal to the maximum transport block size corresponding to the changed coverage enhancement level.

15

19. The apparatus according to any of claims 12-18, further comprising:

transmit the protocol data unit stored in the buffer after the random access procedure is complete when the clean protocol data unit is larger than the maximum transport block size corresponding to the changed coverage enhancement level.

20. The apparatus according to any of claims 12-19, wherein the clean protocol data unit is smaller than or equal to the maximum transport block size of the changed coverage enhancement level.

5 21. The apparatus according to any of claims 12-20, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus at least to:

select a new transport block size for early data transmission that is equal to or smaller than the maximum transport block size corresponding to the changed
10 coverage enhancement level, and that is larger than or equal to the clean protocol data unit.

22. The apparatus according to any of claims 12-21, wherein the transmitted early data is comprised in a message 3 transmission of the random access procedure.

15

23. The apparatus according to any of claims 12-22, wherein the building of the protocol data unit comprises adding one or more bytes to the clean protocol data unit for padding or padding subheader.

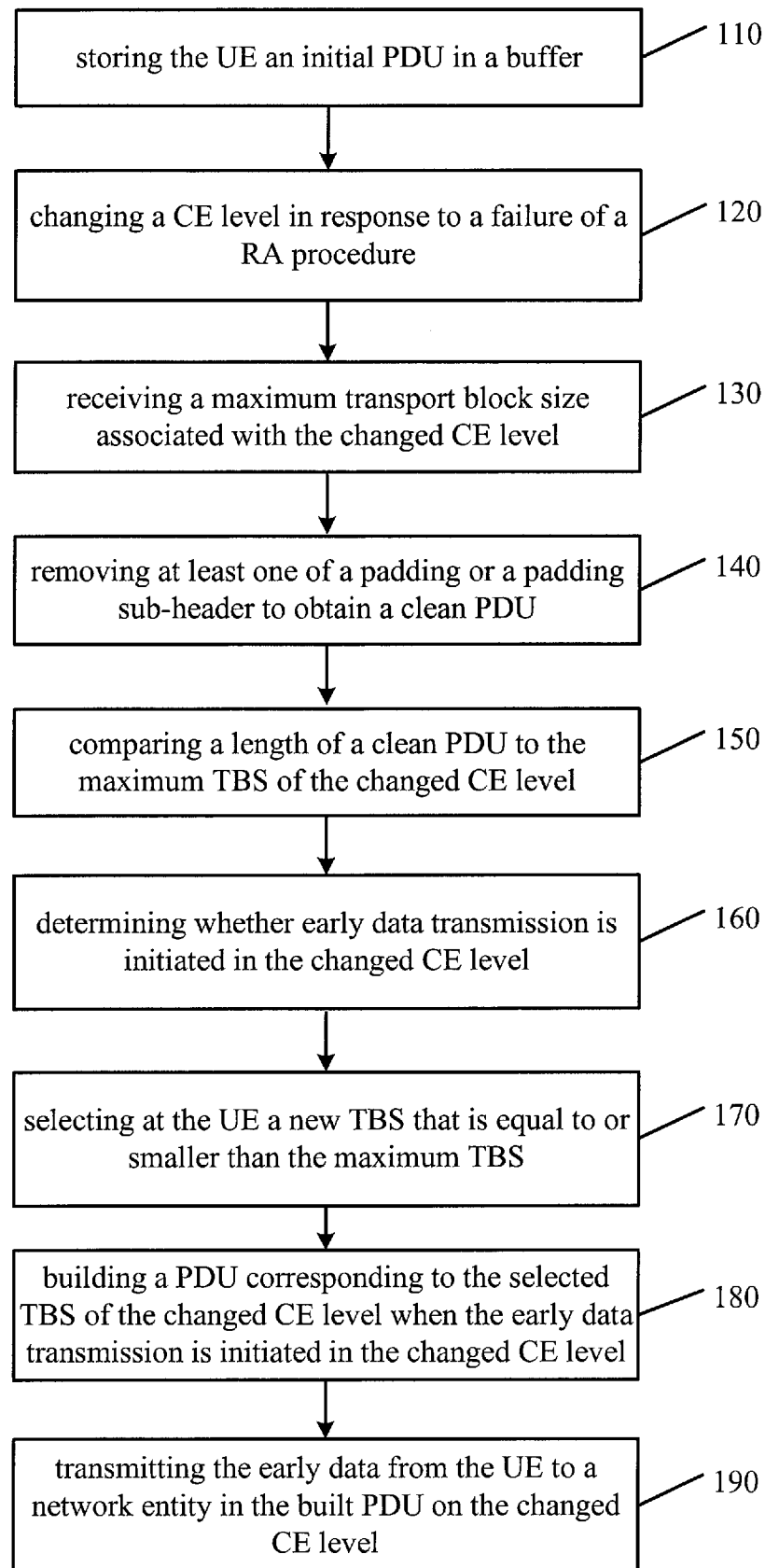


Figure 1

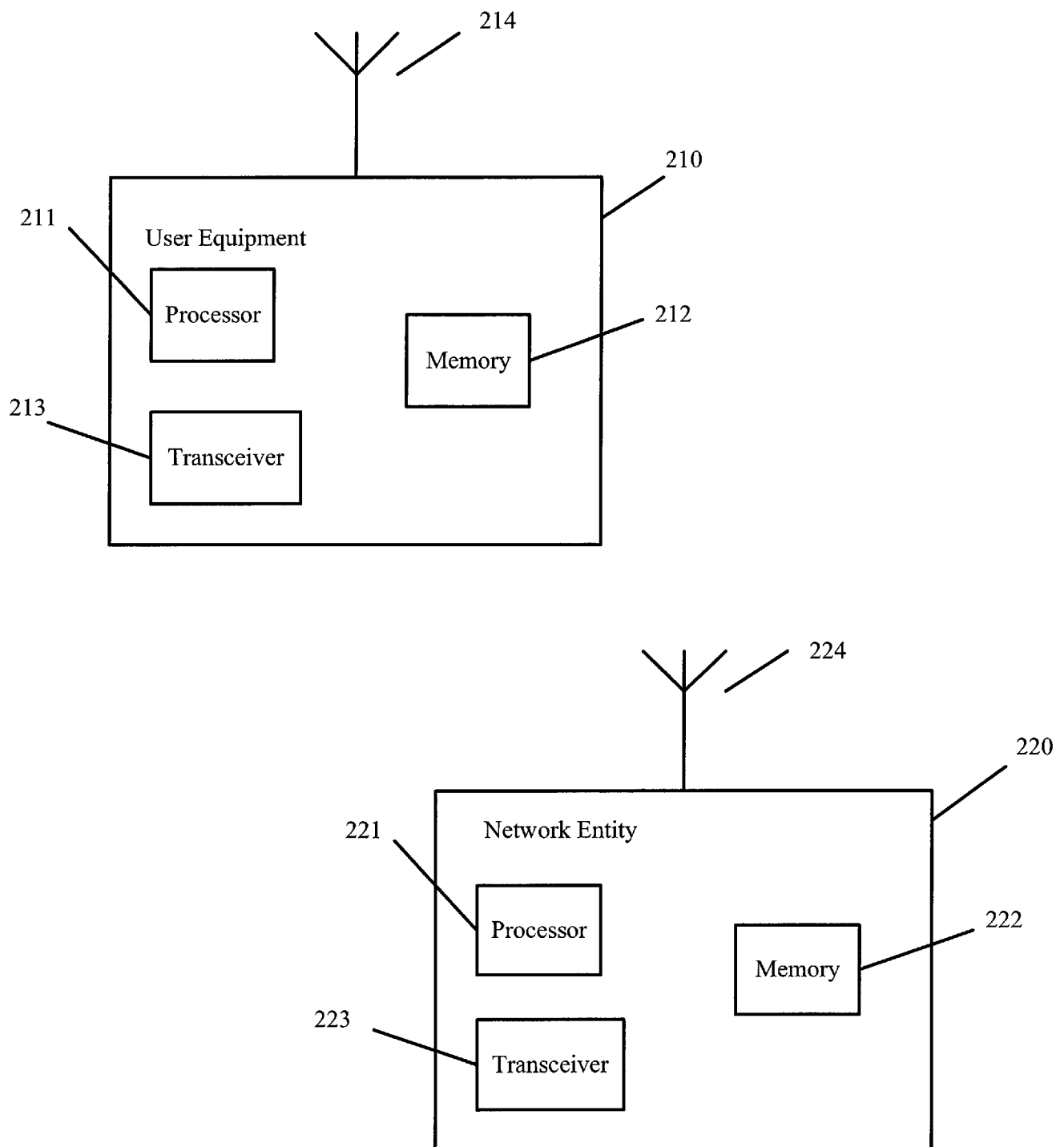


Figure 2

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2018/082071

A. CLASSIFICATION OF SUBJECT MATTER H04W 72/00(2009.01)i According to International Patent Classification (IPC) or to both national classification and IPC																	
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) H04W; H04B; 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) CNPAT, CNKI, EPODOC, WPI, 3GPP: coverage enhancement level, random access, chang+, fail+, unsucces+, early, first, PDU																	
