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(54) **SYSTEMS AND METHODS FOR OPTIMIZED SIGNALING FOR NON IP DATA DELIVERY (NIDD) COMMUNICATION**

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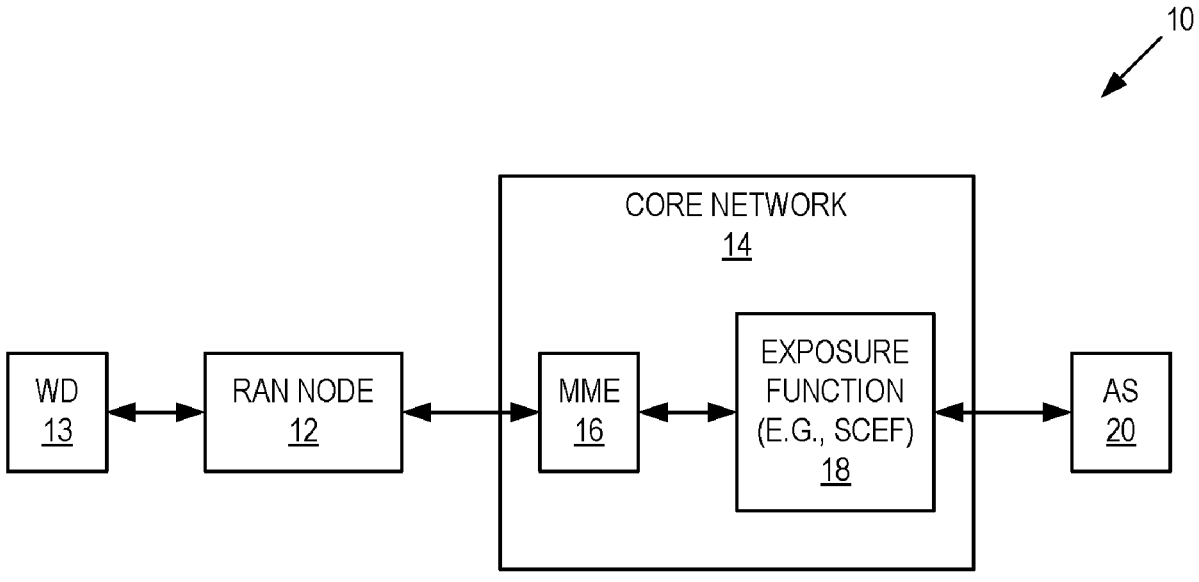
(57) **ABSTRACT**

Systems and methods are disclosed herein that relate to deferring delivery of non-Internet Protocol (IP) data in a wireless communication system via a Non-IP Data Delivery (NIDD) procedure based on a power source status of a serving Radio Access Network (RAN) node of a target wireless device. In some embodiments, a method of operation of a network node comprises receiving, from an exposure function, a NIDD request comprising data from an application server to be delivered to a wireless device via a NIDD procedure. The method further comprises making a determination as to whether to deliver the data to the wireless device via the NIDD procedure based on a power source status of a RAN node associated with the wireless device. In this manner, delivery of the non-IP data can be deferred depending on the power source status of the RAN node.



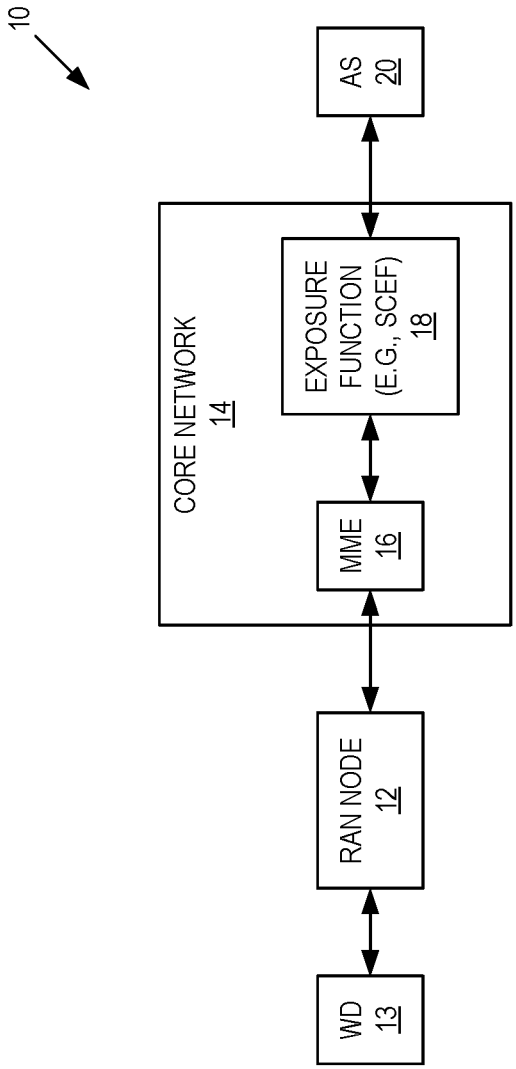

10
AS
20
CORE NETWORK
14
EXPOSURE
FUNCTION
(E.G., SCEF)
18
MME
16
RAN NODE
12
WD
13

FIG. 1

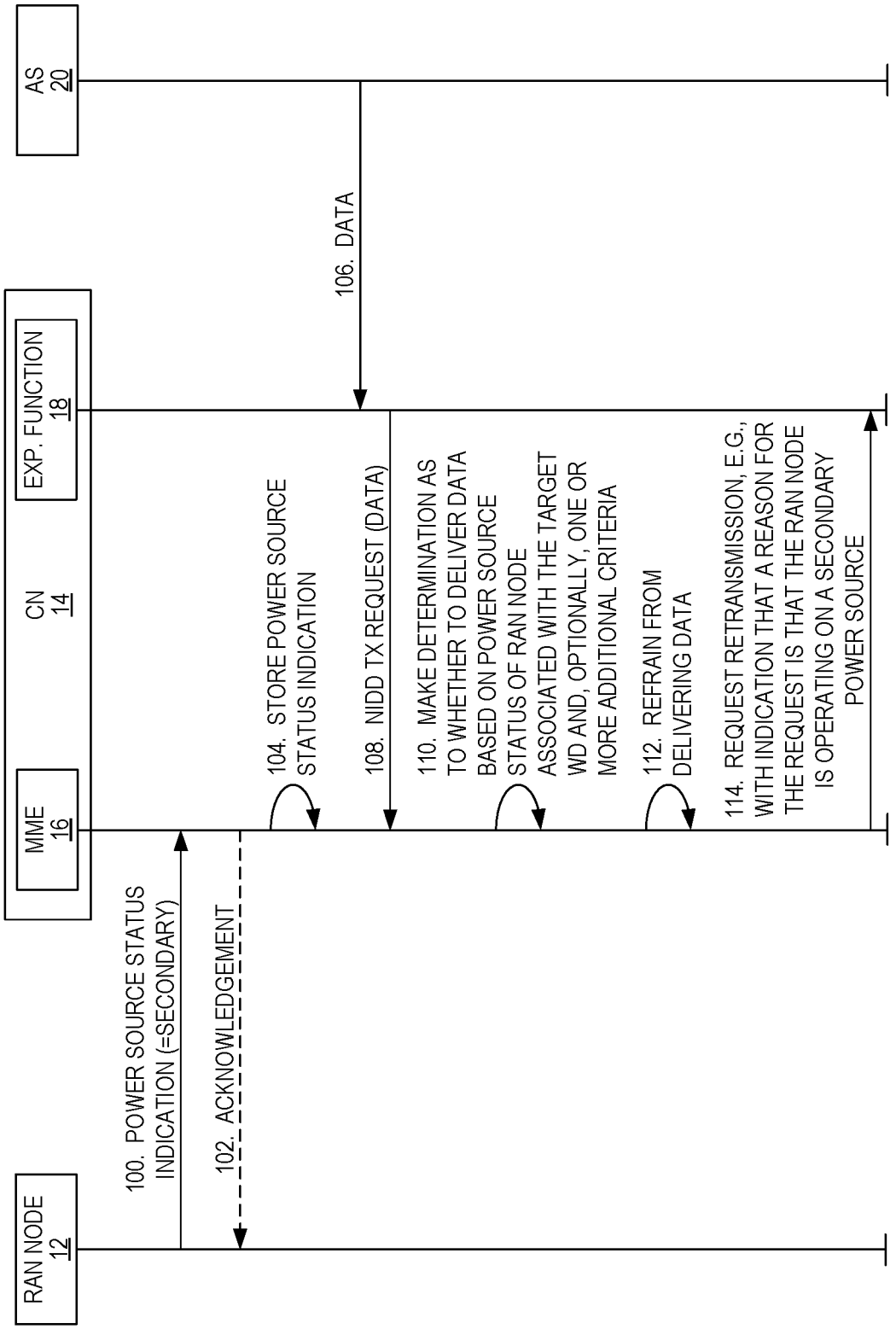

AS 20
106. DATA
CN 14
EXP. FUNCTION 18
MME 16
104. STORE POWER SOURCE STATUS INDICATION
108. NIDD TX REQUEST (DATA)
110. MAKE DETERMINATION AS TO WHETHER TO DELIVER DATA BASED ON POWER SOURCE STATUS OF RAN NODE ASSOCIATED WITH THE TARGET WD AND, OPTIONALLY, ONE OR MORE ADDITIONAL CRITERIA
112. REFRAIN FROM DELIVERING DATA
114. REQUEST RETRANSMISSION, E.G., WITH INDICATION THAT A REASON FOR THE REQUEST IS THAT THE RAN NODE IS OPERATING ON A SECONDARY POWER SOURCE
100. POWER SOURCE STATUS INDICATION (=SECONDARY)
102. ACKNOWLEDGEMENT
RAN NODE 12

FIG. 2A

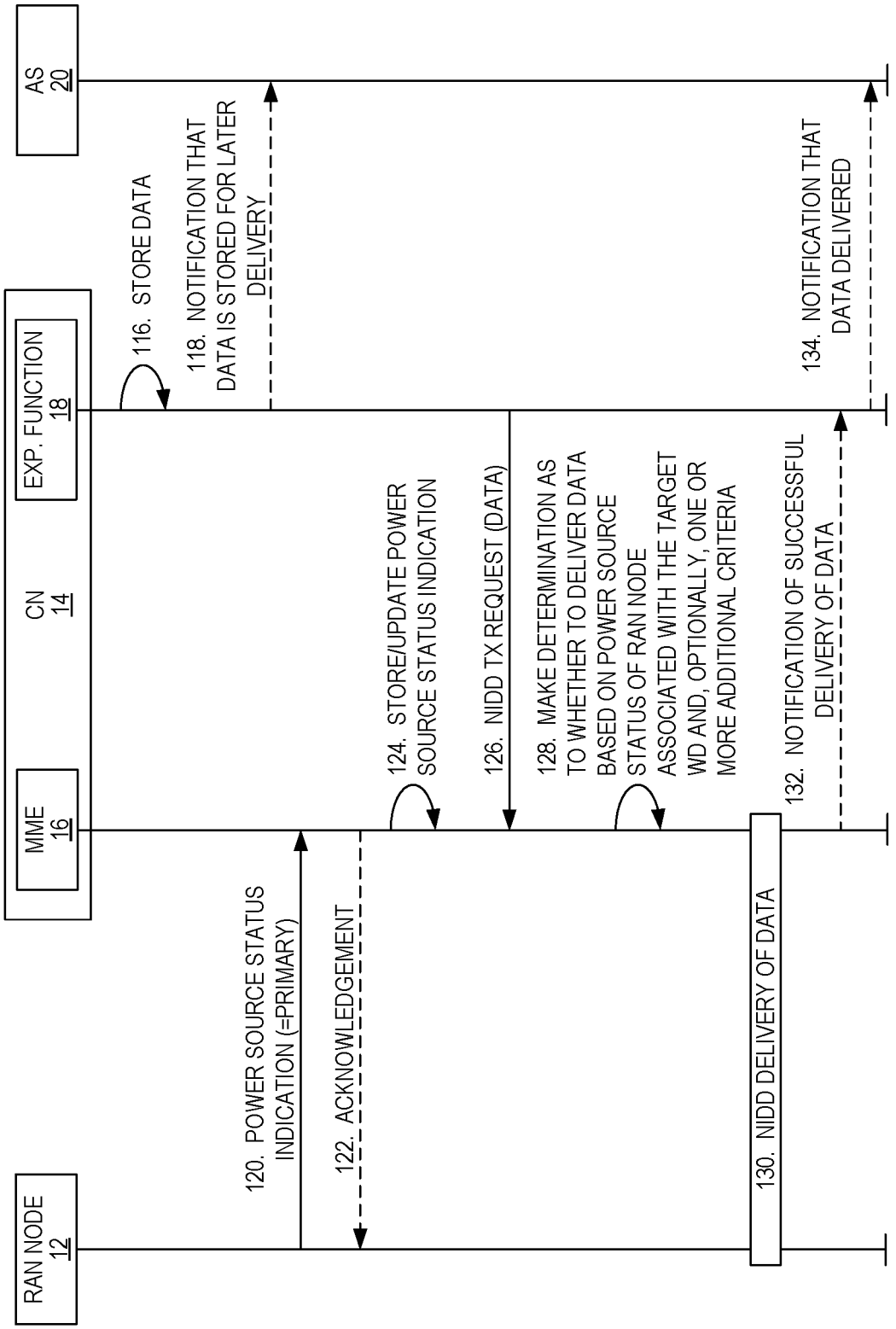

AS 20
CN 14
EXP. FUNCTION 18
MME 16
RAN NODE 12
116. STORE DATA
118. NOTIFICATION THAT DATA IS STORED FOR LATER DELIVERY
120. POWER SOURCE STATUS INDICATION (=PRIMARY)
122. ACKNOWLEDGEMENT
124. STORE/UPDATE POWER SOURCE STATUS INDICATION
126. NIDD TX REQUEST (DATA)
128. MAKE DETERMINATION AS TO WHETHER TO DELIVER DATA BASED ON POWER SOURCE STATUS OF RAN NODE ASSOCIATED WITH THE TARGET WD AND, OPTIONALLY, ONE OR MORE ADDITIONAL CRITERIA
130. NIDD DELIVERY OF DATA
132. NOTIFICATION OF SUCCESSFUL DELIVERY OF DATA
134. NOTIFICATION THAT DATA DELIVERED

