3GPP TSG SA WG2#166 S2-24xxxxx

Orlando, Florida, 18-22 November 2024 (revision of S2-2410366)

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| *CR-Form-v12.3* | | | | | | | | |
| **CHANGE REQUEST** | | | | | | | | |
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|  | **23.288** | **CR** | **1260** | **rev** | **1** | **Current version:** | **19.0.0** |  |
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| *For* [***HELP***](http://www.3gpp.org/3G_Specs/CRs.htm#_blank)*on using this form: comprehensive instructions can be found at* [*http://www.3gpp.org/Change-Requests*](http://www.3gpp.org/Change-Requests)*.* | | | | | | | | |
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| ***Proposed change affects:*** | UICC apps |  | ME |  | Radio Access Network |  | Core Network | **x** |

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| ***Title:*** | Support of a new function dedicated to energy analytics | | | | | | | | | |
|  |  | | | | | | | | | |
| ***Source to WG:*** | Nokia, Verizon, Lenovo | | | | | | | | | |
| ***Source to TSG:*** | SA2 | | | | | | | | | |
|  |  | | | | | | | | | |
| ***Work item code:*** | EnergySys | | | | |  | ***Date:*** | | | 2024-09-25 |
|  |  | | | |  | |  | | |  |
| ***Category:*** | B |  | | | | | ***Release:*** | | | Rel-19 |
|  | *Use one of the following categories:* ***F*** *(correction)* ***A*** *(mirror corresponding to a change in an earlier release)* ***B*** *(addition of feature),* ***C*** *(functional modification of feature)* ***D*** *(editorial modification)*  Detailed explanations of the above categories can be found in 3GPP [TR 21.900](http://www.3gpp.org/ftp/Specs/html-info/21900.htm). | | | | | | | | *Use one of the following releases: Rel-8 (Release 8) Rel-9 (Release 9) Rel-10 (Release 10) Rel-11 (Release 11) … Rel-17 (Release 17) Rel-18 (Release 18) Rel-19 (Release 19)  Rel-20 (Release 20)* | |
|  |  | | | | | | | | | |
| ***Reason for change:*** | | Following the agreement that a new functionality which should support the energy consumption estimates, this CR defines a new function EIF(Energy Information Function) which reuses the NWDAF framework and some NWDAF services.This paper reolves this editor’s note in some agreed CRs at SA2#165:  Editor’s NOTE: It is FFS whether or not EIF will use network data analytics framework as defined in TS 23.288. | | | | | | | | |
|  | |  | | | | | | | | |
| ***Summary of change:*** | | New clauses added to describe a new NF which is dedicated to the handling the analytic for energy consumption estimation | | | | | | | | |
|  | |  | | | | | | | | |
| ***Consequences if not approved:*** | | The Energysys collection and exposure of energy related information is not supported | | | | | | | | |
|  | |  | | | | | | | | |
| ***Clauses affected:*** | | 4.x(new), 6.x (new), 7.1,Annex X(new) | | | | | | | | |
|  | |  | | | | | | | | |
|  | | **Y** | **N** |  | | | |  | | |
| ***Other specs*** | |  | **x** | Other core specifications | | | | TS/TR ... CR ... | | |
| ***affected:*** | |  | **x** | Test specifications | | | | TS/TR ... CR ... | | |
| ***(show related CRs)*** | |  | **x** | O&M Specifications | | | | TS/TR ... CR ... | | |
|  | |  | | | | | | | | |
| ***Other comments:*** | |  | | | | | | | | |
|  | |  | | | | | | | | |
| ***This CR's revision history:*** | |  | | | | | | | | |

*FIRST CHANGE*

## 4.X Energy Information Function

The Energy Information Function (EIF) is a NF which is dedicated to the support of only energy consumption estimation analytics at UE, PDU session and QoS flow granularities. The EIF reuses the NWDAF framework documented in this specification and can support certain NWDAF service operations which are defined as aliases of the corresponding Nnwdaf service operations, as defined in Table 4.x-1 The energy consumption analytics are defined in clause 6.x.3.