C. DOCUMENTS CONSIDERED TO BE RELEVANT <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 5px;"> <thead> <tr> <th style="width: 10%;">Category*</th> <th style="width: 70%;">Citation of document, with indication, where appropriate, of the relevant passages</th> <th style="width: 20%;">Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">A</td> <td>WO 2016167570 A1 (LG ELECTRONICS INC.) 20 October 2016 (2016-10-20) description, paragraphs [88]-[95]</td> <td style="text-align: center;">1-23</td> </tr> <tr> <td style="text-align: center;">A</td> <td>EP 3226644 A1 (HTC CORPORATION) 04 October 2017 (2017-10-04) the whole document</td> <td style="text-align: center;">1-23</td> </tr> <tr> <td style="text-align: center;">A</td> <td>CN 104427459 A (HUAWEI TECHNOLOGIES CO., LTD.) 18 March 2015 (2015-03-18) the whole document</td> <td style="text-align: center;">1-23</td> </tr> <tr> <td style="text-align: center;">A</td> <td>CN 105992372 A (ALCATEL-LUCENT SHANGHAI BELL CO., LTD.) 05 October 2016 (2016-10-05) the whole document</td> <td style="text-align: center;">1-23</td> </tr> </tbody> </table>			Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	A	WO 2016167570 A1 (LG ELECTRONICS INC.) 20 October 2016 (2016-10-20) description, paragraphs [88]-[95]	1-23	A	EP 3226644 A1 (HTC CORPORATION) 04 October 2017 (2017-10-04) the whole document	1-23	A	CN 104427459 A (HUAWEI TECHNOLOGIES CO., LTD.) 18 March 2015 (2015-03-18) the whole document	1-23	A	CN 105992372 A (ALCATEL-LUCENT SHANGHAI BELL CO., LTD.) 05 October 2016 (2016-10-05) the whole document	1-23
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☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.																	