FIG. 2B

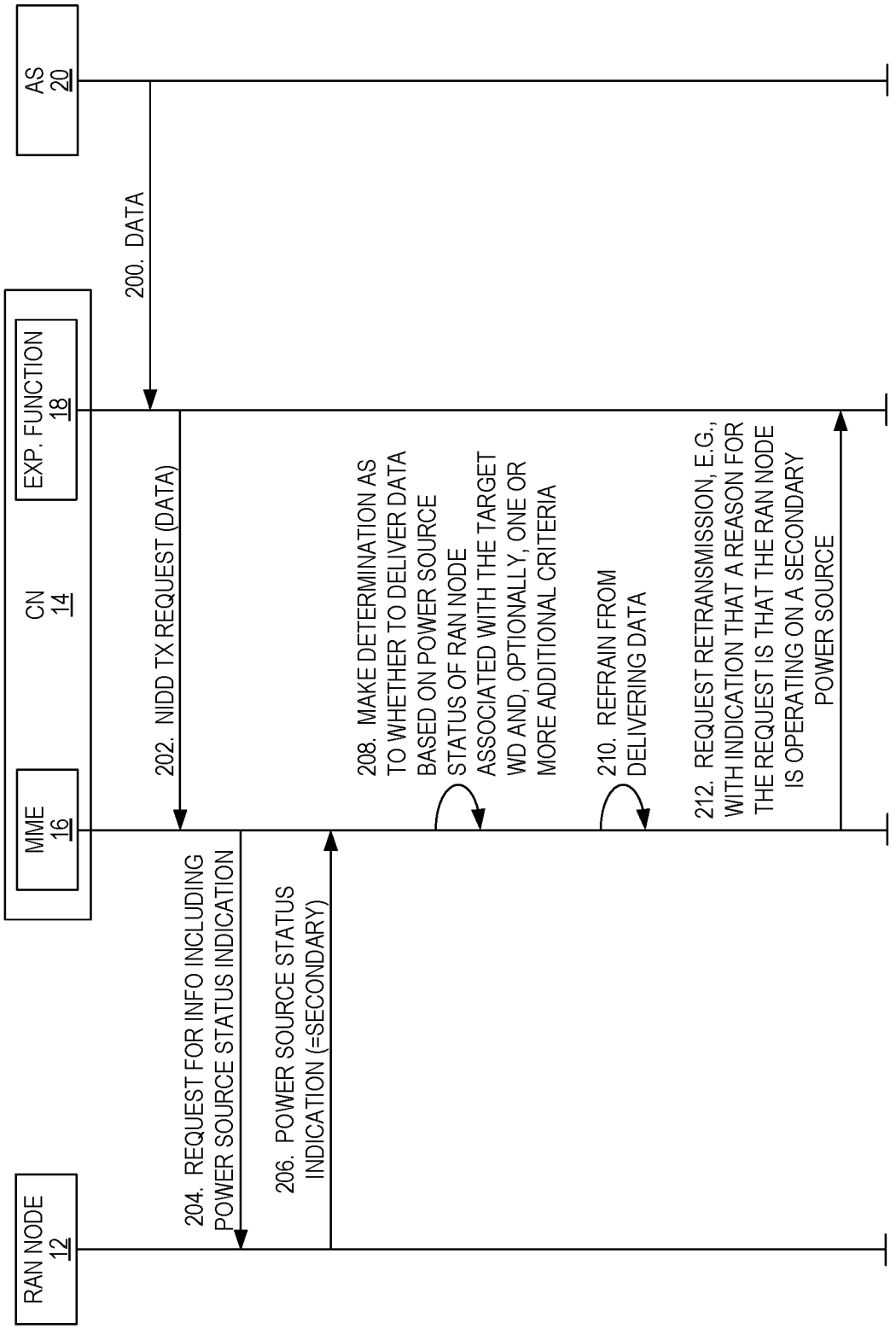

AS
20
200. DATA
CN
14
EXP. FUNCTION
18
MME
16
202. NIDD TX REQUEST (DATA)
208. MAKE DETERMINATION AS TO WHETHER TO DELIVER DATA BASED ON POWER SOURCE STATUS OF RAN NODE ASSOCIATED WITH THE TARGET WD AND, OPTIONALLY, ONE OR MORE ADDITIONAL CRITERIA
210. REFRAIN FROM DELIVERING DATA
212. REQUEST RETRANSMISSION, E.G., WITH INDICATION THAT A REASON FOR THE REQUEST IS THAT THE RAN NODE IS OPERATING ON A SECONDARY POWER SOURCE
RAN NODE
12
204. REQUEST FOR INFO INCLUDING POWER SOURCE STATUS INDICATION
206. POWER SOURCE STATUS INDICATION (=SECONDARY)

FIG. 3A

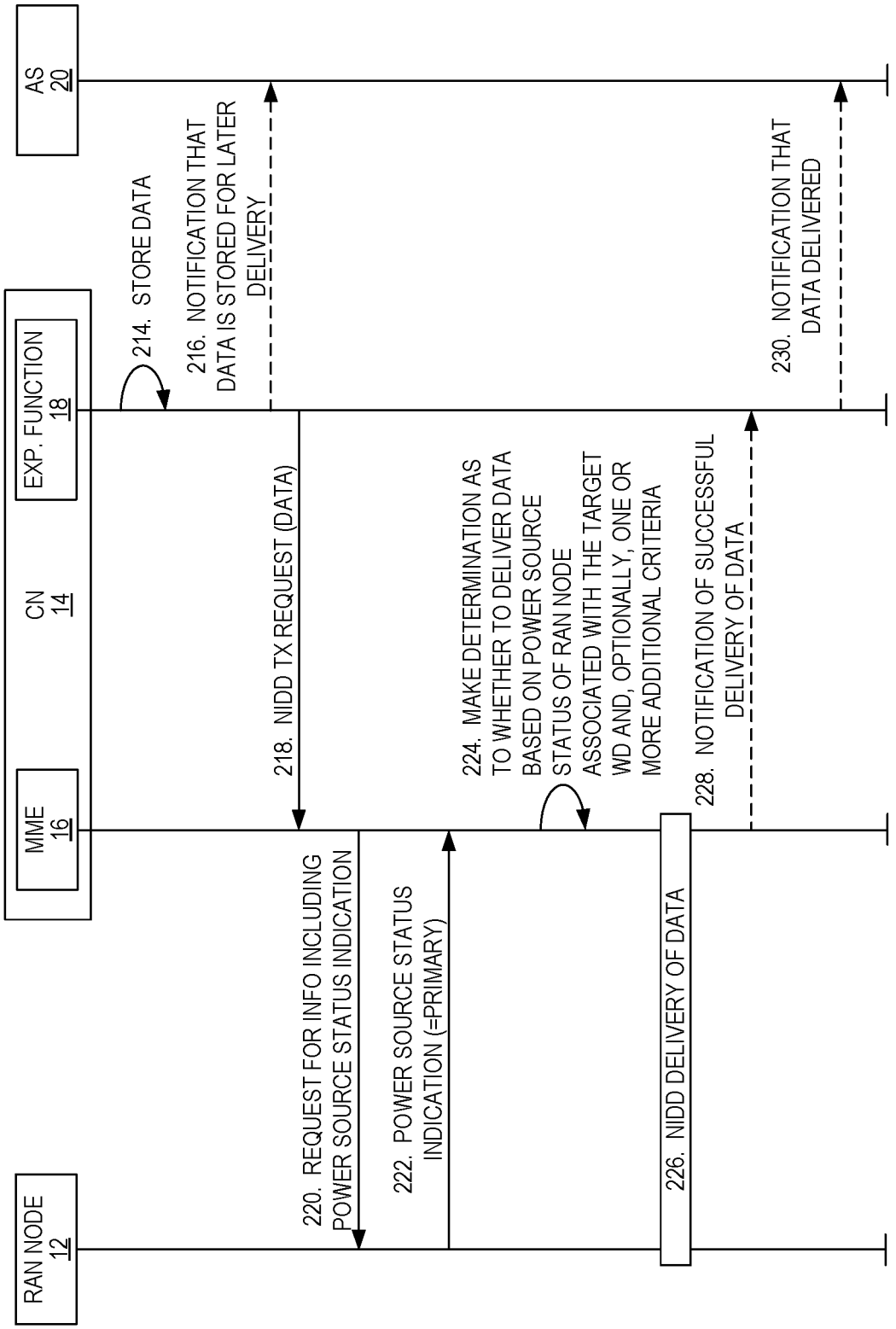

AS 20
CN 14
EXP. FUNCTION 18
MME 16
RAN NODE 12
214. STORE DATA
216. NOTIFICATION THAT DATA IS STORED FOR LATER DELIVERY
218. NIDD TX REQUEST (DATA)
220. REQUEST FOR INFO INCLUDING POWER SOURCE STATUS INDICATION
222. POWER SOURCE STATUS INDICATION (=PRIMARY)
224. MAKE DETERMINATION AS TO WHETHER TO DELIVER DATA BASED ON POWER SOURCE STATUS OF RAN NODE ASSOCIATED WITH THE TARGET WD AND, OPTIONALLY, ONE OR MORE ADDITIONAL CRITERIA
226. NIDD DELIVERY OF DATA
228. NOTIFICATION OF SUCCESSFUL DELIVERY OF DATA
230. NOTIFICATION THAT DATA DELIVERED

FIG. 3B

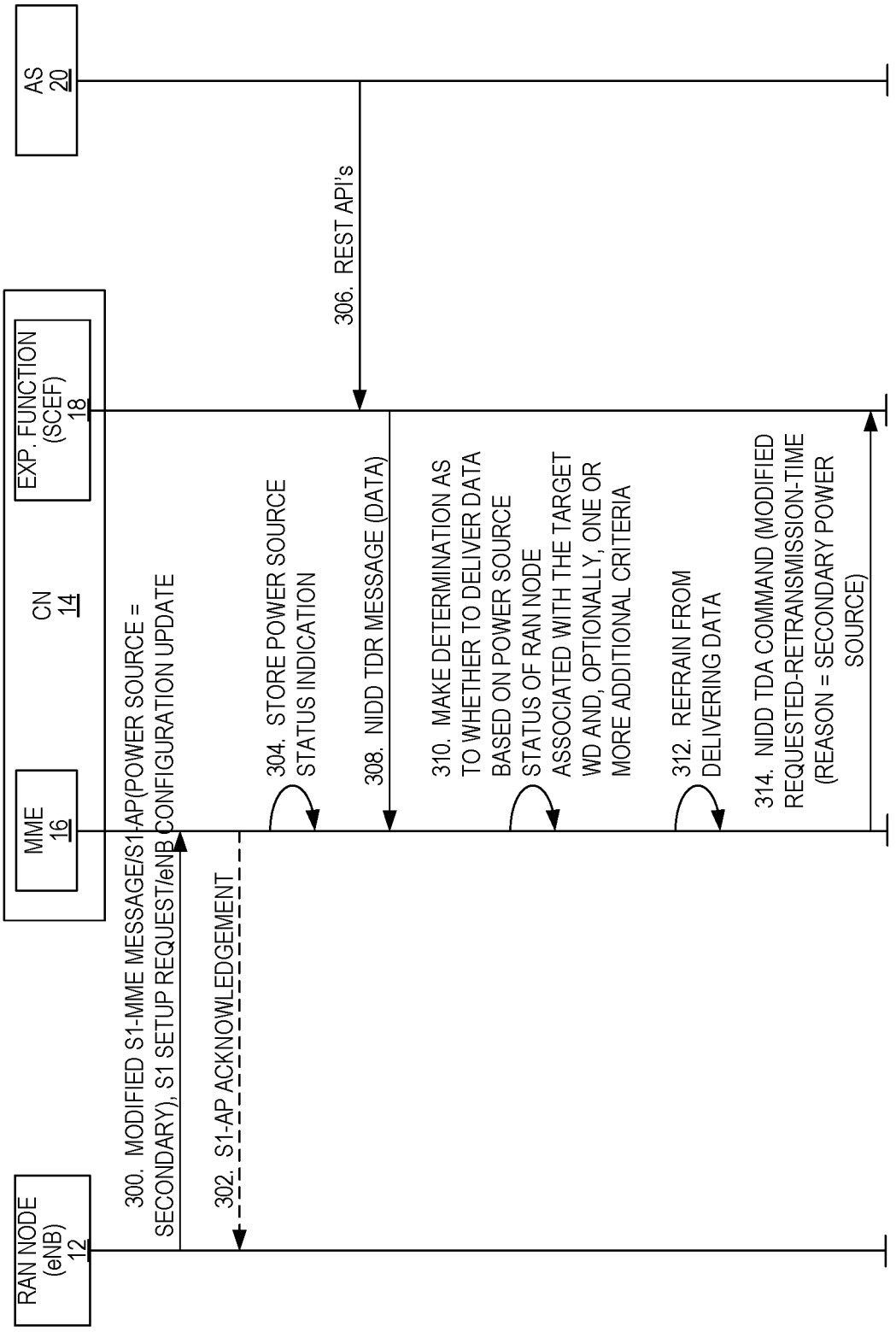

AS
20
EXP. FUNCTION
(SCEF)
18
CN
14
MME
16
RAN NODE
(eNB)
12
306. REST API's
300. MODIFIED S1-MME MESSAGE/S1-AP(POWER SOURCE = SECONDARY), S1 SETUP REQUEST/eNB CONFIGURATION UPDATE
302. S1-AP ACKNOWLEDGEMENT
304. STORE POWER SOURCE STATUS INDICATION
308. NIDD TDR MESSAGE (DATA)
310. MAKE DETERMINATION AS TO WHETHER TO DELIVER DATA BASED ON POWER SOURCE STATUS OF RAN NODE ASSOCIATED WITH THE TARGET WD AND, OPTIONALLY, ONE OR MORE ADDITIONAL CRITERIA
312. REFRAIN FROM DELIVERING DATA
314. NIDD TDA COMMAND (MODIFIED REQUESTED-RETRANSMISSION-TIME (REASON = SECONDARY POWER SOURCE)