The following Service operations alias mappings are defined:

**Table 4.x-1:Mapping of EIF services to NWDAF services**

|  |  |
| --- | --- |
| **Neif service** | **Nnwdaf service** |
| Neif\_AnalyticsSubscription | Nnwdaf\_AnalyticsSubscription |
| Neif\_AnalyticsInfo | Nnwdaf\_AnalyticsInfo |
| Neif\_DataManagement | Nnwdaf\_DataManagement |

*more CHANGES*

## 6.X 3GPP User Plane energy consumption analytics supported by the EIF

### 6.x.1 General

This clause specifies the procedure for an EIF to provide statistics on user plane energy consumption of UEs identified by their UE ID (GPSI or SUPI), PDU session identified by a GPSI or SUPI and DNN/S-NSSAI and a QoS flow identified by a SUPI+ DNN/S-NSSAI or IP-5-tuple or Application ID, according to the information provided by the service consumer.

The EIF collects traffic data usage information related to the requested granularity over the specific time periods that are related to the collection of energy consumption in a PLMN, and then apportions the total usage of energy consumption over the time period by the affected UPFs and NG-RAN nodes based on the ratio of data volume over the overall data volume these UP nodes have handled in the time period.

The EIF derives the used NG-RAN nodes by a UE in a time period T based on the ULI. The EIF then retrieves the total data volume and total energy consumption in these NG-RAN network nodes to then derive the statistics. Similarly, the UPFs are determined based on retrieving from the UDM the registered SMFs for the UE and then the SMF reports the UPFs used by a UE.

The service consumer may be an NF (e.g. SMF, PCF) or an AF.

The consumer of these analytics includes in the request:

- Analytics ID = "UP energy consumption".

- Target of Analytics Reporting as defined in clause 6.1.3 for a single UE (SUPI, GPSI), group of UEs (a list of Internal-Group-Ids) or "any UE"

- Analytics Filter Information containing:

- Optionally: Area of Interest (i.e. the location of UE(s));

- Optionally Application ID

- Optionally S-NSSAI and DNN

- Optionally; IP address 5-tuple

- Optionally, preferred level of accuracy of the analytics.

- An Analytics target period indicates the time period over which the analytics are requested.

- Optionally, a list of analytics subsets that are requested (see clause 6.x.3);

Depending on local regulations, the EIF retrieves user consent for the UE with UDM prior to data collection as defined in clause 6.2.2.2 or clause 6.2.2.3. If user consent to collect data is not granted by the UE, the EIF rejects/cancels any analytics subscriptions to any of the UE related analytics with target for analytics set to the SUPI or GPSI of that UE. If the target for analytics is either an Internal or External Group Id or a list of SUPIs or "any UE", the EIF skips those SUPIs that do not grant user consent.

### 6.x.2 Input Data

The EIF shall be able to collect UE related energy consumption at UE, Session level (S-NSSAI+DNN) and QoS flow level (IP address 5-tupledispersion information from NF(s) and AFs). The information collected by the EIF is based on data from 5GC NFs and OAM:

Table 6.x.2-1 provides the list of inputs received from 5GC NFs at the EIF. The affected 5GC NFs are retrieved from the UDM of the UE based on the provided input parameters including the UE ID and (S-NSSAI, DNN).

Table 6.X.2-1: 5GC NF Input data for UP energy consumption analytics

|  |  |  |
| --- | --- | --- |
| Information | Source | Description |
| UE IP address | SMF | UE IP address. |
| UE ID | SMF | SUPI |
| S-NSSAI +DNN | SMF | Slice and DNN applicable to a PDU session |
| IP 5-Tuple | SMF | IP-5-tuple |
| Timestamp | SMF | Time stamp of the collected information. |
| Data Volume UL/DL per PSA UPF | SMF | Sum of UE per UE, S-NSSAI DNN, or 5-T-uple depending of the finest granularity present. |
| I-UPF ID(s) | SMF | Identifier of any I-UPF(s) used by a PSA UPF |
| ULI (with timestamp) | AMF, SMF | User location information used to derive the NG-RAN nodes used at the designated time. |
| NOTE: The Data volume can be reported either as total volume of the PDU session or periodically. It refers to the Data volume exchanged between the start and stop of the PDU session. When reported periodically, the period can be specified in the requested analytic target period or configured as a default value in the SMF. | | |

There are two modes of data volume collection:

- Non periodical: A mode where the data volume is requested and consequently provided for the total volume of a PDU session from establishment to release.

- Periodical: A mode where data volume is provided periodically between the establishment and the release of a PDU session. The period, for the purpose of these analytics, is configured PLMN-wide by the operator across all NG-RAN nodes and UPFs.

