

ENFORCING POLICY FOR ENERGY CONSUMPTION FOR A SUBSCRIBER IN A WIRELESS COMMUNICATION SYSTEM

TECHNICAL FIELD

[0001] The subject matter disclosed herein relates generally to the field of implementing the enforcing of policy for energy consumption for a subscriber in a wireless communication system. This document defines a network entity for wireless communication, a unified data management entity, a policy control function entity, an access network entity, a charging function entity, and methods in a network entity, unified data management entity, policy control function entity, access network entity and charging function entity.

BACKGROUND

[0002] A wireless communications system may include one or multiple network communication devices, such as base stations, which may support wireless communications for one or multiple user communication devices, which may be otherwise known as user equipment (UE), or other suitable terminology. The wireless communications system may support wireless communications with one or multiple user communication devices by utilizing resources of the wireless communication system (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers, or the like). Additionally, the wireless communications system may support wireless communications across various radio access technologies including third generation (3G) radio access technology, fourth generation (4G) radio access technology, fifth generation (5G) radio access technology, among other suitable radio access technologies beyond 5G (e.g., sixth generation (6G)).

[0003] Wireless networks, e.g., 5GS as specified by the 3rd Generation Partnership Project (3GPP), are permanently enhanced with new features to achieve higher transmission throughput (e.g., bitrates) and network flexibility. This can result in the energy consumption in the network increasing. Furthermore, energy prices may also increase.

Therefore, the network operators may want to introduce new functionality into wireless networks to monitor the energy consumption on different levels.

SUMMARY

[0004] An article “a” before an element is unrestricted and understood to refer to “at least one” of those elements or “one or more” of those elements. The terms “a,” “at least one,” “one or more,” and “at least one of one or more” may be interchangeable. As used herein, including in the claims, “or” as used in a list of items (e.g., a list of items prefaced by a phrase such as “at least one of” or “one or more of” or “one or both of”) indicates an inclusive list such that, for example, a list of at least one of A, B, or C means A or B or C or AB or AC or BC or ABC (i.e., A and B and C). Also, as used herein, the phrase “based on” shall not be construed as a reference to a closed set of conditions. For example, an example step that is described as “based on condition A” may be based on both a condition A and a condition B without departing from the scope of the present disclosure. In other words, as used herein, the phrase “based on” shall be construed in the same manner as the phrase “based at least in part on. Further, as used herein, including in the claims, a “set” may include one or more elements.

[0005] There is provided a network entity for wireless communication, comprising: at least one memory; and at least one processor coupled with the at least one memory and configured to cause the network entity to: determine, one or more first parameters comprising energy-related service restriction information for a user equipment (UE) for enforcement in an access network (AN) of a wireless communication system; and transmit, to a first network entity of the wireless communication system, the one or more first parameters for enforcement in the AN.

[0006] There is further provided a method in a network entity, comprising: determining, one or more first parameters comprising energy-related service restriction information for a UE for enforcement in an AN of a wireless communication system; and transmitting, to a first network entity of the wireless communication system, the one or more first parameters for enforcement in the AN.

[0007] There is further provided an unified data management (UDM) entity for wireless communication, comprising: at least one memory; and at least one processor coupled with the at least one memory and configured to cause the UDM entity to: store subscription information for a UE, wherein the subscription information comprises subscribed energy related information; and transmit, to a network entity, one or more second parameters comprising the subscribed energy related information. The subscribed energy related information optionally comprises at least one of: an indication the UE is enabled for energy related service restrictions; a value for a subscribed aggregated maximum energy rate (AMER) for the UE; a service type to which the subscribed energy related information applies; and a network slice to which the subscribed energy related information applies.

[0008] There is further provided a method in an UDM entity for wireless communication, comprising: storing subscription information for a UE, wherein the subscription information comprises subscribed energy related information; and transmitting, to a network entity, one or more second parameters comprising the subscribed energy related information. The subscribed energy related information optionally comprises at least one of: an indication the UE is enabled for energy related service restrictions; a value for a subscribed aggregated maximum energy rate (AMER) for the UE; a service type to which the subscribed energy related information applies; and a network slice to which the subscribed energy related information applies.

[0009] There is further provided a policy control function (PCF) entity for wireless communication, comprising: at least one memory; and at least one processor coupled with the at least one memory and configured to cause the PCF entity to: determine one or more third parameters comprising energy-related service restriction information for a UE; and provide, to a network entity of a wireless communication system, the one or more third parameters. The one or more third parameters optionally comprise at least one of: a derived AMER for the UE applicable to the AN and to a core network of the wireless communication system; a derived $AMER_{AN}$ for the UE applicable to the AN only; an identifier for the UE; an $AMER_{AN}$ for the UE applicable to the AN only; and one or more associated conditions for the $AMER_{AN}$.

[0010] There is further provided a method in a PCF entity for wireless communication, comprising: determining one or more third parameters comprising energy-related service restriction information for a UE; and providing, to a network entity of a wireless communication system, the one or more third parameters. The one or more third parameters optionally comprise at least one of: a derived AMER for the UE applicable to the AN and to a core network of the wireless communication system; a derived AMER_{AN} for the UE applicable to the AN only; an identifier for the UE; an AMER_{AN} for the UE applicable to the AN only; and one or more associated conditions for the AMER_{AN}.

[0011] There is further provided an AN entity in an AN of a wireless communication system, comprising: at least one memory; and at least one processor coupled with the at least one memory and configured to cause the AN entity to: receive, from a network entity of the wireless communication system, one or more first parameters comprising energy-related service restriction information for a UE for enforcement in the AN; and enforce, in the AN, one or more energy-related service restrictions based on the one or more first parameters.

[0012] There is further provided a method in an AN entity in an AN of a wireless communication system, comprising: receiving, from a network entity of the wireless communication system, one or more first parameters comprising energy-related service restriction information for a UE for enforcement in the AN; and enforcing, in the AN, one or more energy-related service restrictions based on the one or more first parameters.

[0013] There is further provided a charging function (CHF) entity in a wireless communication system, comprising: at least one memory; and at least one processor coupled with the at least one memory and configured to cause the CHF entity to: collect energy related charging data for a UE for a predetermined time period; determine if the collected energy related charging data exceeds a predetermined energy credit limit; and if so: transmit, to a network entity of the wireless communication system, a notification that the predetermined energy credit limit has been exceeded.

[0014] There is further provided a method in a CHF entity in a wireless communication system, comprising: collecting energy related charging data for a UE for a predetermined time period; determining if the collected energy related charging data exceeds a

predetermined energy credit limit; and if so: transmitting, to a network entity of the wireless communication system, a notification that the predetermined energy credit limit has been exceeded.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] Figure 1 illustrates an example of a wireless communications system in accordance with aspects of the present disclosure.

[0016] Figure 2 illustrates an example 200 of signalling flow for enforcing policy for maximum energy consumption for the aggregated traffic of a UE, in accordance with aspects of the present disclosure.

[0017] Figure 3 illustrates an example of a user equipment (UE) 300 in accordance with aspects of the present disclosure.

[0018] Figure 4 illustrates an example of a processor 400 in accordance with aspects of the present disclosure.

[0019] Figure 5 illustrates an example of a network equipment (NE) 500 in accordance with aspects of the present disclosure.

[0020] Figure 6 illustrates a flowchart of a method performed by a NE in accordance with aspects of the present disclosure.

[0021] Figure 7 illustrates a flowchart of a method performed by a NE in accordance with aspects of the present disclosure.

[0022] Figure 8 illustrates a flowchart of a method performed by a NE in accordance with aspects of the present disclosure.

[0023] Figure 9 illustrates a flowchart of a method performed by a NE in accordance with aspects of the present disclosure.

[0024] Figure 10 illustrates a flowchart of a method performed by a NE in accordance with aspects of the present disclosure.

DETAILED DESCRIPTION

[0025] To introduce functionality into wireless networks to monitor energy consumption at different levels, efforts have been made to specify techniques, e.g., within the access network and the core network specified by 3GPP, to increase the energy efficiency while transmitting user data. Also, efforts have been made to reduce the energy consumptions in the end terminal, i.e., user equipment (UE), by increasing the UE's discontinuous transmission or reception of data.

[0026] New use cases and requirements for future networks are envisaged to develop an "energy as a service" framework which allows for the monitoring of the energy consumption within the network and for the exposure of such information "as a service" to network customers or verticals. Currently the 5G network does not have any means to expose the energy consumption or energy efficiency related information to the network customers or verticals.

[0027] Introducing an "energy as a service" capability in the network would allow customers or verticals to have the choice to select proper energy efficiency criteria or other network performance parameters. The intention is to control (e.g., measure and enforce policies) the energy consumption in the network. The new requirements for the "energy as a service" capability that would be offered to the network customers, verticals or user and application service providers will now be introduced.

[0028] As a first requirement, the network should be able to support energy consumption or energy efficiency parameters as part of a communication service. For example, the network operator may want to limit the energy (i.e., rate) consumed by a communication service or by a subscriber (e.g., UE).

[0029] As a further requirement, the network should be able to provide information exposure on the energy consumption on different levels.

[0030] This disclosure herein tends to address these requirements, with specific focus on the first requirement.

[0031] By way of example, two use cases ‘Use Case A’ and ‘Use Case B’ are described to illustrate the deployment of an “energy as a service” capability.

[0032] Firstly, there is Use Case A. In this use case, a network operator monitors the energy consumption (EC) of a service or of a subscriber. This is the energy consumed in the network including the access network (AN) and the core network (CN). The network operator may configure a maximum EC value by the network in a specific period of time (e.g., per minute), or in a specific service area (e.g., per tracking area (TA)). This can be described as a maximum energy consumption rate (ECR). When the maximum ECR value is reached, the network may enforce specific policies to limit the further energy consumption.

[0033] Secondly, there is Use Case B. In this use case, a network operator may have configured a maximum aggregated energy which is allowed to be consumed in the network to: provide a specific service to any subscriber; or to provide services to a specific subscriber. This can be described as an energy credit limit (ECL). The ECL can be measured in kilowatt hours (kWh). For example, the maximum ECL for a ‘subscriber A’ can be 10 kWh per month. After the maximum ECL is consumed, several actions can be taken by the network to limit the energy consumption or to reduce the service level.

[0034] It should be noted that, as described herein, the term ‘maximum energy credit limit’ is distinct from the term ‘maximum energy consumption’. This is because the energy credit limit is a total amount of energy consumed, whereas the maximum energy consumption is a limit to the consumption in a given interval of time.

[0035] This disclosure herein assumes that a service restriction applied to a UE in an attempt to limit energy consumption, is applied to the UE as a whole, i.e., to all services of the UE.

[0036] However, a problem arises when seeking to enforce policy for energy consumption for a subscriber in a wireless communication system/network. When the network determines that service restrictions should be applied due to increased energy consumption (including Use Cases A and B above), there is no current mechanism for actually enforcing the service restriction/s.

[0037] The disclosure herein introduces ‘energy-related service restriction information’ for a UE. Said information may be determined by a network entity i.e., a policy control function (PCF) of a core network. Said information may be provided to an access and mobility management function (AMF) which may then provide energy-related service restriction information for the UE for enforcement in an AN. The enforcement may be through an AN entity of the AN. A unified data repository (UDM) may store and provide subscribed energy-related service restriction information for a UE. A charging function (CHF) may also monitor energy consumption in the wireless communication system/network and provide notifications when a maximum energy consumption or energy credit limit is reached.

[0038] The disclosure herein tends to provide a solution to *how* a network can enforce energy-related service restrictions.

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

[0040] Figure 1 illustrates an example of a wireless communications system 100 in accordance with aspects of the present disclosure. The wireless communications system 100 may include one or more NE 102, one or more UE 104, and a core network (CN) 106. The wireless communications system 100 may support various radio (or wireline) access technologies. In some implementations, the wireless communications system 100 may be a 4G network, such as an LTE network or an LTE-Advanced (LTE-A) network. In some other implementations, the wireless communications system 100 may be a NR network, such as a 5G network, a 5G-Advanced (5G-A) network, or a 5G ultrawideband (5G-UWB) network. In other implementations, the wireless communications system 100 may be a combination of a 4G network and a 5G network, or other suitable radio access technology including Institute of Electrical and Electronics Engineers (IEEE) 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20. The wireless communications system 100 may support radio access technologies beyond 5G, for example, 6G. Additionally, the wireless communications system 100 may support technologies, such as time division multiple access (TDMA), frequency division multiple access (FDMA), or code division multiple access (CDMA), etc.

[0041] The one or more NE 102 may be dispersed throughout a geographic region to form the wireless communications system 100. One or more of the NE 102 described herein may be or include or may be referred to as a network node, a base station, a network element, a network function, a network entity, a radio access network (RAN), a NodeB, an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. An NE 102 and a UE 104 may communicate via a communication link, which may be a wireless or wired connection. For example, an NE 102 and a UE 104 may perform wireless communication (e.g., receive signaling, transmit signaling) over a Uu interface.

[0042] An NE 102 may provide a geographic coverage area for which the NE 102 may support services for one or more UEs 104 within the geographic coverage area. For example, an NE 102 and a UE 104 may support wireless communication of signals related to services (e.g., voice, video, packet data, messaging, broadcast, etc.) according to one or multiple radio access technologies. In some implementations, an NE 102 may be moveable, for example, a satellite associated with a non-terrestrial network (NTN). In some implementations, different geographic coverage areas associated with the same or different radio access technologies may overlap, but the different geographic coverage areas may be associated with different NE 102.

[0043] The one or more UE 104 may be dispersed throughout a geographic region of the wireless communications system 100. A UE 104 may include or may be referred to as a remote unit, a mobile device, a wireless device, a remote device, a subscriber device, a transmitter device, a receiver device, or some other suitable terminology. In some implementations, the UE 104 may be referred to as a unit, a station, a terminal, or a client, among other examples. Additionally, or alternatively, the UE 104 may be referred to as an Internet-of-Things (IoT) device, an Internet-of-Everything (IoE) device, or machine-type communication (MTC) device, among other examples.

[0044] A UE 104 may be able to support wireless communication directly with other UEs 104 over a communication link. For example, a UE 104 may support wireless communication directly with another UE 104 over a device-to-device (D2D) communication link. In some implementations, such as vehicle-to-vehicle (V2V) deployments, vehicle-to-everything (V2X) deployments, or cellular-V2X deployments, the

communication link may be referred to as a sidelink. For example, a UE 104 may support wireless communication directly with another UE 104 over a PC5 interface.

[0045] An NE 102 may support communications with the CN 106, or with another NE 102, or both. For example, an NE 102 may interface with other NE 102 or the CN 106 through one or more backhaul links (e.g., S1, N2, N2, or network interface). In some implementations, the NE 102 may communicate with each other directly. In some other implementations, the NE 102 may communicate with each other or indirectly (e.g., via the CN 106). In some implementations, one or more NE 102 may include subcomponents, such as an access network entity, which may be an example of an access node controller (ANC). An ANC may communicate with the one or more UEs 104 through one or more other access network transmission entities, which may be referred to as a radio heads, smart radio heads, or transmission-reception points (TRPs).

[0046] The CN 106 may support user authentication, access authorization, tracking, connectivity, and other access, routing, or mobility functions. The CN 106 may be an evolved packet core (EPC), or a 5G core (5GC), which may include a control plane entity that manages access and mobility (e.g., a mobility management entity (MME), an access and mobility management functions (AMF)) and a user plane entity that routes packets or interconnects to external networks (e.g., a serving gateway (S-GW), a Packet Data Network (PDN) gateway (P-GW), or a user plane function (UPF)). In some implementations, the control plane entity may manage non-access stratum (NAS) functions, such as mobility, authentication, and bearer management (e.g., data bearers, signal bearers, etc.) for the one or more UEs 104 served by the one or more NE 102 associated with the CN 106.

[0047] The CN 106 may communicate with a packet data network over one or more backhaul links (e.g., via an S1, N2, N2, or another network interface). The packet data network may include an application server. In some implementations, one or more UEs 104 may communicate with the application server. A UE 104 may establish a session (e.g., a protocol data unit (PDU) session, or the like) with the CN 106 via an NE 102. The CN 106 may route traffic (e.g., control information, data, and the like) between the UE 104 and the application server using the established session (e.g., the established PDU session). The

PDU session may be an example of a logical connection between the UE 104 and the CN 106 (e.g., one or more network functions of the CN 106).

[0048] In the wireless communications system 100, the NEs 102 and the UEs 104 may use resources of the wireless communications system 100 (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers)) to perform various operations (e.g., wireless communications). In some implementations, the NEs 102 and the UEs 104 may support different resource structures. For example, the NEs 102 and the UEs 104 may support different frame structures. In some implementations, such as in 4G, the NEs 102 and the UEs 104 may support a single frame structure. In some other implementations, such as in 5G and among other suitable radio access technologies, the NEs 102 and the UEs 104 may support various frame structures (i.e., multiple frame structures). The NEs 102 and the UEs 104 may support various frame structures based on one or more numerologies.

[0049] One or more numerologies may be supported in the wireless communications system 100, and a numerology may include a subcarrier spacing and a cyclic prefix. A first numerology (e.g., $\mu=0$) may be associated with a first subcarrier spacing (e.g., 15 kHz) and a normal cyclic prefix. In some implementations, the first numerology (e.g., $\mu=0$) associated with the first subcarrier spacing (e.g., 15 kHz) may utilize one slot per subframe. A second numerology (e.g., $\mu=1$) may be associated with a second subcarrier spacing (e.g., 30 kHz) and a normal cyclic prefix. A third numerology (e.g., $\mu=2$) may be associated with a third subcarrier spacing (e.g., 60 kHz) and a normal cyclic prefix or an extended cyclic prefix. A fourth numerology (e.g., $\mu=3$) may be associated with a fourth subcarrier spacing (e.g., 120 kHz) and a normal cyclic prefix. A fifth numerology (e.g., $\mu=4$) may be associated with a fifth subcarrier spacing (e.g., 240 kHz) and a normal cyclic prefix.

[0050] A time interval of a resource (e.g., a communication resource) may be organized according to frames (also referred to as radio frames). Each frame may have a duration, for example, a 10 millisecond (ms) duration. In some implementations, each frame may include multiple subframes. For example, each frame may include 10 subframes, and each subframe may have a duration, for example, a 1 ms duration. In some implementations,

each frame may have the same duration. In some implementations, each subframe of a frame may have the same duration.

[0051] Additionally or alternatively, a time interval of a resource (e.g., a communication resource) may be organized according to slots. For example, a subframe may include a number (e.g., quantity) of slots. The number of slots in each subframe may also depend on the one or more numerologies supported in the wireless communications system 100. For instance, the first, second, third, fourth, and fifth numerologies (i.e., $\mu=0$, $\mu=1$, $\mu=2$, $\mu=3$, $\mu=4$) associated with respective subcarrier spacings of 15 kHz, 30 kHz, 60 kHz, 120 kHz, and 240 kHz may utilize a single slot per subframe, two slots per subframe, four slots per subframe, eight slots per subframe, and 16 slots per subframe, respectively. Each slot may include a number (e.g., quantity) of symbols (e.g., OFDM symbols). In some implementations, the number (e.g., quantity) of slots for a subframe may depend on a numerology. For a normal cyclic prefix, a slot may include 14 symbols. For an extended cyclic prefix (e.g., applicable for 60 kHz subcarrier spacing), a slot may include 12 symbols. The relationship between the number of symbols per slot, the number of slots per subframe, and the number of slots per frame for a normal cyclic prefix and an extended cyclic prefix may depend on a numerology. It should be understood that reference to a first numerology (e.g., $\mu=0$) associated with a first subcarrier spacing (e.g., 15 kHz) may be used interchangeably between subframes and slots.

[0052] In the wireless communications system 100, an electromagnetic (EM) spectrum may be split, based on frequency or wavelength, into various classes, frequency bands, frequency channels, etc. By way of example, the wireless communications system 100 may support one or multiple operating frequency bands, such as frequency range designations FR1 (410 MHz – 7.125 GHz), FR2 (24.25 GHz – 52.6 GHz), FR3 (7.125 GHz – 24.25 GHz), FR4 (52.6 GHz – 114.25 GHz), FR4a or FR4-1 (52.6 GHz – 71 GHz), and FR5 (114.25 GHz – 300 GHz). In some implementations, the NEs 102 and the UEs 104 may perform wireless communications over one or more of the operating frequency bands. In some implementations, FR1 may be used by the NEs 102 and the UEs 104, among other equipment or devices for cellular communications traffic (e.g., control information, data).

In some implementations, FR2 may be used by the NEs 102 and the UEs 104, among other equipment or devices for short-range, high data rate capabilities.

[0053] FR1 may be associated with one or multiple numerologies (e.g., at least three numerologies). For example, FR1 may be associated with a first numerology (e.g., $\mu=0$), which includes 15 kHz subcarrier spacing; a second numerology (e.g., $\mu=1$), which includes 30 kHz subcarrier spacing; and a third numerology (e.g., $\mu=2$), which includes 60 kHz subcarrier spacing. FR2 may be associated with one or multiple numerologies (e.g., at least 2 numerologies). For example, FR2 may be associated with a third numerology (e.g., $\mu=2$), which includes 60 kHz subcarrier spacing; and a fourth numerology (e.g., $\mu=3$), which includes 120 kHz subcarrier spacing.

[0054] The disclosure herein tends to overcome the problem of there being no solutions to enforce energy-related service restrictions for a UE.

[0055] For the purpose of this disclosure, it is assumed that Use Cases A and B described above tend to apply. When any of the scenarios described in Use Case A or Use Case B occur, a wireless communication system/network may apply at least one of the following service restriction policies: service restrictions for the UE; and a different charging rate (e.g., higher charging) for the services of the UE (subscriber). Service restrictions for the UE may include, for example the data traffic being gated. This can include either: the data bitrate being reduced or in general a decreased QoS requirements may apply; the service being stopped until an EC rate is reduced in the network or a maximum ECL is increased; or the available energy for data transmission being limited. Further details are given below for exemplar service restrictions referred to as 'service restriction A' and 'service restriction B'.

[0056] The disclosure herein further assumes that the service restriction/s apply to a UE as a whole, i.e., to all services of the UE. The service restriction may apply either: to the best-effort traffic only; or to any service (e.g. traffic to/from a specific application server) of the UE which is subject to a specific Quality of Service (QoS) policy. In the latter case service degradation may occur, i.e., the service level agreement (SLA) between the service customer and the network operator may not be fulfilled. However, since the SLA itself would include the energy limitation policy, it is considered as acceptable to impact the QoS

and the SLA. Also, the SLA may include an alternative (i.e., lower level) QoS which may apply in scenarios when the energy-related service restrictions apply.

[0057] As previously introduced, the proposed solution tends to relate to a core network (CN) of a wireless communication system creating service restrictions and informing an AN of the wireless communication system to enforce the service restrictions. One reason to enforce the service restrictions at the AN (which may comprise one or more Access Types) is that the AN aggregates the whole traffic of the UE. Exemplar service restrictions will now be introduced.

[0058] A first example of a service restriction shall be referred to as 'service restriction A'. This service restriction applies limitations to the energy with which the network serves the particular service. This would result in limitation of the energy (i.e., translated into energy or power for the transmission and/or reception of radio signals) to transmit the data of the service. It may be assumed that the EC in the network (e.g., for the data transmission of a UE) is split into the EC in the CN and the EC in the AN. The EC in the CN can be assumed as constant per data unit (e.g., per data amount), whereas the EC in the wireless AN is dynamic and depends on the radio conditions between the UE and the base station. In some embodiments, the limitation of the energy can be translated into limitation of the transmission energy (or transmission power) in the AN, and it is called UE-AMER AN and is enforced in the AN.

[0059] A further example of a service restriction shall be referred to as 'service restriction B'. This service restriction applies a limitation according to a reduced QoS level derived from the EC restrictions. The reduced QoS level or profile is derived (or pre-configured) in the CN (e.g., the AM-PCF or AMF) and enforced in the user plane, i.e., configured via signalling from the CN CP in the anchor UPF and/or RAN. The reduced QoS level may include one of: reduction of the data bitrate (e.g., reduced UE AMBR or reduced MBR for a session or for the UE as a whole), or the data packet transmission delay may be increased (e.g., increased packet delay budget for the transmission), or the data packet loss rate may be increased (i.e. more packet losses are acceptable). The value(s) of the reduced QoS level may be pre-configured in the UE subscription data or pre-configured in the CN CP (e.g., in the AMF or PCF).

[0060] At a general level, certain main features of the solutions described herein will now be discussed.

[0061] The disclosure herein provides an AMF. The AMF receives an indication from the CN (e.g., AM-PCF, CHF/NWDAF) that service restrictions should be enforced due to increased energy consumption (c.f., Use Cases A or B). The indication may include ‘service restriction information to be enforced in the AN’.

[0062] It should be noted that the PCF itself may determine the ‘service restriction information to be enforced in the AN’ based on information locally configured in the PCF or received from NWDAF or CHF.

[0063] The AMF sends ‘service restriction information to be enforced in the AN’ (e.g., a UE-AMER AN) to the AN entity for enforcement, e.g., on per Access Type basis.

[0064] It should be noted that the AMF may receive enhanced UE Subscription data including subscribed energy-related information. The AMF may store such information and use it during: a policy association establishment with the AM-PCF; and/or as an input to derive service restriction information to be enforced in the AN when an indication for energy-related restriction is received from the CHF/NWDAF.

[0065] Figure 2 illustrates an example 200 of signalling flow for enforcing policy (e.g., service restrictions) to limit the EC for the aggregated traffic of a UE, in accordance with aspects of the present disclosure. It is assumed that the service restrictions are applied for the user plane (UP) traffic. The energy-related service restriction/s is/are enforced in the AN, specifically in the radio access network (RAN) based on LTE, NR or other technology. Since the UP data for all PDU Sessions is transmitted over the AN, this is an example of an appropriate place to enforce the energy-related service restriction for the aggregated UE traffic.

[0066] In some embodiments, a new network function called an Energy Consumption (or Collection) Function (e.g., ECF) may be introduced in the CN CP. Such a function may be responsible to collect and store energy consumption information on a specific granularity, e.g., per UE or per network slice or per traffic of a specific application. Alternatively, the EC information may be collected and stored in an existing NF in the CN

CP, e.g., in NWDAF and in CHF. For example, if EC information is collected on UE level, then the CHF may gather such information. On the other hand, if EC information is collected in network slice level or for traffic associated with an application, then the NWDAF may be an appropriate NF to collect such information. Any of the beforehand mentioned NFs can be denoted as 'EC collecting NF'. The 'EC collecting NF' may be configured with a maximum value or threshold for EC consumption of certain granularity. When the energy threshold is reached, the 'EC collecting NF' may trigger an event towards the AM-PCF or to the AMF which will be described with reference to Figure 2 below.

[0067] Furthermore, the Access Network (AN) is a general notion which can either deploy 3GPP based technology (e.g., NG-RAN, LTE, NR, UTRA) or a non-3GPP based technology (e.g., WiFi). The term 'Access Type' can be used to differentiate the 3GPP based technology and the non-3GPP based technology.

[0068] The example 200 of Figure 2 will now be described in greater detail.

[0069] The example 200 shows a UE 220, an AN 230, an AMF 240, a UDR/UDM 250, a PCF (AM) 260, a CHF 270 and an ECH/NWDAF 280. The various procedural steps/message flows 201a-209 will now be described.

[0070] In a first step 201a, the UDM/UDR 250 stores UE subscription data. This subscription data is enhanced to include UE subscription information for energy-related policy restrictions. This information is referred as 'subscribed energy-related information' and may comprise the UE is enabled for service restriction due to energy consumption. In other words, the UE is allowed to be subject of EC control (i.e., a max EC limitation which may be based on an SLA or consent from a user. The user of the UE (e.g., the subscriber) may have indicated his/her consent that service restriction due to energy consumption may apply. The 'subscribed energy-related information' may comprise the value of the aggregated maximum energy rate to be enforced for the UE (e.g., 'UE-AMER' or 'AMER for the UE') when a service restriction event occurs. Regarding the latter, an alternative may be that the reduced bitrate (or reduced QoS level or profile) may be stored e.g., alternative reduced UE-AMBR. Note that the reduced-UE AMBR may be an additional parameter to the known UE-AMBR. The 'subscribed energy-related information' may comprise the service type to which the 'subscribed energy-related information' applies. For

example, the UE-AMER may apply to a.) best-effort services only, b) to non-GBR services; c) to any type of non-mission critical services; or d) to all services. Further, the restrictions may apply to a certain network slice (e.g., identified by S-NSSAI) or DNN. The ‘subscribed energy-related information’ may include parameters like “EC enabled” or “UE-AMER” value.

[0071] In a further step 201b, the CHF 270 may be enhanced to be configured with an energy credit limit (ECL) as described in Use Case B. In such a Use Case, the CHF 270 collects energy-related charging data over a predetermined period, e.g., on a daily, weekly or monthly basis. The CHF 270 monitors the current status of the collected EC data (i.e., the instantly collected EC information) and compares with the maximum ECL. When the maximum ECL is reached, the CHF 270 can trigger the step 205c, for instance, as will be later described.

[0072] In a further step 202, a UE 220 initiates a registration procedure. This is shown as UE 220 providing AMF 240 with a ‘Registration Request’.

[0073] In a further step 203a, the AMF 240 sends a request message to retrieve the UE’s 220 subscription data from the UDM 250. The AMF 240 may include in the request message a SUPI as reference identifier for the UE 220. The step 203a is shown in the example 200 as ‘Request Subscription data’.

[0074] In the further step 203b, the UDM 250 determines as per step 201a that the UE Subscription data includes ‘subscribed energy-related information’. The UDM 250 sends a response message to AMF 240 including the UE’s subscription data which comprises the ‘subscribed energy-related information’. The ‘subscribed energy-related information’ may comprise a ‘maximum EC enabled’ parameter and a UE-AMER/AMER for the UE, for instance, as described in step 201a. The response message may comprise the SUPI. The response message is shown in the example 200 as ‘Response Subscription data’.

[0075] In the further step 203c, when the UE subscription data is updated after the UE 220 has been registered in the network, the UDM 250 sends a notification message to the AMF 240 including the updated information, which in this case may include the ‘subscribed energy-related information’. The subscribed energy-related information may

comprise a ‘maximum EC enabled’ parameter and a UE-AMER/AMER for the UE, for instance. The response message may comprise the SUPI. The notification message is shown in the example 200 as ‘Notification subscription data’.

[0076] In the further step 204a, the AMF 240 requests the access and mobility (AM) policy association establishment to the PCF (e.g., AM-PCF) 260. For this purpose the AMF may use the Npcf_AMPolicyControl_Create service operation. The AMF 240 may include the SUPI (as the UE ID), list TAIs of the registration area, Access Type, and in addition the ‘subscribed energy-related information’. In particular, the AMF 240 may indicate that the UE is subject to service restriction due to EC (i.e., include a maximum EC enabled parameter); and/or the subscribed UE-AMER value (i.e., which can be referred as AMER_{subscribed}). The step 204a is shown in the example 200 as ‘AM Policy Association Est. Req.’.

[0077] In the further step 204b, the PCF (e.g., AM-PCF) 260 sends an AM policy association establishment response message to the AMF 240. This is shown in the example 200 as ‘AM Policy Association Est. Resp’. This message may include the SUPI. In the case where the PCF 260 determines that the energy consumption restriction for the UE has to be enforced (e.g., based on Use Cases A or B), the PCF 260 may provide the ‘energy-related service restriction information’ to the AMF. The ‘energy-related service restriction information’ may include at least one of: a ‘derived UE-AMER’ applicable to both AN and CN; and/or a ‘derived UE-AMER AN’ which is applicable for the AN only; and/or reduced bitrate or reduced QoS level (as previously described herein with regard to service restriction B). Further details about this step will be described in the steps 205a and 205b. The ‘derived UE-AMER’ may be referred to herein as AMER_{derived}. The ‘derived UE-AMER AN’ may be referred to herein as AMER_{derived AN}.

[0078] In the further step 204c, the AMF 240 sends a Registration Accept to the UE 220.

[0079] If the PCF 260 has sent the ‘energy-related service restriction information’ in step 204b, then the AMF 240 stores this information in the UE context and initiates the energy-related service restriction towards the AN 230 as described in steps 206 and 207a below.

[0080] Returning to step 204b and the determination to apply energy-related service restrictions, a first approach will be described with reference to steps 205a-205b of the example 200. For illustrative purposes this alternative is shown as 'Alt. X'.

[0081] In step 205a, at any point of time, the AM-PCF 260 may determine a trigger event notification to the AMF 240 that a service restriction due to a maximum EC being reached needs to apply. In one example, based on Use Case A, the PCF 260 may be triggered by another network function (NF) or by the OAM system that the maximum EC value has been reached in the network, e.g., for a specific period of time (e.g., per minute), or in a specific service area (e.g., per TA). This means that a particular situation has happened when the network has identified that either the EC in a specific area, or the EC of a specific service or network slice has reached a maximum ECR, or energy peak. In another example, based on Use Case B, the PCF 260 may be triggered, e.g., by CHF 270, that an energy credit limit (ECL) has been reached. In other words, the PCF 270 may determine either by itself based on local configuration, or based on input from CHF 270 or NWDAF 280, that the trigger event for service restriction due to maximum EC being reached has occurred.

[0082] Based on any of the above-described trigger events, the PCF 260 may determine an 'energy-related service restriction' which should be applied. Based on the stored UE context from the established AM policy associations, the PCF 260 knows which UEs 220 may be subject to service restriction due to EC (e.g., as per step 204a). The PCF 260 determines policy to be enforced for energy-related service restriction and to which UEs 220 this policy should apply. The PCF 260 may determine to apply/enforce service restriction A or service restriction B, for instance, as hereinbefore discussed.

[0083] The PCF 260 may, for instance, calculate a derived UE-AMER ($AMER_{derived}$) for the UE 220 either based on: the received subscribed UE-AMER as in step 204a or 202; based on local configuration; or based on input from NWDAF 280 (e.g., created based on analytics). In addition, or as an alternative, the PCF 260 may calculate the AN part of the UE-AMER to be enforced in the AN 230. The AN part of the UE-AMER may be referred to herein as $AMER_{AN}$. For this purpose, the PCF 260 may consider the average EC which has been spent or is expected to be consumed in the CN. The PCF 260 may apply Equation 1 to calculate $AMER_{AN}$ based on the derived-AMER or vice versa:

$$AMER_{AN} = \alpha \times AMER_{derived} \quad \text{Equation 1}$$

wherein ‘ α ’ is a number between 0.00 and 1.00, e.g. $\alpha = 0.70$ (or 70%). The value α may be locally configured in the PCF 260 or obtained from NWDAF 280 or by using other means.

[0084] It should be noted that in the case that the Service restriction B is enforced, the AM-PCF 260 can determine a (e.g., reduced) UE-AMBR (updated aggregated maximum bitrate applicable for the UE) to be sent to the AMF 240 as output of the determination that service restriction is required due to maximum EC being reached.

[0085] In a further step 205b, the PCF 260 sends the ‘energy-related service restriction information’ to the AMF 240. For this purpose, the PCF 260 sends an AM Policy Association Establishment response message or notification including the SUPI of the UE 220 and the energy-related service restriction information. For example, the PCF may use the Npcf_AMPolicyControl_UpdateNotify service operation. The ‘energy-related service restriction information’ may comprise the UE-AMER AN (also known as $AMER_{AN}$) and associated conditions where/when it is applicable. For example, the associated conditions can be at least one of: one or more frequency bands, Access Type, QoS type or classifier (e.g., the 5QI or QCI to which it is applicable), or associated service area (e.g., a list of cells, or AN node IDs, or TAIs).

[0086] Returning to step 204b and the determination to apply energy-related service restrictions, a further approach will be described with reference to step 205c of the example 200. For illustrative purposes this alternative is shown as ‘Alt. Y’.

[0087] In the step 205c, the AMF 240 may receive a trigger event notification that service restrictions due to EC needs to be enforced. For this purpose, the AMF 240 may have subscribed for notifications of such events in advance (note that the AMF 240 subscription for such event is not shown in the example 200). The AMF 240 may receive a notification in one of two alternatives. Firstly, the notification may be received from the CHF 270 via reference points N41/N42. For example, this may be applicable for Use Case B when the maximum ECL has been consumed. The CHF 270 may indicate to the AMF 240 that the maximum EC credit limit (for the UE 220 or service) is reached. As an alternative the notification may be received from the NWDAF 280 offering analytics or

some Energy Consumption Function (ECF). The NWDAF 280 or ECF may indicate to the AMF 240 that the maximum EC credit limit (for the UE 220 or service) is reached.

[0088] Based on the notification, the AMF 240 determines to enforce energy-related service restriction. The AMF 240 may determine whether to apply the service restriction A or service restriction B as hereinbefore discussed, e.g., based on local configuration in the AMF 240. In the case that the service restriction A is determined, the AMF 240 may derive the 'UE-AMER' or the 'UE-AMER AN' to be enforced in the AN. For the calculation of the 'UE-AMER' or the 'UE-AMER AN' the AMF 240 may use local configuration or input from NWDAF 280 and may apply the same or similar formula as described in Equation 1. In case that the service restriction B is determined, the AMF 240 may derive an alternative reduce bitrate or reduced QoS level to be applied to the UE 220. For example, the AMF 240 may determine a reduced UE-AMBR value. In one alternative, such reduced UE-AMBR value may be received from the UDM 250 as an alternative UE-AMBR value to be enforced in case that the event of service restriction due to maximum EC reached applies. The original UE-AMBR may still be kept in the UE context.

[0089] Now continuing with the example from either of Alt.X or Alt.Y, in further step 206, the AMF 240 determines to enforce the policy for service restriction towards the Access Network 230 (AN, e.g., NG-RAN or non-3GPP AN). The AMF 240 stores the 'energy-related service restriction information' in a UE context. This may comprise storing service restriction parameters i.e., UE-AMER AN and associated conditions for applicability). The AMF 240 enforces the 'energy-related service restriction information' when the UE 220 transfers from CM-Idle to CM-Connected state; or if the UE 220 is already in the CM-Connected state, the AMF 240 sends an updated UE context message to the AN/AN entity 230.

[0090] In the further step 207a, the AMF 240 sends an N2 message to the AN/AN entity 230. For example, the AMF 240 may send a UE Context Establishment Request message. The AMF 240 includes the 'energy-related service restriction information for the AN' and the associated applicability/validity conditions. The 'energy-related service restriction information for the AN' may include the UE-AMER AN or reduced UE-AMBR (updated reduced aggregated maximum bitrate applicable for the UE 220). The SUPI for

the UE 220 may also be included. The applicability conditions can be at least one of: one or more frequency bands (e.g., n71, n74), Access Type (e.g., 3GPP vs. non-3GPP, or LTE vs. NR); the type of service to which the restrictions are applicable (e.g., best effort services, non-GBR services, non-mission critical services, as any of these can be identified by QoS type or classifier like 5QI or QCI); or associated service area (e.g., a list of cells, or AN node IDs, or TAIs). The applicability conditions indicate to the AN 230 when/where/how the UE-AMER AN (or reduced UE-AMBR) applies. For this purpose, the protocol over the N2 reference point (e.g., NG-AP) may need to be enhanced to enable the transmission of the energy-related service restriction information' to the AN node 230.

[0091] In addition, the AMF 240 may subscribe for notifications about the applicability of the 'energy-related service restriction information for the AN'. The AMF 240 may indicate whether the AN 230 should measure the time duration or the amount of data transmitted under the energy-related restrictions.

[0092] In some embodiments, instead of sending the energy-related restriction information to the AN 230, the AMF 240 may determine to apply a different charging rate for the data amount which is transmitted during the energy-related restriction. The AMF 240 may determine to apply different charging rate based on notification in one of steps 205b or 205c. For this purpose, the AMF 240 may indicate to the AN entity 230 to start measure the amount of data transmitted to/from the UE 220. Such an indication may be called 'start data counting due to energy-based charging'. When the energy-related restrictions do not apply anymore, the AMF 240 may indicate to the AN 230 to 'stop data counting due to energy-based charging'.

[0093] In the further step 207b, the (supporting) AN entity 230 receives from the AMF 240 the 'energy-related service restriction information for the AN' associated with the validity/applicability conditions and stores the information in a UE context. The energy-related service restriction information for the AN may comprise a UE-AMER for a service area (defined by list of cells or TAs). The NG-RAN (not shown) shall apply this UE-AMER for User Plane data transmissions.

[0094] The AN entity 230 may also apply the energy-related service restriction information for the AN. For instance, the AN entity 230 may receive and apply the UE-

AMER AN in the following way. The AN entity 230 limits the energy consumed for the data transmissions in the downlink (DL) up to the allowed UE-AMER AN. For example, the AN entity may reduce the bitrate of the DL data transmission or apply different scheduling strategy or decide to use a different frequency band in order to save transmission energy. In one example, the UE-AMER AN may be 100 W per time window (e.g., per minute) which means that the AN entity 230 measures the transmission power for the DL data and continuously monitors whether the UE-AMER AN is reached. If the UE-AMER AN is reached, the AN entity 230 may stop transmitting data until the next time window.

[0095] In the case that the service restriction B applies, the AN 230 may store both the original UE-AMBR and the reduced UE-AMBR, wherein the reduced UE-AMBR is applied only according to the associated applicability conditions.

[0096] In a further step 207c, the AN entity 230 provides a notification to the AMF 240. This is an N2 Notification including the energy-related service restriction information applied i.e., includes SUPI, UE-AMER AN applied (and for what data amount, time duration, area). Put differently, the AN entity 230 may inform the CN CP (e.g., AMF 240) about the applicability of the restrictions due to EC limitation. For example, the AN 230 may send an N2 Notification including at least the SUPI, the applied UE-AMER AN (or reduced UE-AMBR) and the corresponding energy-related restrictions applicability information. The energy-related restrictions applicability information may include one of: the data amount transmitted under restrictions, or the time duration of the restrictions, or the area of applicability (e.g., list of cells or TAs).

[0097] In the case where the AN 230 has received the above-described indication ‘start data counting due to energy-based charging’ in step 207a, upon reception of a consecutive ‘stop data counting due to energy-based charging’ indication, the AN 230 sends a notification to the AMF 240 about the amount of data transmitted to/from the UE 220 during that time. Alternatively, if the UE context in the AN 230 is released, i.e., the UE 220 transits from an RRC/CM Connected to RRC/CM Idle state, the AN 230 also sends the amount of data transmitted to/from the UE 220 after receiving the indication ‘start data counting due to energy-based charging’ until the transition to RRC/CM Idle state.

[0098] In the further step 208, the AMF 240 may store in the UE's context, the information received in step 207c. The AMF 240 sends a Notification Request to PCF 260 including the energy-related service restriction information applied. Put differently, the AMF 240 may determine to send a Notification message to the AM-PCF 260 or to a CHF 270 in order to inform about the applicability of the energy-related restrictions. The AM-PCF 260 or CHF 270 may have subscribed explicitly (i.e., via explicit signalling containing a subscribe request for notifications) to receive such notifications, or an implicit subscription during steps 205b or 205c may apply as well. For example, the AMF 240 may send a notification message including the UE's SUPI and the corresponding energy-related restrictions applicability information. The energy-related restrictions applicability information may include one of: data amount transmitted under the restrictions, or the time duration of the restrictions, or the area of applicability (e.g., list of cells or TAs).

[0099] In some embodiments, a further step 209 is performed. In this step, a different charging rate for the data/time when the UE-AMER is applied/enforced may also be provisioned to the CHF 270 by the AMF 240. The CHF 270 may apply the different charging rate for the data amount for the time duration when the energy-related restrictions (e.g., the UE-AMER, or UE-AMER AN) have applied. The different charging rate is (pre-)configured in the CHF 270 based on the SLA or subscription profile of the UE 220. For example, if the energy-related restrictions does not apply, a normal charging rate applies, whereas if the energy-related restrictions apply, the charging rate may be lower (or higher) than the normal rate.

[0100] In addition to the above description, the AMF 240 may receive an update notification from AM-PCF 260 (as per step 205b) or from CHF 270 or ECF/NWDAF 280 (as per step 505c) that the energy-related service restriction information does not apply anymore, i.e., the energy-related service restriction information is deleted. Upon removing the energy-related service restriction information, the AMF 240 updates the UE context by removing the energy-related service restriction information and sends an N2 notification to the AN 230 to delete the energy-related service restriction information to be enforced in the AN.

[0101] A benefit of the solutions described herein, particularly with reference to Figure 2 is that a network operator is enabled to apply energy-related service restrictions to a subscriber (e.g., to a UE) if use cases A or B occur. In particular, the CN CP (e.g., the AM-PCF and/or AMF) are able to determine the energy-related conditions and energy-related policies which have to apply to the traffic transmitted to/from the UE.

[0102] The disclosure herein provides a network entity for wireless communication, comprising: at least one memory; and at least one processor coupled with the at least one memory and configured to cause the network entity to: determine, one or more first parameters comprising energy-related service restriction information for a user equipment (UE) for enforcement in an access network (AN) of a wireless communication system; and transmit, to a first network entity of the wireless communication system, the one or more first parameters for enforcement in the AN.

[0103] In certain use cases, a network operator may wish to monitor energy consumption of a service or subscriber (this may include energy consumed in the network including access network and core network). Hence a network operator may configure a maximum energy consumption value for a given period of time or service area. This may correlate with a maximum energy consumption rate, which when reached, the network operator may desire policies to be enforced to limit further energy consumption.

[0104] In certain use cases, a network operator may have configured a maximum aggregated energy which is allowed to be consumed in the network to provide a specific service to any subscriber, or to provide services to a specific subscriber (i.e., an energy credit limit measured in kWh). After the maximum energy credit limit is reached, the network operator may desire to limit the energy consumption or reduce the service level.

[0105] The network entity described herein provides an entity through which a wireless communication system can enforce such energy-related service restrictions. For example, the network entity may be an AMF and may receive parameters relating to energy-related service restriction information from another network entity such as a PCF or UDM/UDR. The AMF may already have such information stored. The AMF can process these parameters (and other information) to determine and provide the energy-related service restriction information to a first network entity which may be an AN entity of the AN. The

AMF can, therefore, enforce the energy-related service restriction information into the AN through the AN entity.

[0106] More generally, this allows customers/verticals to have the choice to select proper energy efficiency criteria or other network performance parameters, and for the provision of an “energy as a service” scenario wherein energy consumption in a network is monitored, the related information is exposed to network customers/verticals, and enforcement action can be taken to manage/control energy consumption.

[0107] The term ‘one or more first parameters’ may also be referred to as a ‘second indication’ in the embodiments described herein. The ‘enforcement’ in the AN can comprise a number of different enforcement activities/procedures. For instance, enforcement can mean limiting the energy consumed for data transmissions in downlink up to an allowed AMER-AN for a UE. This may include reducing bitrate or using an alternative scheduling strategy or different frequency band, to save energy. It may be that enforcement includes the first network entity (i.e., the AN entity) measuring transmission power for downlink data or continuously monitoring whether an AMER AN for a UE is reached, and if so, stopping transmitting data until a subsequent time window.

[0108] In some embodiments, the at least one processor coupled with the at least one memory is further configured to cause the network entity to: receive, from a second network entity, one or more second parameters comprising subscribed energy related information for the UE.

[0109] In some embodiments, the at least one processor coupled with the at least one memory is further configured to cause the network entity to: transmit, to the second network entity, a first request for subscription information for the UE; and receive the one or more second parameters in response to the first request. The first request may comprise an identifier for the UE such as a SUPI.

[0110] In addition, the one or more second parameters comprising subscribed energy related information may be received when UE subscription data is updated at the second network entity (which may be a UDM entity) after a UE is registered in the network. In such embodiments, the second network entity sends a notification message to the network

entity (i.e., the AMF) which includes the updated information (i.e., includes the subscribed energy-related information).

[0111] In some embodiments, the second network entity is a (UDM) entity.

[0112] In some embodiments, the one or more second parameters comprise at least one of: an indication that the UE is enabled for energy related service restrictions; a value for a subscribed aggregated maximum energy rate (AMER) or reduced UE-aggregated maximum bit rate (AMBR) for the UE; a service type or Access Type to which the subscribed energy related information applies (i.e., best effort services, non-GBR services, non-mission critical services, or 3GPP Access Type or non-3GPP Access Type); and a network slice to which the subscribed energy related information applies (i.e., as identified by S-NSSAI or DNN).

[0113] In some embodiments, the at least one processor coupled with the at least one memory is further configured to cause the network entity to: determine, based at least partly on the one or more second parameters, the one or more first parameters.

[0114] In some embodiments, during a policy association establishment procedure, the one or more second parameters comprising the subscribed energy related information for the UE may be provided to a PCF.

[0115] In some embodiments, the at least one processor coupled with the at least one memory is further configured to cause the network entity to: receive, from a third network entity of the wireless communication system, one or more third parameters comprising energy-related service restriction information for the UE; and determine the one or more first parameters, based at least partly on the one or more third parameters.

[0116] The 'one or more third parameters' may also be referred to herein as a 'first indication'.

[0117] In some embodiments, the one or more third parameters comprise at least one of: a derived aggregated maximum energy rate (AMER) for the UE applicable to the AN and to a core network of the wireless communication system; a derived $AMER_{AN}$ for the UE applicable to the AN only; an identifier for the UE (i.e., the identifier may be a SUPI);

an $AMER_{AN}$ for the UE applicable to the AN; and one or more associated conditions for the $AMER_{AN}$.

[0118] The one or more third parameters may comprise, directly, the AMER or $AMER_{AN}$. However, in some embodiments a derived AMER or derived $AMER_{AN}$ may be provided. Such a derived AMER or derived $AMER_{AN}$ is calculated by, for instance, the third network entity based on other parameters as discussed herein. Put differently, the ‘derived’ values are calculated by a network entity.

[0119] In some embodiments, the one or more associated conditions comprise at least one of: one or more frequency bands; an Access Type; a Quality of Service (QoS) type or classifier (which may be a 5QI or QCI); and an associated service area (i.e., list of cells, AN node IDs, TAIs).

[0120] In some embodiments, the $AMER_{AN}$ for the UE is defined by Equation 1.

[0121] In some embodiments, the derived AMER is based on at least one of: a subscribed AMER for the UE, received by the third network entity; a local configuration of the third network entity; and an analytics information received by the third network entity (i.e., from an NWDAF).

[0122] In some embodiments, the at least one processor coupled with the at least one memory is further configured to cause the network entity to: store, the one or more third parameters comprising the energy-related service restriction information, as a context information for the UE. The context information may also be referred to herein as ‘UE context’.

[0123] In some embodiments, the at least one processor coupled with the at least one memory is further configured to cause the network entity to: receive a first notification indicating that the one or more third parameters comprising energy related service restriction information no longer apply or have been updated; and optionally transmit, to the first network entity, a request for the first network entity to delete or update the one or more first parameters comprising the energy related service restriction information for the UE for enforcement in the AN.

[0124] In some embodiments, the network entity i.e., the AMF, may also update the context information for the UE by removing or updating the one or more third parameters stored.

[0125] In some embodiments, the third network entity is a PCF, optionally an AM-PCF.

[0126] In some embodiments, the at least processor coupled with the at least one memory is further configured to cause the network entity to: determine a trigger event for enforcement, in the AN, of an energy-related service restriction corresponding to the one or more first parameters.

[0127] In some embodiments, the network entity determines the trigger event by causing the network entity to receive a second notification of the trigger event from either: the third network entity; or a fourth network entity of the wireless communication system, wherein the fourth network entity is optionally a charging function (CHF) entity or a network data analytics function (NWDAF) entity.

[0128] In some embodiments, the trigger event comprises at least one of: a maximum energy consumption being reached; and a maximum energy credit limit being reached.

[0129] In some embodiments, the third network entity may determine based on a local configuration that a trigger event has occurred. The third network entity may be triggered by another network function or OAM, for instance. The maximum energy consumption or energy credit limit being reached may be specific to an area or service or network slice. The notification of the maximum energy credit limit being reached may come from a CHF, for instance. The notification of the maximum energy credit limit being reached may come from analytics provided by an NWDAF indicating the credit limit has been or will be reached. The network entity may be subscribed for such trigger events in advance.

[0130] In some embodiments, the at least one processor coupled with the at least one memory is configured to cause the network entity to transmit the one or more first parameters in response to: an indication of the UE transferring from a configuration management (CM) Idle state to a CM connected state; or an indication the UE is currently in the CM connected state.

[0131] In some embodiments the network entity is an AMF. In some embodiments the first network entity is an AN entity of the AN.

[0132] The disclosure herein further provides a method in a network entity, comprising: determining, one or more first parameters comprising energy-related service restriction information for a UE for enforcement in an AN of a wireless communication system; and transmitting, to a first network entity of the wireless communication system, the one or more first parameters for enforcement in the AN.

[0133] In some embodiments, the method comprises: receiving, from a second network entity, one or more second parameters comprising subscribed energy related information for the UE.

[0134] In some embodiments, the method comprises: transmitting, to the second network entity, a first request for subscription information for the UE; and receiving the one or more second parameters in response to the first request. The first request may comprise an identifier for the UE such as a SUPI.

[0135] In some embodiments, the second network entity is a (UDM) entity.

[0136] In some embodiments, the one or more second parameters comprise at least one of: an indication that the UE is enabled for energy related service restrictions; a value for a subscribed aggregated maximum energy rate (AMER) or reduced UE-aggregated maximum bit rate (AMBR) for the UE; a service type or access type to which the subscribed energy related information applies (i.e., best effort services, non-GBR services, non-mission critical services, or 3GPP access type or non-3GPP access type); and a network slice to which the subscribed energy related information applies (i.e., as identified by S-NSSAI or DNN).

[0137] In some embodiments, the method comprises: determining, based at least partly on the one or more second parameters, the one or more first parameters.

[0138] In some embodiments, during a policy association establishment procedure, the one or more second parameters comprising the subscribed energy related information for the UE may be provided to a PCF.

[0139] In some embodiments, the method comprises: receiving, from a third network entity of the wireless communication system, one or more third parameters comprising energy-related service restriction information for the UE; and determining the one or more first parameters, based at least partly on the one or more third parameters.

[0140] In some embodiments, the one or more third parameters comprise at least one of: a derived aggregated maximum energy rate (AMER) for the UE applicable to the AN and to a core network of the wireless communication system; a derived AMERAN for the UE applicable to the AN only; an identifier for the UE (i.e., the identifier may be a SUPI); an AMERAN for the UE applicable to the AN; and one or more associated conditions for the AMERAN.

[0141] In some embodiments, the one or more associated conditions comprise at least one of: one or more frequency bands; an access type; a Quality of Service (QoS) type or classifier (which may be a 5QI or QCI); and an associated service area (i.e., list of cells, AN node IDs, TAIs).

[0142] In some embodiments, the AMERAN for the UE is defined by Equation 1.

[0143] In some embodiments, the derived AMER is based on at least one of: a subscribed AMER for the UE, received by the third network entity; a local configuration of the third network entity; and an analytics information received by the third network entity (i.e., from an NWDAF).

[0144] In some embodiments, the method comprises: storing, the one or more third parameters comprising the energy-related service restriction information, as a context information for the UE.

[0145] In some embodiments, the method comprises: receiving a first notification indicating that the one or more third parameters comprising energy related service restriction information no longer apply or have been updated; and optionally transmitting, to the first network entity, a request for the first network entity to delete or update the one or more first parameters comprising the energy related service restriction information for the UE for enforcement in the AN.

[0146] In some embodiments, the network entity i.e., the AMF, may also update the context information for the UE by removing or updating the one or more third parameters stored.

[0147] In some embodiments, the third network entity is a PCF, optionally an AM-PCF.

[0148] In some embodiments, the method comprises: determining a trigger event for enforcement, in the AN, of an energy-related service restriction corresponding to the one or more first parameters.

[0149] In some embodiments, the determining the trigger event comprises receiving a second notification of the trigger event from either: the third network entity; or a fourth network entity of the wireless communication system, wherein the fourth network entity is optionally a charging function (CHF) entity or a network data analytics function (NWDAF) entity.

[0150] In some embodiments, the trigger event comprises at least one of: a maximum energy consumption being reached; and a maximum energy credit limit being reached.

[0151] Some embodiments comprise determining based on a local configuration that a trigger event has occurred. The third network entity may be triggered by another network function or OAM, for instance. The maximum energy consumption or energy credit limit being reached may be specific to an area or service or network slice. The notification of the maximum energy credit limit being reached may come from a CHF, for instance. The notification of the maximum energy credit limit being reached may come from analytics provided by an NWDAF indicating the credit limit has been or will be reached. The network entity may be subscribed for such trigger events in advance.

[0152] In some embodiments, the transmitting the one or more first parameters is performed in response to: an indication of the UE transferring from a configuration management (CM) Idle state to a CM connected state; or an indication the UE is currently in the CM connected state.

[0153] In some embodiments the network entity is an AMF.

[0154] In some embodiments the first network entity is an AN entity of the AN.

[0155] The disclosure herein further provides a UDM entity for wireless communication, comprising: at least one memory; and at least one processor coupled with the at least one memory and configured to cause the UDM entity to: store subscription information for a UE, wherein the subscription information comprises subscribed energy related information optionally comprising at least one of: an indication the UE is enabled for energy related service restrictions; a value for a subscribed AMER for the UE; a service type to which the subscribed energy related information applies (i.e., best effort services, non-GBR services, non-mission critical services); and a network slice to which the subscribed energy related information applies (i.e., as identified by S-NSSAI or DNN); and transmit, to a network entity, one or more second parameters comprising the subscribed energy related information.

[0156] The subscription information may be referred to herein as subscription data.

[0157] The network entity may be an AMF. The AMF may send a request message to the UDM to retrieve the UE subscription data (for instance using the SUPI as a reference identifier). The UDM may determine that the UE subscription information includes subscribed energy related information. The UDM may then send a response message to the AMF including the UE subscription information that includes the one or more second parameters comprising the subscribed energy related information. When the subscription information for the UE is updated (for instance after the UE registers in the wireless communication system/network) the UDM may send a notification message to the AMF indicating the updated information.

[0158] The disclosure herein further provides a method in an UDM entity, comprising: storing subscription information for a UE, wherein the subscription information comprises subscribed energy related information optionally comprising at least one of: an indication the UE is enabled for energy related service restrictions; a value for a subscribed AMER for the UE; a service type to which the subscribed energy related information applies (i.e., best effort services, non-GBR services, non-mission critical services); and a network slice to which the subscribed energy related information applies (i.e., as identified by S-NSSAI or

DNN); and transmitting, to a network entity, one or more second parameters comprising the subscribed energy related information.

[0159] The subscription information may be referred to herein as subscription data.

[0160] The network entity may be an AMF.

[0161] The disclosure herein further provides a PCF entity for wireless communication, comprising: at least one memory; and at least one processor coupled with the at least one memory and configured to cause the PCF entity to: determine one or more third parameters comprising energy-related service restriction information for a UE; and provide, to a network entity of a wireless communication system, the one or more third parameters. The one or more third parameters optionally comprise at least one of: a derived AMER for the UE applicable to the AN and to a core network of the wireless communication system; a derived $AMER_{AN}$ for the UE applicable to the AN only; an identifier for the UE (i.e., the identifier may be a SUPI); an $AMER_{AN}$ for the UE applicable to the AN only; and one or more associated conditions for the $AMER_{AN}$.

[0162] In some embodiments, the one or more associated conditions may comprise at least one of: one or more frequency bands; an access type; a QoS type or classifier (which may be a 5QI or QCI); and an associated service area (i.e., list of cells, AN node IDs, TAIs).

[0163] In some embodiments, the $AMER_{AN}$ for the UE may be defined by Equation 1.

[0164] In some embodiments, the derived AMER is based on at least one of: a subscribed AMER for the UE, received by the PCF entity; a local configuration of the PCF entity; a notification received by the PCF entity from a CHF entity; and an analytics information received by the PCF entity (i.e., from an NWDAF).

[0165] The disclosure herein further provides a method in a PCF entity, comprising: determining one or more third parameters comprising energy-related service restriction information for a UE; and providing, to a network entity of a wireless communication system, the one or more third parameters. The one or more third parameters optionally comprise at least one of: a derived AMER for the UE applicable to the AN and to a core

network of the wireless communication system; a derived $AMER_{AN}$ for the UE applicable to the AN only; an identifier for the UE (i.e., the identifier may be a SUPI); an $AMER_{AN}$ for the UE applicable to the AN only; and one or more associated conditions for the $AMER_{AN}$.

[0166] In some embodiments, the one or more associated conditions may comprise at least one of: one or more frequency bands; an access type; a QoS type or classifier (which may be a 5QI or QCI); and an associated service area (i.e., list of cells, AN node IDs, TAIs).

[0167] In some embodiments, the $AMER_{AN}$ for the UE may be defined by Equation 1.

[0168] In some embodiments, the derived $AMER$ is based on at least one of: a subscribed $AMER$ for the UE, received by the PCF entity; a local configuration of the PCF entity; a notification received by the PCF entity from a CHF entity; and an analytics information received by the PCF entity (i.e., from an NWDAF).

[0169] The disclosure herein further provides an AN entity in an AN of a wireless communication system, comprising: at least one memory; and at least one processor coupled with the at least one memory and configured to cause the AN entity to: receive, from a network entity of the wireless communication system, one or more first parameters comprising energy-related service restriction information for a UE for enforcement in the AN; and enforce, in the AN, one or more energy-related service restrictions based on the one or more first parameters.

[0170] In some embodiments, the one or more first parameters are based at least partly on one or more third parameters comprising energy-related service restriction information for the UE.

[0171] In some embodiments, the one or more third parameters comprise at least one of: a derived aggregated maximum energy rate ($AMER$) for the UE applicable to the AN and to a core network of the wireless communication system; a derived $AMER_{AN}$ for the UE applicable to the AN only; an identifier for the UE (i.e., the identifier may be a SUPI); an $AMER_{AN}$ for the UE applicable to the AN; and one or more associated conditions for the $AMER_{AN}$.

[0172] In some embodiments, the energy-related service restrictions comprises limiting an energy consumed for data transmission in downlink to the UE to the $AMER_{AN}$ for the UE.

[0173] In some embodiments, the energy-related service restrictions comprise at least one of: reducing a bitrate; utilizing an alternative scheduling strategy; utilizing a different frequency band.

[0174] The disclosure herein further provides a method in an AN entity in an AN of a wireless communication system, comprising: receiving, from a network entity of the wireless communication system, one or more first parameters comprising energy-related service restriction information for a UE for enforcement in the AN; and enforcing, in the AN, one or more energy-related service restrictions based on the one or more first parameters.

[0175] In some embodiments, the one or more first parameters are based at least partly on one or more third parameters comprising energy-related service restriction information for the UE.

[0176] In some embodiments, the one or more third parameters comprise at least one of: a derived aggregated maximum energy rate (AMER) for the UE applicable to the AN and to a core network of the wireless communication system; a derived $AMER_{AN}$ for the UE applicable to the AN only; an identifier for the UE (i.e., the identifier may be a SUPI); an $AMER_{AN}$ for the UE applicable to the AN; and one or more associated conditions for the $AMER_{AN}$.

[0177] In some embodiments, the energy-related service restrictions comprises limiting an energy consumed for data transmission in downlink to the UE to the $AMER_{AN}$ for the UE.

[0178] In some embodiments, the energy-related service restrictions comprise at least one of: reducing a bitrate; utilizing an alternative scheduling strategy; utilizing a different frequency band.

[0179] The disclosure herein further provides a charging function (CHF) entity in a wireless communication system, comprising: at least one memory; and at least one processor coupled with the at least one memory and configured to cause the CHF entity to: collect energy related charging data for a UE for a predetermined time period; determine if the collected energy related charging data exceeds a predetermined energy credit limit; and if so: transmit, to a network entity of the wireless communication system, a notification that the predetermined energy credit limit has been exceeded.

[0180] In some embodiments, the network entity comprises an AMF.

[0181] The disclosure herein further provides method in a CHF entity in a wireless communication system, comprising: collecting energy related charging data for a UE for a predetermined time period; determining if the collected energy related charging data exceeds a predetermined energy credit limit; and if so: transmitting, to a network entity of the wireless communication system, a notification that the predetermined energy credit limit has been exceeded.

[0182] In some embodiments, the network entity comprises an AMF.

[0183] Certain novel aspects of the disclosure pertain to the enforcement of energy-related policy for a subscriber in a wireless communication system. An AMF is provided that receives a first indication including energy-related service restriction information for a UE. The AMF transmits a second indication to an AN entity of the wireless communication system comprising energy-related service restriction information for the UE for enforcement in the AN.

[0184] Furthermore, a UDM is provided for storing in a UE subscription information a 'subscribed energy-related information' comprising at least one of: the UE is enabled for service restriction due to energy consumption; the value of the aggregated maximum energy rate to be enforced for the UE (e.g., a UE-AMER) when a service restriction event occurs. The UDM is also configured for transmitting the subscription information for energy-related policy to an AMF.

[0185] The disclosure herein provides a method of a first network function (e.g., an AMF), the method comprising the following steps: receiving a first indication including

energy-related service restriction information for a UE; storing the energy-related service restriction information in a UE context, wherein the AMF may locally store or derive service restriction information to be enforced in the AN when the first indication is received; and transmitting a second indication to an Access Network (AN) entity, wherein the second indication comprises the energy-related service restriction information to be enforced in the AN.

[0186] In some embodiments, the first indication is received from at least one of an AM-PCF. In some embodiments, the energy-related service restriction information includes the maximum aggregated energy rate (with different granularities) to be enforced in the access network (AN) entity.

[0187] In some embodiments, the first indication is received from at least one of an NWDAF, CHF or ECF. In some embodiments, the AMF determines the energy-related service restriction information to include a maximum energy consumption rate (UE-AMER) associated with granularity (with different granularities) to be enforced in the access network (AN) entity.

[0188] Some embodiments further comprise receiving a notification from the AN including information about the applicability of the service restriction.

[0189] Some embodiments further comprise receiving subscribed energy-related information (e.g., prior to receiving the first indication) that the UE is enabled for service restriction due to energy consumption.

[0190] Optionally the subscribed energy-related information may include a value for a maximum aggregated energy rate for the UE.

[0191] In some embodiments, the AMF transmits the subscribed energy-related information to the PCF during the policy association establishment.

[0192] Some embodiments further comprise receiving an update message which removes or updates the energy-related service restriction information.

[0193] Upon removing the energy-related service restriction information, the AMF may delete (in the UE context) the energy-related service restriction information to be enforced

in the AN. Furthermore, the AMF may send an indication to the AN to delete the energy-related service restriction information to be enforced in the AN.

[0194] Figure 3 illustrates an example of a UE 300 in accordance with aspects of the present disclosure. The UE 300 may include a processor 302, a memory 304, a controller 306, and a transceiver 308. The processor 302, the memory 304, the controller 306, or the transceiver 308, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. These components may be coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces.

[0195] The processor 302, the memory 304, the controller 306, or the transceiver 308, or various combinations or components thereof may be implemented in hardware (e.g., circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), or other programmable logic device, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure.

[0196] The processor 302 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, an ASIC, an FPGA, or any combination thereof). In some implementations, the processor 302 may be configured to operate the memory 304. In some other implementations, the memory 304 may be integrated into the processor 302. The processor 302 may be configured to execute computer-readable instructions stored in the memory 304 to cause the UE 300 to perform various functions of the present disclosure.

[0197] The memory 304 may include volatile or non-volatile memory. The memory 304 may store computer-readable, computer-executable code including instructions when executed by the processor 302 cause the UE 300 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such the memory 304 or another type of memory. Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that may be accessed by a general-purpose or special-purpose computer.

[0198] In some implementations, the processor 302 and the memory 304 coupled with the processor 302 may be configured to cause the UE 300 to perform one or more of the functions described herein (e.g., executing, by the processor 302, instructions stored in the memory 304). For example, the processor 302 may support wireless communication at the UE 300 in accordance with examples as disclosed herein. The UE 300 may be a UE 220 of Figure 2. The UE 300 may be configured to support a means for performing aspects of the methods disclosed herein.

[0199] The controller 306 may manage input and output signals for the UE 300. The controller 306 may also manage peripherals not integrated into the UE 300. In some implementations, the controller 306 may utilize an operating system such as iOS®, ANDROID®, WINDOWS®, or other operating systems. In some implementations, the controller 306 may be implemented as part of the processor 302.

[0200] In some implementations, the UE 300 may include at least one transceiver 308. In some other implementations, the UE 300 may have more than one transceiver 308. The transceiver 308 may represent a wireless transceiver. The transceiver 308 may include one or more receiver chains 310, one or more transmitter chains 312, or a combination thereof.

[0201] A receiver chain 310 may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receiver chain 310 may include one or more antennas for receive the signal over the air or wireless medium. The receiver chain 310 may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receiver chain 310 may include at least one demodulator configured to demodulate the receive signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receiver chain 310 may include at least one decoder for decoding the processing the demodulated signal to receive the transmitted data.

[0202] A transmitter chain 312 may be configured to generate and transmit signals (e.g., control information, data, packets). The transmitter chain 312 may include at least one modulator for modulating data onto a carrier signal, preparing the signal for transmission over a wireless medium. The at least one modulator may be configured to support one or more techniques such as amplitude modulation (AM), frequency modulation (FM), or

digital modulation schemes like phase-shift keying (PSK) or quadrature amplitude modulation (QAM). The transmitter chain 312 may also include at least one power amplifier configured to amplify the modulated signal to an appropriate power level suitable for transmission over the wireless medium. The transmitter chain 312 may also include one or more antennas for transmitting the amplified signal into the air or wireless medium.

[0203] Figure 4 illustrates an example of a processor 400 in accordance with aspects of the present disclosure. The processor 400 may be an example of a processor configured to perform various operations in accordance with examples as described herein. The processor 400 may include a controller 402 configured to perform various operations in accordance with examples as described herein. The processor 400 may optionally include at least one memory 404, which may be, for example, an L1/L2/L3 cache. Additionally, or alternatively, the processor 400 may optionally include one or more arithmetic-logic units (ALUs) 406. One or more of these components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g., buses).

[0204] The processor 400 may be a processor chipset and include a protocol stack (e.g., a software stack) executed by the processor chipset to perform various operations (e.g., receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) in accordance with examples as described herein. The processor chipset may include one or more cores, one or more caches (e.g., memory local to or included in the processor chipset (e.g., the processor 400) or other memory (e.g., random access memory (RAM), read-only memory (ROM), dynamic RAM (DRAM), synchronous dynamic RAM (SDRAM), static RAM (SRAM), ferroelectric RAM (FeRAM), magnetic RAM (MRAM), resistive RAM (RRAM), flash memory, phase change memory (PCM), and others).

[0205] The controller 402 may be configured to manage and coordinate various operations (e.g., signaling, receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) of the processor 400 to cause the processor 400 to support various operations in accordance with examples as described herein. For example, the controller 402 may operate as a control unit of the

processor 400, generating control signals that manage the operation of various components of the processor 400. These control signals include enabling or disabling functional units, selecting data paths, initiating memory access, and coordinating timing of operations.

[0206] The controller 402 may be configured to fetch (e.g., obtain, retrieve, receive) instructions from the memory 404 and determine subsequent instruction(s) to be executed to cause the processor 400 to support various operations in accordance with examples as described herein. The controller 402 may be configured to track memory address of instructions associated with the memory 404. The controller 402 may be configured to decode instructions to determine the operation to be performed and the operands involved. For example, the controller 402 may be configured to interpret the instruction and determine control signals to be output to other components of the processor 400 to cause the processor 400 to support various operations in accordance with examples as described herein. Additionally, or alternatively, the controller 402 may be configured to manage flow of data within the processor 400. The controller 402 may be configured to control transfer of data between registers, arithmetic logic units (ALUs), and other functional units of the processor 400.

[0207] The memory 404 may include one or more caches (e.g., memory local to or included in the processor 400 or other memory, such RAM, ROM, DRAM, SDRAM, SRAM, MRAM, flash memory, etc. In some implementations, the memory 404 may reside within or on a processor chipset (e.g., local to the processor 400). In some other implementations, the memory 404 may reside external to the processor chipset (e.g., remote to the processor 400).

[0208] The memory 404 may store computer-readable, computer-executable code including instructions that, when executed by the processor 400, cause the processor 400 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. The controller 402 and/or the processor 400 may be configured to execute computer-readable instructions stored in the memory 404 to cause the processor 400 to perform various functions. For example, the processor 400 and/or the controller 402 may be coupled with or to the memory 404, the processor 400, the controller 402, and the memory 404 may be

configured to perform various functions described herein. In some examples, the processor 400 may include multiple processors and the memory 404 may include multiple memories. One or more of the multiple processors may be coupled with one or more of the multiple memories, which may, individually or collectively, be configured to perform various functions herein.

[0209] The one or more ALUs 406 may be configured to support various operations in accordance with examples as described herein. In some implementations, the one or more ALUs 406 may reside within or on a processor chipset (e.g., the processor 400). In some other implementations, the one or more ALUs 406 may reside external to the processor chipset (e.g., the processor 400). One or more ALUs 406 may perform one or more computations such as addition, subtraction, multiplication, and division on data. For example, one or more ALUs 406 may receive input operands and an operation code, which determines an operation to be executed. One or more ALUs 406 be configured with a variety of logical and arithmetic circuits, including adders, subtractors, shifters, and logic gates, to process and manipulate the data according to the operation. Additionally, or alternatively, the one or more ALUs 406 may support logical operations such as AND, OR, exclusive-OR (XOR), not-OR (NOR), and not-AND (NAND), enabling the one or more ALUs 406 to handle conditional operations, comparisons, and bitwise operations.

[0210] The processor 400 may support wireless communication in accordance with examples as disclosed herein. The processor 400 may be configured to or operable to support a means for performing aspects of the methods disclosed herein.

[0211] Figure 5 illustrates an example of a NE 500 in accordance with aspects of the present disclosure. The NE 500 may include a processor 502, a memory 504, a controller 506, and a transceiver 508. The processor 502, the memory 504, the controller 506, or the transceiver 508, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. These components may be coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces.

[0212] The processor 502, the memory 504, the controller 506, or the transceiver 508, or various combinations or components thereof may be implemented in hardware (e.g.,

circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), or other programmable logic device, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure.

[0213] The processor 502 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, an ASIC, an FPGA, or any combination thereof). In some implementations, the processor 502 may be configured to operate the memory 504. In some other implementations, the memory 504 may be integrated into the processor 502. The processor 502 may be configured to execute computer-readable instructions stored in the memory 504 to cause the NE 500 to perform various functions of the present disclosure.

[0214] The memory 504 may include volatile or non-volatile memory. The memory 504 may store computer-readable, computer-executable code including instructions when executed by the processor 502 cause the NE 500 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such the memory 504 or another type of memory. Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that may be accessed by a general-purpose or special-purpose computer.

[0215] In some implementations, the processor 502 and the memory 504 coupled with the processor 502 may be configured to cause the NE 500 to perform one or more of the functions described herein (e.g., executing, by the processor 502, instructions stored in the memory 504). For example, the processor 502 may support wireless communication at the NE 500 in accordance with examples as disclosed herein. The NE 500 may be an AN 230, an AMF 240, a UDR/UDM 250, a PCF 260, a CHF 270, an NWDAF 280, for instance of Figure 2. The NE 500 may be configured to support a means for performed the methods or aspects of the methods disclosed herein.

[0216] The controller 506 may manage input and output signals for the NE 500. The controller 506 may also manage peripherals not integrated into the NE 500. In some implementations, the controller 506 may utilize an operating system such as iOS®,

ANDROID®, WINDOWS®, or other operating systems. In some implementations, the controller 506 may be implemented as part of the processor 502.

[0217] In some implementations, the NE 500 may include at least one transceiver 508. In some other implementations, the NE 500 may have more than one transceiver 508. The transceiver 508 may represent a wireless transceiver. The transceiver 508 may include one or more receiver chains 510, one or more transmitter chains 512, or a combination thereof.

[0218] A receiver chain 510 may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receiver chain 510 may include one or more antennas for receive the signal over the air or wireless medium. The receiver chain 510 may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receiver chain 510 may include at least one demodulator configured to demodulate the receive signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receiver chain 510 may include at least one decoder for decoding the processing the demodulated signal to receive the transmitted data.

[0219] A transmitter chain 512 may be configured to generate and transmit signals (e.g., control information, data, packets). The transmitter chain 512 may include at least one modulator for modulating data onto a carrier signal, preparing the signal for transmission over a wireless medium. The at least one modulator may be configured to support one or more techniques such as amplitude modulation (AM), frequency modulation (FM), or digital modulation schemes like phase-shift keying (PSK) or quadrature amplitude modulation (QAM). The transmitter chain 512 may also include at least one power amplifier configured to amplify the modulated signal to an appropriate power level suitable for transmission over the wireless medium. The transmitter chain 512 may also include one or more antennas for transmitting the amplified signal into the air or wireless medium.

[0220] Figure 6 illustrates a flowchart of a method 600 in accordance with aspects of the present disclosure. The operations of the method may be implemented by a NE as described herein. In some implementations, the NE may execute a set of instructions to control the function elements of the NE to perform the described functions.

[0221] At 610, the method may include determining, one or more first parameters comprising energy-related service restriction information for a UE for enforcement in an AN of a wireless communication system. The operations of 610 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 610 may be performed by a NE as described with reference to Figure 5.

[0222] At 620, the method may include transmitting, to a first network entity of the wireless communication system, the one or more first parameters for enforcement in the AN. The operations of 620 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 620 may be performed by a NE as described with reference to Figure 5.

[0223] It should be noted that the method described herein describes a possible implementation, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible.

[0224] Figure 7 illustrates a flowchart of a method 700 in accordance with aspects of the present disclosure. The operations of the method may be implemented by a NE as described herein. In some implementations, the NE may execute a set of instructions to control the function elements of the NE to perform the described functions.

[0225] At 710, the method may include storing subscription information for a UE, wherein the subscription information comprises subscribed energy related information. The operations of 710 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 710 may be performed by a NE as described with reference to Figure 5.

[0226] At 720, the method may include transmitting, to a network entity, one or more second parameters comprising the subscribed energy related information. The operations of 720 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 720 may be performed by a NE as described with reference to Figure 5.

[0227] It should be noted that the method described herein describes a possible implementation, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible.

[0228] Figure 8 illustrates a flowchart of a method 800 in accordance with aspects of the present disclosure. The operations of the method may be implemented by a NE as described herein. In some implementations, the NE may execute a set of instructions to control the function elements of the NE to perform the described functions.

[0229] At 810, the method may include determining one or more third parameters comprising energy-related service restriction information for a UE. The operations of 810 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 810 may be performed by a NE as described with reference to Figure 5.

[0230] At 820, the method may include providing, to a network entity of a wireless communication system, the one or more third parameters. The operations of 820 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 820 may be performed by a NE as described with reference to Figure 5.

[0231] It should be noted that the method described herein describes a possible implementation, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible.

[0232] Figure 9 illustrates a flowchart of a method 900 in accordance with aspects of the present disclosure. The operations of the method may be implemented by a NE as described herein. In some implementations, the NE may execute a set of instructions to control the function elements of the NE to perform the described functions.

[0233] At 910, the method may include receiving, from a network entity of the wireless communication system, one or more first parameters comprising energy-related service restriction information for a UE for enforcement in the AN. The operations of 910 may be performed in accordance with examples as described herein. In some implementations,

aspects of the operations of 910 may be performed by a NE as described with reference to Figure 5.

[0234] At 920, the method may include enforcing, in the AN, one or more energy-related service restrictions based on the one or more first parameters. The operations of 920 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 920 may be performed by a NE as described with reference to Figure 5.

[0235] It should be noted that the method described herein describes a possible implementation, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible.

[0236] Figure 10 illustrates a flowchart of a method 1000 in accordance with aspects of the present disclosure. The operations of the method may be implemented by a NE as described herein. In some implementations, the NE may execute a set of instructions to control the function elements of the NE to perform the described functions.

[0237] At 1010, the method may include collecting energy related charging data for a UE for a predetermined time period. The operations of 1010 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1010 may be performed by a NE as described with reference to Figure 5.

[0238] At 1020, the method may include determining if the collected energy related charging data exceeds a predetermined energy credit limit. The operations of 1020 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1020 may be performed by a NE as described with reference to Figure 5.

[0239] At 1030, the method may include, if the collected energy related charging data exceeds the predetermined energy credit limit: transmitting, to a network entity of the wireless communication system, a notification that the predetermined energy credit limit has been exceeded. The operations of 1030 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1030 may be performed by a NE as described with reference to Figure 5.

[0240] It should be noted that the method described herein describes a possible implementation, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible.

[0241] The description herein is provided to enable a person having ordinary skill in the art to make or use the disclosure. Various modifications to the disclosure will be apparent to a person having ordinary skill in the art, and the generic principles defined herein may be applied to other variations without departing from the scope of the disclosure. Thus, the disclosure is not limited to the examples and designs described herein but is to be accorded the broadest scope consistent with the principles and novel features disclosed herein.

[0242] The following abbreviations are relevant in the field addressed by this document: 5GC /5GS, 5 Generation Core network / 5 Generation System; AAA, Authentication, Authorization, and Accounting; AF, Application Function; AMER, Aggregated maximum energy rate; AMF, Access and Mobility Management Function; AN, Access network; AS, Application Server; BS, Base Station; CN, Core network; EC, Energy Consumption; ECF, Energy Consumption function; ECL, Energy credit limit; eNB, Evolved Node-B; EPC/EPS, Evolved packet core / Evolved packet system; gNB, 5G Node-B; ID, Identity; IE, Information Element; LSI-SL, localized service information for network selection; LTE, Long Term Evolution; NAS, Non Access Stratum; MM, Mobility Management; MO, Mobile Originated; MRU, Mobility Registration Update; MT, Mobile Terminated; NEF, Network Exposure Function; NF, Network Function; NR, New Radio; NRF, Network Repository Function; NS, Network Slice; NWDAF, Network Data Analytics Function; OAM, Operations, Administration and Management; PCF, Policy Control Function; PDU, Protocol Data Unit; (H/V)PLMN, (Home/Visited) Public Land Mobile Network; , ; RAN, Radio Access Network; RAT, Radio Access Technology/Type; RPI, Reject Paging Indication; RRU, Radio Remote Unit; SF, Sensing Function; S-NSSAI, Single Network Slice Selection Assistance Information; SM, Session Management ; SMF, Session Management Function; SNPN, Standalone Non-Public Network; SUPI, Subscription Permanent Identifier; TA, Tracking area; TRP, Transmit-Receive Points; UDM, Unified Data Management; UDR, Unified Data Repository; UE, User Equipment; UMTS, Universal Mobile Telecommunication System; UPF, User Plane Function; USIM,

Universal subscriber identity module; and (E)-UTRAN, (Evolved) Universal Terrestrial Radio Access Network.

[0243] The following references are incorporated in their entirety herein: The3GPP Specification TS 22.261, V18.4.0, 2022-09, titled “Service requirements for the 5G system”; the 3GPP Specification TS 23.501, v17.2.0, 2022-09, titled “System Architecture for the 5G System”; the 3GPP Specification TS 23.502, v17.2.0, 2022-09, titled “Procedures for the 5G System”.

CLAIMS

What is claimed is:

1. A network entity for wireless communication, comprising:
at least one memory; and
at least one processor coupled with the at least one memory and configured to cause the network entity to:
determine, one or more first parameters comprising energy-related service restriction information for a user equipment 'UE' for enforcement in an access network 'AN' of a wireless communication system; and
transmit, to a first network entity of the wireless communication system, the one or more first parameters for enforcement in the AN.
2. The network entity of claim 1, wherein the at least one processor coupled with the at least one memory is further configured to cause the network entity to:
receive, from a second network entity, one or more second parameters comprising subscribed energy related information for the UE.
3. The network entity of claim 2, wherein the at least one processor coupled with the at least one memory is further configured to cause the network entity to:
transmit, to the second network entity, a first request for subscription information for the UE; and
receive the one or more second parameters in response to the first request.
4. The network entity of any one of claims 2-3, wherein the second network entity is a Unified Data Management 'UDM' entity.
5. The network entity of any one of claims 2-4, wherein the one or more second parameters comprise at least one of:
an indication that the UE is enabled for energy related service restrictions;

a value for a subscribed aggregated maximum energy rate ‘AMER’ or reduced UE-aggregated maximum bit rate ‘AMBR’ for the UE;

a service type or access type to which the subscribed energy related information applies or; and

a network slice to which the subscribed energy related information applies.

6. The network entity of any one of claims 2-5, wherein the at least one processor coupled with the at least one memory is further configured to cause the network entity to:
determine, based at least partly on the one or more second parameters, the one or more first parameters.

7. The network entity of any preceding claim, wherein the at least one processor coupled with the at least one memory is further configured to cause the network entity to:
receive, from a third network entity of the wireless communication system, one or more third parameters comprising energy-related service restriction information for the UE;
and
determine the one or more first parameters, based at least partly on the one or more third parameters.

8. The network entity of claim 7, wherein the one or more third parameters comprise at least one of:
a derived aggregated maximum energy rate ‘AMER’ for the UE applicable to the AN and to a core network of the wireless communication system;
a derived $AMER_{AN}$ for the UE applicable to the AN only;
an identifier for the UE;
an $AMER_{AN}$ for the UE applicable to the AN; and
one or more associated conditions for the $AMER_{AN}$.

9. The network entity of claim 8, wherein the one or more associated conditions comprise at least one of:
one or more frequency bands;

an access type;
a Quality of Service 'QoS' type or classifier; and
an associated service area.

10. The network entity of any one of claims 8-9, wherein the AMER for the UE is defined by the following Equation:

$$AMER_{AN} = \alpha \times AMER_{derived}$$

wherein ' α ' is a number between 0 and 1.

11. The network entity of any one of claims 8-10, wherein the derived AMER is based on at least one of:

a subscribed AMER for the UE, received by the third network entity;
a local configuration of the third network entity; and
an analytics information received by the third network entity.

12. The network entity of any one of claims 7-11, wherein the at least one processor coupled with the at least one memory is further configured to cause the network entity to:
store, the one or more third parameters comprising the energy-related service restriction information, as a context information for the UE.

13. The network entity of any one of claims 7-12, wherein the at least one processor coupled with the at least one memory is further configured to cause the network entity to:
receive a first notification indicating that the one or more third parameters comprising energy related service restriction information no longer apply or have been updated; and optionally
transmit, to the first network entity, a request for the first network entity to delete or update the one or more first parameters comprising the energy related service restriction information for the UE for enforcement in the AN.

14. The network entity of any one of claims 7-13 wherein the third network entity is a PCF, optionally an AM-PCF.
15. The network entity of any preceding claim, wherein the at least processor coupled with the at least one memory is further configured to cause the network entity to:
 - determine a trigger event for enforcement, in the AN, of an energy-related service restriction corresponding to the one or more first parameters.
16. The network entity of claim 15, wherein the trigger event comprises at least one of:
 - a maximum energy consumption being reached; and
 - a maximum energy credit limit being reached.
17. The network entity of any preceding claim, wherein the at least one processor coupled with the at least one memory is configured to cause the network entity to transmit the one or more first parameters in response to:
 - an indication of the UE transferring from a configuration management 'CM' Idle state to a CM connected state; or
 - an indication the UE is currently in the CM connected state.
18. The network entity of any preceding claim, wherein:
 - the network entity is an AMF;
 - the first network entity is an AN entity of the AN.
19. A UDM entity for wireless communication, comprising:
 - at least one memory; and
 - at least one processor coupled with the at least one memory and configured to cause the UDM entity to:
 - store subscription information for a UE, wherein the subscription information comprises subscribed energy related information optionally comprising at least one of:
 - an indication the UE is enabled for energy related service restrictions;
 - a value for a subscribed AMER for the UE;

a service type to which the subscribed energy related information applies;
and

a network slice to which the subscribed energy related information applies;
transmit, to a network entity, one or more second parameters comprising the
subscribed energy related information.

20. A PCF entity for wireless communication, comprising:
at least one memory; and
at least one processor coupled with the at least one memory and configured to cause
the PCF entity to:
determine one or more third parameters comprising energy-related service
restriction information for a UE; and
provide, to a network entity of a wireless communication system, the one or more
third parameters;
wherein the one or more third parameters optionally comprise at least one of:
a derived AMER for the UE applicable to the AN and to a core network of
the wireless communication system;
a derived $AMER_{AN}$ for the UE applicable to the AN only;
an identifier for the UE;
an $AMER_{AN}$ for the UE applicable to the AN only; and
one or more associated conditions for the $AMER_{AN}$.