EXPOSING ENERGY CONSUMPTION INFORMATION IN COMMUNICATION NETWORK

TECHNICAL FIELD

The present disclosure relates to wireless communications, and more specifically to network entities and methods for exposing energy consumption information in a wireless communication network.

BACKGROUND

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)).

Wireless networks, e.g. 5GS as specified by 3GPP, are continuously being enhanced with new features to achieve higher transmission throughput (e.g. bitrates) and network flexibility. Often this results in the energy consumption in the network increasing and, with rising energy prices, the network operators may want to introduce new functionality to monitor the energy consumption on different levels.

There have been efforts 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, there are efforts 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.

SUMMARY

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.

Some implementations of the method and apparatuses described herein may further include a network entity comprising at least one memory and at least one processor coupled with the at least one memory. The processor is configured to cause the network entity to receive a first request for exposure of energy consumption related information including an energy consumption event identifier, and event filter information, select one of a Unified Data Management, UDM, function or a Network Repository Function, NRF, based on the energy consumption event identifier and/or event filter information, and transmit to the selected UDM function or NRF function a second request to identify an energy consumption collecting Network Function, NF. The processor is further configured to cause the network entity to receive a first response containing an identifier of an energy consumption collecting NF, and transmit a third request to the energy consumption collecting NF to subscribe for monitoring event notifications, the third request containing at least one of the energy consumption event identifier and the event filter information.

In some implementations of the method and apparatuses described herein, the energy consumption event identifier has a type identifying at least one of:

energy consumption status report;

energy consumption prediction report;

energy policy status;

energy credit limit status;

network performance information for a currently activated energy state; and

energy efficiency information.

The event filter information may define at least one of:

a UE-related filter, optionally per UE-level, per PDU Session level or per QoS flow level; and

a service-related filter, optionally per network slice level, per Session level, or per AF level.

The event filter information, or other information within the first request, may further define at least one of a per AN level filter, a CN level filter, and a per Access type level filter.

The processor may be configured to select a UDM if the event filter information defines a UE-related filter, the selected UDM serving a UE associated with the UE-related filter. The processor may be configured to select a NRF function if the event filter information defines a service-related filter, and to include in the second request a service ID. The processor may be configured to cause the network entity to operate, in use, as a Network Exposure Function, NEF, within a core network.

The processor may be further configured to cause the network entity to, receive a notification of an energy consumption event, and transmit the received notification.

The first request may be received on a first control plane interface, the second request may be transmitted on a second control plane interface, and the third request may be transmitted on a third control plane interface.

The first control plane interface may be a control plane interface to an Application Function, AF.

Some implementations of the method and apparatuses described herein may further include a network entity comprising at least one memory and at least one processor coupled with the at least one memory. The processor is configured to cause the network entity to collect energy consumption related information, receive a request to subscribe for monitoring event notifications associated with the collected energy consumption related information, the request containing at least one of an energy consumption event identifier and event filter information, and determine and store at least one monitoring event trigger based on the energy consumption event identifier and/or event filter information. The processor is further configured to cause the network entity to determine occurrence of a monitoring event trigger in the collected energy consumption related information, and transmit a notification of occurrence of the monitoring event trigger.

The collected energy consumption related information may be one of UE-related and service-related energy consumption related information.

The processor may be configured to cause the network entity to operate as one of:

an Energy Consumption Function;
a Charging Function;
a Policy Control Function; and
a Network Data Analytics Function.

The control plane interface may be an interface towards a second network entity operating as a Network Exposure Function, NEF.

The processor may be configured to send the notification over the control plane interface to a sender of the request, or over a second control plane interface to an Application Function.

Some implementations of the method and apparatuses described herein may further include a method performed by a network entity and comprising receiving a first request for exposure of energy consumption related information including an energy consumption event identifier, and event filter information. The method further comprises selecting one of a Unified Data Management, UDM, function or a Network Repository Function, NRF, based on the energy consumption event identifier and/or event filter information, transmitting to the selected UDM function or NRF function a second request to identify an energy consumption collecting Network Function, NF, receiving a first response containing an identifier of an energy consumption collecting NF, and transmitting a third request to the energy consumption collecting NF to subscribe for monitoring events, the third request containing at least one of the energy consumption event identifier and the event filter information.

The energy consumption event identifier has a type identifying at least one of:

energy consumption status report;
energy consumption prediction report;
energy policy status;
energy credit limit status;
network performance information for a currently activated energy state; and
energy efficiency information.

Some implementations of the method and apparatuses described herein may further include a method performed by a network entity and comprising collecting energy consumption related information, receiving a request to subscribe for monitoring event notifications associated with the collected energy consumption related information, the request containing at least one of an energy consumption event identifier and event filter information, and determining and storing at least one monitoring event trigger based on the energy consumption event identifier and/or event filter information. The method further comprises determining occurrence of a monitoring event trigger in the collected energy consumption related information, and transmitting a notification of occurrence of the monitoring event trigger.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates an example of a wireless communications system in accordance with aspects of the present disclosure;

Figure 2 illustrates a signalling flow according to an embodiment;

Figure 3 illustrates an example of a network equipment (NE) 200 in accordance with aspects of the present disclosure;

Figure 4 illustrates a flowchart of a method performed by a first NE in accordance with aspects of the present disclosure; and

Figure 5 illustrates a flowchart of a method performed by a second NE in accordance with aspects of the present disclosure.

DETAILED DESCRIPTION

New use cases and requirements for future networks include the development of an “energy as a service” framework which allows monitoring of the energy consumption within the network and to expose such information “as a service” to network customers or verticals. Currently, 5G networks do not have any means to expose the energy consumption or energy efficiency related information to the network customers or verticals.