For both modes of data collection, if there are multiple PDU sessions for a UE or multiple QoS flows for the same UE for the same application, the EIF aggregates (i.e. sums up) the data volume across all the PDU sessions for the UE to obtain per UE information and across all the QoS flows for the same application to obtain the per application information for the UE.

Table 6.x.2-2 defines the information the EIF retrieves from OAM.

Table 6.x.2-2: OAM Input data for UP energy consumption analytics

|  |  |  |
| --- | --- | --- |
| **Information** | **Source** | **Description** |
| gNB energy consumption | OAM | The Energy consumed by a gNB (ECgNB) over the configured time period. This is based on clause 6.7.3.4.2 of TS 28.554[10] |
| gNB data volume | OAM | The UL/DL data volume handled by a gNB over the configured time period. This is based on clause 6.7.1.1 of TS 28.554[10] |
| UPF energy consumption | OAM | The Energy consumed by a UPF over the configure time period. This is based on clause 6.7.3.1 of TS 28.554[10] |
| UPF data volume | OAM | Data volume consumed at a UPF. For instance, In case of a UPF with N3 interface(s), the data volume of the UPF is obtained by summing up, for all N3 interface(s), the number of octets of incoming GTP data packets on the N3 interface, from (R)AN to UPF (see TS 28.552 [8] clause 5.4.1.3) and the number of octets of outgoing GTP data packets on the N3 interface, from UPF to (R)AN (see TS 28.552 [8] clause 5.4.1.4) |

### 6.x.3 Output analytics

The NWDAF services as defined in the clauses 7.2 and 7.3 are used to expose the following Statistics from a EIF:

- UE energy consumption as defined in Table 6.x.3-1.

- Energy consumption per UE and S-NSSAI, DNN as defined in Table 6.x.3-2.

- Energy consumption for a QoS flow as defined in Table 6.x.3-3.

Table 6.x.3-1: Statistics of Energy consumption per UE

|  |  |
| --- | --- |
| Information | Description |
| UE ID | Identification of the UE via SUPI or GPSI. |
| Time slot entry (1..max) | List of time slots during the Analytics target period. |
| > Time slot start | Time slot start within the Analytics target period. |
| > Duration | Duration of the time slot. |
| > EUE (NOTE 1) | Estimated Energy Consumption for a UE (see Annex X). |
| NOTE 1: Analytics subset that can be used in "list of analytics subsets that are requested" and "Preferred level of accuracy per analytics subset". | |

Table 6.x.3-2: Statistics of Energy consumption a PDU sessions (identified by UE ID + S-NSSAI+ DNN)

|  |  |
| --- | --- |
| Information | Description |
| UE ID | Identification of the UE via SUPI or GPSI. |
| Time slot entry (1..max) | List of time slots during the Analytics target period. |
| > Time slot start | Time slot start within the Analytics target period. |
| > Duration | Duration of the time slot. |
| > DNN | Identifies the data network name (e.g. internet) for which analytics information is provided. |
| > S-NSSAI | Network Slice for which analytics information is provided. |
| > EUE, (S-NSSAI+DNN) (NOTE 1) | Estimated Energy Consumption for a UE PDU session identified by (S-NSSAI, DNN) pair (ee Annex X). |
| NOTE 1: Analytics subset that can be used in "list of analytics subsets that are requested" and "Preferred level of accuracy per analytics subset". | |

Table 6.x.3-3: Statistics of Energy consumption for QoS flow (identified by UE ID + IP-5-tuple)

|  |  |
| --- | --- |
| Information | Description |
| UE ID | Identification of the UE via SUPI or GPSI. |
| Time slot entry (1..max) | List of time slots during the Analytics target period. |
| > Time slot start | Time slot start within the Analytics target period. |
| > Duration | Duration of the time slot. |
| > DNN | Identifies the data network name (e.g. internet) for which analytics information is provided. |
| > S-NSSAI | Network Slice for which analytics information is provided. |
| > Application ID | Identifies the application for which analytics information is provided. |
| > IP-5-tuple | IP-5-tuple |
| > EUE, QoS flow (NOTE 1) | Estimated Energy Consumption for a UE QoS flow identified by the IP-5-tuple (See Annex X). |
| NOTE 1: Analytics subset that can be used in "list of analytics subsets that are requested" and "Preferred level of accuracy per analytics subset". | |

### 6.x.4 Procedures



Figure 6.x.4-1: UP energy consumption analytics by EIF

Figure 6.x.4-1 shows the procedure for EIF to derive UP energy consumption analytics. The steps are described as follows:

1. A consumer NF subscribes to/requests a NWDAF using Neif\_AnalyticsSubscription\_Subscribe or Neif\_AnalyticsInfo\_Request service operation (Analytics ID = UP energy consumption and a set of Analytics Filters defined in clause 6.x.1).