<table style="width: 100%;"> <tr> <td style="width: 50%; vertical-align: top;"> * Special categories of cited documents: “A” document defining the general state of the art which is not considered to be of particular relevance “E” earlier application or patent but published on or after the international filing date “L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) “O” document referring to an oral disclosure, use, exhibition or other means “P” document published prior to the international filing date but later than the priority date claimed </td> <td style="width: 50%; vertical-align: top;"> “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 </td> </tr> </table>			* Special categories of cited documents: “A” document defining the general state of the art which is not considered to be of particular relevance “E” earlier application or patent but published on or after the international filing date “L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) “O” document referring to an oral disclosure, use, exhibition or other means “P” document published prior to the international filing date but later than the priority date claimed	“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention “X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone “Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art “&” document member of the same patent family													
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Date of the actual completion of the international search 20 November 2018		Date of mailing of the international search report 29 December 2018															
Name and mailing address of the ISA/CN STATE INTELLECTUAL PROPERTY OFFICE OF THE P.R.CHINA 6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088 China Facsimile No. (86-10)62019451		Authorized officer TIAN,Tao Telephone No. 86-(10)-53961637															

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2018/082071

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
WO	2016167570	A1	20 October 2016	US	2018097599	A1	05 April 2018
EP	3226644	A1	04 October 2017	US	2017290063	A1	05 October 2017
				CN	107276958	A	20 October 2017
CN	104427459	A	18 March 2015	None			
CN	105992372	A	05 October 2016	None			