

ENFORCING POLICY FOR ENERGY CONSUMPTION FOR A SERVICE 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 service in a wireless communication system. This document defines a network entity, a unified data management entity, a policy control function entity, an access network entity, a charging function entity, and methods in a network entity, a unified data management entity, a policy control function entity, an access network entity, and a 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., 5G 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: receive, from a first network entity of a wireless communication system, one or more first parameters comprising energy-related restriction information for session management of a data session; determine, based at least partly on the one or more first parameters, one or more second parameters comprising energy-related restriction information for session management of the data session for enforcement in an access network (AN) of the wireless communication system; and transmit, to a second network entity of the wireless communication system, the one or more second parameters for enforcement in the AN.

[0006] There is provided a method in a network entity, comprising: receiving, from a first network entity of a wireless communication system, one or more first parameters comprising energy-related restriction information for session management of a data session; determining, based at least partly on the one or more first parameters, one or more second parameters comprising energy-related restriction information for session management of the data session for enforcement in an access network (AN) of the wireless communication

system; and transmitting, to a second network entity of the wireless communication system, the one or more second parameters for enforcement in the AN.

[0007] There is further provided a 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, wherein the subscription information comprises subscribed energy related information for session management of a data session, the subscribed energy related information optionally comprising: an indication that the data session is enabled for energy related service restrictions; a value for a subscribed aggregated maximum energy rate (AMER) for the data session; a service type to which the subscribed energy related information applies; and a network slice to which the subscribed energy related information applies; and transmit, to a network entity, one or more third parameters comprising the subscribed energy related information.

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

[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 first parameters comprising energy-related restriction information for session management of a data session; and provide, to a network entity of an AN of a wireless communication system, the one or more first parameters.

[0010] There is further provided a method in a PCF entity, comprising: determining one or more first parameters comprising energy-related restriction information for session

management of a data session; and providing, to a network entity of an AN of a wireless communication system, the one or more first parameters.

[0011] There is further provided an access network (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 second parameters comprising energy-related restriction information for session management of a data session in the AN; and enforce, in the AN, one or more energy-related restrictions for session management based on the one or more second 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 second parameters comprising energy-related restriction information for session management of a data session in the AN; and enforcing, in the AN, one or more energy-related restrictions for session management based on the one or more second 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 over a predetermined time period for session management; 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 over a predetermined time period for session management; 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 of signalling flow for enforcing policy for maximum EC for a data service traffic, 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 UE 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., to measure and to enforce policies associated with) 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 efficiency parameters as part of 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] The 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 (e.g., a network slice, DNN or traffic from a particular application or application server). 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 (e.g., a network slice, DNN or traffic from a particular application or application server). This can be described as an energy credit limit (ECL). The ECL is shared among all user (or subscribers of the network) using this service. The ECL can be measured in kilowatt hours (kWh). For example, the maximum ECL for a subscriber A can be 1000 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 ‘maximum energy consumption’. This is because the 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] The 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 service in a wireless communication system/network. When the network determines that restriction to a particular service (i.e. traffic associated with a network slice, DNN, QoS flow, or application) 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 restriction information’ for session management (SM) of a data session/service. 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 a session management function (SMF) which may then provide energy-related restriction information for SM of the data session/service 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 restriction information for a data session/service. 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 restrictions for session management of a data session/service.

[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 access 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, N1, N3, 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, N1, N3, 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 conventional solutions to enforce energy-related restrictions for session management of a data session/service.

[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 the Use Cases A and B occur, a wireless communication system/network may apply at least one of the following session restriction policies due to increased energy consumption: service restrictions for a data session (i.e., of a UE); and a different charging rate (e.g., higher charging) for the services (i.e., of the UE/subscriber). For the former, service restrictions may include, for example, the data traffic of a whole PDU session or specific QoS flow being restricted/gated. This can include one or more of: the data bitrate being reduced, or in general, decreased alternative QoS requirements may apply (which may be referred to herein as alternative reduced QoS requirements due to energy-related restrictions) – such a scenario corresponds to the ‘Service Restriction B’ discussed further below; or 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, which corresponds to the ‘Service Restriction A’ discussed further below. Regarding the application of a different charging rate, in such a case the network will continue to serve the UE with the same QoS level as before the event of Use Cases A or B occurring and the charging rate will be increased.

[0056] The disclosure herein further assumes that the service restriction/s apply to traffic from a 3rd party customer or a specific service (e.g., referred further as “service”

wherein the service is identified by traffic associated with one or more applications to/from application servers). When such a restriction applies (which may have temporary nature, i.e., applicable for a time duration until the EC limitations are lifted), the restrictions would reflect to restrictions to the handling of the traffic associated with the service. Such restrictions would affect one or more data Sessions (i.e., PDU Sessions) of a UE, or to part of a data Session (i.e., part of a PDU Session such as a QoS flow). The service itself may be associated with a network slice (identified by S-NSSAI, for instance), DNN, or a traffic filter which results to a QoS flow. The service restriction may apply either: to the best-effort traffic of the service; or to any QoS class of the service. 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] One main idea of the proposed solution is that a core network (CN) creates service restrictions and informs the access network (AN) 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. Example service restrictions will now be introduced.

[0058] A first example of a service restriction is referred to as ‘Service restriction A’. In this service restriction, limitations are applied 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. In one solution of this invention, such limitation of the transmission energy (or power) in the AN is called Session-AMER AN or QoS-flow-AMER AN and is enforced in the AN.

[0059] A further example of a service restriction is referred to as ‘Service restriction B’. In this service restriction, limitations are applied to the QoS characteristics/level/requirements/parameters/profile which are derived from the EC restrictions. This may be called alternative reduced QoS requirements due to energy-related

restrictions. The reduced QoS requirements may apply to a default QoS rule or other QoS rules of the PDU Session. It should be noted that a PDU Session contains one or more QoS flows (e.g. including a default QoS flow), wherein each QoS flow is identified by QoS Flow ID (QFI) and associated with a QoS rule and QoS profile. The QoS profile is a set of QoS parameters sent to the AN. For example, the reduced QoS requirements may include at least one of the following restrictions: reduction of the data bitrate (e.g., reduced Session AMBR for the uplink or downlink for the PDU Session or reduced Session MBR, or Guaranteed Flow Bit Rate (GFBR), or Maximum Flow Bit Rate (MFBR) of any of uplink and downlink traffic), or the data packet transmission delay (e.g. the packet delay budget) may be increased, or the data packet loss rate (i.e. the Maximum Packet Loss Rate for uplink or downlink data) may be increased (i.e., more packet losses are acceptable). The alternative reduced QoS requirements, applicable in situations of increased energy consumption in the network, are derived in the CN (e.g., SM-PCF or SMF) and configured in the user plane, i.e., in the anchor UPF and/or RAN.

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

[0061] The disclosure herein provides an SMF. The SMF receives an indication from the CN (e.g., SM-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 SM-PCF itself may have determined the ‘service restriction information to be enforced in the AN’ based on information locally configured in the SM-PCF or received from NWDAF or CHF.