2. The EIF derives the SMF and optionally AMF (if the ULI is received via AMF) that are used for the UE. The SMF registrations query can include the S-NSSAI, DNN if the requested granularity is per (S-NSSAI+DNN) or per QoS flow.

3. [CONDITIONAL] The EIF may subscribe to the AMF(s) event exposure service to collect data on the ULI of the UEs if the location of the UE is derived directly from ULI received at AMF.

4. The EIF subscribe to the SMF(s) event exposure service to collect input data as in Table 6.X.2-1. EIF can then use such collected data to determine the ULI of the UE (if not provided by the AMF or OAM) and usage data per UE or session determined by S-NSSAI, DNN or QoS flow as requested by the consumer NF.

5. The EIF subscribes to input data in 6.x.2-2 from the OAM according to the data collection principles from the OAM described in clause 6.2.3.

6. The EIF works out the estimations of energy consumption as per request at step 1 based e.g. on the default formula in Annex x.

7. The EIF delivers analytics to the consumer NF by invoking Neif\_AnalyticsSubscription\_Notify or Neif\_AnalyticsInfo\_Request response service operations.

*more CHANGES*

7.1 General

Table 7.1-1 illustrates the NWDAF Services.

**Table 7.1-1: NF services provided by NWDAF**

|  |  |  |  |
| --- | --- | --- | --- |
| **Service Name** | **Service Operations** | **Operation**  **Semantics** | **Example Consumer(s)** |
| Nnwdaf\_AnalyticsSubscription | Subscribe | Subscribe / Notify | PCF, NSSF, AMF, SMF, NEF, AF, OAM, CEF, NWDAF, DCCF, LMF |
|  | Unsubscribe |  | PCF, NSSF, AMF, SMF, NEF, AF, OAM, CEF, NWDAF, DCCF, LMF |
|  | Notify |  | PCF, NSSF, AMF, SMF, NEF, AF, OAM, CEF, NWDAF, DCCF, MFAF, LMF |
|  | Transfer | Request / Response | NWDAF |
| Nnwdaf\_AnalyticsInfo | Request | Request / Response | PCF, NSSF, AMF, SMF, NEF, AF, OAM, CEF, NWDAF, DCCF, LMF |
|  | ContextTransfer | Request / Response | NWDAF |
| Nnwdaf\_DataManagement | Subscribe | Subscribe / Notify | NWDAF, DCCF |
|  | Notify |  | NWDAF, DCCF, MFAF, ADRF |
|  | Fetch | Request / Response | NWDAF, DCCF, MFAF, ADRF |
| Nnwdaf\_MLModelProvision | Subscribe | Subscribe / Notify | NWDAF, LMF |
|  | Unsubscribe |  | NWDAF, LMF |
|  | Notify |  | NWDAF, LMF |
| Nnwdaf\_MLModelInfo | Request | Request / Response | NWDAF, LMF |
| Nnwdaf\_MLModelMonitor | Subscribe | Subscribe / Notify | NWDAF |
|  | Unsubscribe |  | NWDAF |
|  | Notify |  | NWDAF |
|  | Register | Request / Response | NWDAF |
|  | Request |  | NWDAF |
| Nnwdaf\_MLModelTraining | Subscribe | Subscribe / Notify | NWDAF |
|  | Unsubscribe |  | NWDAF |
|  | Notify |  | NWDAF |
| Nnwdaf\_MLModelTrainingInfo | Request | Request / Response | NWDAF |
| Nnwdaf\_RoamingAnalytics | Subscribe | Subscribe / Notify | H-RE-NWDAF, V-RE-NWDAF |
|  | Unsubscribe |  | H-RE-NWDAF, V-RE-NWDAF |
|  | Notify |  | H-RE-NWDAF, V-RE-NWDAF |
|  | Request | Request / Response | H-RE-NWDAF, V-RE-NWDAF |
| Nnwdaf\_RoamingData | Subscribe | Subscribe / Notify | H-RE-NWDAF, V-RE-NWDAF |
|  | Unsubscribe |  | H-RE-NWDAF, V-RE-NWDAF |
|  | Notify |  | H-RE-NWDAF, V-RE-NWDAF |
| NOTE 1: How OAM consumes Nnwdaf services and which Analytics information is relevant is defined in TS 28.550 [7] Annex H and out of the scope of this TS.  NOTE 2: How CEF consumes Nnwdaf services and which Analytics information is relevant is defined in TS 28.201 [21] and out of the scope of this TS.  NOTE 3: The Nnwdaf\_MLModelProvision service and the Nnwdaf\_MLModelInfo service are provided by an NWDAF containing MTLF and consumed by an NWDAF containing AnLF or provided by an NWDAF containing MTLF supporting FL as a server and consumed by an NWDAF containing MTLF. | | | |