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 new requirements for the “energy as a service” offered to the network customers, verticals or user and application service providers may include at least one of:

1) The network should be able to support energy efficiency parameters as part of a communication service. For example, the network operator may want to limit the energy (rate) consumed by a communication service or by a subscriber (e.g. UE).
2) The network should be able to provide information exposure on the energy consumption on different levels.

Embodiments presented here focus on requirement 2), i.e. the ability of the network to expose to an application function (AF), energy consumption on different levels. There may be the following use cases for which the energy consumption events may occur in the network:

Use case A: a network operator monitors the energy consumption (EC) of a service (e.g. a network slice, Data Network Name (DNN) or traffic from a particular application server). This is energy consumed in the network including Application Network (AN) and 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 maximum energy consumption rate (ECR). When the maximum ECR value is reached, the network may enforce specific policies to limit the further energy consumption. The network operator may expose such information to a customer (e.g. an application function, AF).

Use case B: 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 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. The network operator may expose such information to a customer (e.g. an application function, AF).

It is considered beneficial if the network can expose the EC information to an AF when any of the above use cases apply.

There are multiple levels/granularity for the EC information which is monitored (or measured), collected and stored in an EC collecting NF. Such levels/granularity of EC information may be exposed to the AF. The following granularity of EC information may be introduced:

a) Network slice level: the EC information of all traffic transmitted over a specific network slice.
b) Service level (or application level, or application function level): the EC information of all traffic transmitted to/from a specific application or group of applications.
c) UE level: the EC information of all traffic transmitted to/from a specific UE.
d) PDU session level: the EC information of all traffic transmitted over a specific PDU Session of a UE.
e) QoS flow level: the EC information of all traffic transmitted over a specific QoS flow of a UE.

The levels of granularity identified in a) and b) can be referred as service-related levels, since the EC information is collected for all traffic transmitted for a specific application or group of applications (e.g. in the latter case the group of applications can be served by a network slice). On the other hand, the levels of granularity identified in c), d) and e) can be referred as UE-related levels, since the EC information is available for the traffic transmitted for a UE, or PDU Session of a UE or QoS flow of a UE.

In addition, for each of the above identified levels/granularity of EC information, the EC information may be further collected and sub-categorized to the following sub-levels (or sub-granularity) of EC information:

i. Access Network (AN, or RAN) level: the EC information of any level of EC spent (or estimated) in the AN.
ii. Core Network (CN) level: the EC information of any level of EC spent (or estimated) in the CN.
iii. Access Type (AT) level: the EC information on any level of EC spent (or estimated) for a 3GPP AT or for non-3GPP AT.

In other words, for any level of EC information (e.g. network slice level, service level, UE level, etc.), the EC information can be further subdivided into AN part and CN part of EC information. In one example, the EC information of granularity ‘per UE’ can be collected from the start of the month, and may currently be, e.g. 10 KW, wherein:

- the AN part is 9 KW and the CN part is 1 KW; and
- the AT 3GPP can be 8 KW and the AT non-3GPP can be 2 KW.

The EC information may be stored in different NFs in the CN Control Plane (CP), e.g. 5GC. For example, the UE-related EC information (for various levels of EC information) may be collected in the Charging Function (CHF), whereas the service-related EC information (for various levels of EC information) may be collected in the Networks Analytics Function (NWDAF).

When a network (e.g. 5GC) receives a request (e.g. from an AF) for energy consumption (EC) information exposure for a specific granularity, for example on an N33 interface, it is not however clear how the network can internally find the appropriate NF which is able to provide the requested granularity of EC information. In other words, it is not clear which EC collecting NF should be selected to expose the EC information, as the EC information may be stored in various NFs.

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

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 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.

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.

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 112 associated with the same or different radio access technologies may overlap, but the different geographic coverage areas may be associated with different NE 102.

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.

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

An NE 102 may support communications with the CN 106, or with another NE 102, or both. For example, an NE 102 may interface with other NE 102 or the CN 106 through one or more backhaul links (e.g., S1, N2, 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).

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.

The CN 106 may communicate with a packet data network over one or more backhaul links (e.g., via an S1, N2, 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).

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.

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., μ=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., μ=0) associated with the first subcarrier spacing (e.g., 15 kHz) may utilize one slot per subframe. A second numerology (e.g., μ=1) may be associated with a second subcarrier spacing (e.g., 30 kHz) and a normal cyclic prefix. A third numerology (e.g., μ=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., μ=3) may be associated with a fourth subcarrier spacing (e.g., 120

kHz) and a normal cyclic prefix. A fifth numerology (e.g., μ=4) may be associated with a fifth subcarrier spacing (e.g., 240 kHz) and a normal cyclic prefix.

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.

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., μ=0, μ=1, μ=2, μ=3, μ=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., μ =0) associated with a first subcarrier spacing (e.g., 15 kHz) may be used interchangeably between subframes and slots.

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.

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., μ=0), which includes 15 kHz subcarrier spacing; a second numerology (e.g., μ=1), which includes 30 kHz subcarrier spacing; and a third numerology (e.g., μ=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., μ=2), which includes 60 kHz subcarrier spacing; and a fourth numerology (e.g., μ=3), which includes 120 kHz subcarrier spacing.

For the purpose of this description it is assumed that the network may use levels and sub-levels of EC information to support energy efficiency parameters as part of communication service. For example, the network operator may want to limit the energy consumption (rate) consumed by a communication service or by a subscriber (e.g. UE). It is further assumed that the EC information of any level (and sub-level) is stored in the core network (CN) control plane (CP).

Various different NFs may collect and store the EC information in the network (e.g. in the CN CP). The NF which collects and stores the EC information is referred as the “EC collecting NF”. For example, one EC collecting NF can collect and store UE-related EC information, e.g. per UE level, per PDU Session level and per QoS flow level EC information, and in one example such a EC collecting NF can be the CHF. In another example, one EC

collecting NF can collect and store service-related EC information, e.g. per network slice or per service level EC information, and in one example such an EC collecting NF can be a centralized NF in the CN CP (e.g. NWDAF or Energy Consumption Function (ECF)). NB. The ECF may be a new type of NF introduced in the CN CP where the EC data can be collected and stored, and wherein the ECF can store the collected EC data on per level and sub-level of granularity.

The consumer of the exposed EC information may be generalized as an application function (AF). The AF can be either an internal NF in the network or external to the network (e.g. belonging to a third party entity or vertical consumer).

Features of the proposed solution include the following.

The NF which collects and stores UE-related EC information (e.g. per UE, PDU Session or QoS flow) registers itself (as EC collecting NF) with the Unified Data Management (UDM) serving the UE. The NF which collects and stores UE-related EC information service-related EC information (e.g. per network slice or per AF) registers itself with the Network Repository Function (NRF).

The AF sends a request for EC information exposure, which may be formatted as a subscription to an event notification. The characteristics of the event are as follows:

1) The event identifier (event ID or event type) can be at least one of the following:
    i. Energy consumption status report;
    ii. Energy consumption policy status;
    iii. Energy credit limit status; or
    iv. network performance statistic information (e.g. the data rate, packet delay and packet loss) for the currently activated energy state.
2) The event filter can be one of the following:
    i. UE-related granularity, e.g. per UE-level, per PDU Session level or per QoS flow level; or

ii. Service-related granularity, e.g. per network slice level (e.g. identified by S-NSSAI), per Session level (e.g. identified by Service ID) or per AF level (e.g. identified by AF ID).

iii. One or more further filters, for example to further categorize the requested EC information, e.g. per AN level, CN level, or per Access type level.

3) The NEF, which receives the request from the AF, determines to resolve the EC collecting NF based on the event type or based on the event filter of the service exposure request.

i. If the Event Filter indicates UE-related data, the NEF resolves the EC collecting NF by requesting the UDM serving the UE.

ii. If the Event Filter indicates service-related data, the NEF resolves the EC collecting NF by requesting the NRF and including the application/service ID or S-NSSAI/DNN.

iii. If the Event ID indicates 'Energy credit limit status', the NEF resolves the EC collecting NF (e.g. CHF) by requesting the NRF and including the event filter information.

In one alternative or supplementary embodiment, the AF may send the request for EC information exposure directly to an EC collecting NF. For this purpose, the AF may need to be (pre-)configured with the NF identity of the EC collecting NF. Then the AF may use a service provided by the EC collecting NF to subscribe for the EC information exposure, e.g. the AF may use *Neccollectingnf_ECinformation_Subscribe* service operation.

Please note that the term "EC information exposure" is a general term used for both energy consumption (EC) information exposure and energy efficiency (EE) information exposure. In this disclosure mostly the energy consumption (EC) information exposure is used, but this does not preclude also exposure energy efficiency (EE) information.

Figure 2 shows a signalling flow for exposing EC information to an AF. It is assumed that the EC information may be collected and stored in two types of EC collecting NF, namely: 1) an EC collecting NF for UE-related data, and 2) an EC collecting NF for service-related data. Specifically, Figure 2 illustrates the following steps:

0. This step shows the phase of EC information collection in the network. The EC information may include either 1) EC information status report, 2) EC policy status information, or 3) energy credit limit status. The following types of EC collecting NF are assumed for the purspose of this disclosure:

0a: The EC collecting NF collects and stores UE-related EC information (e.g. per UE level, per PDU Session level and per QoS flow level EC information). Such an EC collecting NF can be the CHF.

0b: The EC collecting NF collects and stores service-related EC information (e.g. per network slice or per service level EC information). Such an EC collecting NF can be a centralized NF in the CN CP (e.g. NWDAF or ECF).

The 'EC collecting NF' is a term of the art and can be represented by one or more NFs. In one embodiment, a new NF called Energy Consumption (or Collection) Function (e.g. ECF) may be introduced in the CN CP. The ECF may be responsible for collecting and storing energy consumption information on any of the above mentioned granularities/levels, e.g. per UE or per network slice, etc. Alternatively, the EC information may be collected and stored in an existing NF in the CN CP, e.g. in NWDAF, in CHF or in PCF. In one example, if EC information is collected on a UE level, then the ECF or CHF may gather such information. In another example, if EC information is collected on a network slice level or for traffic associated with a specific application, then the ECF, NWDAF or CHF may collect such information. On the other hand, if the EC collecting NF is supposed to predict the EC information, then the NWDAF may be an appropriate NF to fulfil such task, as the NWDAF is able to provide prediction analytics.

The 'EC collecting NF' may be (pre-)configured with a maximum value or threshold for EC consumption data (e.g. called EC threshold) of a certain granularity, wherein the granularity means per UE, per network slice, per application traffic, etc. When the EC threshold is reached, the 'EC collecting NF' may trigger an event towards the NEF as shown in steps 9a, 9b and 9c.

1. The EC collecting NF for UE-related EC information registers itself with the UDM serving the UE. This means that the EC collecting NF needs to resolve the UDM where the UE is currently registered. Then, the EC collecting NF sends a registration request message to the UDM including at least one of: SUPI, NF ID, serving NF type (NF for EC collection), type of EC information (e.g. per UE, per PDU Session, per QoS flow).