FIG. 4A

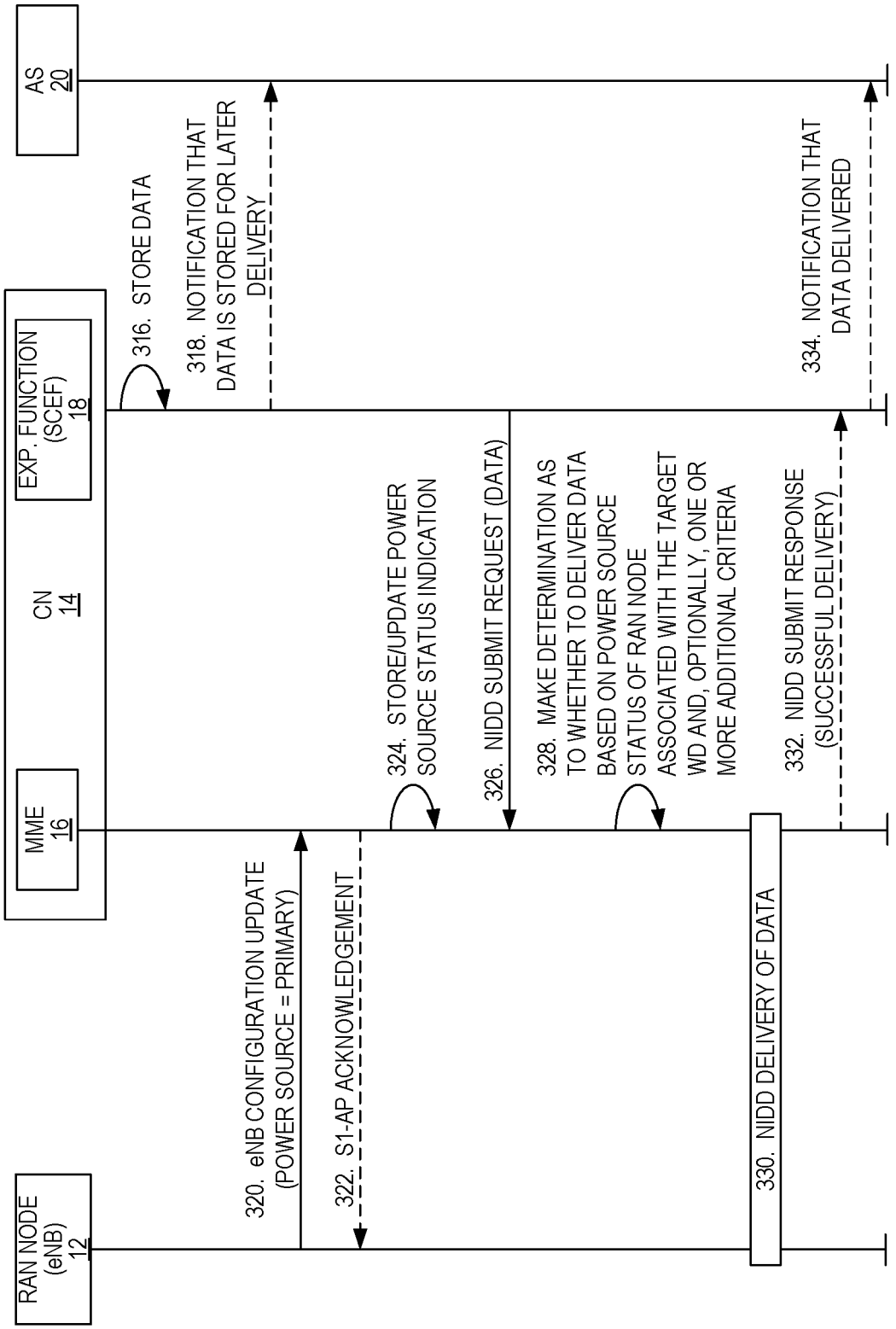

AS 20
EXP. FUNCTION (SCEF) 18
CN 14
MME 16
RAN NODE (eNB) 12
316. STORE DATA
318. NOTIFICATION THAT DATA IS STORED FOR LATER DELIVERY
320. eNB CONFIGURATION UPDATE (POWER SOURCE = PRIMARY)
322. S1-AP ACKNOWLEDGEMENT
324. STORE/UPDATE POWER SOURCE STATUS INDICATION
326. NIDD SUBMIT REQUEST (DATA)
328. MAKE DETERMINATION AS TO WHETHER TO DELIVER DATA BASED ON POWER SOURCE STATUS OF RAN NODE ASSOCIATED WITH THE TARGET WD AND, OPTIONALLY, ONE OR MORE ADDITIONAL CRITERIA
330. NIDD DELIVERY OF DATA
332. NIDD SUBMIT RESPONSE (SUCCESSFUL DELIVERY)
334. NOTIFICATION THAT DATA DELIVERED

FIG. 4B

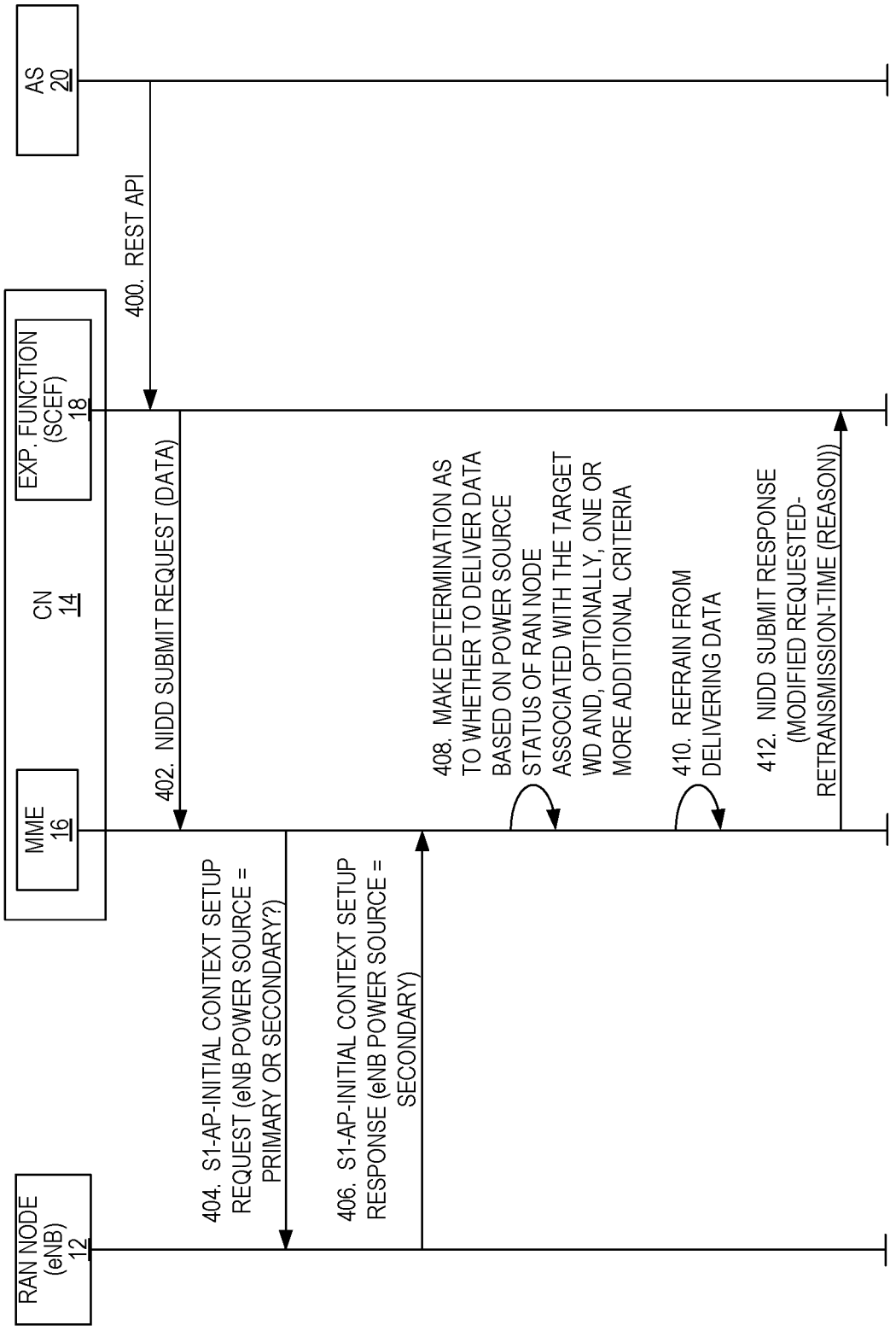

AS
20
400. REST API
EXP. FUNCTION
(SCEF)
18
CN
14
MME
16
402. NIDD SUBMIT REQUEST (DATA)
408. MAKE DETERMINATION AS TO WHETHER TO DELIVER DATA BASED ON POWER SOURCE STATUS OF RAN NODE ASSOCIATED WITH THE TARGET WD AND, OPTIONALLY, ONE OR MORE ADDITIONAL CRITERIA
410. REFRAIN FROM DELIVERING DATA
412. NIDD SUBMIT RESPONSE (MODIFIED REQUESTED-RETRANSMISSION-TIME (REASON))
404. S1-AP-INITIAL CONTEXT SETUP REQUEST (eNB POWER SOURCE = PRIMARY OR SECONDARY?)
406. S1-AP-INITIAL CONTEXT SETUP RESPONSE (eNB POWER SOURCE = SECONDARY)
RAN NODE
(eNB)
12

FIG. 5A

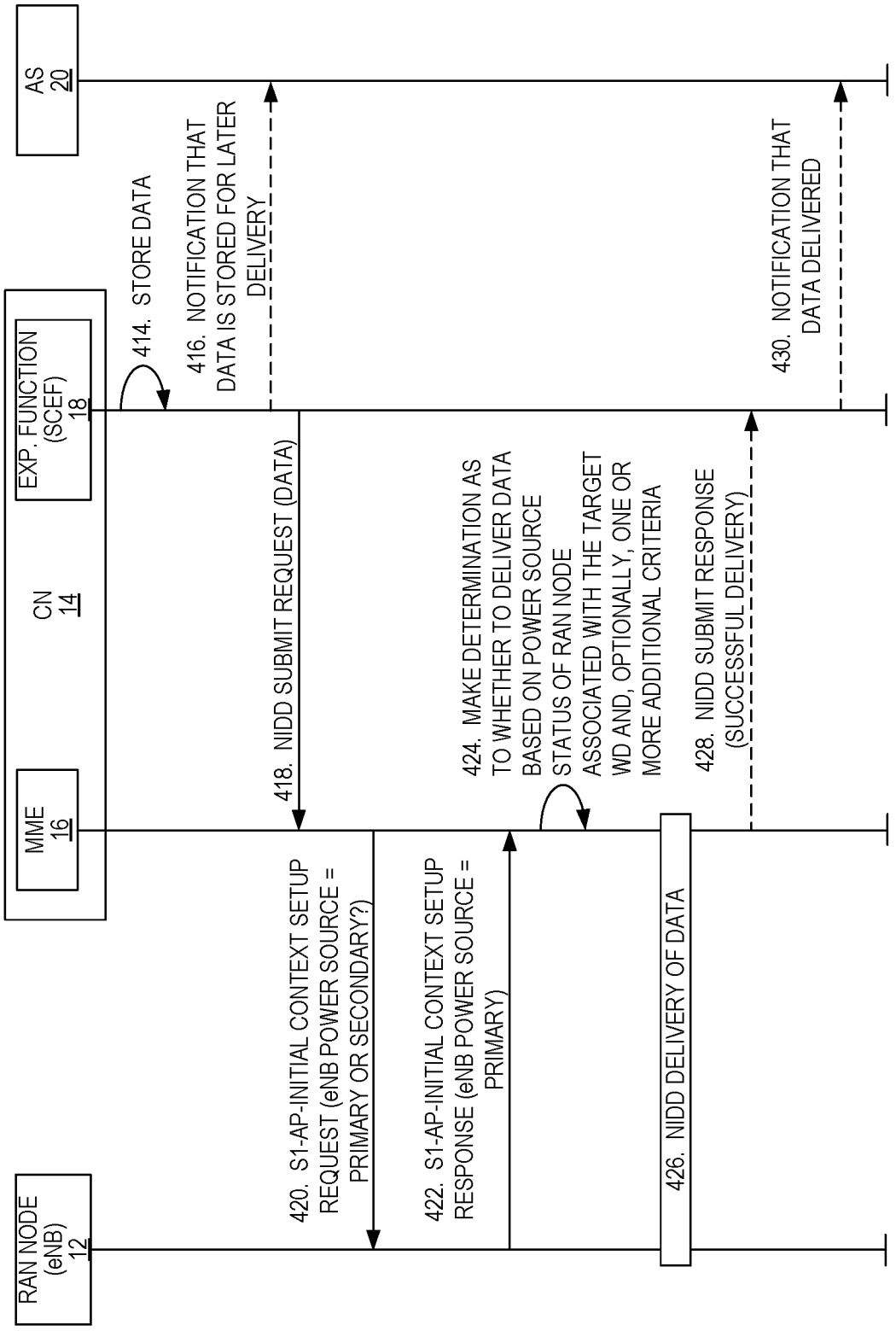

AS 20
EXP. FUNCTION (SCEF) 18
CN 14
MME 16
RAN NODE (eNB) 12
414. STORE DATA
416. NOTIFICATION THAT DATA IS STORED FOR LATER DELIVERY
418. NIDD SUBMIT REQUEST (DATA)
420. S1-AP-INITIAL CONTEXT SETUP REQUEST (eNB POWER SOURCE = PRIMARY OR SECONDARY?)
422. S1-AP-INITIAL CONTEXT SETUP RESPONSE (eNB POWER SOURCE = PRIMARY)
424. MAKE DETERMINATION AS TO WHETHER TO DELIVER DATA BASED ON POWER SOURCE STATUS OF RAN NODE ASSOCIATED WITH THE TARGET WD AND, OPTIONALLY, ONE OR MORE ADDITIONAL CRITERIA
426. NIDD DELIVERY OF DATA
428. NIDD SUBMIT RESPONSE (SUCCESSFUL DELIVERY)
430. NOTIFICATION THAT DATA DELIVERED

FIG. 5B

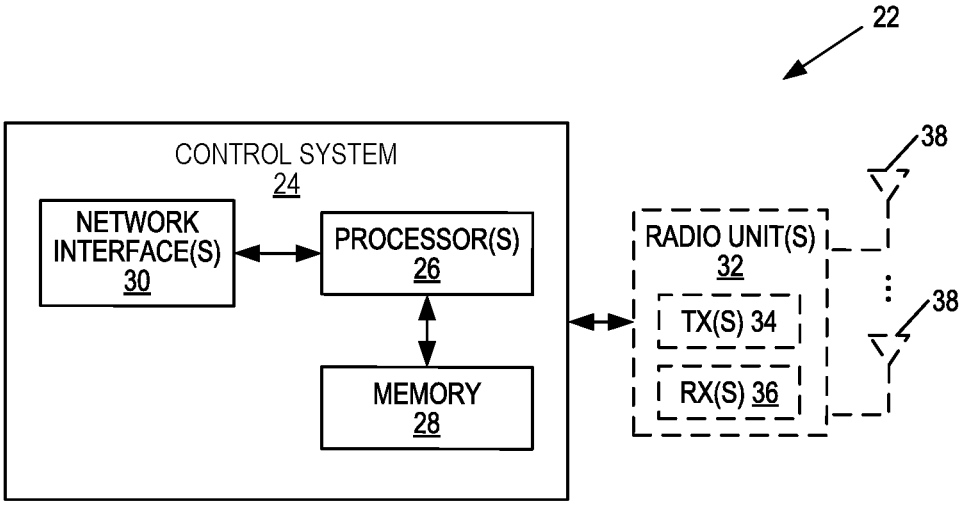

22
CONTROL SYSTEM
24
NETWORK INTERFACE(S)
30
PROCESSOR(S)
26
MEMORY
28
RADIO UNIT(S)
32
TX(S) 34
RX(S) 36
38
38

FIG. 6

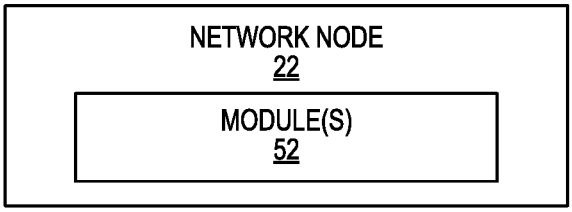

NETWORK NODE
22
MODULE(S)
52

FIG. 8

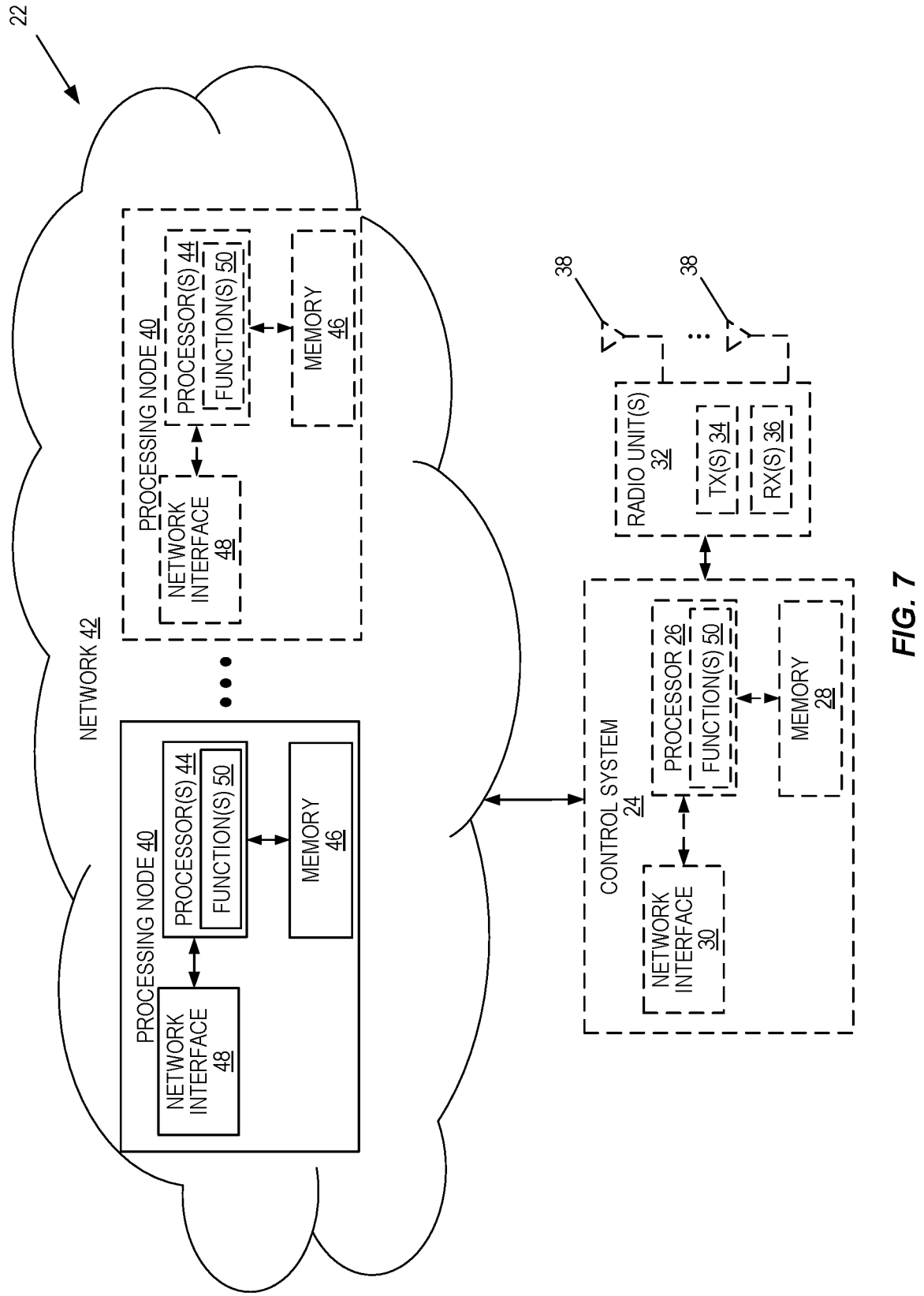

22
NETWORK 42
PROCESSING NODE 40
PROCESSOR(S) 44
FUNCTION(S) 50
MEMORY 46
NETWORK INTERFACE 48
PROCESSING NODE 40
PROCESSOR(S) 44
FUNCTION(S) 50
MEMORY 46
NETWORK INTERFACE 48
38
38
RADIO UNIT(S) 32
TX(S) 34
RX(S) 36
CONTROL SYSTEM 24
PROCESSOR 26
FUNCTION(S) 50
MEMORY 28
NETWORK INTERFACE 30

FIG. 7

SYSTEMS AND METHODS FOR OPTIMIZED SIGNALING FOR NON IP DATA DELIVERY (NIDD) COMMUNICATION

TECHNICAL FIELD

[0001] The present disclosure relates to Non-Internet Protocol (IP) Data Delivery (NIDD).

BACKGROUND

[0002] In a Third Generation Partnership Project (3GPP) system, the end-to-end communications between a Machine Type Communication (MTC) Application in a User Equipment device (UE) and a MTC application in an external network uses services provided by the 3GPP system including services provided by a Services Capability Server (SCS). Different models of communication are foreseen for MTC traffic between an Application Server (AS) and a UE. One model is a hybrid model where the AS connects to an operator's network for direct plane communications with the UE along with the SCS.

[0003] The SCS is an entity that operates to communicate with UEs used for MTC and/or a Service Capability Exposure Function (SCEF) in the Home Public Land Mobile Network (HPLMN). The SCS offers capabilities for use by one or multiple MTC applications. A UE can host one or multiple MTC applications. The corresponding MTC applications in the external network are hosted on one or multiple ASs.

[0004] The SCEF is the key entity within the 3GPP system for service capability exposure that provides a means to securely expose the services and capabilities provided by 3GPP network interfaces (see, e.g., 3GPP Technical Specification (TS) 23.682). When the SCEF belongs to a trusted business partner of the HPLMN, it is still seen as an HPLMN entity by other HPLMN or Visited Public Land Mobile Network (VPLMN) functional entities invoked by the SCEF (e.g., Home Subscriber Service (HSS), Mobility Management Entity (MME), etc.). Applications operating in the trust domain may require only a subset of the functionalities (e.g., authentication, authorization, etc.) provided by the SCEF.

[0005] To enable massive Internet of Things (IoT) expansion, operators will need to embrace Low Power Wide Area (LPWA) technologies, such as Narrowband IoT (NB-IoT) or Long Term Evolution (LTE) Cat-M1/M2 (for IoT and NB-IoT, respectively). IoT devices require small data transfers and 3GPP has determined that delivery via the control plane is much preferred over using the data plane. In this regard, in Release 13, 3GPP has proposed that the SCEF be used for Non-Internet Protocol (IP) Data Delivery (NIDD) as the preferred mechanism for small amounts of data to be transferred between IoT devices and ASs. 3GPP has made NIDD a requirement for small data transfers (see, e.g., 3GPP TS 23.401 V13.10.0 and 3GPP TS 23.682 V13.8.0).

SUMMARY

[0006] Systems and methods are disclosed herein that relate to deferring delivery of non-Internet Protocol (IP) data in a wireless communication system via a Non-IP Data Delivery (NIDD) procedure based on a power source status of a serving Radio Access Network (RAN) node of a target wireless device. In some embodiments, a method of operation of a network node to provide NIDD for a wireless communication system comprises receiving, from an exposure function that exposes a core network to an Application Server (AS), a NIDD request comprising data from the AS to be delivered to a wireless device via a NIDD procedure. The method further comprises making a determination as to whether to deliver the data to the wireless device via the NIDD procedure based on a power source status of a RAN node associated with the wireless device. In this manner, delivery of the non-IP data can be deferred depending on the power source status of the RAN node (e.g., deferred if the RAN node is operating on a secondary power source).

[0007] In some embodiments, making the determination as to whether to deliver the data to the wireless device via the NIDD procedure comprises making the determination to not deliver the data to the wireless device via the NIDD procedure if the power source status of the RAN node is that the RAN node is using a secondary power source, and making the determination to deliver the data to the wireless device via the NIDD procedure if the power source status of the RAN node is that the RAN node is using a primary power source.

[0008] In some embodiments, the method further comprises refraining from delivering the data to the wireless device via the NIDD procedure if the determination is made to not deliver the data to the wireless device via the NIDD procedure, and delivering the data to the wireless device via the NIDD procedure if the determination is made to deliver the data to the wireless device via the NIDD procedure.

[0009] In some embodiments, the method further comprises, if the determination is made to not deliver the data to the wireless device via the NIDD procedure, sending a request to the exposure function for retransmission of the data. In some embodiments, the request for retransmission of the data comprises an indication of a reason for the request for retransmission, the reason being that the RAN node associated with the wireless device is operating on a secondary power source.

[0010] In some embodiments, the method further comprises receiving, from the RAN node, a power source status indication that is indicative of the power source status of the RAN node. The method further comprises storing the power source status indication. Still further, making the determination as to whether to deliver the data to the wireless device via the NIDD procedure comprises making the determination as to whether to deliver the data to the wireless device via the NIDD procedure based on the stored power source status indication.

[0011] In some embodiments, the method further comprises, upon receiving the NIDD request, sending a request to the RAN node associated with the wireless device for information comprising a power source status indication that is indicative of the power source status of the RAN node and receiving the power source status indication from the RAN node. Further, making the determination as to whether to deliver the data to the wireless device via the NIDD procedure comprises making the determination as to whether to deliver the data to the wireless device via the NIDD procedure based on the received power source status indication.

[0012] In some embodiments, making the determination as to whether to deliver the data to the wireless device via the NIDD procedure comprises making the determination as to whether to deliver the data to the wireless device via the NIDD procedure based on the power source status of the RAN node associated with the wireless device and one or more additional criteria. In some embodiments, the NIDD

request comprises a priority indication that indicates a priority assigned to the data, and the one or more additional criteria comprise a criterion based on the priority indication. In some other embodiments, the NIDD request comprises an override indication, and the one or more additional criteria comprise a criterion that the data is to be delivered if the override indication is set regardless of the power source status of the RAN node.

[0013] Embodiments of a network node for providing NIDD in a wireless communication system are also disclosed. In some embodiments, a network node for providing NIDD in a wireless communication system is adapted to receive, from an exposure function that exposes a core network to an AS, a NIDD request comprising data from the AS to be delivered to a wireless device via a NIDD procedure. The network node is further adapted to make a determination as to whether to deliver the data to the wireless device via the NIDD procedure based on a power source status of a RAN node associated with the wireless device. In some embodiments, the network node is further adapted to operate according to any other of the embodiments of the method of operation of the network node disclosed herein.

[0014] In some embodiments, a network node for providing NIDD in a wireless communication system comprises a network interface and circuitry associated with the network interface operable to receive, from an exposure function that exposes a core network to an AS, a NIDD request comprising data from the AS to be delivered to a wireless device via a NIDD procedure and make a determination as to whether to deliver the data to the wireless device via the NIDD procedure based on a power source status of a RAN node associated with the wireless device.

[0015] In some embodiments, in order to make the determination as to whether to deliver the data to the wireless device via the NIDD procedure, the circuitry is further operable to make the determination to not deliver the data to the wireless device via the NIDD procedure if the power source status of the RAN node is that the RAN node is using a secondary power source and make the determination to deliver the data to the wireless device via the NIDD procedure if the power source status of the RAN node is that the RAN node is using a primary power source.

[0016] In some embodiments, the circuitry is further operable to refrain from delivering the data to the wireless device via the NIDD procedure if the determination is made to not deliver the data to the wireless device via the NIDD procedure and deliver the data to the wireless device via the NIDD procedure if the determination is made to deliver the data to the wireless device via the NIDD procedure.

[0017] In some embodiments, the circuitry is further operable to, if the determination is made to not deliver the data to the wireless device via the NIDD procedure, send a request to the exposure function for retransmission of the data. In some embodiments, the request for retransmission of the data comprises an indication of a reason for the request for retransmission, the reason being that the RAN node associated with the wireless device is operating on a secondary power source.

[0018] In some embodiments, the circuitry is further operable to receive, from the RAN node, a power source status indication that is indicative of the power source status of the RAN node, store the power source status indication, and make the determination as to whether to deliver the data to the wireless device via the NIDD procedure based on the stored power source status indication.

[0019] In some embodiments, the circuitry is further operable to, upon receiving the NIDD request, send a request to the RAN node associated with the wireless device for information comprising a power source status indication that is indicative of the power source status of the RAN node, receive the power source status indication from the RAN node, and make the determination as to whether to deliver the data to the wireless device via the NIDD procedure based on the received power source status indication.

[0020] In some embodiments, the circuitry is further operable to make the determination as to whether to deliver the data to the wireless device via the NIDD procedure based on the power source status of the RAN node associated with the wireless device and one or more additional criteria. In some embodiments, the NIDD request comprises an override indication that indicates that the data is to be delivered immediately, and the one or more additional criteria comprise a criterion that the data is to be delivered if the override indication is set regardless of the power source status of the RAN node.

[0021] In some embodiments, a network node for providing NIDD in a wireless communication system comprises a receiving module and a determining module. The receiving module is operable to receive, from an exposure function that exposes a core network to an AS, a NIDD request comprising data from the AS to be delivered to a wireless device via a NIDD procedure. The determining module is operable to make a determination as to whether to deliver the data to the wireless device via the NIDD procedure based on a power source status of a RAN node associated with the wireless device.

[0022] Embodiments of a method of operation of a network node to provide an exposure function for a core network of a wireless communication system are also disclosed. In some embodiments, a method of operation of a network node to provide an exposure function for a core network of a wireless communication system comprises receiving, from an AS, data to be delivered to a wireless device via a NIDD procedure; sending, to a core network node, a first NIDD request comprising the data; receiving, from the core network node, a message that indicates that the network node did not deliver the data; storing the data; and, subsequent to receiving the message from the core network node, sending a second NIDD request comprising the data to the core network node.

[0023] In some embodiments, the message comprises an indication that the data was not delivered due to a power source status of a RAN node associated with the wireless device.

[0024] In some embodiments, the message comprises an indication that the data was not delivered because a RAN node associated with the wireless device is using a secondary power source.

[0025] In some embodiments, the second NIDD request comprises an override indication that indicates that the data is to be delivered immediately.

[0026] In some embodiments, the second NIDD request comprises an override indication that indicates that the data is to be delivered regardless of the power source status of the RAN node associated with the wireless device.

[0027] In some embodiments, the first and/or second NIDD request comprises a priority indication that indicates a priority assigned to the data.

[0028] Embodiments of a network node for providing an exposure function for a core network of a wireless communication system are also disclosed. In some embodiments, a network node for providing an exposure function for a core network of a wireless communication system is adapted to receive, from an AS, data to be delivered to a wireless device via a NIDD procedure; send, to a core network node, a first NIDD request comprising the data; receive, from the core network node, a message that indicates that the network node did not deliver the data; store the data; and, subsequent to receiving the message from the core network node, send a second NIDD request comprising the data to the core network node.

[0029] In some embodiments, a network node for providing an exposure function for a core network of a wireless communication system comprises a network interface and circuitry associated with the network interface operable to: receive, from an AS, data to be delivered to a wireless device via a NIDD procedure; send, to a core network node, a first NIDD request comprising the data; receive, from the core network node, a message that indicates that the network node did not deliver the data; store the data; and, subsequent to receiving the message from the core network node, send a second NIDD request comprising the data to the core network node.

[0030] In some embodiments, the message comprises an indication that the data was not delivered due to a power source status of a RAN node associated with the wireless device.

[0031] In some embodiments, the message comprises an indication that the data was not delivered because a RAN node associated with the wireless device is using a secondary power source.

[0032] In some embodiments, the second NIDD request comprises an override indication that indicates that the data is to be delivered immediately.

[0033] In some embodiments, the second NIDD request comprises an override indication that indicates that the data is to be delivered regardless of the power source status of the RAN node associated with the wireless device.

[0034] In some embodiments, the first and/or second NIDD request comprises a priority indication that indicates a priority assigned to the data.

[0035] In some embodiments, a network node for providing an exposure function for a core network of a wireless communication system comprises a first receiving module, a first sending module, a second receiving module, a storing module, and a second sending module. The first receiving module is operable to receive, from an AS, data to be delivered to a wireless device via a NIDD procedure. The first sending module is operable to send, to a core network node, a first NIDD request comprising the data. The second receiving module is operable to receive, from the core network node, a message that indicates that the network node did not deliver the data. The storing module is operable to store the data. The second sending module is operable to subsequent to receiving the message from the core network node, send a second NIDD request comprising the data to the core network node.

[0036] Embodiments of a method of operation of a RAN node are also disclosed. In some embodiments, a method of operation of a RAN node comprises sending a power source status indication to a core network node, the power source status indication being indicative of a type of power source being used by the RAN node. In some embodiments, the type of power source is either a primary power source or a secondary power source. In some embodiments, sending the power source status indication to the core network node comprises sending the power source status indication to the core network node proactively. In some other embodiments, the method further comprises receiving a request from the core network node for information comprising the power source status indication, wherein sending the power source status indication to the core network node comprises sending the power source status indication to the core network node in response to the request for information.

[0037] Embodiments of a RAN node are also disclosed. In some embodiments, a RAN node is adapted to send a power source status indication to a core network node, the power source status indication being indicative of a type of power source being used by the RAN node.

[0038] In some embodiments, a RAN node comprises a network interface and circuitry associated with the network interface operable to send a power source status indication to a core network node, the power source status indication being indicative of a type of power source being used by the RAN node. In some embodiments, the type of power source is either a primary power source or a secondary power source. In some embodiments, the circuitry is further operable to send the power source status indication to the core network node proactively. In some other embodiments, the circuitry is further adapted to receive a request from the core network node for information comprising the power source status indication and send the power source status indication to the core network node in response to the request for information.

[0039] In some embodiments, a RAN node comprises a sending module operable to send a power source status indication to a core network node, the power source status indication being indicative of a type of power source being used by the RAN node.

[0040] Those skilled in the art will appreciate the scope of the present disclosure and realize additional aspects thereof after reading the following detailed description of the embodiments in association with the accompanying drawing figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0041] The accompanying drawing figures incorporated in and forming a part of this specification illustrate several aspects of the disclosure, and together with the description serve to explain the principles of the disclosure.

[0042] FIG. **1** illustrates one example of a wireless communication system that provides Non-Internet Protocol (IP) Data Delivery (NIDD), e.g., for Machine Type Communication (MTC) according to some embodiments of the present disclosure;

[0043] FIGS. **2**A and **2**B illustrate the operation of the wireless communication system of FIG. **1** in which the Radio Access Network (RAN) node proactively notifies the core network of a power source status of the RAN node and the core network uses the power source status to determine whether to defer delivery of NIDD communication according to some embodiments of the present disclosure;

[0044] FIGS. **3**A and **3**B illustrate the operation of the wireless communication system of FIG. **1** in which the core network obtains the power source status of the RAN node reactively and uses the power source status to determine whether to defer delivery of NIDD communication according to some embodiments of the present disclosure;

[0045] FIGS. **4**A and **4**B illustrate the operation of the wireless communication system in accordance with one example implementation of the embodiment of FIGS. **2**A and **2**B;

[0046] FIGS. **5**A and **5**B illustrate the operation of the wireless communication system in accordance with one example implementation of the embodiment of FIGS. **3**A and **3**B; and

[0047] FIGS. **6** through **8** illustrate example embodiments of a network node.

DETAILED DESCRIPTION

[0048] The embodiments set forth below represent information to enable those skilled in the art to practice the embodiments and illustrate the best mode of practicing the embodiments. Upon reading the following description in light of the accompanying drawing figures, those skilled in the art will understand the concepts of the disclosure and will recognize applications of these concepts not particularly addressed herein. It should be understood that these concepts and applications fall within the scope of the disclosure and the accompanying claims.

[0049] Radio Node: As used herein, a "radio node" is either a Radio Access Network (RAN) node or a wireless device.

[0050] RAN Node: As used herein, a "radio access network node" or "RAN node," which may also be referred to herein simply as a "radio access node" or "radio network node," is any node in a RAN of a cellular communications network that operates to wirelessly transmit and/or receive signals. Some examples of a RAN node include, but are not limited to, a base station (e.g., a New Radio (NR) base station (gNB) in a Third Generation Partnership Project (3GPP) Fifth Generation (5G) NR network or an enhanced or evolved Node B (eNB) in a 3GPP Long Term Evolution (LTE) network), a high-power or macro base station, a low-power base station (e.g., a micro base station, a pico base station, a home eNB, or the like), and a relay node.

[0051] Core Network Node: As used herein, a "core network node" is any type of node in a core network. Some examples of a core network node include, e.g., a Mobility Management Entity (MME), an Access Mobility Function Node in a 5G core network, a Service Capability Exposure Function (SCEF), or the like.

[0052] Wireless Device: As used herein, a "wireless device" is any type of device that has access to (i.e., is served by) a cellular communications network by wirelessly transmitting and/or receiving signals to a radio access node(s). Some examples of a wireless device include, but are not limited to, a User Equipment device (UE) in a 3GPP network and a Machine Type Communication (MTC) device.

[0053] Network Node: As used herein, a "network node" is any node that is either part of the radio access network or the core network of a cellular communications network/system.

[0054] Note that the description given herein focuses on a 3GPP cellular communications system and, as such, 3GPP terminology or terminology similar to 3GPP terminology is oftentimes used. However, the concepts disclosed herein are not limited to a 3GPP system.

[0055] Note that, in the description herein, reference may be made to the term "cell;" however, particularly with respect to 5G NR concepts, beams may be used instead of cells and, as such, it is important to note that the concepts described herein are equally applicable to both cells and beams.

[0056] The existing 3GPP architecture comprises a number of network nodes i.e., eNB, MME, Home Subscriber Service (HSS), Serving Gateway (S-GW), Packet Data Network (PDN) Gateway (P-GW), Policy and Charging Rules Function (PCRF), etc. The MTC end-to-end call flow between the UE and Application Server (AS) for Non-Internet Protocol (IP) Data Delivery (NIDD) primarily involves the UE, MME, and SCEF. The UE is the MTC UE which has embedded MTC event triggering and event data generation logic. The AS probes the MME via the SCEF and eventually reaches out to the UE for any NIDD delivery mechanism (see, e.g., 3GPP Technical Specification (TS) 23.682 V13.8.0). However, the signaling procedures for NIDD happen over the control plane of the MME, RAN, and UE and, as such, these signaling procedures are seen as an additional load over and above signaling for traditional services (i.e., voice and data). Any signaling attempts for MTC communication is seen as an additional overhead above those for data sessions.

[0057] The signaling procedures for NIDD of MTC communication are sometimes critical and sometimes non-critical in nature, i.e. contextually. If the MTC communication corresponds to smart metering, non-production event notification, etc., then the MTC communication can be seen as non-critical communication. However, there can be some critical MTC communication for NIDD such as, e.g., emergency messages related to, e.g., natural disasters, SOS related healthcare messages, traffic monitoring networks, etc.

[0058] When using the 3GPP RAN network, MTC NIDD messages depend on the eNB for paging and UE triggering mechanisms. For an operator, it is cheaper in terms of Operating Expenditure (OPEX) when the eNB is running on a primary power source (i.e., connected to the power grid). Hence, it is viable to transmit and/or receive non-critical MTC NIDD messages when the eNB is operating on a primary power source. However, in some countries or geographical regions (e.g., India), there are many areas where power from the power grid is off quite frequently (e.g., two to five hours per day). When the eNB is not operating on its primary power source, the eNB is operated on a secondary power source (e.g., battery backup using a diesel generator). This leads to very high OPEX when power from the power grid is off and, as such, it is preferable to defer non-critical communication until the eNB is again operating on its primary power source. When the eNB is operating on its secondary power source, signaling priority is given to traditional voice/data sessions and critical NIDD communication considering they are of the nature of immediate revenue realization. There is a need for systems and methods that embed the intelligence in the 3GPP network to gain knowledge of these details and to act accordingly.

[0059] Systems and methods are disclosed herein that address this need by including intelligence for a wireless communication system to understand the power source of a RAN node and decide whether to deliver NIDD messages

(e.g., non-critical MTC messages, e.g., for basic MTC use cases) or defer delivery until a later time (e.g., delay delivery until the RAN node is operating on a primary power source). In some examples, the wireless communication system is a 3GPP network where intelligence is included in the eNB, MME, and SCEF to understand the power source of the eNB and to decide whether to deliver NIDD messages or defer delivery until a later time (e.g., delay delivery until the eNB is operating on a primary power source). The communication session for delivering the NIDD message is contextualized at the SCEF node. Accordingly, when an eNB is incurring higher OPEX as a result operating on a secondary power source, the network (e.g., the SCEF) will store NIDD messages (e.g., non-critical MTC NIDD messages) and defer delivery until a later time (e.g., defer delivery until the eNB is connected to a primary power source). In some embodiments, the SCEF node stores the NIDD messages, e.g., in an internal cache and will retransmit the NIDD messages through the MME either when MME probes and finds that the eNB is running on a primary power source when the eNB proactively notifies the MME that it is connected to the primary source. Embodiments disclosed herein are particularly directed to Mobile Terminal (MT) data flow initiated by the AS towards the UE.

[0060] While not being limited to or by any particular advantage, some advantages of at least some of the embodiments disclosed herein are as follows. Embodiments disclosed herein give flexibility for the network operator to prioritize the signaling traffic on its core network by classifying the signaling messages based on RAN power source and hence lower OPEX. A cheaper power source for the RAN network is more suitable for relaying non-critical MTC messages across the RAN network.

[0061] Embodiments of the present disclosure use the build on 3GPP specifications for the services capability exposure feature. These embodiments catalyze the 3GPP network nodes to be more optimized for delivering Internet of Things (IoT)/Machine to Machine (M2M) use cases with minimum changes to the core network.

[0062] Various embodiments of the present disclosure are disclosed herein. In some example implementations, the network operator is able to choose from various embodiments to select one(s) that is suitable for its implementation. The operator may decide on the flow depending on various parameters including capacity, cost benefits, local location dynamics, etc.

[0063] In this regard, FIG. **1** illustrates one example of a wireless communication system **10** that provides NIDD, e.g., for MTC according to some embodiments of the present disclosure. In this example, the wireless communication system **10** is a 3GPP LTE or LTE-based system; however, the present disclosure is not limited thereto. For example, the embodiments disclosed herein are also applicable to 5G NR, and 5G core network. Note that the names given to the various network nodes described herein are for 3GPP LTE, but different names may be used in other types of networks.

[0064] As illustrated, the wireless communication system **10** includes a RAN node **12** (e.g., an eNB) that provides radio access to a wireless device **13** (e.g., a UE). The RAN node **12** is connected to a core network **14**, which includes a number of core network nodes. These core network nodes include, in this example, a MME **16** and an exposure function **18** (e.g., a SCEF). The exposure function **18** provides access to the core network **14** to one or more ASs **20**, e.g., via a set of Application Program Interface (APIs).

[0065] FIGS. **2**A and **2**B illustrate the operation of the wireless communication system **10** of FIG. **1** according to some embodiments of the present disclosure. As illustrated, the RAN node **12** proactively sends a power source status indication to the core network **14** (step **100**). In this particular example, the RAN node **12** sends the power source status indication to the MME **16**. In general, the power source status indication is an indication of a type of power source on which the RAN node **12** is operating. In the embodiments described herein, the power source is either a primary power source (e.g., the power grid) or a secondary power source (e.g., a battery backup powered by a generator). In this example, the RAN node **12** is operating on a secondary power source and, as such, the power source status indication is set to a value that indicates that the RAN node **12** is operating on a secondary power source. Optionally, the MME **16** responds with an acknowledgment message to thereby acknowledge receipt of the power source status indication from the RAN node **12** (step **102**). The MME **16** stores the power source status indication received from the RAN node **12** (step **104**).

[0066] Subsequently, the AS **20** sends a NIDD request to the core network **14** including non-IP data (i.e., data to be delivered via NIDD) to be delivered to the wireless device **13** (step **106**). In this particular example, the AS **20** sends the NIDD delivery request, and thus the non-IP data, to the exposure function **18**. The exposure function **18** then sends a NIDD transmit request including the non-IP data to the MME **16** (step **108**). Upon receiving the NIDD transmit request, the MME **16** makes a determination as to whether to deliver the non-IP data based on a power source status of the RAN node **12** associated with the wireless device **13** to which the non-IP data is to be delivered and, optionally, one or more additional criteria (step **110**). The power source status of the RAN node **12** is indicated by the power source status indication received from the RAN node **12** in step **100** and stored by the MME **16** in step **104**.

[0067] In some embodiments, the MME **16** makes the determination to not deliver the non-IP data to the wireless device **13** if the power source status of the RAN node **12** is that the RAN node **12** is operating on, or using, a secondary power source, as indicated by the stored power source status indication. Conversely, the MME **16** makes the determination to deliver the non-IP data to the wireless device **13** if the power source status of the RAN node **12** is that the RAN node **12** is operating on, or using, a primary power source, as indicated by the stored power source status indication.

[0068] In addition to the power source status of the RAN node **12**, the MME **16** may optionally take one or more criteria into consideration. For example, in some embodiments, the MME **16** also takes into consideration a priority assigned to the non-IP data (e.g., is the non-IP data critical or non-critical). In some embodiments, if the non-IP data has a high priority, the MME **16** may decide to deliver the non-IP data even if the RAN node **12** is operating on a secondary power source. The priority of the non-IP data may, for example, be indicated in the NIDD transmit request. As another example, the MME **16** also takes into account whether it has received an override indication from the exposure function **18**. The exposure function **18** may, for example, provide an override indication in the NIDD transmit request or otherwise in association with the NIDD

transmit request. If the override indication is set, the MME **16** decides to deliver the non-IP data immediately or regardless of the power source status of the RAN node **12**. The exposure function **18** may decide to set the override indication based on any suitable parameter such as, for example, a priority of the non-IP data which may, as an example, be assigned by the AS **20**, a maximum delivery delay which may, as an example, be assigned by the AS **20** such that delivery of the non-IP data may be delayed by no more than the maximum delivery delay, or the like.

[0069] In this example, the MME **16** makes the determination to not deliver the non-IP data. Upon making the determination to not deliver the non-IP data to the wireless device **13**, the MME **16** refrains from delivering the non-IP data (step **112**) and sends a retransmission request to the exposure function **18** (step **114**). The retransmission request serves as an indication to the exposure function **18** that delivery of the non-IP data has been deferred and that the exposure function **18** should re-attempt delivery at a later time. In some embodiments, the retransmission request includes an indication of a reason that the non-IP data was not delivered, which in this example is set to a value that indicates that the non-IP data was not delivered due to the power source status of the RAN node **12**. The reason may more specifically indicate that the reason for not delivering the non-IP data is that the RAN node **12** is operating on a secondary power source.

[0070] The exposure function **18** stores the non-IP data, e.g., locally at the exposure function **18** (step **116**). Optionally, the exposure function **18** sends a notification to the AS **20** that informs the AS **20** that delivery of the non-IP data has been deferred until a later time (step **118**). The process continues in this manner.

[0071] Sometime thereafter, the RAN node **12** switches operation from the secondary power source to the primary power source and sends a new power source status indication to the core network **14** (step **120**). Again, in this particular example, the RAN node **12** sends the power source status indication to the MME **16**. Since the RAN node **12** is now operating on the primary power source, the power source status indication in step **120** is set to a value that indicates that the RAN node **12** is operating on the primary power source. Optionally, the MME **16** responds with an acknowledgment message to thereby acknowledge receipt of the power source status indication from the RAN node **12** (step **122**). The MME **16** stores the power source status indication received from the RAN node **12** (step **124**).

[0072] Sometime thereafter, the MME **16** receives a NIDD transmission request including the non-IP data from the exposure function **18** (step **126**). Upon receiving the NIDD transmit request from the exposure function **18** in step **126**, the MME **16** again makes a determination as to whether to deliver the non-IP data based on the power source status of the RAN node **12** associated with the wireless device **13** to which the non-IP data is to be delivered and, optionally, one or more additional criteria, as discussed above (step **128**). Now, the power source status of the RAN node **12** is indicated by the new power source status indication received from the RAN node **12** in step **120** and stored by the MME **16** in step **124**.

[0073] In this example, the MME **16** makes the determination to deliver the non-IP data, e.g., since the RAN node **12** is now operating on the primary power source. Upon making the determination to deliver the non-IP data to the wireless device **13**, the MME **16** communicates with the RAN node **12** to perform NIDD delivery of the non-IP data using a suitable NIDD delivery procedure (e.g., using the NIDD procedure defined in 3GPP TS 23.682 V14.3.0) (step **130**). Optionally, the MME **16** sends a notification of successful delivery of the non-IP data to the exposure function **18** (step **132**), and the exposure function **18** then sends a notification to the AS **20** that the non-IP data was delivered (step **134**).

[0074] FIGS. **3**A and **3**B illustrate the operation of the wireless communication system **10** of FIG. **1** according to some embodiments of the present disclosure. This process is similar to that of FIGS. **2**A and **2**B but where the core network **14** requests the power source status indication from the RAN node **12**.

[0075] The AS **20** sends a NIDD request to the core network **14** including non-IP data (i.e., data to be delivered via NIDD) to be delivered to the wireless device **13** (step **200**). In this particular example, the AS **20** sends the NIDD delivery request, and thus the non-IP data, to the exposure function **18**. The exposure function **18** then sends a NIDD transmit request including the non-IP data to the MME **16** (step **202**). Upon receiving the NIDD transmit request, the MME **16** sends a request to the RAN node **12** associated with the wireless device **13** for information including a power source status indication (step **204**). Upon receiving the request, the RAN node **12** sends a power source status indication to the core network **14** (step **206**). In this particular example, the RAN node **12** sends the power source status indication to the MME **16**. As discussed above, in general, the power source status indication is an indication of a type of power source on which the RAN node **12** is operating. In the embodiments described herein, the power source is either a primary power source (e.g., the power grid) or a secondary power source (e.g., a battery backup powered by a generator). In this example, the RAN node **12** is operating on a secondary power source and, as such, the power source status indication is set to a value that indicates that the RAN node **12** is operating on a secondary power source.

[0076] Upon receiving the power source status indication from the RAN node **12**, the MME **16** makes a determination as to whether to deliver the non-IP data based on a power source status of the RAN node **12** associated with the wireless device **13** to which the non-IP data is to be delivered and, optionally, one or more additional criteria (step **208**). The power source status of the RAN node **12** is indicated by the power source status indication received from the RAN node **12** in step **206**.

[0077] As discussed above, in some embodiments, the MME **16** makes the determination to not deliver the non-IP data to the wireless device **13** if the power source status of the RAN node **12** is that the RAN node **12** is operating on, or using, a secondary power source, as indicated by the stored power source status indication. Conversely, the MME **16** makes the determination to deliver the non-IP data to the wireless device **13** if the power source status of the RAN node **12** is that the RAN node **12** is operating on, or using, a primary power source, as indicated by the stored power source status indication.

[0078] In addition to the power source status of the RAN node **12**, the MME **16** may optionally take one or more criteria into consideration. For example, in some embodiments, the MME **16** also takes into consideration a priority assigned to the non-IP data (e.g., is the non-IP data critical

or non-critical). In some embodiments, if the non-IP data has a high priority, the MME **16** may decide to deliver the non-IP data even if the RAN node **12** is operating on a secondary power source. The priority of the non-IP data may, for example, be indicated in the NIDD transmit request. As another example, the MME **16** also takes into account whether it has received an override indication from the exposure function **18**. The exposure function **18** may, for example, provide an override indication in the NIDD transmit request or otherwise in association with the NIDD transmit request. If the override indication is set, the MME **16** decides to deliver the non-IP data immediately or regardless of the power source status of the RAN node **12**. The exposure function **18** may decide to set the override indication based on any suitable parameter such as, for example, a priority of the non-IP data which may, as an example, be assigned by the AS **20**, a maximum delivery delay which may, as an example, be assigned by the AS **20** such that delivery of the non-IP data may be delayed by no more than the maximum delivery delay, or the like.

[0079] In this example, the MME **16** makes the determination to not deliver the non-IP data. Upon making the determination to not deliver the non-IP data to the wireless device **13**, the MME **16** refrains from delivering the non-IP data (step **210**) and sends a retransmission request to the exposure function **18** (step **212**). The retransmission request serves as an indication to the exposure function **18** that delivery of the non-IP data has been deferred and that the exposure function **18** should re-attempt delivery at a later time. In some embodiments, the retransmission request includes an indication of a reason that the non-IP data was not delivered, which in this example is set to a value that indicates that the non-IP data was not delivered due to the power source status of the RAN node **12**. The reason may more specifically indicate that the reason for not delivering the non-IP data is that the RAN node **12** is operating on a secondary power source.

[0080] The exposure function **18** stores the non-IP data, e.g., locally at the exposure function **18** (step **214**). Optionally, the exposure function **18** sends a notification to the AS **20** that informs the AS **20** that delivery of the non-IP data has been deferred until a later time (step **216**). The process continues in this manner.

[0081] Sometime thereafter, the exposure function **18** sends and the MME **16** receives a NIDD transmission request including the non-IP data (step **218**). For instance, upon receiving the retransmission request in step **212** and storing the non-IP data in step **214**, the exposure function **18** may periodically send NIDD transmission requests to the MME **18** for the non-IP data until the non-IP data is delivered or, e.g., some other condition is met (e.g., the AS **20** cancels delivery, a maximum delay has expired, or the like).

[0082] Upon receiving the NIDD transmit request from the exposure function **18** in step **218**, the MME **16** again sends a request to the RAN node **12** associated with the wireless device **13** for information including a power source status indication (step **220**). Upon receiving the request, the RAN node **12** sends a power source status indication to the core network **14** (step **222**). In this example, the RAN node **12** is now operating on the primary power source and, as such, the power source status indication sent to the MME **16** in step **222** is set to a value that indicates that the RAN node **12** is operating on the primary power source.

[0083] The MME **16** again makes a determination as to whether to deliver the non-IP data based on the power source status of the RAN node **12** associated with the wireless device **13** to which the non-IP data is to be delivered and, optionally, one or more additional criteria, as discussed above (step **224**). The power source status of the RAN node **12** is indicated by the new power source status indication received from the RAN node **12** in step **222**.

[0084] In this example, the MME **16** makes the determination to deliver the non-IP data, e.g., since the RAN node **12** is now operating on the primary power source. Upon making the determination to deliver the non-IP data to the wireless device **13**, the MME **16** communicates with the RAN node **12** to perform NIDD delivery of the non-IP data using a suitable NIDD delivery procedure (e.g., using the NIDD procedure defined in 3GPP TS 23.682 V14.3.0) (step **226**). Optionally, the MME **16** sends a notification of successful delivery of the non-IP data to the exposure function **18** (step **228**), and the exposure function **18** then sends a notification to the AS **20** that the non-IP data was delivered (step **230**).

[0085] Examples of the processes of FIGS. **2**A and **2**B and FIGS. **3**A and **3**B will now be provided for 3GPP LTE. However, again, the embodiments disclosed herein are not limited to 3GPP LTE. In operation, the AS **20**/SCEF **18** has an established NIDD service for a given wireless device **13** and has downlink non-IP data to send to the wireless device **13**. After an Evolved Packet System (EPS) NIDD PDN connection is successfully established, bearer context is established and the AS **20**/Services Capability Server (SCS) is authorized to send a NIDD request to the exposure function **18** (which, in this example, is an SCEF). The SCEF **18** then forwards a NIDD Submit Request (User Identity (ID), EPS Bearer ID, SCEF ID, non-IP data, SCEF Wait Time, Maximum Re-transmission time) message toward the MME **16**/Serving General Packet Radio Service Support Node (SGSN) or Access and Mobility management Function (AMF) (for 5G) that is connected to a respective wireless device **13**.

[0086] The MME **16**/SGSN (or AMF for 5G) is made aware of the type of power source on which the RAN node **12** (which in this example is an eNB) associated with the wireless device **13** is operating. Then, the MME **16**/SGSN AMF (for 5G as described in 3GPP TS 23.501) will send a NIDD Submit Response (Cause, Requested Re-Transmission Time) message towards the SCEF **18** depending on whether the eNB **12** is operating on a primary or secondary power source.

[0087] In accordance with the embodiments of FIGS. **2**A and **2**B and FIGS. **3**A and **3**B, whenever there is a change in the power source status for the eNB **12** from primary to secondary or vice versa, the eNB **12** notifies the MME **16** through the S1 interface. This notification will be similar to that of the eNB Configuration Update over S1 interface request and will be acknowledged by the MME **16**. The MME **16** will store this state transition (i.e., power source status indication) of the power source of each eNB **12** in its cache database. When there is a NIDD MT delivery message (NIDD Submit Request) from the SCEF **18** towards the MME **16**, the MME **16** obtains the current power supply state (i.e., the current power source status as indicated by the stored power source status indication) of the eNB **12** from its cache and sends a NIDD Submit Response message to the SCEF **18**. The NIDD Submit Response message states that

delivery of the non-IP data is to be re-attempted, e.g., after a particular retransmission time. The NIDD Submit Response message may also include a reason for the retransmission attempt, where the reason is that the eNB **12** is currently operating on a secondary power source. When the power supply state of the eNB **12** changes from the secondary power source to the primary power source, the eNB **12** notifies the MME **16** via a configuration update message. The MME **16** can further propagate this information back to the SCEF **18** in order to trigger the SCEF **18** to resend the non-IP data to the MME **16** for delivery. After receiving the non-IP data to be delivered from the SCEF **18**, the MME **16** delivers the non-IP data to the wireless device **13** via the eNB **12**. The MME **16** may send an acknowledgement back to the SCEF **18** with NIDD Submit Response stating that the non-IP data was successfully delivered to the wireless device **13**.

[0088] Thus, in the above example, the MME **16** stores the information regarding whether the eNB **12** is running on primary or secondary power. Additionally, the eNB **12** updates the MME **16** if and when the power source is changed. FIGS. **4**A and **4**B illustrate the operation of the wireless communication system **10** in accordance with this example. As illustrated, the serving eNB **12** initiates a S1 Setup Request to broadcast its configuration update message towards the MME **16** including a power source status indication that indicates that it is operating on a secondary power source (step **300**). Optionally, in return, the MME **16** sends an S1AP successful acknowledgement message to the eNB **12** indicating that the MME **16** has received the power source status indication from eNB **12**, where the power source status indication is indicative of the eNB's **12** current power source. The current power source status of the eNB **12** (e.g., the received power source status indication) is stored at the MME **16** (step **304**).

[0089] Any further MT REST API message from the AS **20** towards the SCEF **18** is for the context of NIDD Submit Request directed towards the wireless device **13**. The AS **20** sends a NIDD Submit Request (External Identifier or Mobile Subscriber Integrated Services Digital Network (MSISDN), SCS/AS Reference ID, non-IP data) message to the SCEF **18** (step **306**). If an SCEF EPS bearer context corresponding to the MSISDN is established, then the SCEF **18** will send a NIDD Submit Request (User ID, EPS Bearer ID, SCEF ID, non-IP data, SCEF Wait Time, Maximum Re-transmission time) message toward the MME **16** (step **308**).

[0090] The MME **16** then makes a determination as to whether to deliver the non-IP data to the wireless device **13** based on the stored current power source status of the eNB **12** associated with the wireless device **13** and, optionally, one or more additional criteria, as discussed above (step **310**). Since, in this example, the eNB **12** is operating on the secondary power source, the MME **16** refrains from delivering the non-IP data (step **312**) and sends an NIDD Submit Response (Cause, Requested Re-Transmission Time) message towards the SCEF **18** (step **314**). The Cause parameter (also referred to herein as a reason or reason parameter) will indicate that the non-IP data was not delivered to the wireless device **13** because the serving eNB **12** of the wireless device **13** is currently operating on a secondary power source. The SCEF **18** stores the non-IP data (step **316**) and some indication that the SCEF **18** is to re-transmit a NIDD TDR message for the non-IP data towards the MME **16** at a later time. Optionally, the SCEF **18** notifies the AS **20** that the non-IP data will be re-transmitted to the MME **16** for delivery to the wireless device **13** after a defined period of time.

[0091] When the power source status of the eNB **12** changes, the eNB **12** again broadcasts a configuration update message towards the MME **16** that includes a power source status indication that is set to a value that indicates that the eNB **12** is now operating on the primary power source (step **320**). Optionally, the MME **16** acknowledges receipt of the power source status indication to the eNB **12** (step **322**). The MME **16** stores the current power source status (e.g., the power source status indication) at the MME **16** (step **324**). Optionally, the MME **16** notifies the SCEF **18** of the change in power source status of the eNB **12** to thereby trigger the SCEF **18** to retransmit the NIDD TDR message for the non-IP data. The SCEF **18** resends an NIDD Submit Request message including the non-IP data towards the MME **16** (step **326**). The MME **16** makes a determination to deliver the non-IP data to the wireless device **13** based on the stored power source status of the eNB **12** and, optionally, one or more criteria (step **328**). The MME **16** then pages the wireless device **13** and delivers the non-IP data to the wireless device **13** via the eNB **12** (step **330**). Optionally, the MME **16** sends a NIDD Submit Response Success message towards the SCEF **18** to notify the SCEF **18** of successful delivery (step **332**), and the SCEF **18** notifies the AS **20** (step **334**) that the non-IP data has been delivered.

[0092] In some alternative embodiments, in accordance with the embodiment of FIGS. **3**A and **3**B, the MME **16** checks to see whether the eNB **12** is currently operating on the primary or secondary power source upon receiving a NIDD Submit Request message from the SCEF **18** for delivery of the non-IP data. In other words, upon receiving a NIDD Submit Request from SCEF **18** towards the MME **16**, the MME **16** probes the eNB **12** on the S1 interface with a message similar to a S1 Initial Context Setup Request to obtain a power source status indication from the eNB **12**. This request message directed towards eNB **12** will fetch a power source status indication from the eNB **12** that indicates whether the eNB **12** is operating on a primary or secondary power source. The eNB **12** responds to the MME **16** with a message similar to a Context Setup Response, where this message includes the power source status indication. The MME **16** then decides, based on the current power status of the eNB **12**, whether to deliver the non-IP data to the wireless device **13** or defer delivery of the non-IP data by sending, to the SCEF **18**, a retransmission message (NIDD Submit Response with retransmission cause and time).

[0093] Thus, in the above example, the MME **16** checks whether the eNB **12** is running on primary or secondary power. This example is illustrated in FIGS. **5**A and **5**B. As illustrated, the AS **20** sends a MT REST API message towards the SCEF **18** that includes non-IP data to be delivered to the target wireless device **13** (step **400**). This MT REST API message will be for the context of NIDD Submit Request directed towards the wireless device **13**. The SCEF **18** sends a NIDD Submit Request (User ID, EPS Bearer ID, SCEF ID, non-IP data, SCEF Wait Time, Maximum Re-transmission time) message toward the MME **16** (step **402**).

[0094] The MME **16** sends a Request Message similar to a S1AP Initial Context Setup Request asking for a power source status indication (i.e., an indication of the power

source status) of the serving eNB **12** of the wireless device **13** (step **404**). This message may require additional parameters indicating the eNB **12** power source details. The eNB **12** responds to the MME **16** with an S1AP Initial Context Setup Response including a power source status indication (step **406**). In this example, the eNB **12** is, at this time, operating on the secondary power source and, as such, the power source status indication is set to a value that indicates that the eNB **12** is operating on the secondary power source.

[0095] The MME **16** makes a determination as to whether to deliver the non-IP data based on the current power source status of the eNB **12** and, optionally, one or more additional criteria, as discussed above (step **408**). In this example, the MME **16** decides to defer delivery since the eNB **12** is operating on its secondary power source. As such, the MME **16** refrains from delivering the non-IP data to the wireless device **13** (step **410**) and sends a NIDD Submit Response (Cause, Requested Re-Transmission Time) message towards the SCEF **18** (step **412**). The Cause parameter, which is also referred to herein as a reason or reason parameters, indicates that the non-IP data was not delivered to the wireless device **13** because the serving eNB **12** is currently operating on its secondary power source.

[0096] The SCEF **18** stores the non-IP data (step **414**) and an indication that the MME **16** has requested that the SCEF **18** re-submit the request to deliver the non-IP data at a later time. Optionally, the SCEF **18** notifies the AS **20** that delivery of the non-IP data (i.e., the NIDD message) has been deferred (step **416**).

[0097] At some later time (e.g., after a re-transmission timer has expired), the SCEF **18** sends a NIDD Submit Request message including the non-IP data toward the MME **16** (step **418**). The MME **16** sends a Request Message similar to a S1AP Initial Context Setup Request asking for a power source status indication (i.e., an indication of the power source status) of the serving eNB **12** of the wireless device **13** (step **420**). This message may require additional parameters indicating the eNB **12** power source details. The eNB **12** responds to the MME **16** with an S1AP Initial Context Setup Response including a power source status indication (step **422**). In this example, the eNB is, at this time, operating on the primary power source and, as such, the power source status indication is set to a value that indicates that the eNB **12** is operating on the primary power source.

[0098] The MME **16** makes a determination as to whether to deliver the non-IP data based on the current power source status of the eNB **12** and, optionally, one or more additional criteria, as discussed above (step **424**). In this example, the MME **16** decides to deliver the non-IP data since the eNB **12** is operating on its primary power source. As such, the MME **16** pages the wireless device **13** and delivers the non-IP data to the wireless device **13** via the eNB **12** (step **426**). Optionally, the MME **16** sends an NIDD Submit Response Success message towards the SCEF **18** that notifies the SCEF **18** of successful delivery (step **428**), and the SCEF **18** notifies the AS **20** that the non-IP data has been delivered (step **430**).

[0099] FIG. **6** is a schematic block diagram of a network node **22** according to some embodiments of the present disclosure. The network **22** may be any network node including the RAN node **12**, the MME **16**, the exposure function **18**, or the like. As illustrated, the network node **22** includes a control system **24** that includes circuitry operable to perform the functionality of the network node **22** disclosed herein. In this example, the circuitry includes one or more processors **26** (e.g., Central Processing Units (CPUs), Application Specific Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGAs), Digital Signal Processors (DSPs), and/or the like) and memory **28**. The network node **22** also includes a network interface **30**. If the network node **22** is the RAN node **12**, the network node **22** also includes one or more radio units **32** that each includes one or more transmitters **34** and one or more receivers **36** coupled to one or more antennas **38**. In some embodiments, the functionality of the network node **22** (i.e., the functionality of the RAN node **12**, the MME **16**, or the exposure function **18**) described above may be fully or partially implemented in software that is, e.g., stored in the memory **28** and executed by the processor(s) **26**.

[0100] FIG. **7** is a schematic block diagram that illustrates a virtualized embodiment of the network node **22** (e.g., the RAN node **12**, the MME **16**, or the exposure function **18**) according to some embodiments of the present disclosure. As used herein, a "virtualized" network node **22** is a network node **22** in which at least a portion of the functionality of the network node **22** is implemented as a virtual component (e.g., via a virtual machine(s) executing on a physical processing node(s) in a network(s)). As illustrated, the network node **22** optionally includes the control system **24**, as described with respect to FIG. **6**. In addition, if the network node **22** is the RAN node **12**, the network node **22** also includes the one or more radio units **32**, as described with respect to FIG. **6**. The control system **24** (if present) is connected to one or more processing nodes **40** coupled to or included as part of a network(s) **42** via the network interface **30**. Alternatively, if the control system **24** is not present, the one or more radio units **32** (if present) are connected to the one or more processing nodes **40** via a network interface(s). Alternatively, all of the functionality of the network node **22** (e.g., all of the functionality of the RAN node **12**, the MME **16**, or the exposure function **18**) described herein may be implemented in the processing nodes **40**. Each processing node **40** includes one or more processors **44** (e.g., CPUs, ASICs, DSPs, FPGAs, and/or the like), memory **46**, and a network interface **48**.

[0101] In this example, functions **50** of the network node **22** (e.g., the functions of the RAN node **12**, the MME **16**, or the exposure function **18**) described herein are implemented at the one or more processing nodes **40** or distributed across the control system **24** (if present) and the one or more processing nodes **40** in any desired manner. In some particular embodiments, some or all of the functions **50** of the network node **22** described herein are implemented as virtual components executed by one or more virtual machines implemented in a virtual environment(s) hosted by the processing node(s) **40**. As will be appreciated by one of ordinary skill in the art, additional signaling or communication between the processing node(s) **40** and the control system **24** (if present) or alternatively the radio unit(s) **32** (if present) is used in order to carry out at least some of the desired functions. Notably, in some embodiments, the control system **24** may not be included, in which case the radio unit(s) **32** (if present) communicates directly with the processing node(s) **40** via an appropriate network interface(s).

[0102] In some particular embodiments, if the network node **22** is the RAN node **12**, higher layer functionality (e.g., layer 3 and up and possibly some of layer 2 of the protocol

stack) of the network node **22** may be implemented at the processing node(s) **40** as virtual components (i.e., implemented "in the cloud") whereas lower layer functionality (e.g., layer 1 and possibly some of layer 2 of the protocol stack) may be implemented in the radio unit(s) **32** and/or the control system **24**.

[0103] In some embodiments, a computer program including instructions which, when executed by the at least one processor **26**, **44**, causes the at least one processor **26**, **44** to carry out the functionality of the network node **22** or a processing node **40** according to any of the embodiments described herein is provided. In some embodiments, a carrier containing the aforementioned computer program product is provided. The carrier is one of an electronic signal, an optical signal, a radio signal, or a computer readable storage medium (e.g., a non-transitory computer readable medium such as the memory **28**, **46**).

[0104] FIG. **8** is a schematic block diagram of the network node **22** according to some other embodiments of the present disclosure. The network node **22** includes one or more modules **52**, each of which is implemented in software. The module(s) **52** provide the functionality of the network node **22** described herein.

[0105] For example, if the network node **22** is the RAN node **12**, the module(s) **52** include a receiving module (optional) for receiving a request from the core network **14**, as discussed above, and a sending module operable to send a power source status indication to a core network node (e.g., the MME **16**), the power source status indication being indicative of a type of power source being used by the RAN node **12**.

[0106] As another example, if the network node **22** is the MME **16**, the module(s) **52** include a receiving module and a determining module. The receiving module is operable to receive, from the exposure function **18** that exposes a core network to the AS **20**, a non-IP data delivery request comprising data from the AS **20** to be delivered to a wireless device **13** via a non-IP data delivery procedure. The determining module is operable to make a determination as to whether to deliver the data to the wireless device **13** via the non-IP data delivery procedure based on a power source status of a RAN node **12** associated with the wireless device **13**.

[0107] As another example, if the network node **22** is the exposure function **18**, the module(s) **52** include a first receiving module, a first sending module, a second receiving module, a storing module, and a second sending module. The first receiving module is operable to receive, from the AS **20**, data to be delivered to the wireless device **13** via a non-IP data delivery procedure. The first sending module is operable to send, to a core network node (e.g., the MME **16**), a first non-IP data delivery request comprising the data. The second receiving module is operable to receive, from the core network node (e.g., the MME **16**), a message that indicates that the core network node did not deliver the data. The storing module is operable to store the data. The second sending module is operable to, subsequent to receiving the message from the core network node, send a second non-IP data delivery request comprising the data to the core network node.

[0108] The following acronyms are used throughout this disclosure.

[0109] 3GPP Third Generation Partnership Project

[0110] 5G Fifth Generation

[0111] AMF Access and Mobility Management Function

[0112] API Application Program Interface

[0113] AS Application Server

[0114] ASIC Application Specific Integrated Circuit

[0115] CPU Central Processing Unit

[0116] DSP Digital Signal Processor

[0117] eNB Enhanced or Evolved Node B

[0118] EPS Evolved Packet System

[0119] FPGA Field Programmable Gate Array

[0120] gNB New Radio Base Station

[0121] HPLMN Home Public Land Mobile Network

[0122] HSS Home Subscriber Service

[0123] ID Identity

[0124] IoT Internet of Things

[0125] IP Internet Protocol

[0126] LPWA Low Power Wide Area

[0127] LTE Long Term Evolution

[0128] M2M Machine to Machine

[0129] MME Mobility Management Entity

[0130] MSISDN Mobile Subscriber Integrated Services Digital Network

[0131] MT Mobile Terminal

[0132] MTC Machine Type Communication

[0133] NB-IoT Narrowband Internet of Things

[0134] NIDD Non-Internet Protocol Data Delivery

[0135] NR New Radio

[0136] OPEX Operating Expenditure

[0137] PCRF Policy and Charging Rules Function

[0138] PDN Packet Data Network

[0139] P-GW Packet Data Network Gateway

[0140] RAN Radio Access Network

[0141] SCEF Service Capability Exposure Function

[0142] SCS Services Capability Server

[0143] SGSN Serving General Packet Radio Service Support Node

[0144] S-GW Serving Gateway

[0145] TS Technical Specification

[0146] UE User Equipment

[0147] VPLMN Visited Public Land Mobile Network

[0148] Those skilled in the art will recognize improvements and modifications to the embodiments of the present disclosure. All such improvements and modifications are considered within the scope of the concepts disclosed herein and the claims that follow.

1. A method of operation of a network node to provide non-Internet Protocol, IP, data delivery for a wireless communication system, characterized in that the method comprises:

receiving, from an exposure function that exposes a core network to an application server, a non-IP data delivery request comprising data from the application server to be delivered to a wireless device via a non-IP data delivery procedure; and

making a determination as to whether to deliver the data to the wireless device via the non-IP data delivery procedure based on a power source status of a radio access network node associated with the wireless device, wherein the power source status indicates whether or not the radio access network node is operating with a primary power source or a secondary power source where the radio access network node is capable of transmitting data to the wireless device

regardless of whether the radio access network node is operating with the primary power source or the secondary power source.

2. The method of claim **1** wherein making the determination as to whether to deliver the data to the wireless device via the non-IP data delivery procedure comprises:

making the determination to not deliver the data to the wireless device via the non-IP data delivery procedure if the power source status of the radio access network node is that the radio access network node is using a secondary power source; and

making the determination to deliver the data to the wireless device via the non-IP data delivery procedure if the power source status of the radio access network node is that the radio access network node is using a primary power source.

3. The method of claim **1** further comprising:

refraining from delivering the data to the wireless device via the non-IP data delivery procedure if the determination is made to not deliver the data to the wireless device via the non-IP data delivery procedure; and

delivering the data to the wireless device via the non-IP data delivery procedure if the determination is made to deliver the data to the wireless device via the non-IP data delivery procedure.

4. The method of claim **3** further comprising, if the determination is made to not deliver the data to the wireless device via the non-IP data delivery procedure, sending a request to the exposure function for retransmission of the data.

5. The method of claim **4** wherein the request for retransmission of the data comprises an indication of a reason for the request for retransmission, the reason being that the radio access network node associated with the wireless device is operating on a secondary power source.

6. The method of claim **1** further comprising:

receiving, from the radio access network node, a power source status indication that is indicative of a power source status of the radio access network node; and

storing the power source status indication;

wherein making the determination as to whether to deliver the data to the wireless device via the non-IP data delivery procedure comprises making the determination as to whether to deliver the data to the wireless device via the non-IP data delivery procedure based on the stored power source status indication.

7. The method of claim **1** further comprising, upon receiving the non-IP data delivery request:

sending a request to the radio access network node associated with the wireless device for information comprising a power source status indication that is indicative of a power source status of the radio access network node; and

receiving the power source status indication from the radio access network node;

wherein making the determination as to whether to deliver the data to the wireless device via the non-IP data delivery procedure comprises making the determination as to whether to deliver the data to the wireless device via the non-IP data delivery procedure based on the received power source status indication.

8. The method of claim **1** wherein making the determination as to whether to deliver the data to the wireless device via the non-IP data delivery procedure comprises making the determination as to whether to deliver the data to the wireless device via the non-IP data delivery procedure based on the power source status of the radio access network node associated with the wireless device and one or more additional criteria.

9. The method of claim **8** wherein the non-IP data delivery request comprises a priority indication that indicates a priority assigned to the data, and the one or more additional criteria comprise a criterion based on the priority indication.

10. The method of claim **8** wherein the non-IP data delivery request comprises an override indication, and the one or more additional criteria comprise a criterion that the data is to be delivered if the override indication is set regardless of the power source status of the radio access network node.

11-12. (canceled)

13. A network node for providing non-Internet Protocol, IP, data delivery in a wireless communication system, characterized in that the network node comprises:

a network interface; and

circuitry associated with the network interface operable to:

receive, from an exposure function that exposes a core network to an application server, a non-IP data delivery request comprising data from the application server to be delivered to a wireless device via a non-IP data delivery procedure;

make a determination as to whether to deliver the data to the wireless device via the non-IP data delivery procedure based on a power source status of a radio access network node associated with the wireless device, wherein the power source status indicates whether or not the radio access network node is operating with a primary power source or a secondary power source where the radio access network node is capable of transmitting data to the wireless device regardless of whether the radio access network node is operating with the primary power source or the secondary power source.

14. The network node of claim **13** wherein, in order to make the determination as to whether to deliver the data to the wireless device via the non-IP data delivery procedure, the circuitry is further operable to:

make the determination to not deliver the data to the wireless device via the non-IP data delivery procedure if the power source status of the radio access network node is that the radio access network node is using a secondary power source; and

make the determination to deliver the data to the wireless device via the non-IP data delivery procedure if the power source status of the radio access network node is that the radio access network node is using a primary power source.

15. The network node of claim **13** wherein the circuitry is further operable to:

refrain from delivering the data to the wireless device via the non-IP data delivery procedure if the determination is made to not deliver the data to the wireless device via the non-IP data delivery procedure; and

deliver the data to the wireless device via the non-IP data delivery procedure if the determination is made to deliver the data to the wireless device via the non-IP data delivery procedure.

16. The network node of claim **15** wherein the circuitry is further operable to, if the determination is made to not deliver the data to the wireless device via the non-IP data delivery procedure, send a request to the exposure function for retransmission of the data.

17. The network node of claim **16** wherein the request for retransmission of the data comprises an indication of a reason for the request for retransmission, the reason being that the radio access network node associated with the wireless device is operating on a secondary power source.

18. The network node of claim **13** wherein the circuitry is further operable to:

receive, from the radio access network node, a power source status indication that is indicative of the power source status of the radio access network node;

store the power source status indication; and

make the determination as to whether to deliver the data to the wireless device via the non-IP data delivery procedure based on the stored power source status indication.

19. The network node of claim **13** wherein the circuitry is further operable to, upon receiving the non-IP data delivery request:

send a request to the radio access network node associated with the wireless device for information comprising a power source status indication that is indicative of a power source status of the radio access network node;

receive the power source status indication from the radio access network node; and

make the determination as to whether to deliver the data to the wireless device via the non-IP data delivery procedure based on the received power source status indication.

20. The network node of claim **13** wherein the circuitry is further operable to make the determination as to whether to deliver the data to the wireless device via the non-IP data delivery procedure based on the power source status of the radio access network node associated with the wireless device and one or more additional criteria.

21. The network node of claim **20** wherein the non-IP data delivery request comprises an override indication that indicates that the data is to be delivered immediately, and the one or more additional criteria comprise a criterion that the data is to be delivered if the override indication is set regardless of the power source status of the radio access network node.

22. (canceled)

23. A non-transitory computer readable medium storing instructions executable by processing circuitry of a network node whereby the network node is operable to:

receive, from an exposure function that exposes a core network to an application server, a non-IP data delivery request comprising data from the application server to be delivered to a wireless device via a non-IP data delivery procedure; and

making a determination as to whether to deliver the data to the wireless device via the non-IP data delivery procedure based on a power source status of a radio access network node associated with the wireless device, wherein the power source status indicates whether or not the radio access network node is operating with a primary power source or a secondary power source where the radio access network node is capable of transmitting data to the wireless device regardless of whether the radio access network node is operating with the primary power source or the secondary power source.

24-52. (canceled)

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