Table 7.1-2 shows the analytics information provided by NWDAF service.

**Table 7.1-2: Analytics information provided by NWDAF**

|  |  |  |
| --- | --- | --- |
| **Analytics Information** | **Request Description** | **Response Description** |
| Slice Load level information | Analytics ID: load level information | Load level provided as number of UE registrations and number of PDU sessions for a Network Slice and Network Slice instances as well as resource utilization for Network Slice instances. |
| Observed Service experience information | Analytics ID: Service Experience | Observed Service experience statistics or predictions may be provided for a Network Slice or an Application. They may be derived from an individual UE, a group of UEs or any UE. For slice service experience, they may be derived from an Application, a set of Applications or all Applications on the Network Slice. |
| NF Load information | Analytics ID: NF load information | Load statistics or predictions information for specific NF(s). |
| Network Performance information | Analytics ID: Network Performance | Statistics or predictions on the load in an Area of Interest; in addition, statistics or predictions on the number of UEs that are located in that Area of Interest. |
| UE mobility information | Analytics ID: UE Mobility | Statistics or predictions on UE mobility. When visited AOI(s) is included in the Analytics Filter information, only statistics on UE mobility can be provided. |
| UE Communication information | Analytics ID: UE Communication | Statistics or predictions on UE communication. |
| Expected UE behavioural parameters | Analytics ID: UE Mobility and/or UE Communication | Analytics on UE Mobility and/or UE Communication. |
| UE Abnormal behaviour information | Analytics ID: Abnormal behaviour | List of observed or expected exceptions, with Exception ID, Exception Level and other information, depending on the observed or expected exceptions. |
| End-to-end data volume transfer time | Analytics ID: E2E data volume transfer time | Analytics on E2E data volume transfer time. |
| User Data Congestion information | Analytics ID: User Data Congestion | Statistics or predictions on the user data congestion for transfer over the user plane, for transfer over the control plane, or for both. |
| QoS Sustainability | Analytics ID: QoS Sustainability | For statistics, the information on the location and the time for the QoS change and the threshold(s) that were crossed; or, for predictions, the information on the location and the time when a potential QoS change may occur and what threshold(s) may be crossed. |
| Session Management Congestion Control Experience | Analytics ID: Session Management Congestion Control Experience | Statistics on session management congestion control experience for specific DNN and/or S-NSSAI. |
| Redundant Transmission Experience | Analytics ID: Redundant Transmission Experience | Statistics or predictions aimed at supporting redundant transmission decisions for URLLC services. |
| WLAN performance | Analytics ID: WLAN performance | Statistics or predictions on WLAN performance of UE. |
| Dispersion | Analytics ID: UE Dispersion | Statistics or predictions that identify the location (i.e. areas of interest) or network slice(s) where a UE, or a group of UEs disperse their data volume, or disperse mobility or session management transactions or both. |
| DN Performance | Analytics ID: DN Performance | Statistics or predictions on user plane performance for a specific Edge Computing application. |
| PFD Determination | Analytics ID: PFD Determination | Statistics on PFD information for a known application identifier(s). |
| Movement Behaviour | Analytics ID: Movement Behaviour | Statistics or predictions on movement behaviour for an applicable area. |
| Location Accuracy | Analytics ID: Location Accuracy | Predictions on Location Accuracy. |
| Relative Proximity | Analytics ID: Relative Proximity | Statistics or predictions on Relative Proximity among UEs. |
| PDU Session traffic | Analytics ID: PDU Session traffic | Statistics on whether traffic of UEs via one or multiple PDU sessions is according to the information provided by the service consumer. |