2. The EC collecting NF for service-related EC information registers itself with an NRF serving the network slice or an NRF serving the network. The EC collecting NF sends a registration request message to the NRF including at least one of: NF ID, serving NF type (NF for EC collection), type of EC information collected at the NF (e.g. per network slice, per session, per application, per AF ID) and the associated identifier of the information (e.g. S-NSSAI, DNN, application ID, etc.). The EC collecting NF may also register with the Binding Support Function (BSF).

3. The AF sends a request message to subscribe for notifications for EC information. For example, the AF may use either an existing NEF SBI provided service and service operation (e.g. *Nnef_EventExposure* with Subscribe/Unsubscribe/Notify service operations) or a new NEF SBI provided service or service operation can be introduced (e.g. *Nnef_ECinformation* with Subscribe/Unsubscribe/Notify service operations) in order to subscribe for energy-related events.

For example, the AF may use the service operation *Nnef_EventExposure_Subscribe* or *Nnef_ECinformation_Subscribe* to create a new subscription for exposure of particular EC information, and the service operation may include at least one of: (one or more) Event ID(s), (one or more) Event Filters, (one or more) External Application Identifier(s), Event Reporting Information. The event IDs, event filters and Event Reporting Information are described further below.

The ‘target UE identifier(s)’ indicates the UE or UEs that the request is or are targeting, i.e. one or a list of individual UE(s), a group of UE represented by Internal Group Identifier(s), or any UE accessing the combination of DNN, S-NSSAI and DNAI(s). The ‘target UE

identifier(s)' may be in the form of Generic Public Subscription Identifier (GPSI) or external ID or external group ID. The 'target service identifier(s)' may identify the target traffic for which the EC information exposure applies. The target traffic may be identified by the combination of DNN and optionally S-NSSAI, and application identifier (application ID), application function ID or traffic filtering information.

The energy-related monitoring events are categorized by using event identifier (Event ID) or event type. The following Event ID (or event type) may be introduced:

a) Energy consumption status (report): this event ID means that the network (CN CP) exposes the currently collected EC information collected and stored in an EC collecting NF. For example, a network customer (e.g. represented by an AF) can request reports for the current EC status for a particular granularity and/or sub-granularity of EC information. When this event occurs, the network (e.g. EC collecting NF) sends a notification to the corresponding AF (e.g. alternatively via NEF), wherein the notification contains the current EC status report.
b) Prediction on energy consumption (report): this event ID means that the network (CN CP) exposes the EC information which is predicted to be consumed by the CN CP (e.g. 5GC). When this event occurs, the network (e.g. EC collecting NF) sends a notification to the corresponding AF (e.g. alternatively via NEF), wherein the notification contains the prediction or estimation of the EC, i.e. not the real value of the EC, as the real value may be difficult to measure.
c) Energy policy status: this Event ID describes whether a particular energy policy is enabled in the network. For example, a maximum energy rate may have been enabled in the network for a specific granularity of EC information. Please refer to the Use case A. When this event occurs, the network (e.g. EC collecting NF) sends a notification to the corresponding AF (e.g. alternatively via NEF), wherein the notification contains information indicating whether the maximum energy rate is enabled or disabled for the corresponding granularity, (e.g. described in the Event Filter parameters). If the maximum energy rate is enabled, the EC collecting NF may further include information indicating which particular maximum energy rate is

currently applied, if there are multiple possible energy rates (in which case the PCF or other NF may have determined the energy rate).

d) Energy credit limit status (or energy credit threshold reached): this Event ID describes whether a (pre-)configured maximum energy credit limit is reached in the network. Please refer to the Use case B above. This event may occur when 1) the maximum ECL is reached or 2) the consumed energy falls below the maximum ECL. The ECL or threshold may be also sent in this step 3 from the AF to the NEF to be configured as a monitoring threshold in the EC collecting NF. Further, this event ID may include further related input parameters regarding a policy information which is to be enforced, when the maximum ECL is reached. When this event occurs, the network (e.g. EC collecting NF) sends a notification to the corresponding AF (e.g. alternatively via NEF), wherein the notification contains the result that 1) the ECL has been reached and optionally the time point when it was reached or 2) the ECL is not anymore reached or is undergone and optionally the time duration for which the ECL applied.

e) Network performance information (e.g. the data rate, packet delay and packet loss) for the current activated energy state. For example, the network customer and the network operator may have agreed on different levels of energy-related service level agreements (SLAs) under different energy states of the network. In other words, different levels of QoS may have been configured for the same application/service ID and depending on the energy consumption in the network, the network (e.g. CN CP) can determine to use one of these QoS levels. This event ID is created at the CN CP and sent to the service consumer (e.g. AF) when the level of QoS is changed. The event ID may additionally include input parameters relating to the network performance statistics to be measured (e.g. the data rate, packet delay and packet loss). The reports may be sent either periodically or based on a change from one level to another level according to the Reporting information associated with this Event ID. When this event occurs, the network (e.g. EC collecting NF) sends a notification to the corresponding AF (e.g. alternatively via NEF), wherein the notification contains the network performance information (e.g. the data rate, packet delay and packet loss)

applied during the activated restriction due to increased energy consumption, and optionally the duration of the restriction or applicability of the event.

f) Energy efficiency (EE) information: it means the relation between a useful output (e.g. data amount) and energy consumption. It is assumed that the EC collecting NF can also provide the EE information. For this purpose, the EC collecting NF collects and stores both: the amount of data transmitted with a certain QoS level (e.g. QFI) and the corresponding EC information for this data. In other words, the EC collecting NF can collect the EE information for any QoS level traffic associated with a service ID, but also the EE information on per QoS level granularity. When this event occurs, the network (e.g. EC collecting NF) sends a notification to the corresponding AF (e.g. alternatively via NEF), wherein the notification contains the EE information according to the Event Filter.

For each of the above-mentioned Event IDs, the Event Filter information may be included. The Event Filter information describes the granularity and/or sub-granularity of EC information for any of the event IDs. At least one of the following Event Filters parameters may be introduced:

a) UE-related granularity, meaning that the EC information is associated with a UE ID. The UE-related granularity can be one of:
    - Per UE-level: the EC (or EE) information of all traffic transmitted to/from a specific UE.
    - Per PDU session level: the EC (or EE) information of all traffic transmitted over a specific PDU Session of a UE.
    - Per QoS flow level: the EC (or EE) information of all traffic transmitted over a specific QoS flow of a UE or of a PDU Session. Please note that a QoS flow may be associated with QFI and/or traffic filters corresponding to a specific application. In other words, this granularity of EC information expresses the EC consumed in the network to transmit the traffic of the application to the specific UE.

b) Service-related granularity, meaning that the EC (or EE) information is associated with a service ID (or application ID, S-NSSAI and/or DNN). The service-related granularity can be one of:
    - Per network slice level: the EC (or EE) information of all traffic transmitted over a specific network slice. This can be identified by S-NSSAI.
    - Per session/service level: the EC (or EE) information of all traffic transmitted to/from a specific application or group of applications. This can be identified by Service ID or application ID, or AF ID.
c) The event filter may have sub-sequent filters, for example to further categorize the requested EC information, e.g. per AN level, CN level, or per Access type level.

The parameters introduced in the Event Filter information are presented here merely as an example. Such parameters can be included in the message in step 3 as independent parameters, i.e. outside the Event Filter information.

For each of the above-mentioned Event IDs, Event Reporting information may be included. The Event Reporting information can be one of the following:

a) A period of time for which the information of the event ID is collected or predicted and exposed. For example, this can be the duration for which the EC information is collected or predicted, or the duration for which an event ID lasts (e.g. in case of event IDs “b)” or “c)”). For example, this can be defined as start time and end time (e.g. expressed in time of day, month, etc.)
b) A period of time for which the event ID should be monitored and exposed. In other words, this can be the validity of subscribed the event ID. For example, this can be defined as start time and end time (e.g. expressed in time of day, month, etc.)
c) A trigger value at which an event ID should be created and exposed. For example, the AF may request a maximum threshold value for the specific subscribed event ID. In one example of event ID “a)” or “b)” the trigger value may be set to an energy consumption threshold and if the threshold is reached then the EC collecting NF sends an event notification to the service consumer (e.g. AF).

d) A Periodic notification which includes the periodicity of the event notifications sent to the service consumer (e.g. AF).

In the case when the AF would like to modify an existing subscription, the AF may include Subscription Correlation ID and the parameters to be updated. The NEF may authorize and/or authenticate the request received by the AF. If the authentication and authorisation is successful, the NEF proceeds with steps 4 or 6 below.

In one alternative embodiment, the request for EC information exposure for UE-related granularity (i.e. the EC information is associated with a UE ID) may be sent in an independent request from the AF to the CN CP (e.g. NEF). Further, the request for EC information exposure for service-related granularity (i.e. the EC information is associated with a Service ID) is sent in an independent request from the AF to the CN CP (e.g. NEF). In other words, the 'target UE identifier(s)' and the 'target service identifier(s)' in the request message from the AF will identify the type of EC information exposure request. The NEF may determine that for the case when 'target UE identifier(s)' is used, the NEF needs to contact the UDM/UDR to retrieve the EC collecting NF ID. Furthermore, the NEC may determine that, for the case when 'target service identifier(s)' is used, the NEF needs to contact the NRF or Binding Support Function (BSF) to retrieve the EC collecting NF ID. In this alternative, the Event Filter information do not include the UE ID or service ID, but rather includes the sub-granularity of the EC information like either (a) per PDU Session level or per QoS level if the UE-related information is requested; or (b) per AN level, CN level, or per Access type level if service-level information is requested.

Alternative with UE-related EC information request:

4. The NEF determines to resolve the EC collecting NF: based on the event type; or based on the event filter; or based on the 'target UE identifier(s)' and the 'target service identifier(s)'. If the information received in step 3 (e.g. Event Filter information, or 'target UE identifier(s)') indicates UE-related data, the NEF resolves the EC collecting NF by requesting the UDM serving the UE.

The UDM replies with the EC collecting NF ID which fulfils the input criteria (e.g. ECF/CHF). The NEF uses the EC collecting NF ID in the request in step 5.

In one example, the request received in step 3 may include event ID “c)” and Event Filter set to UE ID (e.g. GPSI). The UDM may reply to the NEF with the CHF ID which collects the UE’s EC information. The NEF will then forward the request received in step 3 to the CHF ID.

5. The NEF sends a request to the EC collecting NF to subscribe for the (monitoring) event notification.

The NEF may send a Subscribe Request message for event notifications including at least one of: event ID, event filter information (one or more SUPIs, [per UE, per PDU Session, per QoS flow]), event reporting information, notification target address (e.g. NEF or AF), event threshold. The event ID, event filter information and event reporting information may be the same or similar to the description provided in step 3.

The ‘event threshold’ parameter may be included if the AF would like to configure a threshold for the event. For example, this may be appropriate in case of event ID “d)” from step 3 where the ECL can be configured in the EC collecting NF together with the request for the event ID.

The 'notification target address’ parameter indicates to which NF ID the notification message should be sent when the event occurs. For example, the 'notification target address’ may indicate 1) the NEF, which sends the request, or 2) an AF which sent the request in step 3, or any other AF ID or NF ID. This parameter allows the EC collecting NF to send the notification directly to an AF.

It is also possible that the NEF sends a subscribe request message for event notifications to the AMF, e.g. in case that the AMF collects specific EC information for a UE. In such a case, the AMF is acting as EC collecting NF.

The NEF may use an existing service and service operation to send the request message (e.g. in the case where an existing NF is used as EC collecting NF such as NWDAF, or CHF, or AMF). Alternatively, a new service and service operation may be introduced. For example, if a new NF like ECF is used as EC collecting NF, then the service operation may be called e.g. *Necf_Subscribe_Notify*.

If the NEF has already subscribed for notifications and the monitoring event(s) information needs to be updated (e.g. updated event filter information), the NEF sends a new subscribe request with the updated information. Alternatively, if the NEF has already subscribed for notifications and the NEF would like to stop the monitoring event(s), the NEF sends an unsubscribe request message to delete the monitoring configuration in the EC collecting NF.

The EC collecting NF processes the received request. This includes determining and storing one or more triggers matching the required events, i.e. based on the energy consumption event identifier and/or event filter information included in the request. The EC collecting NF may send a response message to the NEF that the request has been successfully processed and accepted. Alternatively, if the EC collecting NF cannot process or accept the request, the EC collecting NF may respond with a failure message, indicating the reason for failure to the NEF. Afterwards, the EC collecting NF creates an internal process for monitoring the subscribed event. The call flow continues with step 9a.

Alternative with service-related EC information request:

6. The NEF determines to resolve the EC collecting NF: based on the received event ID or based on the event filter, or based on the ‘target service identifier(s)’ received from step 3. If the information received in step 3 (e.g. the Event Filter information, or ‘target service identifier(s)’) indicates service-related data, the NEF resolves the EC collecting NF by sending a request to the NRF or BSF and including at least one of: the requested NF type (e.g. EC collecting NF) and input information derived from the event filter, e.g. S-NSSAI, application ID or the service ID; or the ‘target service identifier(s)’.

The NRF uses the input criteria/information (e.g. EC collecting NF type and S-NSSAI/or application ID) to resolve the NF providing the requested service. The NRF replies to the NEF with the EC collecting NF ID which fulfils the input criteria. For example, the NEF includes the ECF, CHF, or NWDAF ID. The NEF uses the EC collecting NF ID in the request in step 7.

7. The NEF sends a request to the resolved EC collecting NF to subscribe for the (monitoring) event notification. The NEF may send the Subscribe Request message for event notifications including at least one of: event ID, event filter [S-NSSAI, application ID, Service ID, AF ID], notification target address (e.g. NEF or AF). The event ID, event filter information and event reporting information may be same or similar as the description provided in step 3. The 'notification destination' parameter indicates to which NF the notification message has to be sent.

Further details (e.g. for update or unsubscribe of events, or reply from the EC collecting NF to the NEF) as described in step 5 also apply to step 7.

For both alternatives, the following steps are carried out.

8. The NEF sends a response to the AF in response to step 3. For example, the NEF may send a Subscribe Response message including the success or failure of the steps 4-7. If the NEF reports a failure to the AF, the NEF includes the reason for failure, e.g. due to failed authentication, or inability to serve the monitoring event currently or similar cause. The NEF may indicate also a time at which a new request may be sent from the AF.

9a. The EC collecting NF runs a monitoring process (i.e. maintain a state) according to the request from step 5 or step 7. The EC collecting NF creates a state/context for each of the requests from step 5 or step 4. When the event according to the subscription from step 5 or 7 occurs, then the EC collecting NF creates a notification message to the NEF/AF and includes the occurred event information.

The event occurrence is determined considering at least one of the following information:

a) The event information received in step 5 or step 7 and the determined and stored event triggers.
b) The EC data collected during step 0a or 0b.
c) Further measurements regarding the bitrate or QoS parameters which were used for data transmission during the energy-based restrictions or energy which corresponds to the network performance information (e.g. the data rate, packet delay and packet loss) for an activated energy state. Such information is relevant for the case of event ID described in bullet "e)" in step 3.
d) Internal (pre-)configuration in the EC collecting NF such as maximum ECL level. The pre-configured information can be related to different granularity, e.g. per UE, per S-NSSAI, or per traffic from a specific application ID (which may correspond to a service ID).
e) The EC collecting NF creates a notification message with a content corresponding to each of the different event IDs received in step 5 or step 7 and described in step 3.
f) The EC collecting NF creates a notification message according to the Event Reporting information received in step 5 or step 7 (which is described in step 3).

9b. For the UE-related EC information request, the EC collecting NF sends a notification message to the NF corresponding to the notification target address (e.g. NEF or AF). The content of the notification message corresponds to the event ID received in step 5 or step 7. The expected content of the notification message is described in step 3 for each of the Event IDs in bullet a) through e).

The EC collecting NF may use an existing service and service operation to send the notification message (e.g. in case where an existing NF is used as EC collecting NF such as NWDAF, or CHF, or AMF). Alternatively, a new service and service operation may be introduced. For example, if a new NF such as an ECF is used as EC collecting NF, then the service operation may be called, e.g. *Necf_EventExposure_Notify*.

9c. For the service-related EC information request, this step is carried out and is the same as step 9b, but the sending entity is a different EC collecting NF, namely one for collecting UE-related data.

9d. This step is the same as step 9b, but the sending entity is a different EC collecting NF, namely the AMF.

10. When the NEF is the receiver of the notification sent from the EC collecting NF, the NEF transmits the received notification further to the AF. The content of the notification message is not modified by the NEF, i.e. the NEF merely relays the content of the message received in steps 9b, 9c or 9d.

The NEF may use the *Nnef_EventExposure_Notify* service operation to send the notification to the AF.

It will be appreciated that the approach presented here may provide a flexible mechanism to expose EC information for different purposes (i.e. for different event IDs) and on different granularities (i.e. event filters). It can be applied for both either exposing UE-related EC information or service-related EC information both inside and outside of a core network.

The solution presented here and illustrated in Figure 2 can be applied to public networks, i.e. Public Land Mobile Networks (PLMNs) or to private networks, e.g. Non-Public Networks (NPN) or Standalone NPNs.

The solution from Figure 2 shows how the AF subscribes for one or more monitoring events for energy consumption exposure. It is also possible that at any time the AF may update this subscription, i.e. the AF may send a new *Nnef_EventExposure_Subscribe* or *Nnef_ECinformation_Subscribe* service operation or *Nnef_EventExposure_Modify* or *Nnef_ECinformation_Modify/Update* service operation to update at least one of the event IDs, event filter information or the Event Reporting Information. It is also possible that the AF may decide to terminate the exposure of EC information and for this purpose the AF may

use *Nnef_EventExposure_Unsubscribe* or *Nnef_ECinformation_Unsubscribe* service operation. This will cause the NEF, EC collecting NF and other NFs in the CN CP to delete the states or contexts which were created in order to expose the EC information exposure.

Figure 3 illustrates an example of a NE 200 in accordance with aspects of the present disclosure. The NE may be operated, for example, as the above described NEF or EC collecting NF. The NE 200 may include a processor 202, a memory 204, a controller 206, and a transceiver 208. The processor 202, the memory 204, the controller 206, or the transceiver 208, 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.

The processor 202, the memory 204, the controller 206, or the transceiver 208, 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.

The processor 202 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 202 may be configured to operate the memory 204. In some other implementations, the memory 204 may be integrated into the processor 202. The processor 202 may be configured to execute computer-readable instructions stored in the memory 204 to cause the NE 200 to perform various functions of the present disclosure.

The memory 204 may include volatile or non-volatile memory. The memory 204 may store computer-readable, computer-executable code including instructions when executed by the processor 202 cause the NE 200 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as the memory 204 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.

In some implementations, the processor 202 and the memory 204 coupled with the processor 202 may be configured to cause the NE 200 to perform one or more of the functions described herein (e.g., executing, by the processor 202, instructions stored in the memory 204). For example, the processor 202 may support wireless communication at the NE 200 in accordance with examples as disclosed herein. The NE 200 may be configured to support a means for causing the network entity to receive a first request for exposure of energy consumption related information including an energy consumption event identifier, and event filter information, selecting one of a Unified Data Management, UDM, function or a Network Repository Function, NRF, based on the energy consumption event identifier and/or event filter information, and transmitting to the selected UDM function or NRF function a second request to identify an energy consumption collecting Network Function, NF. The means is further configured to cause the network entity to receive a first response containing an identifier of an energy consumption collecting NF, and transmit a third request to the energy consumption collecting NF to subscribe for monitoring event notifications, the third request containing at least one of the energy consumption event identifier and the event filter information.

The controller 206 may manage input and output signals for the NE 200. The controller 206 may also manage peripherals not integrated into the NE 200. In some implementations, the controller 206 may utilize an operating system such as iOS®, ANDROID®, WINDOWS®, or other operating systems. In some implementations, the controller 206 may be implemented as part of the processor 202.

In some implementations, the NE 200 may include at least one transceiver 208. In some other implementations, the NE 200 may have more than one transceiver 208. The transceiver 208

may represent a wireless transceiver. The transceiver 208 may include one or more receiver chains 210, one or more transmitter chains 212, or a combination thereof.

A receiver chain 210 may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receiver chain 210 may include one or more antennas for receiving the signal over the air or wireless medium. The receiver chain 210 may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receiver chain 210 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 210 may include at least one decoder for decoding the demodulated signal to receive the transmitted data.

A transmitter chain 212 may be configured to generate and transmit signals (e.g., control information, data, packets). The transmitter chain 212 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 212 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 212 may also include one or more antennas for transmitting the amplified signal into the air or wireless medium.

Figure 4 illustrates a flowchart of a method 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. At 300, the method may include receiving a first request for exposure of energy consumption related information including an energy consumption event identifier, and event filter information. The operations of 300 may be performed in accordance with examples as described herein. In some

implementations, aspects of the operations of 300 may be performed by a NE as described with reference to Figure 3.

At 301, the method may include selecting one of a Unified Data Management, UDM, function or a Network Repository Function, NRF, based on the energy consumption event identifier and/or event filter information. The operations of 301 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 301 may be performed by a NE as described with reference to Figure 3.
At 302, the method may include transmitting to the selected UDM function or NRF function a second request to identify an energy consumption collecting Network Function, NF. The operations of 302 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 302 may be performed by a NE as described with reference to Figure 3.

At 303, the method may include receiving a first response containing an identifier of an energy consumption collecting NF. The operations of 303 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 303 may be performed by a NE as described with reference to Figure 3.
At 304, the method may include transmitting a third request to the energy consumption collecting NF to subscribe for monitoring events, the third request containing at least one of the energy consumption event identifier and the event filter information. The operations of 304 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 304 may be performed by a NE as described with reference to Figure 3.

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.

Figure 5 illustrates a flowchart of a method 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.

At 400, the method may include collecting energy consumption related information. The operations of 400 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 400 may be performed by a NE as generally illustrated in Figure 3.

At 401, the method may include receiving a request to subscribe for monitoring event notifications associated with the collected energy consumption related information, the request containing at least one of an energy consumption event identifier and event filter information. The operations of 401 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 401 may be performed by a NE as generally illustrated in Figure 3.

At 402, the method may include determining and storing at least one monitoring event trigger based on the energy consumption event identifier and/or event filter information. The operations of 402 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 402 may be performed by a NE as generally illustrated in Figure 3.

At 403, the method may include determining occurrence of a monitoring event trigger in the collected energy consumption related information. The operations of 403 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 403 may be performed by a NE as generally illustrated in Figure 3.

At 404, the method may include transmitting a notification of occurrence of the monitoring event trigger. The operations of 404 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 404 may be performed by a NE as generally illustrated in Figure 3.

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.

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.

CLAIMS

1. A network entity 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 a first request for exposure of energy consumption related information including

an energy consumption event identifier, and

event filter information,

select one of a Unified Data Management, UDM, function or a Network Repository Function, NRF, based on the energy consumption event identifier and/or event filter information,

transmit to the selected UDM function or NRF function a second request to identify an energy consumption collecting Network Function, NF,

receive a first response containing an identifier of an energy consumption collecting NF, and

transmit a third request to the energy consumption collecting NF to subscribe for monitoring event notifications, the third request containing at least one of the energy consumption event identifier and the event filter information.

2. The network entity of claim 1, wherein the energy consumption event identifier has a type identifying at least one of:

energy consumption status report;

energy consumption prediction report;

energy policy status;

energy credit limit status;

network performance information for a currently activated energy state; and

energy efficiency information.

3. The network entity of claim 1 or 2, wherein the event filter information defines at least one of:

a UE-related filter, optionally per UE-level, per PDU Session level or per QoS flow level; and

a service-related filter, optionally per network slice level, per Session level, or per AF level.

4. The network entity of claim 3, wherein the event filter information, or other information within the first request, further defines at least one of a per AN level filter, a CN level filter, and a per Access type level filter.

5. The network entity of claim 3 or 4, wherein the processor is configured to select a UDM if the event filter information defines a UE-related filter, the selected UDM serving a UE associated with the UE-related filter.

6. The network entity of claim 3 or 4, wherein the processor is configured to select a NRF function if the event filter information defines a service-related filter, and to include in the second request a service ID.

7. The network entity of any preceding claim, wherein the processor is configured to cause the network entity to operate, in use, as a Network Exposure Function, NEF, within a core network.

8. The network entity of any preceding claim, the processor being further configured to cause the network entity to,
receive a notification of an energy consumption event, and
transmit the received notification.

9. The network entity of preceding claim, wherein the first request is received on a first control plane interface, the second request is transmitted on a second control plane interface, and the third request is transmitted on a third control plane interface.

10. The network entity of claim 9, wherein the first control plane interface is a control plane interface to an Application Function, AF.

11. A network entity 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

collect energy consumption related information,

receive a request to subscribe for monitoring event notifications associated with the collected energy consumption related information, the request containing at least one of an energy consumption event identifier and event filter information,

determine and store at least one monitoring event trigger based on the energy consumption event identifier and/or event filter information,

determine occurrence of a monitoring event trigger in the collected energy consumption related information, and

transmit a notification of occurrence of the monitoring event trigger.

12. The network entity of claim 11, wherein collected energy consumption related information is one of UE-related and service-related energy consumption related information.

13. The network entity of claim 12, wherein the processor is configured to cause the network entity to operate as one of:

an Energy Consumption Function;

a Charging Function;

a Policy Control Function; and

a Network Data Analytics Function.

14. The network entity of any one of claims 11 to 13, wherein the control plane interface is an interface towards a second network entity operating as a Network Exposure Function, NEF.

15. The network entity of any one of claims 11 to 14, wherein the processor is configured to send the notification over the control plane interface to a sender of the request, or over a second control plane interface to an Application Function.

16. A method performed by a network entity and comprising:

receiving a first request for exposure of energy consumption related information including

an energy consumption event identifier, and

event filter information;

selecting one of a Unified Data Management, UDM, function or a Network Repository Function, NRF, based on the energy consumption event identifier and/or event filter information;

transmitting to the selected UDM function or NRF function a second request to identify an energy consumption collecting Network Function, NF;

receiving a first response containing an identifier of an energy consumption collecting NF; and

transmitting a third request to the energy consumption collecting NF to subscribe for monitoring events, the third request containing at least one of the energy consumption event identifier and the event filter information.

17. The method of claim 16, wherein the energy consumption event identifier has a type identifying at least one of:

energy consumption status report;

energy consumption prediction report;

energy policy status;

energy credit limit status;

network performance information for a currently activated energy state; and

energy efficiency information.

18. A method performed by a network entity and comprising:

collecting energy consumption related information;

receiving a request to subscribe for monitoring event notifications associated with the collected energy consumption related information, the request containing at least one of an energy consumption event identifier and event filter information;

determining and storing at least one monitoring event trigger based on the energy consumption event identifier and/or event filter information;

determining occurrence of a monitoring event trigger in the collected energy consumption related information; and

transmitting a notification of occurrence of the monitoring event trigger.