[0063] The SMF sends ‘service restriction information to be enforced in the AN’ (e.g., an AMER AN) to the AN entity for enforcement, e.g., on per Access Type basis (in case of an MA-PDU Session).

[0064] The SMF may receive enhanced PDU Session Subscription data including subscribed energy-related information. The SMF may store such information and use it during: a SM policy association establishment with the SM-PCF; and/or as 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] The disclosure here provides an SM-PCF or an SMF that determines whether to apply Service Restriction A or B (described above). Then the SM-PCF or SMF configure correspondingly the UP resource for how to transmit the data of the associated service for which the EC restrictions apply.

[0066] Figure 2 illustrates an example 200 of signalling flow for enforcing policy for maximum EC for a data service traffic (i.e., traffic of a specific service), in accordance with aspects of the present disclosure. The data service traffic may map to a whole PDU Session or a QoS flow of the PDU Session. It is assumed that the service restrictions are applied for the user plane (UP) traffic. The energy-related service restriction is 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.

[0067] 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 function may be responsible to collect and store EC information on a specific granularity, e.g., per UE or per network slice or per traffic of an application. Alternatively, the EC information may be collected and stored in an existing NF in the CN CP, e.g., in NWDAF or in CHF. For example, if EC information is collected on per 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 collect such information. Any of the beforehand mentioned NFs can be denoted as an ‘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 SM-PCF or to the SMF which is shown in step 206a or step 206c in Figure 2.

[0068] 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 identify the 3GPP based technology and the non-3GPP based technology.

[0069] The example 200 of Figure 2 will now be described in greater detail.

[0070] The example 200 shows a UE 220, a RAN 230, an AMF 240, a SMF 245, a UDR/UDM 250, a SM-PCF 260, a CHF 270 and an ECH/NWDAF 280. The various procedural steps/message flows 201a-209 will now be described.

[0071] In a first step 201a, the UDM/UDR 250 is enhanced to store SM Subscription data including PDU Session subscription information for energy-related policy restrictions. This information is referred as ‘subscribed SM energy-related information’ or ‘subscribed energy-related information for session management’ and may comprise at least one of: an indication that the PDU Session is subject to service restriction due to energy consumption, i.e., subject of EC control; the value of an aggregated maximum energy rate (AMER) to be enforced for the PDU Session (e.g., Session-AMER) when service restriction event occurs; the service type to which the ‘subscribed energy-related information’ applies. For example, the Session-AMER may apply to: best-effort services only; to non-GBR services; to any type of non-mission critical services; traffic associated with a particular application which maps to a particular QoS Flow ID; or to all services of the PDU Session. Further, the restrictions may apply to a certain network slice (e.g., identified by S-NSSAI) or DNN. In the example 200, it is shown that the ‘subscribed energy-related information’ may include parameters like “EC enabled” or a “ Session-AMER” value.

[0072] In the further step 201b, the UDM/UDR 250 may store, as part of the subscription data, ‘Application-level’ subscription data which is provisioned for a particular service, wherein the ‘service’ means traffic associated with one or more applications (e.g. identified by application identifier). Such ‘Application-level’ subscription data is used mainly by the PCF 260 (e.g., SM-PCF) to derive the policy control rules for a PDU Session on which the traffic of the application(s) will be carried. It is proposed that the ‘Application level’ subscription data is enhanced to include application-level energy-related information for SM i.e., a maximum energy consumption for a service or application traffic.

[0073] In the further step 201c, the CHF 270 (or another EC collecting NF, e.g., NWDAF or ECF) may be enhanced to be configured with an energy credit limit (ECL) as described in Use Case B. In such a case, the CHF 270 collects energy-related charging data for a time duration, e.g., on a daily, weekly or monthly basis. The CHF 270 monitors the current status of the collected EC data and compares with the maximum ECL. When the maximum ECL is reached, the CHF 270 can trigger step 205c as will be later described. The energy credit limit may apply: to the EC collected for any single UE's traffic for the service (e.g. QoS flow) or PDU Session, wherein it is identified by a certain network slice and/or DNN; or to the EC collected from all UEs using the service. The former is a UE-level ECL, whereas the latter is the EC used by all UEs together to transmit traffic to/from the certain service, i.e., it is a service-level ECL.

[0074] In the further step 202, the SM-PCF 260 may request the Application-level subscription data from the UDM/UDR 250 for a particular service. The Application-level subscription data is stored in the UDM/UDR 250 as described in step 201b. The SM-PCF 260 may receive the application-level energy-related information for the service. The application-level energy-related information may contain at least one of: a maximum energy consumption (rate) for the service, and an applicability level (e.g., for which QoS level). The step 202 refers to application-level energy-related information for the service as 'Subs. application-level energy-related information for SM'.

[0075] In further step 203, a UE 220 registers with the network. This is shown as UE 220, RAN 230, AMF 240, SMF 245 and UDM/UDR 250 performing a 'UE registration procedure'.

[0076] In a further step 204a, a PDU Session Establishment Request is provided by UE 220 to AMF 240. This may include S-NSSAI, DNN, and N1 SM container.

[0077] In a further step 204b, a N11 Session Establishment Request is provided by AMF 240 to SMF 245. This may include SUPI, and N1 SM container.

[0078] In a further step 204c, the SMF 245 requests the SM subscription data from the UDM 250. The UDM 250 determines as per step 201a that the SM subscription data includes 'subscribed SM energy-related information'. The UDM 250 sends a response

message including the SM subscription data which comprises the ‘subscribed energy-related information’. This is shown in step 204c as ‘SM Subscription data request/response (Subs. energy-related information for SM)’.

[0079] Examples of ‘subscribed energy-related information’ will now be introduced. One or more of the examples may be included in the subscribed energy-related information referred to in Figure 2.

[0080] A first example of subscribed energy-related information comprises an indication that the PDU session is enabled (i.e., allowed) for service restriction due to increased energy consumption. In other words, the PDU Session is allowed to be subject of EC control.

[0081] A further example of subscribed energy-related information comprises a value of the aggregated maximum energy rate to be enforced for the PDU Session (e.g., Session-AMER) when energy-related service restriction event occurs.

[0082] A further example of subscribed energy-related information comprises an alternative reduced QoS level (or QoS class or parameters for the default QoS flow) due to energy-related service restriction. This may include reduced bitrate, e.g., alternative reduced Session-AMBR, or alternative (e.g., increased) packet delay or an alternative packet loss rate. Please note that the “reduced Session-AMBR” is an additional parameter to the known Session-AMBR parameter associated with a PDU Session.

[0083] A further example of subscribed energy-related information comprises the service type or QoS class to which the ‘subscribed energy-related information’ applies. This is associated with the “Service Restriction B” scenario described herein. For example, the Session-AMER may apply to: best-effort services only (e.g., having a QCI = 9); or to any non-GBR services; or to any type of non-mission critical services; or to all services. It should be noted that the different service types are identified by a specific QoS flow ID (QFI) or QoS class ID (QCI) value.

[0084] In some alternative embodiments, the parameters described above for the ‘subscribed energy-related information’ may be (pre-)configured in the SMF 245 instead of being sent from the UDM 250 to the SMF 245.

[0085] When the SM subscription data is updated in the UDM 250 after the UE 220 has been registered in the network, then the UDM 250 sends a notification message to the SMF 245 including the updated information, which in this case may include the ‘subscribed SM energy-related information’.

[0086] In the further step 205a, the SMF 245 sends a request to establish a session management (SM) policy association establishment to the PCF 260 (e.g., SM-PCF). For this purpose the SMF may use the Npcf_SMPolicyControl_Create service operation. The SMF 245 includes at least the SUPI (as UE ID) and in addition the ‘subscribed SM energy-related information’ if provided in step 204b. In particular, the SMF 245 may indicate that the SM is subject to service restriction due to EC.

[0087] The SM-PCF 260 sends an SM policy association response message to the SMF 245. This message usually contains one or more policy rules (each with a corresponding traffic filter to identify the traffic from different applications or application servers) which apply to the traffic transmitted over the PDU Session. Each policy and charging control (PCC) rule may result in a different QoS flow within the PDU Session. In other words, one or more services (i.e., traffic to/from a particular application server identified by a traffic filter) may be provided within the PDU Session or data session, wherein each service may be mapped to a different QoS flow within the ‘data session’.

[0088] In case that the SM-PCF 260 determines that the energy consumption restriction has to be enforced (e.g., based on Use Cases A or B), the SM-PCF 260 may include ‘energy-related restriction information for SM’ also referred to herein as ‘energy-related service restriction information’. The energy-related service restriction information may include at least one of: a ‘Session-AMER’ applicable to both AN and CN; or a ‘Session-AMER AN’ which is applicable for the AN only. The SM policy association establishment request/response may comprise, specifically, a PCC rule such as to apply AMER per DNN, S-NSSAI, QoS, for instance. Further details about this step are described in step 206.

[0089] In the further step 205b, the SMF 245 sends a PDU Session establishment response message to the UE 220. This may include S-NSSAI, DNN, and N1 SM container. The response message from SMF 245 is shown as being provided to UE 220 via AMF 240.

[0090] If the PCF 260 has sent the ‘energy-related service restriction information’ in step 205a, then the SMF 245 can initiate the energy-related service restriction towards the AN (RAN 230) as will be described in step 207a.

[0091] Returning to step 205 and the determination to apply energy-related service restrictions, a first approach will be described with reference to steps 206a-206b of the example 200. For illustrative purposes this alternative is shown as ‘Alt X’.

[0092] In the further step 206a, at any point of time, the SM-PCF 260 may determine a trigger event notification to the SMF 245 that a service restriction due to a maximum EC being reached needs to apply. In one example, based on “Use Case A”, the SM-PCF 260 may be triggered by another network function (NF) or by an OAM system that a maximum EC value for a service 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 occurred 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 SM-PCF 260 may be triggered, e.g., by a CHF 270, that the energy credit limit (ECL) has been reached. In other words, the PCF 260 may determine either by itself based on a 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.

[0093] Based on any of these trigger events, the SM-PCF 260 may determine one or more ‘energy-related service restrictions’ which should apply. The SM-PCF 260 determines the policy to be enforced for energy-related service restriction i.e., whether to apply Service Restriction A or B (described above). Optionally, the SM-PCF 260 determines to which specific network area the service restriction may apply (e.g., when the UE 220 is in a certain location area). The SM-PCF 260 determines the ‘energy-related service restriction’ information based on one of the “Service restriction A” or “Service restriction B” as described above. This is shown in the example 200 as ‘Determine to activate EC limitation for the session/slice’.

[0094] In the case that the Service Restriction A is enforced, the SM-PCF 260 may calculate a derived Session-AMER (e.g., a derived AMER for the whole PDU Session) or

QoS-flow-AMER (e.g., a derived AMER for one or more QoS flows that are part of the PDU session). For such a calculation the SM-PCF 260 may use either: the received application-level energy-related information as in step 202; or based on a local configuration in the SM-PCF 260; or based on input from NWDAF 280 (e.g., created based on analytics). In addition, or as an alternative, the SM-PCF 260 may calculate/derive the AN part of the Session-AMER or the AN part of the QoS-flow-AMER to be enforced in the AN. For this purpose, the SM-PCF 260 may consider the average EC which has been spent or expected to be consumed in the CN. The SM-PCF 260 may apply Equation 1 or 2 below:

$$AMER_{\text{Session AN}} = \alpha \times (AMER_{\text{Session}})_{\text{derived}} \quad \text{Equation 1}$$

$$AMER_{\text{QoS AN}} = \alpha \times (AMER_{\text{QoS}})_{\text{derived}} \quad \text{Equation 2}$$

wherein ‘ α ’ is a number between 0 and 1, $AMER_{\text{Session AN}}$ and $AMER_{\text{QoS AN}}$ are the AN part of the Session-AMER and QoS-flow AMER respectively, $(AMER_{\text{Session}})_{\text{derived}}$ and $(AMER_{\text{QoS}})_{\text{derived}}$ are the derived Session-AMER and QoS-flow AMER respectively.

[0095] More specifically, the factor ‘ α ’ may be a value between 0.00 and 1.00, e.g., $\alpha = 0.70$ (or 70%). The factor ‘ α ’ may be locally configured in the PCF 260 or obtained from NWDAF 280 or by using other means.

[0096] In the further step 206b, the SM-PCF 260 sends the ‘energy-related restriction information for SM’ to the SMF 245. For example, the PCF may use the Npcf_AMPolicyControl_UpdateNotify service operation. For this purpose, the SM-PCF 260 sends an SM Policy Association update message or notification including the UE’s 220 SUPI and PDU Session ID, and energy-related restriction information for SM. The ‘energy-related restriction information for SM’ may comprise the Session-AMER AN or QoS-flow-AMER AN and the associated conditions where/when it is applicable (i.e., per DNN, S-NSSAI, per QoS etc). For example, the applicability conditions can be at least one of: one or more frequency bands, Access Type, QoS class 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).

[0097] Returning again to step 205 and the determination to apply energy-related service restrictions, a further approach will be described with reference to steps 206c of the example 200. For illustrative purposes this alternative is shown as Alt. Y (i.e., as an alternative to Alt. X).

[0098] In the step 206c, the SMF 245 may receive a trigger event notification that service restrictions due to EC need to be enforced. For this purpose, the SMF 245 may have subscribed for notification of such events in advance (it should be noted that the SMF subscription for such event is not shown in the example 200). The SMF 245 may receive a notification in one of a number of alternative scenarios. For example, a notification may be received from the CHF 270 via reference points N40. This may be applicable for Use Case B when the maximum ECL has been consumed. The CHF 270 may indicate to the SMF 245 that the maximum EC credit limit (for the service) is reached. As a further example, a notification may be received from the NWDAF 280 offering analytics or an Energy Consumption Function (ECF). The NWDAF 280 or ECF may indicate to the SMF 245 that the maximum EC credit limit (for the service) is reached. This is shown as “N40 Notification (max. EC credit reached)”.

[0099] Based on the notification, the SMF 245 determines to enforce energy-related service restriction. The SMF 245 may determine whether to apply “Service restriction A” or “Service restriction B”, e.g., based on local configuration in the SMF 245.

[0100] In the case that the Service Restrict A is determined, the SMF 245 may derive a ‘Session-AMER’ or the ‘Session-AMER AN’ to be enforced in the AN. For the calculation/derivation of the ‘Session-AMER’ or the ‘Session-AMER AN’ the SMF 245 may use a local configuration or input from NWDAF 280 and may apply the same or similar formulae of Equations 1 and 2.

[0101] In the case that the Service Restriction B is determined, the SMF 245 may derive an alternative reduce QoS profile as described already in step 206a. In some embodiments, such a reduced Session-AMBR value may be received from the UDM 250 as

described in step 204c as an alternative Session-AMBR value to be enforced in case that the event of service restriction due to maximum EC reached applies. The original Session-AMBR may still be kept in the UE context in the SMF 245.

[0102] Continuing now with the example 200 when either of Alt.X or Alt.Y alternatives are used, there is further step 207a. In this step the SMF 245 determines to enforce the policy for SM restriction (e.g., due to increased energy consumption) towards the Access Network (AN, e.g., NG-RAN 230 or non-3GPP AN). The SMF 245 stores the ‘energy-related restriction information for SM’ in the SM context. The SMF 245 enforces the ‘energy-related restriction information for SM’ when the SMF 245 sends the N2 SM container information to the AN entity (i.e., to RAN 230).

[0103] In the case of Service Restriction A, the SMF 245 sends the N2 SM container message to the AN entity (RAN 230) including the ‘energy-related restriction information for SM for the AN’ and the associated applicability/validity conditions. The ‘energy-related restriction information for SM for the AN’ may include the Session-AMER AN or QoS-flow-AMER AN. Put differently, the AMER *per level (DNN/S-NSSAI/QoS flow)* may be provided. This may be provided via AMF 240.

[0104] In the case of Service Restriction B, the SMF 245 sends the updated (i.e., reduced) QoS profile/parameters to the user plane entities (e.g., AN 230 and one or more UPFs). In other words, the SMF 245 sends a) the updated QoS uplink and/or downlink packet detection rule (PDR) and associated QoS parameters to the UPF (e.g., anchor UPF) via N4 reference point and b) the updated QoS profile to the AN entity 230 encapsulated in N2 SM container message. It is noted that the uplink and/or downlink Session-AMBR or MBR per QoS flow (e.g. for both GBR QoS Flows or Non-GBR QoS Flows) are enforced by the UPF (e.g. anchor UPF or Branching Point). In other words, the SMF 245 sends the reduced QoS requirements restrictions to the UPF. The signalling between the SMF 245 and UPF is not shown in Figure 2.

[0105] In addition, the SMF 245 may subscribe for notifications about the applicability of the ‘energy-related service restriction information for the AN’. The SMF 245 may indicate whether the AN (i.e., RAN 230) should measure the time duration or the amount of data transmitted under the energy-related restrictions.

[0106] In another embodiment, instead of sending the energy-related restriction information to the AN (i.e., RAN 230), the SMF 245 may determine to apply different charging rate for the data amount which is transmitted during the energy-related restriction. The SMF 245 may determine to apply different charging rate based on notification in one of steps 206b or 206c. For this purpose, the SMF 245 may indicate to the AN entity 230 via N2 SM container message 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 SMF 245 may indicate to the AN to ‘stop data counting due to energy-based charging’. The described AN behaviour applies to step 207b.

[0107] In another embodiment, when the policy for SM restriction (e.g. due to increased energy consumption) are lifted, i.e. the ‘energy-related restriction information for SM’ are not applicable any more, the SMF 245 needs to update or remove the Service Restriction A or Service Restriction B. In other words, the SMF 245 needs to remove the ‘energy-related restriction information for SM’ in the AN and/or UPF. For example, in case of Service Restriction B, the SMF 245 needs to update the QoS requirements in the AN and UPF to restore the QoS level for normal service (i.e., without energy-related restriction). The SMF 245 is notified to lift the ‘energy-related restriction information for SM’ either in step 206b or step 206c. Furthermore, it is noted that the SMF 245 may store in the PDU Session context both, the original policy rules (i.e., without energy-related restrictions) and the policy rules for ‘energy-related restriction information for SM’. The trigger of the removal of the ‘energy-related restriction information for SM’ and the corresponding signalling, e.g., in step 207b, is not shown in Figure 2.

[0108] In the further step 207b, the (supporting) AN entity (i.e., RAN 230) receives from the SMF 245 the ‘energy-related restriction information for SM for the AN’ associated with the validity/applicability conditions and stores the information in the SM context. The AN entity (RAN 230) enforces the Session-AMER AN or QoS-AMER AN for the associated service area (defined by list of cells or TAs) if available. The Session-AMER AN or QoS-AMER AN are applied for User Plane data transmissions, i.e., for the data radio bearers (DRBs) associated with the data/PDU Session.

[0109] The AN entity (RAN 230) may apply the UE-AMER AN in the following way: the AN entity (RAN 230) limits the energy consumed for the data transmissions in the DL up to the allowed Session-AMER AN. For example, the AN entity (RAN 230) 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 Session-AMER AN may be 100 W per time window (e.g., minute) which means that the AN entity (RAN 230) measures the transmission power for the DL data and continuously monitors whether the Session-AMER AN is reached. If the Session-AMER AN is reached, the AN entity (RAN 230) may stop transmitting data until the next time window. This may be performed when the UE 220 is in a ‘connected state’.

[0110] In addition, the SMF 245 may subscribe for notifications about the applicability of the ‘energy-related service restriction information for the AN’. The SMF 245 may indicate whether the AN (i.e., RAN 230) should measure the time duration or the amount of data transmitted under the energy-related restrictions.

[0111] In another embodiment, instead of sending the energy-related restriction information to the AN (i.e., RAN 230), the SMF 245 may determine to apply different charging rate for the data amount which is transmitted during the energy-related restriction. The SMF 245 may determine to apply different charging rate based on notification in one of steps 205b or 205c. For this purpose, the SMF may indicate to the AN entity 230 to start to measure the amount of data transmitted to/from the UE 220. Such indication may be called ‘start data counting due to energy-based charging’. When the energy-related restrictions do not apply anymore, the SMF 245 may indicate to the AN ‘stop data counting due to energy-based charging’.

[0112] In further step 207c, the AN entity 230 may inform the SMF 245 via N2 SM information container about the applicability of the restrictions due to EC limitation. The AN entity 230 may send an N2 SM Notification including the SUPI, the applied Session-AMER AN (or reduced Session-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).

[0113] In case that the AN entity 230 has received an 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 entity 230 sends an N2 SM notification to the SMF 245 about the amount of data transmitted to/from the UE 220 during that time/area. Alternatively, if the UE context in the AN is released, i.e., the UE 220 transits from RRC/CM Connected to RRC/CM Idle state, the AN entity 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. As the UE 220 provides an N2 SM Notification to SMF 245 via AMF 240. This may include a SUPI.

[0114] In a further step 208, the SMF 245 may store in the UE’s context the information received in step 207c. The SMF 245 may determine to send a Notification message to the SM-PCF 260 and/or to a CHF 270 in order to inform about the applicability of ‘energy-related SM restriction information’ for the PDU Session. The SM-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 206b or 206c may apply as well. For example, the SMF 245 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). The notification message may comprise an identifier for the RAN 230 and CN consumed energy per PDU-Session or QoF-flow.

[0115] In a further step 209, in some embodiments, the CHF 270 may apply different charging rate for the data amount or for the time duration when the ‘energy-related SM restriction information’ (e.g., the Session/QoS-AMER, or Session/QoS-AMER AN, or reduced Session AMBR) 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 would apply in the CHF 270, whereas if the energy-related restrictions apply, the charging rate applied in the CHF 270 may be lower (or higher) than the normal rate.

[0116] In addition to the above description, the SMF 245 may receive an update notification from SM-PCF 260 (as per step 206b) or from CHF 270 or ECF/NWDAF 280 (as per step 206c) that the energy-related restriction information for SM does not apply anymore, i.e., the energy-related restriction information for SM is deleted. Upon removing the energy-related restriction information for SM, the SMF 245 may update the PDU Session context by removing the energy-related restriction information for SM; and send a N2 SM container to the AN (i.e., RAN 230) to delete the energy-related restriction information for SM to be enforced in the AN.

[0117] A benefit of the solutions described herein, and more specifically the example 200 of Figure 2, is that a network operator tends to be enabled to apply energy-related service restrictions to a PDU Session or to one or more QoS flows of a PDU Session if Use Cases A and B occur. In particular, the CN CP (e.g., the SM-PCF and/or SMF) are able to determine the energy-related conditions and energy-related policies which has to apply to the traffic transmitted over the PDU Session (or one or more QoS flows).

[0118] 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: receive, from a first network entity of a wireless communication system, one or more first parameters comprising energy-related restriction information for session management of a data session; determine, based at least partly on the one or more first parameters, one or more second parameters comprising energy-related restriction information for session management of the data session for enforcement in an access network (AN) of the wireless communication system; and transmit, to a second network entity of the wireless communication system, the one or more second parameters for enforcement in the AN.

[0119] In certain use cases, a network operator may wish to monitor energy consumption of a service i.e., a network slice, DNN, or traffic from a particular application server (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.

[0120] 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 i.e., a network slice, DNN or traffic from a particular application server. This can be described as an energy credit limit that is shared among all users (or subscribers of a network) using the particular service or in the particular session. After the maximum energy credit limit is reached, the network operator may desire to limit the energy consumption or reduce the service level.

[0121] The network entity provides an entity through which a wireless communication system can enforce such energy-related session management restrictions. For example, the network entity may be an SMF receiving the one or more first parameters from a PCF (the first network entity) of a core network. The SMF can process the one or more first parameters (and other information) and provide the energy-relevant session management restriction information to a second network entity which may be an AN entity of the AN. The SMF can, therefore, enforce the required energy-related session management restriction information into the AN through the AN entity.

[0122] 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. Put differently, when a network determines that restrictions to particular services are required (i.e., to network slice, DNN, QoS flow) the disclosure herein tends to solve the problem of ‘how’ the network enforces the service restriction.

[0123] The one or more first parameters may be referred to herein as a ‘first indication’.

[0124] The one or more second parameters may be referred to herein as a ‘second indication’.

[0125] The energy-related restriction information for SM may be referred to herein as ‘energy related SM restriction information’.

[0126] The term ‘data session’ may also be referred to herein as a ‘data connection’. One or more services may be provided within a ‘data session’ wherein each service may be mapped to a different QoS flow within the ‘data session’.

[0127] 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 [UDM entity], one or more third parameters comprising subscribed energy related information for session management of the data session.

[0128] The subscribed energy related information for session management may be referred to herein as subscribed SM energy related information. Such information may be received at a more general level as part of SM subscription data.

[0129] 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 third network entity, a first request for subscription information for the data session; and receive the one or more third parameters in response to the first request.

[0130] In some embodiments, the one or more third parameters comprising subscribed energy related information for session management may be received prior to receiving the one or more first parameters.

[0131] The subscribed energy related information may include a value for a maximum aggregated energy rate applicable for the data session or for a QoS flow.

[0132] In some embodiments, the third network entity is a Unified Data Management (UDM) entity.

[0133] In some embodiments, the one or more third parameters comprise at least one of: an indication that the data session (i.e., a PDU session) is enabled for energy related service restrictions; a value for a subscribed aggregated maximum energy rate (AMER) for the data session; a service type to which the subscribed energy related information applies (for instance, best effort services, non-GBR services, non-mission critical services, a

particular application server traffic wherein all of the above may map to a particular QoS flow or QFI/QCI value); or all services; and a network slice to which the subscribed energy related information applies (i.e., identified by S-NSSAI or DNN).

[0134] 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 first network entity, during a policy association establishment procedure, the one or more third parameters comprising the subscribed energy related information for the data session; and/or determine, based at least partly on the one or more third parameters, the one or more second parameters.

[0135] In some embodiments, the at least one processor coupled with the at least one memory is configured to cause the network entity to determine a trigger event for enforcement, in the AN, of one or more energy-related session management restrictions corresponding to the one or more second parameters.

[0136] In some embodiments, the at least one processor coupled with the at least one memory is configured to cause the network entity to determine the trigger event by causing the network entity to receive a first notification of the trigger event from either: the first 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.

[0137] In some embodiments, the trigger event comprises at least one of: a maximum energy consumption being reached (i.e., for the data session, energy consumption in a specific area or specific service or network slice); and a maximum energy credit limit being reached (i.e., for the data session, for a service).

[0138] In some embodiments, the first network entity may determine based on a local configuration that a trigger event has occurred. The first 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 a data session, 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.

[0139] In some embodiments, the one or more first parameters comprises at least one of: an aggregated maximum energy rate for either the data session ($AMER_{session}$) or a QoS flow ($AMER_{QoS}$) that is applicable to the AN and to a core network of the wireless communication system; an aggregated maximum energy rate for the data session ($AMER_{sessionAN}$) or a QoS flow ($AMER_{QoSAN}$) that is applicable to the AN only; a derived $AMER_{session}$ or a derived $AMER_{QoS}$ that is applicable to the AN and to the core network of the wireless communication system; a derived $AMER_{sessionAN}$ or a derived $AMER_{QoSAN}$ that is applicable to the AN only; an identifier for a UE of the data session (i.e., a UE ID or SUPI); an identifier for the data session (i.e., PDU session ID); one or more associated conditions for application of the $AMER_{session}$, $AMER_{QoS}$, $AMER_{sessionAN}$, $AMER_{QoSAN}$; and one or more alternative reduced Session-aggregated maximum bit-rate (AMBR) values or QoS-flow AMBR values or derived versions thereof.

[0140] The one or more first parameters may comprise, directly, the AMER or AMER-AN for the data session or the QoS flow. 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 first network entity, based on other parameters as discussed herein. Put differently, the ‘derived’ values are calculated by a network entity.

[0141] In some embodiments, the one or more associated conditions comprise at least one of: one or more frequency bands; an Access Type; a QoS type/class- or classifier (i.e., 5QI, QCI); and an associated service area (i.e., list of cells, AN node IDs, TAIs).

[0142] In some embodiments, the $AMER_{SessionAN}$ and the $AMER_{QoSAN}$ are defined by Equations 1 and 2.

[0143] In some embodiments, the derived $AMER_{session}$ or derived $AMER_{QoS}$ are based on at least one of: an application-level energy related information received by the first network entity; a local configuration of the first network entity; and an analytics information received by the first network entity (i.e., from NWDAF).

[0144] 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 first parameters comprising the energy-related restriction information for session management as a context information for the data session.

[0145] The context information may be referred to herein as SM context information or PDU session context information.

[0146] In some embodiments, the at least one processor coupled with the at least one memory is configured to cause the network entity to: receive, from the first network entity, a second notification indicating that the one or more first parameters comprising energy related restriction information for session management no longer apply or have been updated; and optionally transmit, to the second network entity, a request for the second network entity to delete or update the one or more second parameters comprising the energy related restriction information for session management of the data session for enforcement in the AN.

[0147] In some embodiments, the network entity i.e., the SMF, may also update the context information for the data session by removing or updating the one or more first parameters stored.

[0148] In some embodiments, the at least one memory coupled with the at least one processor is further configured to cause the network entity to: receive, from the second network entity, a third notification indicating a time or date during which energy-related restrictions for session management apply in the AN.

[0149] In some embodiments the network entity is a Session Management Function (SMF).

[0150] In some embodiments, the first network entity is a Policy Control Function (PCF), optionally a SM-PCF.

[0151] In some embodiments, the second network entity is an AN entity of the AN.

[0152] The disclosure herein further provides a method in a network entity for wireless communication, comprising: receiving, from a first network entity of a wireless

communication system, one or more first parameters comprising energy-related restriction information for session management of a data session; determining, based at least partly on the one or more first parameters, one or more second parameters comprising energy-related restriction information for session management of the data session for enforcement in an access network (AN) of the wireless communication system; and transmitting, to a second network entity of the wireless communication system, the one or more second parameters for enforcement in the AN.

[0153] In some embodiments, the method comprises: receiving, from a third network entity [UDM entity], one or more third parameters comprising subscribed energy related information for session management of the data session.

[0154] In some embodiments, the method comprises: transmitting, to the third network entity, a first request for subscription information for the data session; and receiving the one or more third parameters in response to the first request.

[0155] In some embodiments, the method comprises receiving the one or more third parameters comprising subscribed energy related information for session management prior to receiving the one or more first parameters.

[0156] The subscribed energy related information may include a value for a maximum aggregated energy rate applicable for the data session or for a QoS flow.

[0157] In some embodiments, the third network entity is a Unified Data Management (UDM) entity.

[0158] In some embodiments, the one or more third parameters comprise at least one of: an indication that the data session (i.e., a PDU session) is enabled for energy related service restrictions; a value for a subscribed aggregated maximum energy rate (AMER) for the data session; a service type to which the subscribed energy related information applies (for instance, best effort services, non-GBR services, non-mission critical services, a particular application server traffic wherein all of the above may map to a particular QoS flow or QFI/QCI value); or all services; and a network slice to which the subscribed energy related information applies (i.e., identified by S-NSSAI or DNN).

[0159] In some embodiments, the method comprises: transmitting, to the first network entity, during a policy association establishment procedure, the one or more third parameters comprising the subscribed energy related information for the data session; and/or determining, based at least partly on the one or more third parameters, the one or more second parameters.

[0160] In some embodiments, the method comprises determining a trigger event for enforcement, in the AN, of one or more energy-related session management restrictions corresponding to the one or more second parameters.

[0161] In some embodiments, the method comprises determining the trigger event by causing the network entity to receive a first notification of the trigger event from either: the first 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.

[0162] In some embodiments, the trigger event comprises at least one of: a maximum energy consumption being reached (i.e., for the data session, energy consumption in a specific area or specific service or network slice); and a maximum energy credit limit being reached (i.e., for the data session, for a service).

[0163] In some embodiments, the first network entity may determine based on a local configuration that a trigger event has occurred. The first 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 a data session, 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.

[0164] In some embodiments, the one or more first parameters comprises at least one of: an aggregated maximum energy rate for either the data session ($AMER_{session}$) or a QoS flow ($AMER_{QoS}$) that is applicable to the AN and to a core network of the wireless

communication system; an aggregated maximum energy rate for the data session ($AMER_{sessionAN}$) or a QoS flow ($AMER_{QoSAN}$) that is applicable to the AN only; a derived $AMER_{session}$ or a derived $AMER_{QoS}$ that is applicable to the AN and to the core network of the wireless communication system; a derived $AMER_{sessionAN}$ or a derived $AMER_{QoSAN}$ that is applicable to the AN only; an identifier for a UE of the data session (i.e., a UE ID or SUPI); an identifier for the data session (i.e., PDU session ID); one or more associated conditions for application of the $AMER_{session}$, $AMER_{QoS}$, $AMER_{sessionAN}$, $AMER_{QoSAN}$; and one or more alternative reduced Session-aggregated maximum bit-rate (AMBR) values or QoS-flow AMBR values or derived versions thereof.

[0165] The one or more first parameters may comprise, directly, the AMER or AMER-AN for the data session or the QoS flow. 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 first network entity, based on other parameters as discussed herein. Put differently, the ‘derived’ values are calculated by a network entity.

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

[0167] In some embodiments, the $AMER_{SessionAN}$ and the $AMER_{QoSAN}$ are defined by Equations 1 and 2.

[0168] In some embodiments, the derived $AMER_{session}$ or derived $AMER_{QoS}$ are based on at least one of: an application-level energy related information received by the first network entity; a local configuration of the first network entity; and an analytics information received by the first network entity (i.e., from NWDAF).

[0169] In some embodiments, the method comprises: storing, the one or more first parameters comprising the energy-related restriction information for session management as a context information for the data session.

[0170] In some embodiments, the method comprises: receiving, from the first network entity, a second notification indicating that the one or more first parameters comprising energy related restriction information for session management no longer apply or have been

updated; and optionally transmitting, to the second network entity, a request for the second network entity to delete or update the one or more second parameters comprising the energy related restriction information for session management of the data session for enforcement in the AN.

[0171] In some embodiments, the network entity i.e., the SMF, may also update the context information for the data session by removing or updating the one or more first parameters stored.

[0172] In some embodiments, the method comprises: receiving, from the second network entity, a third notification indicating a time or date during which energy-related restrictions for session management apply in the AN.

[0173] In some embodiments the network entity is a Session Management Function (SMF).

[0174] In some embodiments, the first network entity is a Policy Control Function (PCF), optionally a SM-PCF.

[0175] In some embodiments, the second network entity is an AN entity of the AN.

[0176] 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, wherein the subscription information comprises subscribed energy related information for session management of a data session, the subscribed energy related information optionally comprising: an indication that the data session (i.e., a PDU session) is enabled for energy related service restrictions; a value for a subscribed aggregated maximum energy rate (AMER) for the data session; a service type to which the subscribed energy related information applies (i.e., best effort services, non-GBR services, non-mission critical services, a particular application server traffic that maps to a particular QoS flow, all services); and a network slice to which the subscribed energy related information applies (i.e., as identified by S-NSSAI or DNN); transmit, to a network entity, one or more third parameters comprising the subscribed energy related information.

[0177] The subscription information may be referred to herein as subscription data.

[0178] The UDM entity may store application-level subscription data that is enhanced to include a maximum energy consumption for the data session or for a service.

[0179] The network entity may be an SMF. The UDM may determine that the subscription information includes subscribed energy related information for session management. The UDM may then send a response message to the SMF including the subscription information that includes the one or more third parameters comprising the subscribed energy related information for session management. When the subscription information is updated in the UDM (for instance after the UE registers in the wireless communication system/network) the UDM may send a notification message to the SMF indicating the updated information.

[0180] The disclosure herein further provides a method in a UDM entity for wireless communication, comprising: storing subscription information, wherein the subscription information comprises subscribed energy related information for session management of a data session, the subscribed energy related information optionally comprising: an indication that the data session (i.e., a PDU session) is enabled for energy related service restrictions; a value for a subscribed aggregated maximum energy rate (AMER) for the data session; a service type to which the subscribed energy related information applies (i.e., best effort services, non-GBR services, non-mission critical services, a particular application server traffic that maps to a particular QoS flow, all services); and a network slice to which the subscribed energy related information applies (i.e., as identified by S-NSSAI or DNN); transmitting, to a network entity, one or more third parameters comprising the subscribed energy related information.

[0181] The subscription information may be referred to herein as subscription data.

[0182] The UDM entity may store application-level subscription data that is enhanced to include a maximum energy consumption for the data session or for a service.

[0183] The network entity may be an SMF. The UDM may determine that the subscription information includes subscribed energy related information for session management. The UDM may then send a response message to the SMF including the

subscription information that includes the one or more third parameters comprising the subscribed energy related information for session management. When the subscription information is updated in the UDM (for instance after the UE registers in the wireless communication system/network) the UDM may send a notification message to the SMF indicating the updated information.

[0184] 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 first parameters comprising energy-related restriction information for session management of a data session; and provide, to a network entity of an AN of a wireless communication system, the one or more first parameters.

[0185] In some embodiments, the one or more first parameters comprise at least one of: an aggregated maximum energy rate for either the data session ($AMER_{session}$) or a QoS flow ($AMER_{QoS}$) that is applicable to the AN and to a core network of the wireless communication system; an aggregated maximum energy rate for the data session ($AMER_{sessionAN}$) or a QoS flow ($AMER_{QoSAN}$) that is applicable to the AN only; a derived $AMER_{session}$ or a derived $AMER_{QoS}$ that is applicable to the AN and to the core network of the wireless communication system; a derived $AMER_{sessionAN}$ or a derived $AMER_{QoSAN}$ that is applicable to the AN only; an identifier for a UE of the data session (i.e., a UE ID or SUPI); an identifier for the data session (i.e., PDU session ID); one or more associated conditions for application of the $AMER_{session}$, $AMER_{QoS}$, $AMER_{sessionAN}$, $AMER_{QoSAN}$ or derived versions thereof; one or more alternative reduced Session-aggregated maximum bit-rate (AMBR) values or QoS-flow AMBR values; and one or more alternative QoS classes applicable during a service restriction of the data session due to increased energy consumption.

[0186] The one or more first parameters may comprise, directly, the AMER or AMER-AN for the data session or the QoS flow. 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 first network entity based on other parameters as discussed herein. Put differently, the ‘derived’ values are calculated by a network entity.

[0187] The one or more associated conditions comprise at least one of: one or more frequency bands; an Access Type; a QoS type/class- or classifier (i.e., 5QI, QCI); and an associated service area (i.e., list of cells, AN node IDs, TAIs).

[0188] The $AMER_{SessionAN}$ and the $AMER_{QoSAN}$ may be defined by Equations 1 and 2.

[0189] In some embodiments, the derived $AMER_{session}$ or derived $AMER_{QoS}$ are based on at least one of: an application-level energy related information received by the PCF entity; a local configuration of the PCF entity; and an analytics information received by the PCF entity (i.e., from NWDAF).

[0190] In some embodiments, the PCF entity may request application-level subscription data from a UDM entity for a particular service/data session. The PCF may receive said subscription data comprising application-level energy related information. This may contain a maximum energy consumption for the service/session and an applicability level (i.e., QoS level or class).

[0191] The disclosure herein further provides a method in a PCF entity for wireless communication, comprising: determining one or more first parameters comprising energy-related restriction information for session management of a data session; and providing, to a network entity of an AN of a wireless communication system, the one or more first parameters.

[0192] In some embodiments, the one or more first parameters comprise at least one of: an aggregated maximum energy rate for either the data session ($AMER_{session}$) or a QoS flow ($AMER_{QoS}$) that is applicable to the AN and to a core network of the wireless communication system; an aggregated maximum energy rate for the data session ($AMER_{sessionAN}$) or a QoS flow ($AMER_{QoSAN}$) that is applicable to the AN only; a derived $AMER_{session}$ or a derived $AMER_{QoS}$ that is applicable to the AN and to the core network of the wireless communication system; a derived $AMER_{sessionAN}$ or a derived $AMER_{QoSAN}$ that is applicable to the AN only; an identifier for a UE of the data session (i.e., a UE ID or SUPI); an identifier for the data session (i.e., PDU session ID); one or more associated conditions for application of the $AMER_{session}$, $AMER_{QoS}$, $AMER_{sessionAN}$, $AMER_{QoSAN}$ or derived versions thereof; one or more alternative reduced Session-aggregated maximum

bit-rate (AMBR) values or QoS-flow AMBR values; and one or more alternative QoS classes applicable during a service restriction of the data session due to increased energy consumption.

[0193] The one or more first parameters may comprise, directly, the AMER or AMER-AN for the data session or the QoS flow. 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 first network entity based on other parameters as discussed herein. Put differently, the ‘derived’ values are calculated by a network entity.

[0194] The one or more associated conditions comprise at least one of: one or more frequency bands; an Access Type; a QoS type/class- or classifier (i.e., 5QI, QCI); and an associated service area (i.e., list of cells, AN node IDs, TAIs).

[0195] The $AMER_{SessionAN}$ and the $AMER_{QoSAN}$ may be defined by Equations 1 and 2.

[0196] In some embodiments, the derived $AMER_{session}$ or derived $AMER_{QoS}$ are based on at least one of: an application-level energy related information received by the PCF entity; a local configuration of the PCF entity; and an analytics information received by the PCF entity (i.e., from NWDAF).

[0197] In some embodiments, the PCF entity may request application-level subscription data from a UDM entity for a particular service/data session. The PCF may receive said subscription data comprising application-level energy related information. This may contain a maximum energy consumption for the service/session and an applicability level (i.e., QoS level or class).

[0198] 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 second parameters comprising energy-related restriction information for session management of a data session in the AN; and enforce, in the AN, one or more energy-related restrictions for session management based on the one or more second parameters.

[0199] In some embodiments, the energy-related restrictions comprise limiting an energy consumed for data transmission in downlink to an AMER for the AN for the data session or for a QoS flow (i.e., for the associated service area).

[0200] In some embodiments, the energy-related restrictions comprise at least one of: reducing a bitrate; utilizing an alternative scheduling strategy; utilizing a different frequency band.

[0201] 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 second parameters comprising energy-related restriction information for session management of a data session in the AN; and enforcing, in the AN, one or more energy-related restrictions for session management based on the one or more second parameters.

[0202] In some embodiments, the energy-related restrictions comprise limiting an energy consumed for data transmission in downlink to an AMER for the AN for the data session or for a QoS flow (i.e., for the associated service area).

[0203] In some embodiments, the energy-related restrictions comprise at least one of: reducing a bitrate; utilizing an alternative scheduling strategy; utilizing a different frequency band.

[0204] 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 over a predetermined time period for session management; 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.

[0205] In some embodiments, the network entity comprises an SMF.

[0206] The disclosure herein further provides a method in a charging function (CHF) entity in a wireless communication system, comprising: collecting energy related charging data over a predetermined time period for session management; 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.

[0207] In some embodiments, the network entity comprises an SMF.

[0208] Certain novel aspects of the disclosure pertain to the enforcement of energy-related policy for a service in a wireless communication system. A SMF is provided that receives a first indication including energy-related restriction information for session management of a data session/service. The SMF transmits a second indication to an AN entity of the wireless communication system comprising energy-related restriction information for session management of a data session/service for enforcement in the AN.

[0209] Furthermore, a UDM/UDR is provided for storing in a SM subscription information a ‘subscribed energy-related information’ comprising at least one of: a data session/service is enabled for service restriction due to energy consumption; the value of the aggregated maximum energy rate to be enforced for the SM (e.g., Session-AMER) when a service restriction event occurs. The UDM/UDR is also configured for transmitting the subscription information for energy-related policy to the SMF. The UDR may also store an ‘Application level’ subscription data that is enhanced to include a maximum energy consumption for the data session/service.

[0210] The disclosure herein provides a method of a first network function (e.g., a SMF), the method comprising the following steps: receiving a first indication including energy-related SM restriction information; storing the energy-related SM restriction information in a PDU session context; and transmitting a second indication to an Access Network (AN) entity, wherein the second indication comprises the energy-related SM restriction information to be enforced in the AN.

[0211] In some embodiments the first indication is received from a SM-PCF and the energy-related SM restriction information includes a maximum energy consumption rate

associated with granularity (e.g., per session or per QoS flow) to be enforced in an access network (AN) entity.

[0212] In some embodiments, the first indication is received from at least one of a NWDAF, a CHF or an ECF. In some embodiments, the SMF determines the energy-related SM restriction information including a maximum energy consumption rate associated with granularity (e.g., per session or per QoS flow) to be enforced in an access network (AN) entity.

[0213] Some embodiments further comprise receiving a notification from the AN entity including information about the time or data during which the SM restriction applied in the AN.

[0214] Some embodiments further comprise receiving subscribed SM energy-related information (e.g., prior to receiving the first indication) that a device or data session or service is enabled for SM restriction due to energy consumption.

[0215] In some embodiments the subscribed SM energy-related information may include a value for maximum aggregated energy rate applicable for the session or the QoS flow.

[0216] Some embodiments further comprise receiving an update message to remove or update the energy-related SM restriction information.

[0217] In some embodiments, upon removing the energy-related SM restriction information, the SMF may delete the energy-related SM restriction information to be enforced in the AN and optionally send a N2 SM container to the AN to delete the energy-related SM restriction information to be enforced in the AN.

[0218] 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.

[0219] 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.

[0220] 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.

[0221] 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 as 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.

[0222] 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 herein.

[0223] 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.

[0224] 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.

[0225] 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 receiving 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 received 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 and processing the demodulated signal to receive the transmitted data.

[0226] 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.

[0227] 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).

[0228] 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).

[0229] 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.

[0230] 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.

[0231] The memory 404 may include one or more caches (e.g., memory local to or included in the processor 400) or other memory, such as 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).

[0232] 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.

[0233] 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.

[0234] 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 implementing aspects of the methods described herein.

[0235] 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.

[0236] 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.

[0237] 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.

[0238] 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 as 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.

[0239] 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 a RAN 230, an AMF 240, a SMF 245, a UDR/UDM 250, a SM-PCF 260, a CHF 270 or an ECF/NWDAF 280 of Figure 2. The NE 500 may be configured to support a means for performing aspects of the methods described herein.

[0240] 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.

[0241] 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.

[0242] 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 receiving 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 received 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 and processing the demodulated signal to receive the transmitted data.

[0243] 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.

[0244] 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.

[0245] At 610, the method may include receiving, from a first network entity of a wireless communication system, one or more first parameters comprising energy-related restriction information for session management of a data session. 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.

[0246] At 620, the method may include determining, based at least partly on the one or more first parameters, one or more second parameters comprising energy-related restriction information for session management of the data session for enforcement in an access network (AN) of the wireless communication system. 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.

[0247] At 630, the method may include transmitting, to a second network entity of the wireless communication system, the one or more second parameters for enforcement in the AN. The operations of 630 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 630 may be performed by a NE as described with reference to Figure 5.

[0248] 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.

[0249] 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.

[0250] At 710, the method may include storing subscription information, wherein the subscription information comprises subscribed energy related information for session management of a data session. 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.

[0251] At 720, the method may include transmitting, to a network entity, one or more third 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.

[0252] 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.

[0253] 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.

[0254] At 810, the method may include determining one or more first parameters comprising energy-related restriction information for session management of a data session. 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.

[0255] At 820, the method may include providing, to a network entity of an AN of a wireless communication system, the one or more first 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.

[0256] 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.

[0257] 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.

[0258] At 910, the method may include receiving, from a network entity of the wireless communication system, one or more second parameters comprising energy-related restriction information for session management of a data session 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.

[0259] At 920, the method may include enforcing, in the AN, one or more energy-related restrictions for session management based on the one or more second 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.

[0260] 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.

[0261] 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.

[0262] At 1010, the method may include collecting energy related charging data over a predetermined time period for session management. 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.

[0263] 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.

[0264] At 1030, the method may include 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.

[0265] 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.

[0266] 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.

[0267] 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; AMBR, Aggregated maximum bitrate; 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; PCC, Policy and charging control; PCF, Policy Control Function; PDU, Protocol Data Unit; PLMN, Public Land Mobile Network; HPLMN, Home Public Land Mobile Network; VPLMN, 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.

[0268] The following references are incorporated in their entirety herein: The 3GPP 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”; and the 3GPP Specification TS 23.502, v17.2.0, 2022-09, titled “Procedures for the 5G System”.