**Table 7.1-3: Analytics information provided by EIF**

|  |  |  |
| --- | --- | --- |
| **Analytics Information** | **Request Description** | **Response Description** |
| UP Energy Consumption | Analytics ID: UP energy consumption | Statistics of energy consumption for the User Plane for a UE, PDU session or QoS flow |

*MORE CHANGES*

Annex X (Normative):  
Default Formulae for Energy consumption estimation at EIF

This annex defines default formulae an EIF should support for the calculation of an approximation of the energy consumed in the network by a UE, for a PDU session or for a QoS flow. Other methods could be supported, but these are outside the scope of this specification.

These formulae estimate the energy consumed based on information related to the energy consumed withing a well defined and time aligned period T by a UPF or a gNB that is available from SA5 specifications (see TS 28.554[10]]), and then apportioning a fraction of the energy consumed at such user plane entities to a UE, a Sessions or a QoS flow based on the fraction of the data volume handled by the gNB or UPF withing the period T for the UE, PDU session or QoS flow.

These formulas allows estimation of energy consumed withing time intervals that are multiples of the period T defined in a PLMN.

The first step is the identification of the energy consumption for a UE, session or QoS flow within a period T

Let:

1. be the energy consumed at a UPF within a time period (source OAM).
2. be the energy consumed at a gNB within a time period T (source OAM)
3. be the overall data volume handled for all UEs at a gNB within a time period T (source OAM)
4. be the overall data volume handled for all UEs at a gNB within a time period T (source OAM)
5. *DVUE,gNB* be the data volume handled for a UEs at a gNB within a time period T (source SMFs of the UE with identification of gNB based on ULI reporting)
6. *DVUE,UPF* be the data volume handled for a UEs at a UPF within a time period T (source SMF of the UE)
7. *DVSession,gNB* be the data volume handled for a session at a gNB within a time period T (source SMF of the UE+S-NSSAI+DNN and gNB identified based on ULI reporting)
8. *DVSession,UPF* be the data volume handled for a session at a UPFand within a time period T (source SMF of the UE+S-NSSAI+DNN)
9. *DVFlow,gNB* be the data volume handled for a QoS flow at a gNB within a time period T (source SMF of the UE+S-NSSAI+DNN and IP 5-Tuple and gNB identified based on ULI reporting)
10. *DVFlow,UPF* be the data volume handled for a QoS flow at a UPF and within a time period T (source SMF of the UE+S-NSSAI+DNN and IP 5-Tuple)

It is assumed that the system knows which UPFs and RAN nodes are used by the UE/session/QoS flow at all times. The ULI is required to be reported from gNB to AMF as part of handover procedures and this is reported also to the SMF by AMF so the SMF and AMF bot are aware of the ULI. the EIF can fetch the ULI from any of these nodes.

The UPFs used by a PDU are the PSA UP and any I-UPFs. The I-UPF IDs are reported in charging information to the PSA UPF and form this to the SMF. It is expected the EIF retrieve data volume per UE,PDU session, QoS flow from SMFs alongside the identitied of the PSA UPF and the I-UPFs used.

To derive the approximation of energy consumed at a gNB over a period of time T by a UE, PDU session, QoS flow, the formulas are:

Similarly, to derive the energy consumed at a UPF over a time period T by a UE, session, QoS flow the formulas are:

NOTE: or are coefficients that express the normalized energy consumed per unit of data volume in the interval T. In general, these values are not constant and e.g. for the gNB can vary depending on the number of UEs served, the location oft he UE even when the same amount of data is sent and received.

Lastly, to derive the energy consumed in the network in the time interval T by a UE (), Session ()QoS flow (()) the formula is:

where is the set of all gNBs used by the UE in an interval T, I the set of all UPFs used by the UE in an interval T.

where is the set of all gNBs used by the PDU Session in an interval T, is the set of all UPFs used by the PDU Session in an interval T.

where is the set of all gNBs used by the QoS Flow in an interval T, is the set of all UPFs used by the QoS Flow in an interval T.

To calculate the value of energy consumed in a time window encompassing n periods T, it is necessary to add up the energy calculated for each such n time periods T. For instance, to compute the energy consumed in a time period including N time period T to a time period T1 to a time period TN for a UE the formula is:

We can then derive similar formulas for session and QoS flows: