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650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - APE 7112B
Association à but non lucratif enregistrée à la
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Contents

Foreword

This Technical Specification has been produced by the 3rd Generation Partnership Project (3GPP).

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- y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.
- z the third digit is incremented when editorial only changes have been incorporated in the document.

1 Scope

The present document specifies end-to-end Key Performance Indicators (KPIs) for the 5G network and network slicing.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] Void.

[3] ITU-T Recommendation E.800: "Definitions of terms related to quality of service".

[4] 3GPP TS 24.501: " Non-Access-Stratum (NAS) protocol for 5G System (5GS); Stage 3".

[5] 3GPP TS 38.331: "NR; Radio Resource Control (RRC); Protocol specification".

[6] 3GPP TS 28.552: "Management and orchestration; 5G performance measurements".

[7] 3GPP TS 23.501: " System Architecture for the 5G System; Stage 2".

[8] ETSI ES 203 228 V1.2.1 (2017-04): "Environmental Engineering (EE); Assessment of mobile network energy efficiency".

[9] 3GPP TS 28.310: "Management and orchestration; Energy efficiency of 5G".

[10] ETSI 202 336-12 V1.2.1 (2019-02): "Environmental Engineering (EE); Monitoring and control interface for infrastructure equipment (power, cooling and building environment systems used in telecommunication networks); Part 12: ICT equipment power, energy and environmental parameters monitoring information model".

[11] ETSI GS NFV-IFA 027 V4.0.2 (2020-11): "Network Functions Virtualisation (NFV) Release 4; Management and Orchestration; Performance Measurements Specification".

[12] 3GPP TS 38.314: "NR; layer 2 measurements".

[13] 3GPP TS 22.261: "Service requirements for the 5G system".

[14] 3GPP TS 38.214: "NR; Physical layer procedures for data".

[15] 3GPP TS 38.321: "NR; Medium Access Control (MAC) protocol specification".

[16] 3GPP TS 38.473: "NG-RAN; F1 Application Protocol (F1AP)".

[17] 3GPP TS 28.318: "Management and Orchestration; Network and Service Operations for Energy Utilities (NSOEU)".

[18] 3GPP TS 28.313: "Management and orchestration; Self-Organizing Networks (SON) for 5G networks".

[19] 3GPP TS 37.340: "Evolved Universal Terrestrial Radio Access (E-UTRA) and NR; Multi-connectivity; Overall Description; Stage 2".

3 Definitions of terms, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in 3GPP TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in 3GPP TR 21.905 [1].

3.2 Abbreviations

For the purposes of the present document, the abbreviations given in 3GPP TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in 3GPP TR 21.905 [1].

EE	Energy Efficiency
J	Joule
kbit	kilobit (1000 bits)
RTT	Round Trip Time
EN-DC	E-UTRA-NR Dual Connectivity

4 End to end KPI concept and overview

The following KPI categories are included in the present document:

- Accessibility (see the definition in [3]).
- Integrity (see the definition in [3]).
- Utilization.
- Retainability (see the definition in [3]).
- Mobility.
- Energy Efficiency.
- Reliability (See the definition in [13]).
- Availability.

5 KPI definitions template

a) Name (Mandatory): This field shall contain the name of the KPI.

b) Description (Mandatory): This field shall contain the description of the KPI.
Within this field it should describe if the KPI is focusing on network or user view. This filed should also describe the logical KPI formula to derive the KPI. For example, a success rate KPI's logical formula is the number of successful events divided by all events.

b-1) Measurement result of the KPI (Mandatory): This field shows the measurement result of the KPI. The measurement result shall have the type, optional unit, optional range. The followings are the examples:

- Integer, percentage, 0 - 100;
- Integer, time interval (second or millisecond or microsecond);
- Integer;
- Integer, kbit per second;

- Integer, active DRB releases per second;
- Integer, bits per Joule;
- Integer, seconds or milliseconds per Joule;
- Integer, users per Joule;
- Integer, Joule;
- Integer, bits per second and Herz;
- Integer, kbits per second and Joule.

b-2) Measurement method of the KPI (Mandatory): This field shows the measurement method of the KPI. The measurement method of the KPI shall be one of the following:

- MEAN: This KPI is produced to reflect a mean measurement value based on a number of sample results.
- RATIO: This KPI is produced to reflect the percentage of a specific case occurrence to all the cases.
- CUM: This KPI is produced to reflect a cumulative measurement which is always increasing.

c) Formula definition (Optional):
This field should contain the KPI formula using the 3GPP defined measurement names.
This field can be used only when the measurement(s) needed for the KPI formula are defined in 3GPP TS for performance measurements (TS 28.552 [6]). This field shall clarify how the aggregation shall be done, for the KPI object level(s) defined in d).

d) KPI Object (Mandatory):
This field shall contain the DN of the object instance where the KPI is applicable, including the object where the measurement is made. The DN identifies one object instance of the following IOC:

- NetworkSliceSubnet

  SubNetwork
- NetworkSlice
- NRCellDU
- NRCellCU

e) Remark (Optional):
This field is for additional information required for the KPI definition,
e.g. the definition of a call in UTRAN.

6 End to end KPI definitions

6.1 KPI Overview

The KPI categories defined in [3] will be reused by the present document.

6.2 Accessibility KPI

6.2.1 Mean registered subscribers of network and network slice through AMF

a) AMFMeanRegNbr.

b) This KPI describe the mean number of subscribers that are registered to a network slice instance. It is obtained by counting the subscribers in AMF that are registered to a network slice instance.

b-1) Integer

b-2) MEAN

c)

$$AMFMeanRegNbr = \sum_{AMF} RM.RegisteredSubNbrMean.SNSSAI$$

d) SubNetwork, NetworkSlice

6.2.2 Registered subscribers of network through UDM

a) UDMRegNbr.

b) This KPI describe the total number of subscribers that are registered to a network through UDM. It is corresponding to the measurement RM.RegisteredSubUDMNbrMean that counts subscribers registered in UDM.

b-1) Integer

b-2) MEAN

c)

$$UDMRegNbr = \sum_{UDM} RM.RegisteredSubUDMNbrMean$$

d) SubNetwork

6.2.3 Registration success rate of one single network slice

a) RSR.

b) This KPI describes the ratio of the number of successfully performed registration procedures to the number of attempted registration procedures for the AMF set which related to one single network slice and is used to evaluate accessibility provided by the end-to-end network slice and network performance. It is obtained by successful registration procedures divided by attempted registration procedures.

b-1) Integer, percentage

b-2) RATIO

c)

$$RSR = \frac{\sum_{\mathrm{Type}} \mathrm{AMF.5GSRegisSucc.Type}}{\sum_{\mathrm{Type}} \mathrm{AMF.5GSRegisAtt.Type}} \times 100\%$$

NOTE: Above measurements with subcounter .*Type* should be defined in 3GPP TS 24.501 [4].

d) NetworkSlice

6.2.4 Partial DRB Accessibility for UE services

a) Partial DRB Accessibility.

b) This KPI describes the DRBs setup success rate, including the success rate for setting up RRC connection and NG signalling connection. It is obtained as the success rate for RRC connection setup multiplied by the success rate for NG signalling connection setup multiplied by the success rate for DRB setup. The success rate for RRC connection setup and for NG signalling connection setup shall exclude setups with establishment cause mo-Signalling [5].

b-1) Integer, percentage, 0-100

b-2) RATIO

c)

$$\text{Partial DRBAccessibility 5QI} = (\sum \text{RRC.ConnEstabSucc.}Cause / \sum \text{RRC.ConnEstabAtt.}Cause) * (\sum \text{UECNTXT.ConnEstabSucc.}Cause / \sum \text{UECNTXT.ConnEstabAtt.}Cause) * (\text{DRB.EstabSucc.5QI} / \text{DRB.EstabAtt.5QI}) * 100$$

$$\text{Partial DRB Accessibility SNSSAI} = (\sum \text{RRC.ConnEstabSucc.}Cause / \sum \text{RRC.ConnEstabAtt.}Cause) * (\sum \text{UECNTXT.ConnEstabSucc.}Cause / \sum \text{UECNTXT.ConnEstabAtt.}Cause) * (\text{DRB.EstabSucc.SNSSAI} / \text{DRB.EstabAtt.SNSSAI}) * 100$$

The sum over causes shall exclude the establishment cause mo-Signalling [5].

For KPI on SubNetwork level the measurement shall be the averaged over all NRCellCUs in the SubNetwork.

d) SubNetwork, NRCellCU.

6.2.5 PDU session Establishment success rate of one network slice (S-NSSAI)

a) PDUSessionEstSR.

b) This KPI describes the ratio of the number of successful PDU session establishment request to the number of PDU session establishment request attempts for all SMF which related to one network slice (S-NSSAI) and is used to evaluate accessibility provided by the end-to-end network slice and network performance. It is obtained by the number of successful PDU session requests divided by the number of attempted PDU session requests.

b-1) Integer, percentage, 0-100

b-2) RATIO

c)

$$PDUSessionEstSR = \frac{\sum_{SMF} SM.PduSessionCreationSucc.SNSSAI}{\sum_{SMF} SM.PduSessionCreationReq.SNSSAI} \times 100$$

d) NetworkSlice

6.2.6 Maximum registered subscribers of network slice through AMF

a) AMFMaxRegNbr.

b) This KPI describe the maximum number of subscribers that are registered to a network slice. It is obtained by counting the subscribers in AMF that are registered to a network slice.

b-1) Integer

b-2) CUM

c)

$$AMFMaxRegNbr = \sum_{AMF} RM.RegisteredSubNbrMax.SNSSAI$$

d) NetworkSlice

6.2.7 Total DRB accessibility for UE services

a) Total DRB accessibility.

b) This KPI describes the total DRBs accessibility obtained as the ratio of the number of successfully established DRBs and number of services intended to be setup by the end user that shall result into a DRB establishment via Initial Context setup procedure. Added DRB setup and RRC Resume procedure. The number of services intended to be setup by the end user that shall result into a DRB establishment via Initial Context setup procedure is obtained as number of attempted establishments of DRB via Initial Context setup procedure amplified by inverse of the UE-associated logical NG-connection success ratio further amplified by inverse of the RRC Connection setup state success ratio. The number of services intended to be setup by the end user that shall result into a DRB establishment via added DRB setup procedure is measured directly in gNB via number of attempted establishments of DRB via added DRB setup procedure. Finally the number of services intended to be setup by the end user that shall result into a DRB establishment via RRC Resume procedure is provided as number of attempted establishments of DRB via RRC Resume procedure amplified by inverse of the RRC Resume success ratio. The success rate for RRC connection setup and for UE-associated logical NG-connection setup shall exclude setups with establishment cause mo-Signalling [5]. The success rate for RRC resume shall exclude setups related to RNA update.

b-1) Integer, percentage, 0-100

b-2) RATIO

c)

DRBAccessibility 5QI = 100 * (DRB.InitialEstabSucc.5QI + (DRB.EstabSucc.5QI-DRB.InitialEstabSucc.5QI) + DRB.ResumeSucc.5QI)/(DRB.InitialEstabAtt.5QI/((RRC connection setup success rate /100)*(UE-associated logical NG-connection success ratio/100)) + (DRB.EstabAtt.5QI-DRB.InitialEstabAtt.5QI) + DRB.ResumeAtt.5QI/(RRC Resume success rate/100))

DRBAccessibility SNSSAI = 100 * (DRB.InitialEstabSucc. SNSSAI + (DRB.EstabSucc. SNSSAI - DRB.InitialEstabSucc. SNSSAI) + DRB.ResumeSucc. SNSSAI)/(DRB.InitialEstabAtt. SNSSAI /((RRC connection setup success rate /100)*(UE-associated logical NG-connection success ratio /100)) + (DRB.EstabAtt. SNSSAI - DRB.InitialEstabAtt. SNSSAI) + DRB.ResumeAtt. SNSSAI /(RRC Resume success rate/100))

Where:

RRC Resume success rate = 100* ∑RRC.ResumeSucc.cause /∑(RRC.ResumeAtt.cause - RRC.ResumeFallbackToSetupAtt.cause)

where all but the causes related to RNA update shall be included.

RRC connection setup success rate = 100* (∑(RRC.ConnEstabSucc.Cause + RRC.ResumeSuccByFallback.cause) + RRC.ReEstabSuccWithoutUeContext) /(∑(RRC.ConnEstabAtt.Cause + RRC.ResumeFallbackToSetupAtt.cause) + RRC.ReEstabFallbackToSetupAtt)

UE-associated logical NG-connection success ratio = 100*(∑UECNTXT.ConnEstabSucc.Cause/∑ UECNTXT.ConnEstabAtt.Cause)

The sum over causes shall exclude the establishment cause mo-Signalling [5].

The sum over causes for RRC resume shall exclude the causes related to RNA update [5].

For KPI on SubNetwork level the measurement shall be the averaged over all NRCellCUs in the SubNetwork.

d) SubNetwork, NRCellCU.

6.2.8 Mean CM-Connected subscribers of network slice through AMF

a) AMFMeanCmConNbr.

b) This KPI describe the mean number of subscribers in a period that are not only registered to a network slice but also established a PDU session related to the network slice. And subscribers also have a NAS signalling connection with the AMF over N1. It is obtained by counting the subscribers in AMF that are showed "cm-connected" state for a network slice.

b-1) Integer

b-2) CUM

c)

$$AMFMeanCmCnNbr = \sum_{AMF} CM - ConnectedSubNbrMean.SNSSAI$$

d) NetworkSlice.

6.2.9 Maximum on-line subscribers of network slice through AMF

a) AMFMaxCmConNbr.

b) This KPI describe the maximum number of subscribers in a period that are not only registered to a network slice but also established a PDU session related to a network slice. And subscribers also have a NAS signalling connection with the AMF over N1. It is obtained by counting the subscribers in AMF that are showed "cm-connected" state for a network slice.

b-1) Integer

b-2) CUM

c)

$$AMFMeanCmConNbr = \sum_{AMF} CM - ConnectedSubNbrMean.SNSSAI$$

d) NetworkSlice.

6.2.10 PFCP session established success rate of one network and one network slice

a) PFCPSessionEstSR.

b) This KPI describes the successful rate of PFCP session established in a network or a network slice e on the UPF.

b-1) Integer, percentage

b-2) RATIO

c)

$$PFCPsessionEstSR = \frac{UPF.PFCPSessionCreationSucc.SNSSAI}{UPF.PFCPSessionCreationReq.SNSSAI}$$

d) Subnetwork, NetworkSlice.

6.2.11 Group-level N4 session establishment success rate of one 5G VN group

a) GrouplevelN4SessionEstSR.

b) This KPI describes the ratio of the number of successful group-level N4 session establishment request to the number of group-level N4 session establishment request attempts for all SMF related to one 5G VN group communication and is used to evaluate accessibility provided by the end-to-end network slice and network performance. It is obtained by the number of successful group-level N4 session requests divided by the number of attempted group-level N4 session requests.

b-1) Integer, percentage

b-2) RATIO

c)

$$GrouplevelN4SessionEstSR = \frac{\sum_{SMF} SM.GrouplevelN4SessionCreationSucc.InternalgroupID}{\sum_{SMF} SM.GrouplevelN4SessionCreationReq.InternalgroupID}$$

d) NetworkSlice.

6.2.12 PDU session Establishment success rate of one 5G VN Group (InternalgroupID)

a) PDUSessionEstSR.

b) This KPI describes the ratio of the number of successful PDU session establishment request to the number of PDU session establishment request attempts for all SMF which related to one 5G VN Group (InternalgroupID) and is used to evaluate accessibility provided by the 5G VN Group and network performance. It is obtained by the number of successful PDU session requests divided by the number of attempted PDU session requests.

b-1) Integer, percentage, 0-100

b-2) RATIO

c)

$$PDUSessionEstSR = \frac{\sum_{SMF} SM.PduSessionCreationSucc.InternalgroupID}{\sum_{SMF} SM.PduSessionCreationReq.InternalgroupID} \times 100$$

d) NetworkSlice.

6.2.13 Positive Paging Rate

a) AMFPositivePagingRate.

b) The KPI describes the positive paging rate, i.e. the amount of paging requests that result in UEs transitioning from triggering a mobile terminated call (thus moving from Idle/Inactive to Connected Mode), w.r.t total number of paging requests. When Combined with PagingDiscardRate_DU, RANPagingDiscardRate_CU and CNPagingDiscardRate_CU (from all CUs, and their respective DUs, belonging to the same AMF), this ratio will be used to quantify the impact of false paging occasions, i.e. paging occasions that do not result in a UEs triggering mobile terminated calls, on network side paging resource utilisation as well as on UE's power consumption: low rates will imply non optimal network resource utilisation and high UE wake up rate (wake up here is defined by Idle/Inactive to Connected mode transition) or equivalently higher UE power consumption.

b-1) Integer, percentage

b-2) RATIO

c) Below is the equation for AMFPositivePagingRate:

$$AMFPositivePagingRate = \frac{MM.Paging5GSucc}{MM.Paging5GReq} \times 100\%$$

Measurement names: MM.Paging5GSucc, MM.Paging5GReq

d) AMF.

6.2.14 PDU Session Per Establishment Request Rate

a) PDUSessionEstablishRatePerReqType.

b) This metric shows the percentage of PDU establishment requests, per PDU Request Type, w.r.t all PDU establishment requests that a AMF receives from all UEs it serves.

b-1) Integer, percentage

b-2) RATIO

c) To measure the percentage of PDU establishment requests, per PDU Request Type:

$$PDUSessionEstablishedRatePerReqType.I = \frac{SM.PDUSessionEstablishReq.I}{\sum_I SM.PDUSessionEstablishedReq.I} \times 100$$

Measurement names: SM.PDUSessionEstablishReq.I, SM.PDUSessionEstablishReq.I

d) AMFFunction

6.2.15 PDU Session Per Establishment Request Reject Rate

a) PDUSessionRejectRateReqType

b) This metric shows the percentage of PDU establishment requests that get rejected by the AMF, w.r.t all PDU establishment requests that the same AMF receives from all UEs it serves, broken down by PDU Request Type.

b-1) Integer, percentage

b-2) RATIO

c) To measure the PDU establishment request Reject rate, per PDU Request Type:

$$PDUSessionRejectRateReqType = \frac{SM.PDUSessionEstablishReject.I}{SM.PDUSessionEstablishReq.I} \times 100$$

Measurement names: SM.PDUSessionEstablishReject.I, SM.PDUSessionEstablishReq.I

d) AMFFunction

6.2.16 MA PDU session Establishment success rate of network slice

a) MAPDUSessionEstSR.

b) This KPI describes the ratio of the number of successful MA PDU session establishment request to the number of MA PDU session establishment request attempts for all SMF which related to one network slice and is used to evaluate accessibility provided by the end-to-end network slice and network performance. It is obtained by the number of successful MA PDU session requests divided by the number of attempted MA PDU session requests.

b-1) Integer, percentage, 0-100

b-2) RATIO

c)

$$MAPDUSessionEstSR = \frac{\sum_{SMF} SM.MAPDUSessionCreationSucc.SNSSAI}{\sum_{SMF} SM.MAPDUSessionCreationReq.SNSSAI} \times 100$$

d) NetworkSlice

6.2.17 Extended DRX Negotiation Success Rate

a) eDRXNegotiationSuccessRate.

b) This KPI describes the ratio of the number of successfully performed registration procedures, where AMF configures extended DRX to UEs requesting this latter, to the number of attempted registration procedures, by those same UEs, requesting extended DRX to be configured to them. This KPI is used to evaluate accessibility performance to extended DRX feature for UEs requesting it.

b-1) Integer, percentage

b-2) RATIO

c)

$$eDRXNegotiationSuccessRate = \frac{RM.RegEdrxAccept}{RM.RegEdrxReq} \times 100\%$$

d) AMF

6.3 Integrity KPI

6.3.1 Latency and delay of 5G networks

6.3.1.0 Void

6.3.1.1 Downlink latency in gNB-DU

a) DLLat_gNBDU.

b) This KPI describes the gNB-DU part of the packet transmission latency experienced by an end-user. It is used to evaluate the gNB latency contribution to the total packet latency. It is the average (arithmetic mean) of the time from reception of IP packet to gNB-DU until transmission of first part of that packet over the air interface, for a packet arriving when there is no previous data in queue for transmission to the UE. This KPI can optionally be split into KPIs per QoS level (mapped 5QI or QCI in EN-DC architecture) and per S-NSSAI.

b-1) Integer, time interval (0.1 mS)

b-2) MEAN

c)

$$\mathrm{DLLat\_gNBDU} = \mathrm{DRB.RlcSduLatencyDl}$$

or optionally

$$\mathrm{DLLat\_gNBDU.}QoS = \mathrm{DRB.RlcSduLatencyDl.QoS}$$

where QOS identifies the target QoS quality of service class.

or optionally

$$\mathrm{DLLat\_gNBDU.}SNSSAI = \mathrm{DRB.RlcSduLatencyDl.}SNSSAI$$

where *SNSSAI* identifies the S-NSSAI.

d) NRCellDU

6.3.1.2 Integrated downlink delay in RAN

6.3.1.2.1 Downlink delay in NG-RAN for a sub-network

a) DLDelay_NR_SNw.

b) This KPI describes the average packet transmission delay through the RAN part to the UE. It is used to evaluate delay performance of NG-RAN in downlink for a sub-network. It is the weighted average packets delay from reception of IP packet in gNB-CU-UP until the last part of an RLC SDU packet was received by the UE according to received HARQ feedback information for UM mode or until the last part of an RLC SDU packet was received by the UE according to received RLC ACK for AM mode. This KPI can optionally be split into KPIs per QoS level (mapped 5QI or QCI in EN-DC architecture) and per S-NSSAI.

b-1) Integer, time interval (0.1 mS)

b-2) MEAN

c) Below are the equations for average "Integrated downlink delay in RAN" for this KPI on SubNetwork level. The "Integrated downlink delay in RAN" is the sum of average DL delay in gNB-CU-UP of the sub-network (DLDelay_gNBCUUP_SNw) and the average DL delay in gNB-DU of the sub-network (DLDelay_gNBDU_SNw):

$$\mathrm{DLDelay\_NR\_SNw} = \mathrm{DLDelay\_gNBCUUP\_SNw} + \mathrm{DLDelay\_gNBDU\_SNw}$$

or optionally

$$\mathrm{DLDelay\_NR\_SNw}.QOS = \mathrm{DLDelay\_gNBCUUP\_SNw}.QOS + \mathrm{DLDelay\_gNBDU\_SNw}.QOS$$

where *QOS* identifies the target quality of service class.

or optionally

$$\mathrm{DLDelay\_NR\_SNw}.SNSSAI = \mathrm{DLDelay\_gNBCUUP\_SNw}.SNSSAI + \mathrm{DLDelay\_gNBDU\_SNw}.SNSSAI$$

where *SNSSAI* identifies the S-NSSAI.

d) SubNetwork

NOTE: If the HARQ process is configured with disabled HARQ feedback for NTN (refer to 38.321[15]), this KPI is not available for UM mode.

6.3.1.2.2 Downlink delay in NG-RAN for a network slice subnet

a) DLDelay_NR_Nss.

b) This KPI describes the average packet transmission delay through the RAN part to the UE. It is used to evaluate delay performance of NG-RAN in downlink for a network slice subnet. It is the weighted average packets delay from reception of IP packet in gNB-CU-UP until the last part of an RLC SDU packet was received by the UE according to received HARQ feedback information for UM mode or until the last part of an RLC SDU packet was received by the UE according to received RLC ACK for AM mode.

b-1) Integer, time interval (0.1 mS)

b-2) MEAN

c) Below is the equation for average "Integrated downlink delay in RAN" for this KPI on NetworkSliceSubnet level. The "Integrated downlink delay in RAN" for network slice subnet is the sum of average DL delay in gNB-CU-UP of the network slice subnet (DLDelay_gNBCUUP_Nss) and the average DL delay in gNB-DU of the network slice subnet (DLDelay_gNBDU_Nss):

$$\mathrm{DLDelay\_NR\_Nss}.SNSSAI = \mathrm{DLDelay\_gNBCUUP\_Nss}.SNSSAI + \mathrm{DLDelay\_gNBDU\_Nss}.SNSSAI$$

where *SNSSAI* identifies the S-NSSAI that the network slice subnet supports.

d) NetworkSliceSubnet

NOTE: If the HARQ process is configured with disabled HARQ feedback for NTN (refer to 38.321[15]), this KPI is not available for UM mode.

6.3.1.3 Downlink delay in gNB-DU

6.3.1.3.1 Downlink delay in gNB-DU for a NRCellDU

a) DLDelay_gNBDU_Cell.

b) This KPI describes the average packet transmission delay through the gNB-DU part to the UE. It is used to evaluate delay performance of gNB-DU in downlink. It is the average packets delay time from arrival of an RLC SDU at the RLC ingress F1-U termination until the last part of an RLC SDU packet was received by the UE according to received HARQ feedback information for UM mode or until the last part of an RLC SDU packet was received by the UE according to received RLC ACK for AM mode. This KPI can optionally be split into KPIs per QoS level (mapped 5QI or QCI in EN-DC architecture) and per S-NSSAI.

b-1) Integer, time interval (0.1 mS)

b-2) MEAN

c) Below is the equation for average DL delay in gNB-DU for a NRCellDU:

$$\mathrm{DLDelay\_gNBDU\_Cell} = \mathrm{DRB.RlcSduDelayDl} + \mathrm{DRB.AirIfDelayDl}$$

and optionally:

$$\mathrm{DLDelay\_gNBDU}.QOS = \mathrm{DRB.RlcSduDelayDl}.QOS + \mathrm{DRB.AirIfDelayDl}.QOS$$

where *QOS* identifies the target quality of service class.

and optionally:

$$\mathrm{DLDelay\_gNB}.SNSSAI = \mathrm{DRB.RlcSduDelayDl}.SNSSAI + \mathrm{DRB.AirIfDelayDl}.SNSSAI$$

where *SNSSAI* identifies the S-NSSAI.

d) NRCellDU

NOTE: If the HARQ process is configured with disabled HARQ feedback for NTN (refer to 38.321[15]), this KPI is not available for UM mode.

6.3.1.3.2 Downlink delay in gNB-DU for a sub-network

a) DLDelay_gNBDU_SNw.

b) This KPI describes the average packet transmission delay through the gNB-DU part to the UE. It is used to evaluate delay performance of gNB-DU in downlink for a sub-network. It is the weighted average packets delay time from arrival of an RLC SDU at the RLC ingress F1-U termination until the last part of an RLC SDU packet was received by the UE according to received HARQ feedback information for UM mode or until the last part of an RLC SDU packet was received by the UE according to received RLC ACK for AM mode. This KPI can optionally be split into KPIs per QoS level (mapped 5QI or QCI in EN-DC architecture) and per S-NSSAI.

b-1) Integer, time interval (0.1 mS)

b-2) MEAN

c) Below is the equation for average DL delay in gNB-DU for a sub-network, where:

i) W is the measurement for the weighted average, one of the following:

- the DL data volume of the NR cell;
- the number of UL user data packets of the NR cell;
- any other types of weight defined by the consumer of KPI

ii) the #NRCellDU is the number of NRCellDU's in the SubNetwork.

$$DLDelay\_gNBDU\_SNw = \frac{\sum_{1}^{\#NRCellDU}((DRB.RlcSduDelayDl + DRB.AirIfDelayDl) * W)}{\sum_{1}^{\#NRCellDU}(W)}$$

and optionally KPI on SubNetwork level per QoS and per S-NSSAI:

$$DLDelay\_gNBDU\_SNw.QoS = \frac{\sum_{1}^{\#NRCellDU}((DRB.RlcSduDelayDl.QoS + DRB.AirIfDelayDl.QoS) * W.QoS)}{\sum_{1}^{\#NRCellDU}(W.QoS)}$$

$$DLDelay\_gNBDU\_SNw.SNSSAI = \frac{\sum_{1}^{\#NRCellDU}((DRB.RlcSduDelayDl.SNSSAI + DRB.AirIfDelayDl.SNSSAI) * W.SNSSAI)}{\sum_{1}^{\#NRCellDU}(W.SNSSAI)}$$

d) SubNetwork

NOTE: If the HARQ process is configured with disabled HARQ feedback for NTN (refer to 38.321[15]), this KPI is not available for UM mode.

6.3.1.3.3 Downlink delay in gNB-DU for a network slice subnet

a) DLDelay_gNBDU_Nss.

b) This KPI describes the average packet transmission delay through the gNB-DU part to the UE. It is used to evaluate delay performance of gNB-DU in downlink for a network slice subnet. It is the weighted average packets delay time from arrival of an RLC SDU at the RLC ingress F1-U termination until the last part of an RLC SDU packet was received by the UE according to received HARQ feedback information for UM mode or until the last part of an RLC SDU packet was received by the UE according to received RLC ACK for AM mode.

b-1) Integer, time interval (0.1 mS)

b-2) MEAN

c) Below is the equation for average DL delay in gNB-DU for a network slice subnet, where:

i) W is the measurement for the weighted average, one of the following:

- the DL data volume of the NR cell;
- the number of DL user data packets of the NR cell;
- any other types of weight requested by the consumer of KPI;

ii) the #NRCellDU is the number of NRCellDU's associated with the NetworkSliceSubnet.

$$DLDelay\_gNBDU\_Nss.SNSSAI = \frac{\sum_{1}^{\#NRCellDU}((DRB.RlcSduDelayDl.SNSSAI + DRB.AirIfDelayDl.SNSSAI) * W.SNSSAI)}{\sum_{1}^{\#NRCellDU}(W.SNSSAI)}$$

d) NetworkSliceSubnet

NOTE: If the HARQ process is configured with disabled HARQ feedback for NTN (refer to 38.321[15]), this KPI is not available for UM mode.

6.3.1.4 Downlink delay in gNB-CU-UP

6.3.1.4.1 Downlink delay in gNB-CU-UP

a) DLDelay_gNBCUUP.

b) This KPI describes the average packet transmission delay through the gNB-CU-UP to the gNB-DU. It is used to evaluate the delay performance of gNB-CU-UP in downlink. It is the average packets delay from reception of IP packet in gNB-CU-UP until the time of arrival, at the gNB-DU, of the RLC SDU at the RLC ingress F1-U termination. This KPI can optionally be split into KPIs per QoS level (mapped 5QI or QCI in EN-DC architecture) and per S-NSSAI.

b-1) Integer, time interval (0.1 mS)

b-2) MEAN

c) Below the equation for average DL delay in a gNB-CU-CP:

$$\mathrm{DLDelay\_gNBCUUP} = \mathrm{DRB.PdcpSduDelayDl} + \mathrm{DRB.PdcpF1Delay}$$

and optionally:

$$\mathrm{DLDelay\_gNBCUUP}.QOS = \mathrm{DRB.PdcpSduDelayDl}.QOS + \mathrm{DRB.PdcpF1Delay}.QOS$$

where *QOS* identifies the target quality of service class.

and optionally:

$$\mathrm{DLDelay\_gNBCUUP}.SNSSAI = \mathrm{DRB.PdcpSduDelayDl}.SNSSAI + \mathrm{DRB.PdcpF1Delay}.SNSSAI$$

where *SNSSAI* identifies the S-NSSAI.

d) GNBCUUPFunction

e) In non-split gNB scenario, the value of DRB.PdcpF1Delay (optionally DRB.PdcpF1Delay.*QOS*, and optionally *DRB.PdcpF*1Delay.*SNSSAI)* is set to zero because there are no F1-interfaces in this scenario.

6.3.1.4.2 Downlink delay in gNB-CU-UP for a sub-network

a) DLDelay_gNBCUUP_SNw.

b) This KPI describes the average packet transmission delay through the gNB-CU-UP to the gNB-DU. It is used to evaluate the delay performance of gNB-CU-UP in downlink for a sub-network. It is the weighted average packets delay from reception of IP packet in gNB-CU-UP until the time of arrival, at the gNB-DU, of the RLC SDU at the RLC ingress F1-U termination. This KPI can optionally be split into KPIs per QoS level (mapped 5QI or QCI in EN-DC architecture) and per S-NSSAI.

b-1) Integer, time interval (0.1 mS)

b-2) MEAN

c) Below is the equation for average UL delay in gNB-CU-UP for a sub-network, where:

i) W is the measurement for the weighted average, one of the following:

- the DL data volume in gNB-CU-UP;
- the number of DL user data packets in gNB-CU-UP;
- any other types of weight requested by the consumer of KPI;

ii) the # GNBCUUPFunctions is the number of GNBCUUPFunctions's in the SubNetwork.

$$DLDelay\_gNBCUUP\_SNw = \frac{\sum_{1}^{\#GNBCUUPFunction}((DRB.PdcpSduDelayDl + DRB.PdcpF1Delay) \times W)}{\sum_{1}^{\#GNBCUUPFunction}(W)}$$

and optionally KPI on SubNetwork level per QoS and per S-NSSAI:

$$DLDelay\_gNBCUUP\_SNw.QoS = \frac{\sum_{1}^{\#GNBCUUPFunction}((DRB.PdcpSduDelayDl.QoS + DRB.PdcpF1Delay.QoS) \times W.QoS)}{\sum_{1}^{\#GNBCUUPFunction}(W.QoS)}$$

$$DLDelay\_gNBCUUP\_SNw.SNSSAI = \frac{\sum_{1}^{\#GNBCUUPFunction}((DRB.PdcpSduDelayDl.SNSSAI + DRB.PdcpF1Delay.SNSSAI) \times W.SNSSAI)}{\sum_{1}^{\#GNBCUUPFunction}(W.SNSSAI)}$$

d) SubNetwork

e) In non-split gNB scenario, the value of DRB.PdcpF1Delay (optionally DRB.PdcpF1Delay.*QOS*, and optionally DRB.PdcpF1Delay.*SNSSAI)* is set to zero because there are no F1-interfaces in this scenario.

6.3.1.4.3 Downlink delay in gNB-CU-UP for a network slice subnet

a) DLDelay_gNBCUUP_Nss.

b) This KPI describes the average packet transmission delay through the gNB-CU-UP to gNB-DU. It is used to evaluate the delay performance of gNB-CU-UP in downlink for a network slice subnet. It is the weighted average packets delay from reception of IP packet in gNB-CU-UP until the time of arrival, at the gNB-DU, of the RLC SDU at the RLC ingress F1-U termination.

b-1) Integer, time interval (0.1 mS)

b-2) MEAN

c) Below is the equation for average UL delay in gNB-CU-UP for a network slice subnet, where:

i) W is the measurement for the weighted average, one of the following:

- the DL data volume in gNB-CU-UP;
- the number of DL user data packets in gNB-CU-UP;
- any other types of weight requested by the consumer of KPI;

ii) the # GNBCUUPFunctions is the number of GNBCUUPFunctions' associated with the NetworkSliceSubnet.

$$DLDelay\_gNBCUUP\_Nss.SNSSAI = \frac{\sum_{1}^{\#GNBCUUPFunction}((DRB.PdcpSduDelayDl.SNSSAI + DRB.PdcpF1Delay.SNSSAI) \times W.SNSSAI)}{\sum_{1}^{\#GNBCUUPFunction}(W.SNSSAI)}$$

d) NetworkSliceSubnet

e) In non-split gNB scenario, the value of DRB.PdcpF1Delay.*SNSSAI* is set to zero because there are no F1-interfaces in this scenario.

6.3.1.5 Uplink delay in gNB-DU

6.3.1.5.1 Uplink delay in gNB-DU for a NR cell

a) ULDelay_gNBDU_Cell.

b) This KPI describes the average packet transmission delay through the gNB-DU part from the UE in a NR cell. It is used to evaluate delay performance of gNB-DU in uplink. It is the average packet delay from when an UL RLC SDU was scheduled, as per the scheduling grant provided, until time when the RLC SDU is sent to PDCP or CU for split gNB. This KPI can optionally be split into KPIs per QoS level (mapped 5QI or QCI in EN-DC architecture) and per S-NSSAI.

b-1) Integer, time interval (0.1 mS)

b-2) MEAN

c) Below is the equation for average UL delay in gNB-DU for a NRCellDU:

$$\text{ULDelay\_gNBDU\_Cell} = \text{DRB.RlcDelayUI} + \text{DRB.AirIfDelayUI}$$

and optionally:

$$\text{ULDelay}_{\text{gNBDU}}.QoS = \text{DRB. RlcDelayUl.}QOS + \text{DRB. AirIfDelayUl.}QOS$$

where *QOS* identifies the target quality of service class.

and optionally:

$$\text{ULDelay\_gNBDU.}SNSSAI = \text{DRB. RlcDelayUl.}SNSSAI + \text{DRB. AirIfDelayUl.}SNSSAI$$

where *SNSSAI* identifies the S-NSSAI.

d) NRCellDU

6.3.1.5.2 Uplink delay in gNB-DU for a sub-network

a) ULDelay_gNBDU_SNw.

b) This KPI describes the average packet transmission delay through the gNB-DU part from the UE for a sub-network. It is used to evaluate delay performance of gNB-DU in uplink for a sub-network. It is the weighted average packet delay from when an UL RLC SDU was scheduled, as per the scheduling grant provided, until time when the RLC SDU is sent to PDCP or CU for split gNB. This KPI can optionally be split into KPIs per QoS level (mapped 5QI or QCI in EN-DC architecture) and per S-NSSAI.

b-1) Integer, time interval (0.1 mS)

b-2) MEAN

c) Below is the equation for average UL delay in gNB-DU for a sub-network, where:

i) W is the measurement for the weighted average, one of the following:

- the UL data volume of the NR cell;
- the number of UL user data packets of the NR cell;
- any other types of weight defined by the consumer of KPI.

ii) the #NRCellDU is the number of NRCellDU's in the SubNetwork.

$$ULDelay\_gNB\_SNw = \frac{\sum_1^{\#NRCellDU}((DRB.RlcDelayUl + DRB.AirIfDelayUl) \times W)}{\sum_1^{\#NRCellDU}(W)}$$

and optionally KPI on SubNetwork level per QoS and per S-NSSAI:

$$ULDelay\_gNB\_SNw.QoS = \frac{\sum_1^{\#NRCellDU}((DRB.RlcDelayUl.QoS + DRB.AirIfDelayUl.QoS) \times W.QoS)}{\sum_1^{\#NRCellDU}(W.QoS)}$$

$$ULDelay\_gNB\_SNw.SNSSAI = \frac{\sum_1^{\#NRCellDU}((DRB.RlcDelayUl.SNSSAI + DRB.AirIfDelayUl.SNSSAI) \times W.SNSSAI)}{\sum_1^{\#NRCellDU}(W.SNSSAI)}$$

d) SubNetwork

6.3.1.5.3 Uplink delay in gNB-DU for a network slice subnet

a) ULDelay_gNBDU_Nss.

b) This KPI describes the average packet transmission delay through the gNB-DU part from the UE for a network slice subnet. It is used to evaluate delay performance of gNB-DU in uplink for a network slice subnet. It is the weighted average packet delay from when an UL RLC SDU was scheduled, as per the scheduling grant provided, until time when the RLC SDU is sent to PDCP or CU for split gNB.

b-1) Integer, time interval (0.1 mS)

b-2) MEAN

c) Below is the equation for average UL delay in gNB-DU for a network slice subnet, where

i) W is the measurement for the weighted average, one of the following:

- the UL data volume of the NR cell;
- the number of UL user data packets of the NR cell;
- any other types of weight requested by the consumer of KPI;

ii) the #NRCellDU is the number of NRCellDU's associated with the NetworkSliceSubnet.

$$ULDelay\_gNBDU\_Nss.SNSSAI = \frac{\sum_{1}^{\#NRCellDU}\left((DRB.RlcDelayUl.SNSSAI + DRB.AirIfDelayUl.SNSSAI) \times W.SNSSAI\right)}{\sum_{1}^{\#NRCellDU}(W.SNSSAI)}$$

d) NetworkSliceSubnet

6.3.1.6 Uplink delay in gNB-CU-UP

6.3.1.6.1 Uplink delay in gNB-CU-UP

a) ULDelay_gNBCUUP.

b) This KPI describes the average packet transmission delay through the gNB-CU-UP from gNB-DU. It is used to evaluate delay performance of gNB-CU-UP in uplink. It is the average packet delay from when the RLC SDU is sent to PDCP or CU for split gNB, until time when the corresponding PDCP SDU was sent to the core network from gNB-CU-UP. This KPI can optionally be split into KPIs per QoS level (mapped 5QI or QCI in EN-DC architecture) and per S-NSSAI.

b-1) Integer, time interval (0.1 mS)

b-2) MEAN

c) Below the equation for average UL delay in a gNB-CU-CP:

$$\mathrm{ULDelay\_gNBCUUP} = \mathrm{DRB.PdcpReordDelayUl} + \mathrm{DRB.PdcpF1Delay}$$

and optionally:

$$\mathrm{ULDelay\_gNBCUUP.}QoS = \mathrm{DRB.PdcpReordDelayUl.}QoS + \mathrm{DRB.PdcpF1Delay.}QoS$$

where *QOS* identifies the target quality of service class.

and optionally:

$$\mathrm{ULDelay\_gNBCUUP.}SNSSAI = \mathrm{DRB.PdcpReordDelayUl.}SNSSAI + \mathrm{DRB.PdcpF1Delay.}SNSSAI$$

where *SNSSAI* identifies the S-NSSAI.

d) GNBCUUPFunction

e) It is assumed that the F1 uplink delay is the same as the F1 downlink delay. In non-split gNB scenario, the value of DRB.PdcpF1Delay (optionally DRB.PdcpF1Delay.*QOS*, and optionally *DRB.PdcpF*1Delay.*SNSSAI)* is set to zero because there are no F1-interfaces in this scenario.

6.3.1.6.2 Uplink delay in gNB-CU-UP for a sub-network

a) ULDelay_gNBCUUP_SNw.

b) This KPI describes the average packet transmission delay through the gNB-CU-UP part from the gNB-DU for a sub-network. It is used to evaluate delay performance of gNB-CU-UP in uplink for a sub-network. It is the weighted average packet delay from when the RLC SDU is sent to PDCP or CU for split gNB, until time when the corresponding PDCP SDU was sent to the core network from gNB-CU-UP. This KPI can optionally be split into KPIs per QoS level (mapped 5QI or QCI in EN-DC architecture) and per S-NSSAI.

b-1) Integer, time interval (0.1 mS)

b-2) MEAN

c) Below is the equation for average UL delay in gNB-CU-UP for a sub-network, where:

i) W is the measurement for the weighted average, one of the following:

- the UL data volume in gNB-CU-UP;
- the number of UL user data packets in gNB-CU-UP;
- any other types of weight requested by the consumer of KPI;

ii) the # GNBCUUPFunctions is the number of GNBCUUPFunctions' in the SubNetwork.

$$ULDelay\_gNBCUUP\_SNw = \frac{\sum_{1}^{\#GNBCUUPFunction}((DRB.PdcpReordDelayUl + DRB.PdcpF1Delay) \times W)}{\sum_{1}^{\#GNBCUUPFunction}(W)}$$

and optionally KPI on SubNetwork level per QoS and per S-NSSAI:

$$ULDelay\_gNBCUUP\_SNw.QoS = \frac{\sum_{1}^{\#GNBCUUPFunction}((DRB.PdcpReordDelayUl.QoS + DRB.PdcpF1Delay.QoS) \times W.QoS)}{\sum_{1}^{\#GNBCUUPFunction}(W.QoS)}$$

$$ULDelay\_gNBCUUP\_SNw.SNSSAI = \frac{\sum_{1}^{\#GNBCUUPFunction}((DRB.PdcpReordDelayUl.SNSSAI + DRB.PdcpF1Delay.SNSSAI) \times W.SNSSAI)}{\sum_{1}^{\#GNBCUUPFunction}(W.SNSSAI)}$$

d) SubNetwork

e) It is assumed that the F1 uplink delay is the same as the F1 downlink delay. In non-split gNB scenario, the value of DRB.PdcpF1Delay (optionally DRB.PdcpF1Delay.*QOS*, and optionally DRB.PdcpF1Delay.*SNSSAI)* is set to zero because there are no F1-interfaces in this scenario.

6.3.1.6.3 Uplink delay in gNB-CU-UP for a network slice subnet

a) ULDelay_gNBCUUP_Nss.

b) This KPI describes the average packet transmission delay through the gNB-CU-UP part from the gNB-DU for a network slice subnet. It is used to evaluate delay performance of gNB-CU-UP in uplink for a network slice subnet. It is the weighted average packet delay from when the RLC SDU is sent to PDCP or CU for split gNB, until time when the corresponding PDCP SDU was sent to the core network from gNB-CU-UP. This KPI can optionally be split into KPIs per QoS level (mapped 5QI or QCI in EN-DC architecture) and per S-NSSAI.

b-1) Integer, time interval (0.1 mS)

b-2) MEAN

c) Below is the equation for average UL delay in gNB-CU-UP for a network slice subnet, where:

i) W is the measurement for the weighted average, one of the following:

- the UL data volume in gNB-CU-UP;
- the number of UL user data packets in gNB-CU-UP;
- any other types of weight requested by the consumer of KPI;

ii) the # GNBCUUPFunctions is the number of GNBCUUPFunctions's associated with the NetworkSliceSubnet.

$$ULDelay\_gNBCUUP\_Nss = \frac{\sum_{1}^{\#GNBCUUPFunction}((DRB.PdcpReordDelayUl.SNSSAI + DRB.PdcpF1Delay.SNSSAI) \times W.SNSSAI)}{\sum_{1}^{\#GNBCUUPFunction}(W.SNSSAI)}$$

d) NetworkSliceSubnet

e) It is assumed that the F1 uplink delay is the same as the F1 downlink delay. In non-split gNB scenario, the value of DRB.PdcpF1Delay.*SNSSAI* is set to zero because there are no F1-interfaces in this scenario.

6.3.1.7 Integrated uplink delay in RAN

6.3.1.7.1 Uplink delay in NG-RAN for a sub-network

a) ULDelay_NR_SNw.

b) This KPI describes the average packet transmission delay through the RAN part from the UE for a sub-network. It is used to evaluate delay performance of NG-RAN in uplink. It is the weighted average packet delay from when an UL RLC SDU was scheduled, as per the scheduling grant provided, until time when the corresponding PDCP SDU was sent to the core network from gNB-CU-UP. This KPI can optionally be split into KPIs per QoS level (mapped 5QI or QCI in EN-DC architecture) and per S-NSSAI.

b-1) Integer, time interval (0.1 mS)

b-2) MEAN

c) Below are the equations for average "Integrated uplink delay in RAN" for this KPI on SubNetwork level. The "Integrated uplink delay in RAN" is the sum of average UL delay in gNB-CU-UP of the sub-network (ULDelay_gNBCUUP_SNw) and the average UL delay in gNB-DU of the sub-network (ULDelay_gNBDU_SNw):

$$\mathrm{ULDelay\_NR\_SNw} = \mathrm{ULDelay\_gNBCUUP\_SNw} + \mathrm{ULDelay\_gNBDU\_SNw}$$

or optionally

$$\mathrm{ULDelay\_\ NR\_SNw}.QOS = \mathrm{ULDelay\_gNBCUUP\_SNw}.QOS + \mathrm{ULDelay\_gNBDU\_SNw}.QOS$$

where *QOS* identifies the target quality of service class.

or optionally

$$\mathrm{ULDelay\_NR\_SNw}.SNSSAI = \mathrm{ULDelay\_gNBCUUP\_SNw}.SNSSAI + \mathrm{ULDelay\_gNBDU\_SNw}.SNSSAI$$

where *SNSSAI* identifies the S-NSSAI.

d) SubNetwork

6.3.1.7.2 Uplink delay in NG-RAN for a network slice subnet

a) ULDelay_NR_Nss.

b) This KPI describes the average packet transmission delay through the RAN part from the UE for a network slice subnet. It is used to evaluate delay performance of NG-RAN in uplink. It is the weighted average packet delay from when an UL RLC SDU was scheduled, as per the scheduling grant provided, until time when the corresponding PDCP SDU was sent to the core network from gNB-CU-UP. This KPI can optionally be split into KPIs per QoS level (mapped 5QI or QCI in EN-DC architecture) and per S-NSSAI.

b-1) Integer, time interval (0.1 mS)

b-2) MEAN

c) Below is the equation for average "Integrated uplink delay in RAN" for this KPI on NetworkSliceSubNet level. The "Integrated uplink delay in RAN" for network slice subnet is the sum of average UL delay in gNB-CU-UP of the network slice subnet (ULDelay_gNBCUUP_Nss) and the average UL delay in gNB-DU of the network slice subnet (ULDelay_gNBDU_Nss):

$$\text{ULDelay\_NR\_Nss}.SNSSAI = \text{ULDelay\_gNBCUUP\_Nss}.SNSSAI + \text{ULDelay\_gNBDU\_Nss}.SNSSAI$$

where *SNSSAI* identifies the S-NSSAI that the network slice subnet supports.

d) NetworkSliceSubnet

6.3.1.8 E2E delay for network slice

6.3.1.8.1 Average e2e uplink delay for a network slice

a) DelayE2EUlNs.

b) This KPI describes the average e2e UL packet delay between the PSA UPF and the UE for a network slice. It is the weighted average packet delay from the time when an UL RLC SDU was scheduled at the UE until the time when the corresponding GTP PDU was received by the PSA UPF.

b-1) Integer, time interval (0.1 mS)

b-2) MEAN

c) This KPI is the weighted average of UL packet delay between PSA UPF and UE, for all N3 interfaces (modelled by EP_N3 MOIs) and N9 interfaces (modelled by EP_N9 MOIs) of all PSA UPFs supporting the network slice (modelled by NetworkSlice MOI) identified by the S-NSSAI.

This KPI is calculated in the equation below, where Wn3 and Wn9 are the measurements for the weighted average, Wn3 is one of the following:

- the data volume of UL GTP PDUs received by PSA UPF on the N3 interface;
- the number of UL GTP PDUs received by PSA UPF on the N3 interface;
- any other types of weight defined by the consumer of KPI.

And Wn9 is one of the following:

- the data volume of UL GTP PDUs received by PSA UPF on the N9 interface;
- the number of UL GTP PDUs received by PSA UPF on the N9 interface;
- any other types of weight defined by the consumer of KPI.

$$DelayE2EUlNs = \frac{\sum_{EP\_N3}(GTP.DelayUlPsaUpfUeMean.SNSSAI \times Wn3.SNSSAI) + \sum_{EP\_N9}(GTP.DelayUlPsaUpfUeMean.SNSSAI \times Wn9.SNSSAI)}{\sum_{EP\_N3} Wn3.SNSSAI + \sum_{EP\_N9} Wn9.SNSSAI}$$

Where the *SNSSAI* identifies the S-NSSAI.

d) NetworkSlice.

6.3.1.8.2 Average e2e downlink delay for a network slice

a) DelayE2EDlNs.

b) This KPI describes the average e2e DL packet delay between the PSA UPF and the UE for a network slice. It is the weighted average packet delay from the time when an GTP PDU has been sent by the PSA UPF until time when the corresponding RLC SDU was received by the UE.

   b-1) Integer, time interval (0.1 mS)

   b-2) MEAN

c) This KPI is the weighted average of DL packet delay between PSA UPF and UE, for all N3 interfaces (modelled by EP_N3 MOIs) and N9 interfaces (modelled by EP_N9 MOIs) of all PSA UPFs supporting the network slice (modelled by NetworkSlice MOI) identified by the S-NSSAI.

   This KPI is calculated in the equation below, where Wn3 and Wn9 are the measurements for the weighted average, Wn3 is one of the following:

   - the data volume of DL GTP PDUs transmitted by PSA UPF on the N3 interface;
   - the number of DL GTP PDUs transmitted by PSA UPF on the N3 interface;
   - any other types of weight defined by the consumer of KPI.

   And Wn9 is one of the following:

   - the data volume of DL GTP PDUs transmitted by PSA UPF on the N9 interface;
   - the number of DL GTP PDUs transmitted by PSA UPF on the N9 interface;
   - any other types of weight defined by the consumer of KPI.

$$DelayE2EDlNs = \frac{\sum_{EP\_N3}(GTP.DelayDlPsaUpfUeMean.SNSSAI \times GTP.Wn3.SNSSAI) + \sum_{EP\_N9}(GTP.DelayDLPsaUpfUeMean.SNSSAI \times Wn9.SNSSAI)}{\sum_{EP\_N3} Wn3.SNSSAI + \sum_{EP\_N9} Wn9.SNSSAI}$$

   Where the *SNSSAI* identifies the S-NSSAI.

d) NetworkSlice.

6.3.2 Upstream throughput for network and Network Slice Instance

a) UTSNSI.

b) This KPI describes the upstream throughput of one single network slice by computing the packet size for each successfully received UL packet through the network slice during each observing granularity period and is used to evaluate integrity performance of the end-to-end network slice. It is obtained by measuring the total number of upstream octets provided by N3 interface from NG-RAN to all UPFs, related to the single network slice, divided by the granularity period (in milliseconds).

   b-1) Integer, kbit/s

   b-2) MEAN

c)

$$UTSNSI = \frac{\sum_{UPF} GTP.InDataOctN3UPF.SNSSAI}{GranularityPeriod} \times 8$$

d) NetworkSlice, SubNetwork.

6.3.3 Downstream throughput for Single Network Slice Instance

a) DTSNSI.

b) This KPI describes the downstream throughput of one single network slice instance by computing the packet size for each successfully transmitted DL packet through the network slice instance during each observing granularity period and is used to evaluate integrity performance of the end-to-end network slice instance. It is obtained by measuring the total number of downstream octets provided by N3 interface from all UPFs to NG-RAN, related to the single network slice, divided by the granularity period (in milliseconds).

b-1) Integer, kbit/s

b-2) MEAN

c)

$$DTSNSI = \frac{\sum_{UPF} GTP.OutDataOctN3UPF.SNSSAI}{GranularityPeriod} \times 8$$

d) NetworkSlice, SubNetwork.

6.3.4 Upstream Throughput at N3 interface

a) UGTPTN.

b) This KPI describes the throughput of incoming GTP data packets on the N3 interface (measured at UPF) which have been generated by the GTP-U protocol entity on the N3 interface, during a granularity period. This KPI is used to evaluate upstream GTP throughput integrity performance at the N3 interface. It is obtained by measuring the total number of octets GTP data packets upstream throughput provided by N3 interface from NG-RAN to UPF, divided by the granularity period (in milliseconds).

b-1) Integer, kbit/s

b-2) MEAN

c)

$$UGTPTN = \frac{GTP.InDataOctN3UPF}{GranularityPeriod} \times 8$$

d) UPFFunction

6.3.5 Downstream Throughput at N3 interface

a) DGTPTN.

b) This KPI describes the throughput of downstream GTP data packets on the N3 interface (transmitted downstream from UPF) which have been generated by the GTP-U protocol entity on the N3 interface, during a granularity period. This KPI is used to evaluate integrity performance at N3 interface. It is obtained by measuring the total number of octets GTP data packets downstream throughput provided by N3 interface from UPF to NG-RAN, divided by the granularity period (in milliseconds).

b-1) Integer, kbit/s

b-2) MEAN

c)

$$DGTPTN = \frac{GTP.OutDataOctN3UPF}{GranularityPeriod} \times 8$$

d) UPFFunction

6.3.6 RAN UE Throughput

6.3.6.1 Void

6.3.6.2 RAN UE Throughput definition

To achieve a Throughput measurement (below examples are given for DL) that is independent of file size and gives a relevant result it is important to remove the volume and time when the resource on the radio interface is not fully utilized. (Successful transmission, buffer empty in figure 1).

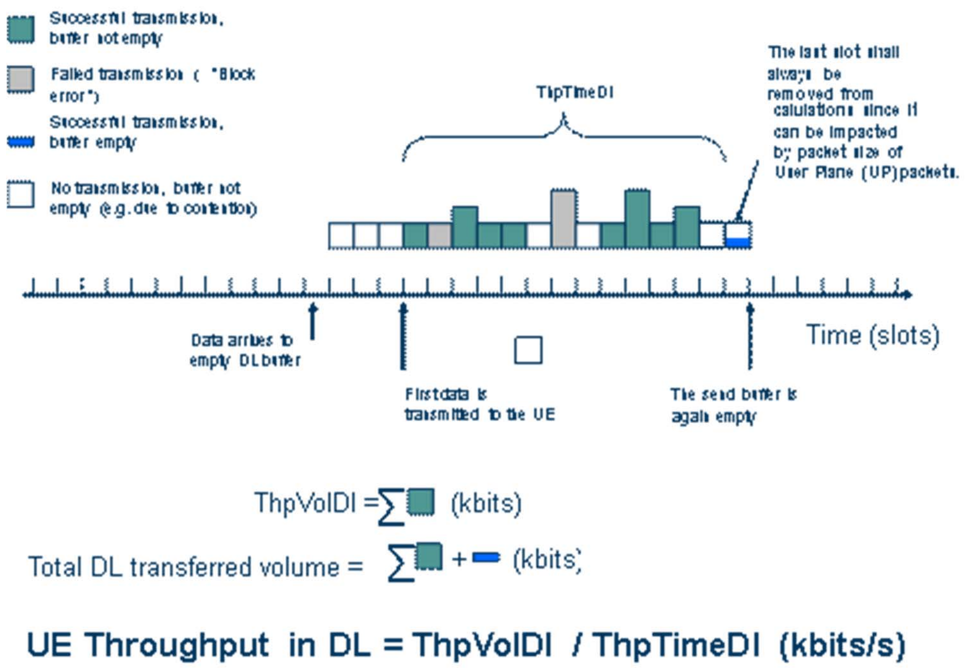


Figure 1

To achieve a throughput measurement that is independent of bursty traffic pattern, it is important to make sure that idle gaps between incoming data is not included in the measurements. That shall be done as considering each burst of data as one sample.

6.3.6.3 DL RAN UE throughput

6.3.6.3.1 DL RAN UE throughput for a NRCellDU

a) DlUeThroughput_Cell.

b) This KPI describes the average DL RAN UE throughput for a NRCellDU. This KPI can optionally be split into KPIs per QoS level (mapped 5QI or QCI in EN-DC architecture) and per S-NSSAI.

b-1) Integer, kbit/s

b-2) MEAN

c) Below is the equation for average DL RAN UE throughput for a NRCellDU:

DlUeThroughput_Cell = DRB.UEThpDl

and optionally:

DlUeThroughput_Cell.*QOS* = DRB.UEThpDl.*QOS* where *QOS* identifies the target quality of service class;

and optionally:

DlUeThroughput_Cell.*SNSSAI* = DRB.UEThpDl.*SNSSAI*

where *SNSSAI* identifies the S-NSSAI.

d) NRCellDU

6.3.6.3.2 DL RAN UE throughput for a sub-network

a) DlUeThroughput_SNw.

b) This KPI describes the average DL RAN UE throughput for a sub-network. This KPI can optionally be split into KPIs per QoS level (mapped 5QI or QCI in EN-DC architecture) and per S-NSSAI.

b-1) Integer, kbit/s

b-2) MEAN

c) Below is the equation for average DL RAN UE throughput for a sub-network, where:

i) W is the measurement for the weighted average, it is one of the following:

- the DL data volume of the NR cell;
- a weight defined by the consumer of KPI;

ii) the #NRCellDU is the number of NRCellDU's in the SubNetwork.

$$DlUeThroughput\_SNw = \frac{\sum_1^{\#NRCellDU}(W)}{\sum_1^{\#NRCellDU}\left(\frac{W}{DRB.UEThpDl}\right)}$$

and optionally KPI on SubNetwork level per QoS and per S-NSSAI:

$$DlUeThroughput\_SNw.QoS = \frac{\sum_1^{\#NRCellDU}(W.QoS)}{\sum_1^{\#NRCellDU}\left(\frac{W.QoS}{DRB.UEThpDl.QoS}\right)}$$

$$DlUeThroughput\_SNw.SNSSAI = \frac{\sum_1^{\#NRCellDU}(W.SNSSAI)}{\sum_1^{\#NRCellDU}\left(\frac{W.SNSSAI}{DRB.UEThpDl.SNSSAI}\right)}$$

d) SubNetwork

6.3.6.3.3 DL RAN UE throughput for a network slice subnet

a) DlUeThroughput_Nss.

b) This KPI describes the average DL RAN UE throughput for a network slice subnet.

b-1) Integer, kbit/s

b-2) MEAN

c) Below is the equation for average DL RAN UE throughput for a network slice subnet, where:

i) W is the measurement for the weighted average, it is one of the following:

- the DL data volume of the NR cell;
- a weight defined by the consumer of KPI;

ii) the #NRCellDU is the number of NRCellDU's associated with the NetworkSliceSubnet.

$$DlUeThroughput\_Nss.SNSSAI = \frac{\sum_{1}^{\#NRCellDU}(W.SNSSAI)}{\sum_{1}^{\#NRCellDU}\left(\frac{W.SNSSAI}{DRB.UEThpDl.SNSSAI}\right)}$$

where the *SNSSAI* identifies the S-NSSAI that the NetworkSliceSubnet supports.

d) NetworkSliceSubnet

6.3.6.4 UL RAN UE throughput

6.3.6.4.1 UL RAN UE throughput for a NRCellDU

a) UlUeThroughput_Cell.

b) This KPI describes the average UL RAN UE throughput for a NRCellDU. This KPI can optionally be split into KPIs per QoS level (mapped 5QI or QCI in EN-DC architecture) and per S-NSSAI.

b-1) Integer, kbit/s

b-2) MEAN

c) Below is the equation for average UL RAN UE throughput for a NRCellDU:

UlUeThroughput_Cell = DRB.UEThpUl

and optionally:

UlUeThroughput_Cell.*QOS* = DRB.UEThpUl.*QOS*

where *QOS* identifies the target quality of service class

and optionally:

UlUeThroughput_Cell.*SNSSAI* = DRB.UEThpUl.*SNSSAI*

where *SNSSAI* identifies the S-NSSAI.

d) NRCellDU

6.3.6.4.2 UL RAN UE throughput for a sub-network

a) UlUeThroughput_SNw.

b) This KPI describes the average UL RAN UE throughput for a sub-network. This KPI can optionally be split into KPIs per QoS level (mapped 5QI or QCI in EN-DC architecture) and per S-NSSAI.

b-1) Integer, kbit/s

b-2) MEAN

c) Below is the equation for average UL RAN UE throughput for a sub-network, where:

i) W is the measurement for the weighted average, it is one of the following:

- the UL data volume of the NR cell;
- a weight defined by the consumer of KPI;

ii) the #NRCellDU is the number of NRCellDU's in the SubNetwork.

$$UlUeThroughput\_SNw = \frac{\sum_1^{\#NRCellDU}(W)}{\sum_1^{\#NRCellDU}\left(\frac{W}{DRB.UEThpUl}\right)}$$

and optionally KPI on SubNetwork level per QoS and per S-NSSAI:

$$UlUeThroughput\_SNw.QoS = \frac{\sum_1^{\#NRCellDU}(W.QoS)}{\sum_1^{\#NRCellDU}\left(\frac{W.QoS}{DRB.UEThpUl.QoS}\right)}$$

$$UlUeThroughput\_SNw.SNSSAI = \frac{\sum_1^{\#NRCellDU}(W.SNSSAI)}{\sum_1^{\#NRCellDU}\left(\frac{W.SNSSAI}{DRB.UEThpUl.SNSSAI}\right)}$$

d) SubNetwork

6.3.6.4.3 UL RAN UE throughput for a network slice subnet

a) UlUeThroughput_Nss.

b) This KPI describes the average UL RAN UE throughput for a network slice subnet.

b-1) Integer, kbit/s

b-2) MEAN

c) Below is the equation for average UL RAN UE throughput for a network slice subnet, where:

i) W is the measurement for the weighted average, it is one of the following:

- the UL data volume of the NR cell;
- a weight defined by the consumer of KPI

ii) the #NRCellDU is the number of NRCellDU's associated with the NetworkSliceSubnet.

$$UlUeThroughput\_Nss.SNSSAI = \frac{\sum_1^{\#NRCellDU}(W.SNSSAI)}{\sum_1^{\#NRCellDU}\left(\frac{W.SNSSAI}{DRB.UEThpUl.SNSSAI}\right)}$$

where the *SNSSAI* identifies the S-NSSAI that the NetworkSliceSubnet supports.

d) NetworkSliceSubnet

6.3.7 Upstream throughput for 5G VN Group

a) UTSNSI_5GVNGroup.

b) This KPI describes the upstream throughput of one 5G VN Group by computing the packet size for each successfully received UL packet during each observing granularity period and is used to evaluate integrity performance of the 5G VN Group. It is obtained by measuring the total number of upstream octets provided by N3 interface from NG-RAN to all UPFs, related to one 5G VN Group, divided by the granularity period (in milliseconds)

b-1) Integer, kbit/s

b-2) MEAN

c)

$$UTSNSI\_5GVNGroup = \frac{\sum_{UPF} GTP.InDataOctN3UPF.InternalgroupID}{GranularityPeriod} \times 8$$

d) NetworkSlice, SubNetwork.

6.3.8 Downstream throughput for 5G VN Group

a) DTSNSI_5GVNGroup.

b) This KPI describes the downstream throughput of one 5G VN Group by computing the packet size for each successfully transmitted DL packet through the 5G VN Group during each observing granularity period and is used to evaluate integrity performance of the 5G VN Group. It is obtained by measuring the total number of downstream octets provided by N3 interface from all UPFs to NG-RAN, related to one 5G VN Group, divided by the granularity period (in milliseconds).

b-1) Integer, kbit/s

b-2) MEAN

c)

$$DTSNSI\_5GVNGroup = \frac{\sum_{UPF} GTP.OutDataOctN3UPF.InternalgroupID}{GranularityPeriod} \times 8$$

d) NetworkSlice, SubNetwork.

6.3.9 Downstream throughput for a Network Slice at gNB

a) $DlThroughputNS_{gNBNgU}$.

b) This KPI describes the downstream throughput of a network slice instance at gNB/CU-UP end on the NgU interface. It is obtained by measuring the total number of downstream octets provided over NgU interface from UPF to NG-RAN, related to the single network slice, divided by the granularity period (in milliseconds).

b-1) Integer, kbit/s

b-2) MEAN

c)

$$DlThroughputNS_{gNBNgU} = \frac{\sum_{gNB} GTP.InDtatOctNgUgNB.SNSSAI}{granularityPeriod} \times 8$$

d) NetworkSliceSubnet, SubNetwork.

6.3.10 Upstream throughput for a Network Slice at gNB

a) $UlThroughputNS_{gNBNgU}$.

b) This KPI describes the upstream throughput of a network slice instance at gNB/CU-UP end on the NgU interface. It is obtained by measuring the total number of upstream octets provided over NgU interface from NG-RAN to UPF, related to the single network slice, divided by the granularity period (in milliseconds).

b-1) Integer, kbit/s

b-2) MEAN

c)

$$UlThroughputNS_{gNBNgU} = \frac{\sum_{gNB} GTP.OutDtatOctNgUgNB.SNSSAI}{granularityPeriod} \times 8$$

d) NetworkSliceSubnet, SubNetwork.

6.3.11 Capacity GTP

6.3.11.1 UL GTP capacity between PSA UPF and NG-RAN

a) GTP.CapMaxUlPsaUpfNgran.

b) This KPI describes the maximum achievable UL GTP transmission rate between PSA UPF and NG-RAN.

  b-1) Integer, kbit/s

  b-2) MEAN

c) It is obtained by counting the UL available data volume between PSA UPF and NG-RAN for the measured 5QI or S-NSSAI for each time interval ([t, t+Δt]) during the collection period, taking the arithmetic peak value and then dividing it by Δt.

d) NetworkSlice, SubNetwork, UPFunction

6.3.11.2 DL GTP capacity PSA UPF and NG-RAN

a) GTP.CapMaxDlPsaUpfNgran.

b) This KPI describes the maximum achievable DL GTP transmission rate between PSA UPF and NG-RAN.

  b-1) Integer, kbit/s

  b-2) MEAN

c) It is obtained by counting the DL available data volume between PSA UPF and NG-RAN for the measured 5QI or S-NSSAI for each time interval ([t, t+Δt]) during the collection period, taking the arithmetic peak value and then dividing it by Δt.

d) NetworkSlice, SubNetwork, GNBCUUPFunction.

6.3.11.3 UL GTP capacity between PSA UPF and UE

a) GTP.CapMaxUlPsaUpfUe.

b) This KPI describes the maximum achievable UL GTP transmission rate between PSA UPF and UE.

  b-1) Integer, kbit/s

  b-2) MEAN

c) It is obtained by counting the UL available data volume between PSA UPF and UE for the measured S-NSSAI for each time interval ([t, t+Δt]) during the collection period, taking the arithmetic peak value and then dividing it by Δt.

d) NetworkSlice, SubNetwork, UPFunction

6.3.11.4 DL GTP capacity PSA UPF and UE

a) GTP.CapMaxDlPsaUpfUe.

b) This KPI describes the maximum achievable DL GTP transmission rate between PSA UPF and UE.

  b-1) Integer, kbit/s

  b-2) MEAN

c) It is obtained by counting the DL available data volume between PSA UPF and UE for the measured S-NSSAI for each time interval ([t, t+Δt]) during the collection period, taking the arithmetic peak value and then dividing it by Δt.

d) NetworkSlice, SubNetwork, UPFunction

6.4 Utilization KPI

6.4.1 Mean number of PDU sessions of network and network Slice Instance

a) PDUSesMeanNbr.

b) This KPI describes the mean number of PDU sessions that are successfully established in a network slice . It is obtained by successful PDU session establishment procedures of SMFs which is related to the network slice.

b-1) Integer

b-2) MEAN

c)

$$PDUSesMeanNbr = \sum_{SMF} SM.SessionNbrMean.SNSSAI$$

d) NetworkSlice

6.4.2 Virtualised Resource Utilization of Network Slice Instance

a) VirtualResUtilization.

b) This KPI describes utilization of virtualised resource (e.g. processor, memory, disk) that are allocated to a network slice. It is obtained by the usage of virtualised resource (e.g. processor, memory, disk) divided by the system capacity that allocated to the network slice.

b-1) Integer, percentage

b-2) Ratio

NOTE: In the present document, this KPI is for the scenario when NF is not shared between different network slice.

c)

$$VRU_{Processor} = \frac{MeanProcessorUsage}{System\ Capacity_{Processor}} \times 100\%$$

$$VRU_{Memory} = \frac{MeanMemoryUsage}{System\ Capacity_{Memory}} \times 100\%$$

$$VRU_{Disk} = \frac{MeanDiskUsage}{System\ Capacity_{Disk}} \times 100\%$$

d) NetworkSlice

6.4.3 PDU session establishment time of network slice

a) PDUEstTime.

b) This KPI describes the time of successful PDU session establishment which related to one single network slice and is used to evaluate utilization provided by the end-to-end network slice and network performance. It is obtained by measuring the time between the receipt by SMF from AMF of "Nsmf_PDUSession_UpdateSMContext Request", which includes N2 SM information received from (R)AN to the SMF and the sending of a "Nsmf_PDUSession_CreateSMContext Request" or "Nsmf_PDUSession_UpdateSMContext Request" message from AMF to the SMF.

b-1) Integer, time interval (millisecond)

b-2) MEAN

c)

$$PDUEstTime = SM.Pdu.SessionTimeMean.SNSSAI$$

d) NetworkSlice

6.4.4 Mean number of successful periodic registration updates of Single Network Slice

a) RegUpdMeanNbr.

b) This KPI describes the mean number of successfully periodic registration updates in a network slice at the AMF. It is obtained by summing successful of periodic registration updates at the AMFs which is related to the network slice after registration accept by the AMF to the UE that sent the periodic registration update request.

b-1) Integer

b-2) MEAN

c)

$$RegUpdMeanNbr = \sum_{AMF} AM.RegNbrMean.SNSSAI$$

d) NetworkSlice

6.4.5 Maximum number of PDU sessions of network slice

a) PDUSesMaxNbr.

b) This KPI describes the maximum number of PDU sessions that are successfully established in a network slice. It is obtained by successful PDU session establishment procedures of SMFs which is related to the network slice.

b-1) Integer

b-2) CUM

c)

$$PDUSesMaxNbr = \sum_{SMF} SM.SessionNbrMax.SNSSAI$$

d) NetworkSlice

6.4.6 PDU session establishment time of 5G VN Group

a) Group-levelPDUEstTime.

b) This KPI describes the time of successful PDU session establishment which related to one 5G VN Group and is used to evaluate utilization provided by the end-to-end network slice and network performance. It is obtained by measuring the time between the receipt by SMF from AMF of "Nsmf_PDUSession_UpdateSMContext Request", which includes N2 SM information received from (R)AN to the SMF and the sending of a "Nsmf_PDUSession_CreateSMContext Request" or "Nsmf_PDUSession_UpdateSMContext Request" message from AMF to the SMF.

b-1) Integer, time interval (millisecond) b-2) MEAN

c)

$$\text{Group} - \text{levelPDUEstTime} = \text{SM.PduSessionTimeMean.InternalgroupID}$$

d) NetworkSlice

6.4.7 Mean number of MA PDU sessions of network slice

a) MaPDUSesMeanNbr.

b) This KPI describes the mean number of MA PDU sessions that are successfully established in a network slice. It is obtained by successful MA PDU session establishment procedures of SMFs which is related to the network slice.

b-1) Integer

b-2) MEAN

c)

$$MaPDUSesMeanNbr = \sum_{SMF} SM.MaPduSessionNbrMean.SNSSAI$$

d) NetworkSlice

6.4.8 Maximum number of MA PDU sessions of network slice

a) MaPDUSesMaxNbr.

b) This KPI describes the maximum number of MA PDU sessions that are successfully established in a network slice. It is obtained by successful MA PDU session establishment procedures of SMFs which is related to the network slice.

b-1) Integer

b-2) CUM

c)

$$MaPDUSesMaxNbr = \sum_{SMF} SM.MaPduSessionNbrMax.SNSSAI$$

d) NetworkSlice

6.4.9 Connected Mode RRM Relaxation Usage rate

a) ConnectedModeMeasRelaxationUsage.

b) This KPI describes the ratio of the number of UE side connected mode RRM relaxation sessions (such a session starts when UE sends a UAI with MeasRelaxationFulfilment-r17 IE with value True till it sends another UAI with MeasRelaxationFulfilment-r17 IE with value False) that conclude (these sessions conclude when the UE sends UAI with MeasRelaxationFulfilment-r17 IE with value False) to the number of all such sessions. This KPI is used to evaluate the utilization of this feature in the field.

b-1) Integer, percentage

b-2) RATIO

c)

$$ConnectedModeMeasRelaxationUsage = \frac{RRC.UAI.MeasRelaxationFulfilment.False}{RRC.UAI.MeasRelaxationFulfilment.True} \times 100\%$$

d) NRCellCU

6.4.10 High load ratio based on PRB usage distribution

a) PrbHighLoadRatio.

b) This KPI describes the high load ratio for a NRCellDU in a statistical period. The KPI can be obtained based on the measurement Distribution of DL Total PRB Usage defined in TS 28.552. The numerator of this KPI is the number of high load samples at which the DL PRB usage is larger than a certain threshold PRBTH1. And the denominator is the number of effective samples at which the DL PRB usage is larger than another threshold PRBTH2. This KPI can be used to evaluate the resource load of cells in transient high-load scenario and the result can be further used in the determination of network resource expansion.

b-1) Real, percentage, 0-1

b-2) RATIO

c) Below is the equation for high load ratio based on PRB usage distribution for NRCellDU:

$$PrbHighLoadRatio = \frac{\sum_{RRU.PrbTotDlDist \geq PRBTH1} number\ of\ samples\ in\ RRU.PrbTotDlDist}{\sum_{RRU.PrbTotDlDist \geq PRBTH2} number\ of\ samples\ in\ RRU.PrbTotDlDist}$$

Where RRU.PrbTotDlDist is the distribution of samples with total usage (in percentage) of PRBs on the downlink in different ranges as defined in clause 5.1.1.2.3 in TS 28.552. PRBTH1 is a threshold representing high load. PRBTH2 is effective sample filtering threshold. Both PRBTH1 and PRBTH2 are vendor or operator specific.

d) NRCellDU

6.4.11 Average air-interface efficiency achievable per UE within the observed NRCellDU

a) AvgCqiEfficiency_Cell.

b) The KPI describes the average air-interface efficiency for a NRCellDU according to CQI tables. The KPI takes into account both the channel rank(RI) and the channel quality(CQI), and can comprehensively reflect the overall channel quality of the cell.

b-1) Real, refers to that of efficiency defined in TS 38.214 [14]

b-2) MEAN

c) Below is the equation for average air-interface efficiency for NRCellDU:

$$AvgCqiEfficiency\_Cell = \frac{\sum_{X,Y,Z} Y \times CARR.WBCQIDist.BinX.BinY.BinZ \times efficiency_{CQI_X}^{TableZ}}{\sum_{X,Y,Z} CARR.WBCQIDist.BinX.BinY.BinZ}$$

Where $efficiency_{CQI_X}^{TableZ}$ is the efficiency used in the CQI table defined in TS 38.214 [14].

d) NRCellDU

6.4.12 Air interface downlink average efficiency based on MCS

a) AvgDlMcsEfficiency_Cell.

b) The KPI describes the air-interface downlink efficiency for a NRCellDU according to PDSCH MCS index tables in TS 38.214 [14]. The KPI takes spatial multiplexing into account based on the MCS distribution measurement in TS 28.552 [6], and can comprehensively reflect the average efficiency of the cell both in SU MIMO and MU MIMO scenarios.

b-1) Real, refers to that of efficiency defined in TS 38.214 [14]

b-2) MEAN

c) Below is the equation for air-interface downlink average efficiency based on MCS for NRCellDU:

$$AvgDlMcsEfficiency\_Cell = \frac{\sum_{X,Y,Z} X \times CARR.PDSCHMCSDist.BinX.BinY.BinZ \times efficiency_Z^y}{MI(T)}$$

Where X represents the index of rank value (1 to 8), Y represents the index of table value (1 to 4), and Z represents the index of the MCS value (0 to 31).

$efficiency_Z^Y$ is the efficiency when table index =Y and MCS index =Z used in PDSCH MCS tables defined in clause 5.1.3.1 in TS 38.214 [14].

$M1(T)$ is the total used DL PRBs in statistical period T, which is specified in clause 5.1.1.2.1 in TS 28.552 [6].

d) NRCellDU

NOTE: The MCS efficiency here is based on scheduled PRB and decided by the MCS index which is defined in TS 38.214 [14] in clause 5.1.3.1.

6.4.13 Air interface uplink average efficiency based on MCS

a) AvgUlMcsEfficiency_Cell.

b) The KPI describes the air-interface uplink efficiency for a NRCellDU according to PUSCH MCS index tables in TS 38.214 [14]. The KPI takes spatial multiplexing into account based on the MCS distribution measurement in TS 28.552 [6], and can comprehensively reflect the average efficiency of the cell both in SU MIMO and MU MIMO scenarios.

b-1) Real, refers to that of efficiency defined in TS 38.214 [14]

b-2) MEAN

c) Below is the equation for air-interface uplink average efficiency based on MCS for NRCellDU:

$$AvgUlMcsEfficiency\_Cell = \frac{\sum_{X,Y,Z} X \times CARR.PUSCHMCSDist.BinX.BinY.BinZ \times efficiency_Z^y}{MI(T)}$$

Where X represents the index of rank value (1 to 8), Y represents the index of table value (1 to 2), and Z represents the index of the MCS value (0 to 31).

$efficiency_Z^Y$ is the efficiency when table index =Y and MCS index =Z used in PUSCH MCS tables defined in clause 6.1.4.1 in TS 38.214 [14].

$M1(T)$ is the total used UL PRBs in statistical period T, which is specified in clause 5.1.1.2.2 in TS 28.552 [6].

d) NRCellDU

NOTE: The MCS efficiency here is based on scheduled PRB and decided by the MCS index which is defined in TS 38.214 [14] in clause 5.1.3.1.

6.5 Retainability KPI

6.5.1 QoS flow Retainability

6.5.1.1 Definition

a) QoSRetain_R1, QoSRetain_R2.

b) This KPI shows how often an end-user abnormally loses a QoS flow during the time the QoS flow is used. It is obtained by number of QoS flows with data in a buffer that was abnormally released, normalized with number of data session time units.

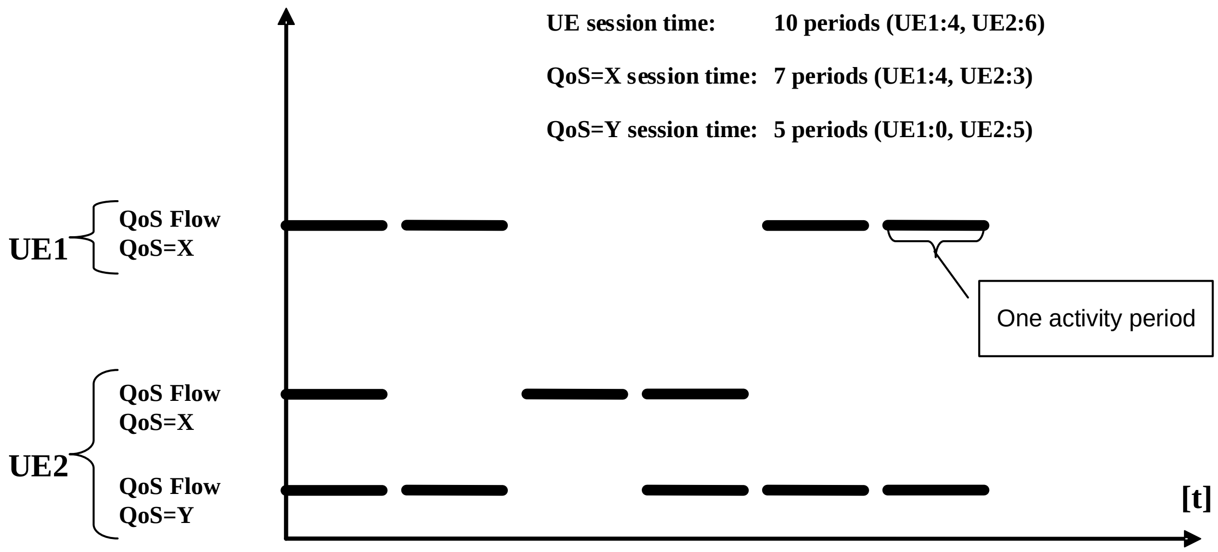
  b-1) Integer, active release / second

  b-2) MEAN

c) To measure QoS flow Retainability for a single QoS level (R1) is fairly straight forward.

$$R1_{QoS\_x} = \frac{QF.RelActNbr.QoS_{QoS\_x}}{QF.SessionTimeQoS.QoS_{QoS\_x}}$$

However to measure the QoS flow Retainability for UEs is not as straight forward. The measurement R1 is defined to look at the activity level of just one QoS level at the time, so to use this formula and measurements in an aggregated way to get QoS flow Retainability on UE level will not be accurate (e.g. for an UE with multiple QoS flows there might be QoS flows that are active at the same time, hence aggregating the QoS level measurements for session time will give a larger session time than the total UE session time. See picture below).



Hence a measurement QoS flow Retainability on UE level is defined (R2) to provide a measurement for the overall QoS flow Retainability.

$$R2 = \frac{\sum_{QoS} QF.RelActNbr.QoS}{QF.SessionTimeUE}$$

d) SubNetwork, NRCellCU

e) The definition of the service provided by 5GS is QoS flows.

6.5.1.2 Extended definition

The retainability rate is defined as:

$$\frac{Number\ of\ abnormally\ released\ QoS\ flow\ with\ data\ in\ any\ of\ the\ buffers}{Active\ QoS\ flow\ Time}[Releases/Session\ time]$$

To define (from a QoS flow Retainability point of view) if a QoS flow is considered active or not, the QoS flows can be divided into two groups:

- For QoS flows with bursty flow, a QoS flow is said to be active if there is user data in the PDCP queue in any of the directions or if any data (UL or DL) has been transferred during the last 100 ms.
- For QoS flows with continuous flow, the QoS flow (and the UE) is seen as being active in the context of this measurement as long as the UE is in RRC connected state, and the session time is increased from the first data transmission on the QoS flow until 100 ms after the last data transmission on the QoS flow.

A particular QoS flow is defined to be of type continuous flow if the mapped 5QI is any of {1, 2, 65, 66}.

6.5.2 DRB Retainability

6.5.2.1 Definition

a) DRBRetain

b) This KPI shows how often an end-user abnormally loses a DRB during the time the DRB is active. It is obtained by number of DRBs that were abnormally released and that were active at the time of release, normalized with number of data session time units.

 b-1) Integer, active release / second

 b-2) MEAN

c) DRB Retainability for a single mapped 5QI level (R1) and for a single S-NSSAI (R1) are defined as:

$$R1_{5QI\_x} = \frac{DRB.RelActNbr.5QI_{5QI\_x}}{DRB.SessionTime.5QI_{5QI\_x}}$$

and

$$R1_{SNSSAI\_x} = \frac{DRB.RelActNbr.SNSSAI_{SNSSAI\_x}}{DRB.SessionTime.SNSSAI_{SNSSAI\_x}}$$

d) SubNetwork, NRCellCU

e) The definition of the service provided by 5GS is DRBs.

6.5.2.2 Extended definition

To define (from a DRB Retainability point of view) if a DRB is considered active or not, the DRB can be divided into two groups:

- For DRBs with bursty flow, a DRB is said to be active if any data (UL or DL) has been transferred during the last 100 ms.
- For DRBs with continuous flow, the DRB (and the UE) is seen as being active in the context of this measurement as long as the UE is in RRC connected state, and the session time is increased from the first data transmission on the DRB until 100 ms after the last data transmission on the DRB.

A particular DRB is defined to be of type continuous flow if the mapped 5QI is any of {1, 2, 65, 66}.

6.6 Mobility KPI

6.6.1 NG-RAN handover success rate

a) GRANHOSR.

b) A KPI that shows how often a handover within NR-RAN is successful, regardless if the handover was made due to bad coverage or any other reason. This KPI is obtained by successful handovers to the same or another gNB divided by attempted handovers to the same or another gNB. This KPI covers legacy Handover.

b-1) Integer, percentage

b-2) RATIO

c)

$$GRANHOSR = \frac{(MM.HoExeInterSucc + MM.HoExeIntraSucc)}{(MM.HoExeInterReq + MM.HoExeIntraReq)} \times \frac{(MM.HoPrepInterSucc + MM.HoPrepIntraSucc)}{(MM.HoPrepInterReq + MM.HoPrepIntraReq)} \times 100[\%]$$

d) SubNetwork, NRCellCU.

6.6.2 Mean Time of Inter-gNB handover Execution of Network Slice

a) InterGNBHOMeanTime.

b) This KPI describes the time of successful Mean Time of Inter-gNB handover which related to one single network slice and is used to evaluate utilization provided by the end-to-end network slice and network performance. This KPI is obtained by measuring the time between the receipt by the Source NG-RAN from the Target NG-RAN of a "Release Resource" and the sending of a "N2 Path Switch Request" message from Source NG-RAN to the Target NG-RAN over a granularity period.

b-1) Integer, time interval (millisecond)

b-2) MEAN

c) -

d) Subnetwork

6.6.3 Successful rate of mobility registration updates of Single Network Slice

a) MobilityRegUpdateSR.

b) This KPI describes the successful rate of mobility registration updates in a network slice at the AMF. This KPI is obtained by dividing the number of successful mobility registration updates at the AMFs by number of mobility registration update requests received by the AMFs of single network slice.

b-1) Integer, percentage

b-2) RATIO

c) -

d) NetworkSlice

6.6.4 5GS to EPS handover success rate

a) 5GSEPSHOSR.

b) A KPI that shows how often a handover from 5GS to EPS is successful, regardless if the handover was made due to bad coverage or any other reason. This KPI is obtained by successful handovers from 5GS to EPS system divided by the total number of handovers attempt's from 5GS to EPS system.

b-1) Integer, percentage

b-2) RATIO

c)

$$5GSEPSHOSR = \frac{(MM.HoOut5gsToEpsSucc)}{(MM.HoOutExe5gsToEpsReq)} \times \frac{(MM.HoOut5gsToEpsPrepSucc)}{(MM.HoOut5gsToEpsPrepReq)} \times 100[\%]$$

d) SubNetwork, NRCellCU.

6.6.5 NG-RAN handover success rate for all handover types

a) GRANHOSRA.

b) A KPI that shows how often a handover within NR-RAN is successful, regardless if the handover was made due to bad coverage or any other reason. This KPI is obtained by successful handovers to the same or another gNB divided by attempted handovers to the same or another gNB. This KPI covers legacy Handover, Conditional Handover, DAPS Handover and LTM cell switch.

b-1) Integer, percentage

b-2) RATIO

c)

$$GRANSHORA = \frac{\begin{pmatrix} M.HoExeInterSucc+MM.HoExeIntraSucc+MM.ChoExeInterSucc+MM.ChoExeIntraSucc+ \\ MM.DapsHoExeInterSucc+MM.DapsHoExeIntraSucc+MM.LTMCellSwitchExeIntraSucc+ \\ MM.HoPrepInterSucc+MM.HoPrepIntraSucc+MM.ChoPrepInterSuccUes+ \\ MM.ChoPrepIntraSuccUes+MM.DapsHoPrepInterSucc+MM.DapsHoPrepIntraSucc \end{pmatrix}}{\begin{pmatrix} MM.HoExeInterReq+MM.HoExeIntraReq+MM.ConfigInterReqChoUes+ \\ MM.ConfigIntraReqChoUes+MM.DapsHoExeInterReq+ \\ MM.ConfigIntraReqLTMCellSwitchUes+MM.HoPrepInterReq+MM.HoPrepIntraReq+ \\ MM.ChoPrepInterReqUes+MM.ChoPrepIntraReqUes+MM.DapsHoPrepInterReq+ \\ MM.DapsHoIntraReq \end{pmatrix}} \times 100\%$$

d) SubNetwork, NRCellCU.

6.7 Energy Efficiency (EE) KPI

6.7.1 NG-RAN data Energy Efficiency (EE)

6.7.1.1 Definition

a) $EE_{MN,DV}$.

b) A KPI that shows mobile network data energy efficiency in operational NG-RAN. Data Volume (DV) divided by Energy Consumption (EC) of the considered network elements.

b-1) Integer, bit/J

b-2) RATIO

c)

- for non-split gNBs.

$$EE_{MN,DV} = \frac{\sum_{Samples}(DRB.PdcpSduVolumeUl+DRB.PdcpSduVolumeDl)}{\sum_{Samples} PEE.Energy}$$

- for split gNBs.

$$EE_{MN,DV} = \frac{\sum_{Samples}\begin{pmatrix} DRB.F1uPdcpSduVolumeUl + DRB.XnuPdcpSduVolumeUl + DRB.X2uPdcpSduVolumeUl + \\ DRB.F1uPdcpSduVolumeDl + DRB.XnuPdcpSduVolumeDl + DRB.X2uPdcpSduVolumeDl \end{pmatrix}}{\sum_{Samples} PEE.Energy}$$

d) SubNetwork

e) The Data Volume (in kbits) is obtained by measuring amount of DL/UL PDCP SDU bits of the considered network elements over the measurement period. For split-gNBs, the Data Volume is calculated per Interface (F1-U, Xn-U, X2-U). The Energy Consumption (in kWh) is obtained by measuring the PEE.Energy of the considered network elements over the same period of time. The samples are aggregated at the NG-RAN node level. The 3GPP management system responsible for the management of the gNB (single or multiple vendor gNB) shall be able to collect PEE measurements data from all PNFs in the gNB, in the same way as the other PM measurements.

6.7.2 Network slice Energy Efficiency (EE)

6.7.2.1 Generic Network Slice Energy Efficiency (EE) KPI

$$Generic\ Network\ Slice\ EE\ KPI = \frac{Performance\ of\ network\ slice (P_{ns})}{Energy\ Consumption\ of\ network\ slice\ (EC_{ns})}$$

Where:

- 'Performance of network slice' (P_{ns}) is defined per type of network slice.
- 'Energy Consumption of network slice' (EC_{ns}) is defined independently from any type of network slice.

For one unit of EC_{ns}, the higher P_{ns} is, the higher the generic network slice EE KPI is, i.e. the more energy efficient the network slice is.

6.7.2.2 Energy efficiency of eMBB network slice

a) $EE_{eMBB,DV}$.

b) A KPI that shows the energy efficiency of network slices of type eMBB. The P_{ns} for a network slice of type eMBB is obtained by summing up UL and DL data volumes at N3 interface(s) of the network slice.

$$P_{eMBB\ DV} = \sum_{UPF}(GTP.InDataOctN3UPF.SNSSAI + GTP.OutDataOctN3UPF.SNSSAI) \times 8$$

where *SNSSAI* identifies the S-NSSAI.

This KPI is obtained by the sum of UL and DL data volumes at N3 interface(s) of the network slice, divided by the energy consumption of the network slice.

b-1) Integer, bit/J

b-2) RATIO

c)

$$EE_{eMBB\ DV} = \frac{\sum_{UPF}(GTP.InDataOctN3UPF.SNSSAI + GTP.OutDataOctN3UPF.SNSSAI) \times 8}{EC_{ns}}$$

d) NetworkSlice

e) In case of redundant transmission paths over the N3 interface for high reliability communication (cf. TS 23.501 [7] clause 5.33.2), it is expected that the data volume is counted once. In particular:

In case of Dual Connectivity based end to end Redundant User Plane Paths (cf. TS 23.501 [7] clause 5.33.2.1), in which a UE may set up two redundant PDU Sessions over the 5G network, the Data Volume related to only one PDU session is to be considered.

In case of redundant transmission with two N3 tunnels between the PSA UPF and a single NG-RAN node (cf. TS 23.501 [7] figure 5.33.2.2-1) which are associated with a single PDU Session, the Data Volume related to only one N3 tunnel is to be considered.

In case of two N3 and N9 tunnels between NG-RAN and PSA UPF for redundant transmission (cf. TS 23.501 [7] figure 5.33.2.2-2) associated with a single PDU Session, the Data Volume related to only one N3 tunnel is to be considered.

For the measurement of the energy efficiency of the 5G core network, the 3GPP management system in charge of collecting the data volume measurements listed here above shall consider them only once in case of redundant transmission over the N3 interface.

6.7.2.2a Energy efficiency of eMBB network slice – RAN-based

6.7.2.2a.1 Definition

a) $EE_{RANonlyeMBB,DV}$.

b) A KPI that shows the energy efficiency of network slices of type eMBB based on NR measurements. The Pns for a network slice of type eMBB is obtained by summing up UL and DL data volumes at F1-U, Xn-U and X2-U interface(s) of gNBs, on a per S-NSSAI basis.

b-1) Integer, bit/J

b-2) RATIO

c)

For non-split gNBs:

$$P_{RANonlyeMBB\ DV} = \sum_{Samples} DRB.PdcpSduVolumeUl.SNSSAI + DRB.PdcpSduVolumeDl.SNSSAI$$

where:

- DRB.PdcpSduVolumeUl.*SNSSAI* is the Data Volume (amount of PDCP SDU bits) in the uplink delivered to PDCP layer per S-NSSAI - see TS 28.552 [4] clause 5.1.2.1.2.1.
- DRB.PdcpSduVolumeDl.*SNSSAI* is the Data Volume (amount of PDCP SDU bits) in the downlink delivered to PDCP layer per S-NSSAI - see TS 28.552 [4] clause 5.1.2.1.1.1.

For split gNBs:

$$P_{RANonlyeMBB\ DV} = \sum_{Samples} \begin{pmatrix} DRB.F1uPdcpSduVolumeDl.DNSSAI + DRB.F1uPdcpSduVolumeUl.SNSSAI + \\ DRB.XnuPdcpSduVolumeDl.SNSSAI + DRB.XnuPdcpSduVolumeUl.SNSSAI + \\ DRB.X2uPdcpSduVolumeDl.SNSSAI + DRB.X2uPdcpSduVolumeUl.SNSSAI \end{pmatrix}$$

where:

- DRB.F1uPdcpSduVolumeDl.*SNSSAI* is the number of DL PDCP SDU bits sent to GNB-DU (F1-U interface) per S-NSSAI - see TS 28.552 [4] clause 5.1.3.6.2.3.
- DRB.F1uPdcpSduVolumeUl.*SNSSAI* is the number of UL PDCP SDU bits entering the GNB-CU-UP from GNB-DU (F1-U interface) per S-NSSAI - see TS 28.552 [4] clause 5.1.3.6.2.4.
- DRB.XnuPdcpSduVolumeDl.*SNSSAI* is the number of DL PDCP SDU bits sent to external gNB-CU-UP (Xn-U interface) per S-NSSAI - see TS 28.552 [4] clause 5.1.3.6.2.3.
- DRB.XnuPdcpSduVolumeUl.*SNSSAI* is the number of UL PDCP SDU bits entering the GNB-CU-UP from external gNB-CU-UP (Xn-U interface) per S-NSSAI - see TS 28.552 [4] clause 5.1.3.6.2.4.

- DRB.X2uPdcpSduVolumeDl.*SNSSAI* is the number of DL PDCP SDU bits sent to external eNB (X2-U interface) per S-NSSAI - see TS 28.552 [4] clause 5.1.3.6.2.3.
- DRB.X2uPdcpSduVolumeUl.*SNSSAI* is the number of UL PDCP SDU bits entering the GNB-CU-UP from external eNB (X2-U interface) per S-NSSAI - see TS 28.552 [4] clause 5.1.3.6.2.4.

The final Network Slice EE KPI definition, based on Data Volume, for RAN-only eMBB type of network slice, would be defined as follows:

$$EE_{RANonlyeMBB\ DV} = \frac{P_{RANonlyeMBB\ DV}}{EC_{RANonlyns}}$$

where $EC_{RANonlyns}$ is the energy consumption of the RAN-only network slice over the same observation period.

NOTE: Void

d) NetworkSlice

6.7.2.3 Energy efficiency of URLLC network slice

6.7.2.3.1 Introduction

This KPI is defined with two variants.

6.7.2.3.2 Based on latency of the network slice

a) $EE_{URLLC,Latency}$.

b) A KPI that shows the energy efficiency of network slices of type URLLC. The P_{ns} for a network slice of type URLLC is the inverse of the average end-to-end User Plane (UP) latency of the network slice. In this KPI variant, latency are the only factor considered for evaluating the performance of network slice.

$$P_{URLLC,Latency} = \frac{1}{Network\ slice\ mean\ latency}$$

where 'Network slice mean latency' is defined as the average end-to-end User Plane (UP) latency of the network slice, and where the average end-to-end User Plane (UP) latency for one S-NSSAI is defined by:

$$Network\ slice\ mean\ latency = DelayE2EUlNs + DelayE2EDlNs$$

This KPI is obtained by the inverse of the average end-to-end User Plane (UP) latency of the network slice divided by the energy consumption of the network slice.

b-1) Integer, $(0.1ms * J)^{-1}$

b-2) RATIO

c)

$$EE_{URLLC,Latency} = \frac{1}{Network\ slice\ mean\ latency \times EC_{ns}}$$

d) NetworkSlice

6.7.2.3.3 Based on both latency and Data Volume (DV) of the network slice

a) $EE_{URLLC,DV,Latency}$.

b) A KPI that shows the energy efficiency of network slices of type URLLC. The P_{ns} for a network slice of type URLLC is the sum of UL and DL traffic volumes at N3 or N9 interface(s) on a per S-NSSAI basis multiplied by the inverse of the end-to-end User Plane (UP) latency of the network slice. In this KPI variant, data volume and latency are two factors considered for evaluating the performance of network slice. This KPI is applicable for the cases where, for example, the URLLC network slice is deployed and operators want to evaluate the Energy Efficiency of the slice at different periods of time, such as the busy hours in the morning and the idle hours in the mid night, in which both latency performance and the data volume performance can vary.

$$P_{URLLC,DV,Latency} = \frac{w_{N3} \times DV_{N3} + w_{N9} \times DV_{N9}}{(DelayE2EUlNs + DelayE2EDlNs)}$$

where

$$DV_{N3} = \sum_{PSA\ UPF} 8 \times (GTP.OutDataOctN3UPF.SNSSAI + GTP.InDataOctN3UPF.SNSSAI)$$

$$DV_{N9} = \sum_{PSA\ UPF} 8 \times (GTP.OutDataOctN9PsaUpf.SNSSAI + GTP.InDataOctN9PsaUpf.SNSSAI)$$

w_{N3} and w_{N9} are the weight for DV_{N3} and DV_{N9} respectively. w_{N3} and w_{N9} can be decided according to the deployment of PSA UPF. For example, in cases where PSA UPF has only N9 tunnels, such as the ones described in TS 23.501[7] clause 5.6.4 and clause 5.33.2.2, w_{N3} can be set to 0 and W_{N9} can be set to 1, so that only N9 interface is considered. In the cases where PSA UPF has only N3 tunnels, w_{N3} can be set to 1 and w_{N9} can be set to 0, so that only N3 interface is considered.

This KPI is obtained by the product of the sum of the weighted UL and DL traffic data volumes at N3 interface(s) or N9 interface of the PSA UPF of the network slice multiplied by the inverse of the end-to-end User Plane (UP) latency of the network slice, divided by the energy consumption of the network slice.

b-1) Integer, bit/(0.1ms*J)

b-2) RATIO

c)

$$EE_{URLLC,DV,Latency} = \frac{w_{N3} \times DV_{N3} + w_{N9} \times DV_{N9}}{(DelayE2EUlNs + DelayE2EDlNs) \times EC_{ns}}$$

d) NetworkSlice

6.7.2.4 Energy efficiency of MIoT network slice

6.7.2.4.1 Based on the number of registered subscribers of the network slice

a) $EE_{MIoT,RegSubs}$.

b) A KPI that shows the energy efficiency of network slices of type MIoT. In this case, the P_{ns} for a network slice of type MIoT is the maximum number of subscribers registered to the network slice.

$$P_{MIoT,RegSubs} = \sum_{AMF} RM.RegisteredSubNbrMax.SNSSAI$$

where *SNSSAI* identifies the S-NSSAI.

This KPI is obtained by the maximum number of registered subscribers to the network slice divided by the energy consumption of the network slice.

b-1) Integer, user/J

b-2) RATIO

c)

$$EE_{MIoT,RegSubs} = \frac{\sum_{AMF} RM.RegisteredSubNbrMax.SNSSAI}{EC_{ns}}$$

d) NetworkSlice

6.7.2.4.2 Based on the number of active UEs in the network slice

a) $EE_{MIoT,ActiveUEs}$.

b) A KPI that shows the energy efficiency of network slices of type MIoT. In this case, the P_{ns} for a network slice of type MIoT is the mean number of active UEs of the network slice.

$$P_{MIoT,ActiveUEs} = \sum_{gNBDU}(DRB.MeanActiveUeDl.SNSSAI + DRB.MeanActiveUeUl.SNSSAI)$$

where *SNSSAI* identifies the S-NSSAI.

This KPI is obtained by the mean number of active UEs of the network slice divided by the energy consumption of the network slice.

b-1) Integer, UE/J

b-2) RATIO

c)

$$EE_{MIoT,ActiveUEs} = \frac{\sum_{gNBDU}(DRB.MeanActiveUeDl.SNSSAI + DRB.MeanActiveUeUl.SNSSAI)}{EC_{nc}}$$

d) NetworkSlice

6.7.3 5G Energy Consumption (EC)

6.7.3.1 NF Energy Consumption (EC)

6.7.3.1.1 Definition

a) EC_{NF}.

b) This KPI describes the Energy Consumption (EC) of a 5G Network Function (NF). This KPI is obtained by summing up the energy consumption of PNF(s) and/or VNF(s) which compose the NF.

b-1) Integer, J

b-2) CUM

c)

$$EC_{NF} = \sum_{PNF} EC_{PNF} + \sum_{VNF} EC_{VNF}$$

- How a 5GC NF is composed of VNFs and PNFs is implementation specific. In particular, whether a VNF instance (respectively PNF) is shared or not between more than one NF is implementation specific. Hence, the case where a VNF instance (resp. PNF) is shared between multiple NFs is out of scope of the present document.
- EC_{PNF} represents the Energy Consumption (EC) of a PNF.
- EC_{VNF} represents the Energy Consumption (EC) of a VNF. It is obtained by summing up the Energy Consumption (EC) of all its constituent VNFCs.
- In the present document:
  - # EC_{PNF} is measured according to ETSI ES 202 336-12 [10].
  - # It is considered that EC_{VNF} cannot be measured hence is estimated. Therefore the resulting EC_{NF} KPI is defined as:

$$EC_{NF} = \sum_{PNF} EC_{PNF,measured} + \sum_{VNF} EC_{VNF,estimated}$$

6.7.3.1.2 Estimated Virtualized Network Function (VNF) energy consumption

a) $EC_{VNF,estimated}$.

b) A KPI that gives an estimation of the energy consumption of a VNF. This KPI is obtained by summing up the estimated energy consumption of its constituent Virtualized Network Function Components (VNFC).

b-1) Integer, J

b-2) CUM

c)

$$EC_{VNF,estimated} = \sum_{VNFC} EC_{VNFC,estimated}$$

d) ManagedFunction

e) In the present document, the energy consumption of the VNFC is estimated as per clause 6.7.3.1.3.

6.7.3.1.3 Estimated Virtualized Network Function Component (VNFC) energy consumption

a) $EC_{VNFC,estimated}$.

b) A KPI that gives an estimation of the energy consumption of a VNFC. In the present document, this KPI is obtained by taking the estimated energy consumption of the virtual compute resource instance on which the VNFC runs.

b-1) Integer, J

b-2) CUM

c)

$$EC_{VNFC,estimated} = EC_{virtualCompute,estimated}$$

d) ManagedFunction

e) In the present document, the energy consumption of the virtual compute resource instance is estimated based on either:

- its mean vCPU usage, as per clause 6.7.3.1.4. The method for calculating $EC_{VNFC,estimated}$ is described in TS 28.310 [9] clause 6.3.2.2.1, or
- its mean vMemory usage, as per clause 6.7.3.1.5, or
- its mean vDisk usage, as per clause 6.7.3.1.6, or
- its I/O traffic volume, as per clause 6.7.3.1.7.

6.7.3.1.4 Estimated virtual compute resource instance energy consumption based on mean vCPU usage

a) $EC_{virtualCompute,estimated,VCpuUsageMean}$.

b) A KPI that gives an estimation of the energy consumption of a virtual compute resource instance. The energy consumption of a virtual compute resource instance X is estimated as a proportion of the energy consumption of the NFVI node on which the virtual compute resource instance X runs. This proportion is obtained by dividing the vCPU mean usage of the virtual compute resource instance X, by the sum of the vCPU mean usage of all virtual compute resource instances running on the same NFVI Node as X.

b-1) Integer, J

b-2) RATIO

c)

$$EC_{virtualCompute,estimated,VCpuUsageMean} = \frac{VCpuUsageMean}{\sum_{virtualCompute} VCpuUsageMean} \times EC_{NFVINode,measured}$$

d) ManagedFunction

e)

- VCpuUsageMean is the mean vCPU usage of the virtual compute resource instance during the observation period, provided by ETSI NFV MANO (see clause 7.1.2 of ETSI GS NFV-IFA 027 [11]).

  $\sum_{virtualCompute} VCpuUsageMean$ is sum of the vCPU mean usage of all virtual compute resource instances running on the same NFVI Node during the same observation period, all separately provided by NFV MANO (see clause 7.1.2 of ETSI GS NFV-IFA 027 [11]).

- $EC_{NFVINode,measured}$ is the energy consumption of the NFVI node on which the virtual compute resource runs, measured during the same observation period, as per ETSI ES 202 336-12 [10].

6.7.3.1.5 Estimated virtual compute resource instance energy consumption based on mean vMemory usage

a) $EC_{virtualCompute,estimated,VMemoryUsageMean}$.

b) A KPI that gives an estimation of the energy consumption of a virtual compute resource instance. The energy consumption of a virtual compute resource instance X is estimated as a proportion of the energy consumption of the NFVI node on which the virtual compute resource instance X runs. This proportion is obtained by dividing the vMemory mean usage of the virtual compute resource instance X, by the sum of the vMemory mean usage of all virtual compute resource instances running on the same NFVI Node as X.

b-1) Integer, J

b-2) RATIO

c)

$$EC_{virtualCompute,estimated,VMemoryUsageMean} = \frac{VMemoryUsageMean}{\sum_{virtualCompute} VMemoryUsageMean} \times EC_{NFVINode,measured}$$

d) ManagedFunction

e)

- VMemoryUsageMean is the mean memory usage of the virtual compute resource instance during the observation period, provided by NFV MANO.

- $\sum_{virtualCompute} VMemoryUsageMean$ is the sum of the mean memory usage of all virtual compute resource instances running on the same NFVI node during the same observation period, all separately provided by NFV MANO (see clause 7.1.4 of [11].

- $EC_{NFVINode,measured}$ is the energy consumption of the NFVI node on which the virtual compute resource runs, measured during the same observation period, as per ETSI ES 202 336-12 [10]. The measurement defined in TS 28.552 [6] clause 5.1.1.19.3 can be used to measure $EC_{NFVINode,measured}$.

6.7.3.1.6 Estimated virtual compute resource instance energy consumption based on mean vDisk usage

a) $EC_{virtualCompute,estimated,VDiskUsageMean}$.

b) A KPI that gives an estimation of the energy consumption of a virtual compute resource instance. The energy consumption of a virtual compute resource instance X is estimated as a proportion of the energy consumption of the NFVI node on which the virtual compute resource instance X runs. This proportion is obtained by dividing the vDisk mean usage of the virtual compute resource instance X, by the sum of the vDisk mean usage of all virtual compute resource instances running on the same NFVI Node as X.

b-1) Integer, J

b-2) RATIO

c)

$$EC_{virtualCompute,estimated,VDiskUsageMean} = \frac{VDiskUsageMean}{\sum_{virtualCompute} VDiskUsageMean} \times EC_{NFVINode,measured}$$

d) ManagedFunction

e)

- VDiskUsageMean is the mean disk usage of the virtual compute resource instance during the observation period, provided by NFV MANO.
- $\sum_{virtualCompute} VDiskUsageMean$ is the sum of the mean disk usage of all virtual compute resource instances running on the same NFVI Node during the same observation period, all separately provided by NFV MANO (see clause 7.1.6 of [11].
- $EC_{NFVINode,measured}$ is the energy consumption of the NFVI node on which the virtual compute resource runs, measured during the same observation period, as per ETSI ES 202 336-12 [10]. The measurement defined in TS 28.552 [6] clause 5.1.1.19.3 can be used to measure $EC_{NFVINode,measured}$.

6.7.3.1.7 Estimated virtual compute resource instance energy consumption based on I/O traffic volume

a) $EC_{virtualCompute,estimated,IOTrafficVolume}$.

b) A KPI that gives an estimation of the energy consumption of a virtual compute resource instance. The energy consumption of a virtual compute resource instance X is estimated as a proportion of the energy consumption of the NFVI node on which the virtual compute resource instance X runs. This proportion is obtained by dividing the I/O traffic volume of the virtual compute resource instance X, by the sum of the I/O traffic volume of all virtual compute resource instances running on the same NFVI Node as X.

b-1) Integer, J

b-2) RATIO

c)

$$EC_{virtualCompute,estimated,IOTrafficVolume} = \frac{IOTrafficVolume}{\sum_{virtualCompute} IOTrafficVolume} \times EC_{NFVINode,measured}$$

d) ManagedFunction

e)

- IOTrafficVolume is the sum of the incoming and outgoing traffic volumes of the virtual compute resource instance during the observation period, provided by NFV MANO.
    i) Incoming traffic volume is obtained by measuring the number of incoming bytes on virtual compute (VNetByteIncoming - cf. clause 7.1.8 of [11]) during the observation period.
    ii) Outgoing traffic volume is obtained by measuring the number of outgoing bytes on virtual compute (VNetByteOutgoing - cf. clause 7.1.9 of [11]) during the observation period.

$$IOTrafficVolume = VNetByteIncoming + VNetByteOutgoing$$

- $\sum_{virtualCompute} IOTrafficVolume$ is the sum of the incoming and outgoing traffic volumes of all virtual compute resource instances running on the same NFVI node during the same observation period, all separately provided by NFV MANO (see clauses 7.1.8 and 7.1.9 of [11]).

- $EC_{NFVINode,measured}$ is the energy consumption of the NFVI node on which the virtual compute resource runs, measured during the same observation period, as per ETSI ES 202 336-12 [10]. The measurement defined in TS 28.552 [6] clause 5.1.1.19.3 can be used to measure $EC_{NFVINode,measured}$.

6.7.3.2 5GC Energy Consumption (EC)

6.7.3.2.1 Definition

a) EC_{5GC}.

b) This KPI describes the Energy Consumption (EC) of the 5G Core Network (CN). It is obtained by summing up the Energy Consumption of all the Network Functions (EC_{NF}) that compose the 5G core network. For the Energy Consumption (EC) of Network Functions, see clause 6.7.3.1.

   b-1) Integer, J

   b-2) CUM

c)

$$EC_{5GC} = \sum_{NF} EC_{NF}$$

d) Subnetwork

6.7.3.3 Network Slice Energy Consumption (EC)

a) EC_{ns}.

b) This KPI describes the Energy Consumption (EC) of the network slice. It is obtained by summing up the Energy Consumption of all the Network Functions (EC_{NF}) that compose the network slice.

   b-1) Integer, J

   b-2) CUM

c)

$$EC_{ns} = \sum_{NF} EC_{NF}$$

The definition of EC_{ns} based on the following principles:

For all gNBs in the network slice, clause 5.1.1.19.3 (PNF Energy consumption) of TS 28.552 [6] applies. This measurement is obtained according to the method defined in ETSI ES 202 336-12 [10] – clauses 4.4.3.1, 4.4.3.4, Annex A

In case a 5GC NF is composed of Virtualized Network Functions (VNF) and/or Physical Network Functions (PNF), clause 6.7.3.1 of this document defines the NF Energy Consumption (EC).

In case a NF is shared between multiple network slices, the participation of the NF to the energy consumption of the network slice has to be estimated, as it can't be measured:

- In case of a gNB shared between multiple network slices, the energy consumption attributable to each network slice is estimated as a proportion of the total gNB energy consumption, where the proportion is calculated as the data volume of the network slice relatively to the total data volume carried by the gNB.

- In case of a AMF shared between multiple network slices, the energy consumption attributable to each network slice is estimated as a proportion of the total estimated AMF energy consumption, where the proportion is calculated as the mean number of registered subscribers of the network slice relatively to the overall mean number of registered subscribers of the AMF during the same time period (see TS 28.552 [6] clause 5.2.1.1 for the definition of the mean number of registered subscribers).

- In case of a SMF shared between multiple network slices, the energy consumption attributable to each network slice is estimated as a proportion of the total estimated SMF energy consumption, where the proportion is calculated as the mean number of PDU sessions of the network slice relatively to the overall mean number of PDU sessions of the SMF during the same time period (see TS 28.552 [6] clause 5.3.1.1 for the definition of the mean number of PDU sessions).

- In case of a UPF shared between multiple slices, the energy consumption attributable to each network slice is estimated as a proportion of the total estimated UPF energy consumption, where the proportion is calculated as the data volume of the network slice relatively to the overall data volume of the UPF during the same time period.

  - 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 [6] 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 [6] clause 5.4.1.4).

  - In case of a PSA UPF with no N3 interface(s), the data volume of the UPF is obtained by summing up, for all N9 interface(s), the number of octets of incoming GTP data packets on the N9 interface for PSA UPF (see TS 28.552 [6] clause 5.4.4.2.3) and the number of octets of outgoing GTP data packets on the N9 interface for PSA UPF (see TS 28.552 [6] clause 5.4.4.2.4).

- The case of other 5GC NFs shared between network slices is not addressed in the present document.

d) NetworkSlice

6.7.3.4 NG-RAN Energy Consumption (EC)

6.7.3.4.1 NG-RAN EC

a) EC_{NG-RAN}.

b) This KPI describes the Energy Consumption (EC) of the NG-RAN. It is obtained by summing up the Energy Consumption of all the gNBs that constitute the NG-RAN.

   b-1) Integer, J

   b-2) CUM

c)

$$EC_{NG-RAN} = \sum_{gNB} EC_{gNB}$$

d) Subnetwork

6.7.3.4.2 gNB EC

a) EC_{gNB}.

b) This KPI describes the Energy Consumption (EC) of the gNB. It is obtained by summing up the Energy Consumption of all the Network Functions (NF) that constitute the gNB. For the Energy Consumption of Network Functions (EC_{NF}), see clause 6.7.3.1.

   b-1) Integer, J

   b-2) CUM

c)

$$EC_{gNB} = \sum_{NF} EC_{NF}$$

d) ManagedElement

6.7.4 5GC Energy Efficiency (EE)

6.7.4.1 Generic 5GC Energy Efficiency (EE)KPI

$$Generic\ 5GC\ EE\ KPI = \frac{UsefulOutput\ of\ 5GC(UsefulOutput_{5GC})}{Energy\ Consumption\ of\ 5GC(EC_{5GC})}$$

where:

- 'Useful Output of 5GC' ($UsefulOutput_{5GC}$) is the useful output of 5GC. It can be defined differently, depending on which 5GC network functions are considered.
- 'Energy Consumption of 5GC' (EC_{5GC}) is the Energy Consumption of 5GC.

For one unit of EC_{5GC}, the higher $UsefulOutput_{5GC}$ is, the higher the generic 5GC EE KPI is, i.e. the more energy efficient the 5GC is.

6.7.4.2 title

a) $EE_{5GC,UO,UP,DV}$.

b) A KPI that shows the energy efficiency of 5GC. This KPI is based on the useful output of 5GC user plane. The useful output of the 5GC user plane is obtained by summing up UL and DL data volumes at N3 interface(s).

$$UsefulOutput_{5GC,DV} = \sum_{UPF}(GTP.InDataOctN3UPF + GTP.OutDataOctN3UPF) \times 8$$

This KPI is obtained by the sum of UL and DL data volumes at N3 interface(s), divided by the energy consumption of 5GC.

b-1) Integer, bit/J

b-2) RATIO

c)

$$EE_{5GC,UO,UP,DV} = \frac{\sum_{UPF}(GTP.InDataOctN3UPF + GTP.OutDataOctN3UPF) \times 8}{EC_{5GC}}$$

d) SubNetwork

e) In case of redundant transmission paths over the N3 interface for high reliability communication (cf. TS 23.501 [7] clause 5.33.2), it is expected that the data volume is counted once. In particular:

- In case of Dual Connectivity based end to end Redundant User Plane Paths (see TS 23.501 [7] clause 5.33.2.1), in which a UE may set up two redundant PDU Sessions over the 5G network, the Data Volume related to only one PDU session is to be considered.
- In case of redundant transmission with two N3 tunnels between the PSA UPF and a single NG-RAN node (cf. TS 23.501 [7] figure 5.33.2.2-1) which are associated with a single PDU Session, the Data Volume related to only one N3 tunnel is to be considered.
- In case of two N3 and N9 tunnels between NG-RAN and PSA UPF for redundant transmission (see TS 23.501 [7] figure 5.33.2.2-2) associated with a single PDU Session, the Data Volume related to only one N3 tunnel is to be considered.

For the measurement of the energy efficiency of the 5G core network, the 3GPP management system in charge of collecting the data volume measurements listed here above shall consider them only once in case of redundant transmission over the N3 interface.

6.7.5 Energy efficiency evaluated from network availability

6.7.5.1 Introduction

The KPI is defined from a network availability performance dimension perspective.

6.7.5.2 Energy efficiency of cell based on availability

a) $EE_{Cell,AvailAvgTimeCU}$.

b) A KPI that shows the energy efficiency of a cell in a gNB based on availability performance. This KPI is obtained by dividing cell availability KPI by the average energy consumption per cell in a gNB over the same observation period.

  b-1) Integer, sec/J

  b-2) RATIO

c)

$$EE_{Cell,AvailAvgTimeCU} = \frac{CellAvailAvg_{TimeCU}}{EC_{per\ cell\ of\ gNB}}$$

d) GNBCUCPFunction

e) The cell availability KPI is defined in clause 6.10.1.1.1. The average energy consumption per cell in a gNB is obtained by considering energy consumption of gNB (EC_{gNB}) for a given time period and dividing it by total number of cells in a gNB that are operational in same time duration/period. EC_{gNB} is defined in clause 6.7.3.4.2.

NOTE: The cell availability KPI is for the split gNB deployment scenario. The average energy consumption for cell is derived using a weighted average of EC_{gNB} over the number of cells. The weight defined by the consumer of KPI.

6.7.6 Energy efficiency evaluated from network quality

6.7.6.1 Introduction

These KPIs about energy efficiency evaluated from network quality performance perspective are defined with two variants for sub-network or network slice subnet.

6.7.6.2 Energy efficiency of a sub-network based on DL UE throughput

a) $EE_{SNw,DLUeThroughput}$.

b) A KPI that shows the energy efficiency of a sub-network based on DL UE throughput. This KPI is obtained by DL RAN UE throughput for a sub-network KPI divided by the average energy consumption per gNB of the sub-network over the same observation period.

  b-1) Integer, kbit/(sec*J)

  b-2) RATIO

c)

$$EE_{SNw,DLUeThroughput} = \frac{DlUeThroughput\_SNw}{EC_{per\ gNB\ of\ sub-network}}$$

d) SubNetwork

e) The DL RAN UE throughput for a sub-network KPI is defined in clause 6.3.6.3.2. The average energy consumption per gNB of the sub-network is obtained by summing up the Energy Consumption (EC_{gNB}) of all the gNBs that constitute the sub-network and then dividing the result by the total number of gNBs present in the sub-network. EC_{gNB} is defined in clause 6.7.3.4.2. The use of $EC_{per\ gNB\ of\ sub\text{-}network}$ in the denominator enables this KPI to be used to compare the EE of sub-networks of different sizes/scales.

NOTE: The average energy consumption for gNB is derived using a weighted average of the energy consumption of EC_{gNB} over the number of gNBs present in the subnetwork. The weight defined by the consumer of KPI.

6.7.6.3 Energy efficiency of a sub-network based on UL UE throughput

a) $EE_{SNw,ULUeThroughput}$.

b) A KPI that shows the energy efficiency of a sub-network based on UL UE throughput. This KPI is obtained by UL RAN UE throughput for a sub-network KPI divided by the average energy consumption per gNB of the sub-network over the same observation period.

b-1) Integer, kbit/(sec*J)

b-2) RATIO

c)

$$EE_{SNw,ULUeThroughput} = \frac{UlUeThroughput\_SNw}{EC_{per\ gNB\ of\ sub-network}}$$

d) SubNetwork

e) The UL RAN UE throughput for a sub-network KPI is defined in clause 6.3.6.4.2. The average energy consumption per gNB of the sub-network is obtained by summing up the Energy Consumption (EC_{gNB}) of all the gNBs that constitute the sub-network and then dividing the result by the total number of gNBs present in the sub-network. EC_{gNB} is defined in clause 6.7.3.4.2. The use of $EC_{per\ gNB\ of\ sub\text{-}network}$ in the denominator enables this KPI to be used to compare the EE of sub-networks of different sizes/scales.

NOTE: The average energy consumption for gNB is derived using a weighted average of the energy consumption of EC_{gNB} over the number of gNBs present in the subnetwork. The weight defined by the consumer of KPI.

6.7.6.4 Energy efficiency of a network slice subnet based on DL UE throughput

a) $EE_{Nss,DLUeThroughput}$.

b) A KPI that shows the energy efficiency of a network slice subnet based on DL UE. This KPI is obtained by DL RAN UE throughput for a network slice subnet KPI divided by the average energy consumption per gNB of the network slice subnet over the same observation period.

b-1) Integer, kbit/(sec*J)

b-2) RATIO

c)

$$EE_{Nss,DLUeThroughput} = \frac{DlUeThroughput\_Nss}{EC_{per\ gNB\ of\ Nss}}$$

d) NetworkSliceSubnet

e) The DL RAN UE throughput for a network slice subnet KPI is defined in clause 6.3.6.3.3. The average energy consumption per gNB of the network slice subnet is obtained by summing up the Energy Consumption (EC_{gNB}) of all the gNBs that constitute the network slice subnet and then dividing the result by the total number of gNBs present in the network slice subnet. EC_{gNB} is defined in clause 6.7.3.4.2. The use of $EC_{per\ gNB\ of\ Nss}$ in the denominator enables this KPI to be used to compare the EE of network slice subnets of different sizes/scales.

NOTE: The average energy consumption for gNB is derived using a weighted average of the energy consumption of EC_{gNB} over the number of gNBs present in the network slice subnet. The weight defined by the consumer of KPI.

6.7.6.5 title

a) $EE_{Nss,ULUeThroughput}$.

b) A KPI that shows the energy efficiency of a network slice subnet based on UL UE throughput. This KPI is obtained by UL RAN UE throughput for a network slice subnet KPI divided by the average energy consumption per gNB of the network slice subnet over the same observation period.

b-1) Integer, kbit/(sec*J)

b-2) RATIO

c)

$$EE_{Nss,ULUeThroughput} = \frac{UlUeThroughput\_Nss}{EC_{per\ gNB\ of\ Nss}}$$

d) NetworkSliceSubnet

e) The UL RAN UE throughput for a network slice subnet KPI is defined in clause 6.3.6.3.3. The average energy consumption per gNB of the network slice subnet is obtained by summing up the Energy Consumption (EC_{gNB}) of all the gNBs that constitute the network slice subnet and then dividing the result by the total number of gNBs present in the network slice subnet. EC_{gNB} is defined in clause 6.7.3.4.2. The use of $EC_{per\ gNB\ of\ Nss}$ in the denominator enables this KPI to be used to compare the EE of network slice subnets of different sizes/scales.

NOTE: The average energy consumption for gNB is derived using a weighted average of the energy consumption of EC_{gNB} over the number of gNBs present in the network slice subnet. The weight defined by the consumer of KPI.

6.7.7 gNB Estimated Carbon Emission (ECE)

6.7.7.1 Definition

a) ECE_{gNB}.

b) This KPI provides the Estimated Carbon Emission of a gNB (ECE_{gNB}) over a time period. The Estimated Carbon Emission of a gNB (ECE_{gNB}) is the Energy Consumption of the gNB (EC_{gNB}) multiplied by the Carbon Emission Factor of the energy source which powers the gNB (CEF). The CEF of the energy supply is the sum of all CEFs of its energy sources as configured in energySourceCef (see TS 28.310 [9]). The KPI object, i.e., ManagedElement is associated with EnergySupplyInfo through IOC EnergyInfoGroup as described in TS 28.310[9].

b-1) Integer, kg CO_2eq

b-2) CUM

c) This calculation formula is obtained as:

$$ECE_{gNB} = EC_{gNB} \times CEF$$

where:

- EC_{gNB} is the Energy Consumption of the gNB as defined in TS 28.554 clause 6.7.3.4.2. Its unit is kWh.

- CEF_{gNB} indicates Carbon Emission Factor. The CEF of the energy supply is the sum of all CEFs of its energy sources as configured in energySourceCef (see TS 28.310 [9]). Its unit is kg CO_2eq/kWh.

d) ManagedElement

NOTE: This KPI is applicable for the gNBs that are powered using single energy supply. The accuracy of this KPI is dependent on the accuracy of the CEF information configured by the operator.

6.7.7.2 NG-RAN Estimated Carbon Emission

a) $ECE_{NG\text{-}RAN}$.

b) This KPI provides the Estimated Carbon Emission (ECE) of the NG-RAN over a time period. It is obtained by summing up the Estimated Carbon Emission of all the gNBs that constitute the NG-RAN.

b-1) kg CO_2eq

b-2) CUM

c)

$$ECE_{NG-RAN} = \sum_{gNB} ECE_{gNB}$$

d) Subnetwork

NOTE: ng-eNB is not considered in this KPI.

6.8 Reliability KPI

6.8.1 Definition

6.8.1.0 Introduction

Reliability is defined (see TS 22.261 [13] clause 3.1) in the context of network layer packet transmissions, as the percentage value of the packets successfully delivered to a given system entity within the time constraint required by the targeted service out of all the packets transmitted.

6.8.1.1 Packet transmission reliability KPI in DL on Uu

a) DLRelPSR_Uu.

b) This KPI describes the Reliability based on Packet Success Rate(PSR) Percentage between gNB and UE. It is used to evaluate the Uu interface reliability contribution to the total network downlink reliability. It is the percentage of RLC SDU packets which are successfully received in UE out of the total RLC SDU packets transmitted by gNB. It is a measure of the DL packet delivery success i.e. PSR% over Uu interface. It is a percentage value (%). This KPI can optionally be split into KPIs per QoS level (mapped 5QI or QCI in EN-DC architecture) and per S-NSSAI.

b-1) Integer, percentage, 0-100

b-2) RATIO

c) Below is the equation for downlink Reliability in RAN based on PSR percentage between gNB and UE.

$$DLRelPSR\_Uu = \left[\frac{N(T1,drbid)}{N(T1,drbid)+Dloss(T1,drbid)}\right] \times 100$$

where N(T1,drbid) and Dloss(T1,drbid) are as defined in TS 38.314.

Or optionally

$$DLRelPSR\_Uu.QoS = \left[\frac{N(T1,drbid).QoS}{N(T1,drbid).QoS+Dloss(T1,drbid).QoS}\right] \times 100$$

where QoS identifies the target QoS quality of service class.

Or optionally

$$DLRelPSR\_Uu.SNSSAI = \left[\frac{N(T1,drbid).SNSSAI}{N(T1,drbid).SNSSAI+Dloss(T1,drbid).SNSSAI}\right] \times 100$$

where SNSSAI identifies the S-NSSAI.

d) NRCellDU

6.8.1.2 Packet transmission reliability KPI in UL on Uu

a) ULRelPSR_Uu.

b) This KPI describes the Reliability based on Packet Success Rate Percentage between UE and gNB. It is used to evaluate the Uu interface reliability contribution to the total network uplink reliability. It is the percentage of PDCP SDU packets which are successfully received in gNB out of the total PDCP SDU packets transmitted by UE. It is a measure of the UL packet delivery success i.e. PSR% over Uu interface. It is a percentage value (%). This KPI can optionally be split into KPIs per QoS level (mapped 5QI or QCI in EN-DC architecture) and per S-NSSAI.

b-1) Integer, percentage, 0-100

b-2) RATIO

c)

$$ULRelPSR\_Uu = DRB.PacketSuccessRateUlgNBUu \times 100$$

where DRB_PacketSuccessRateUlgNBUu is as defined in TS 28.552 [6].

Or optionally:

$$ULRelPSR_{Uu}.QoS = DRB.PacketSuccessRateUlgNBUu.QOS \times 100$$

where QoS identifies the target QoS quality of service class.

Or optionally:

$$ULRelPSR_{Uu}.SNSSAI = DRB.PacketSuccessRateUlgNBUu.SNSSAI \times 100$$

where SNSSAI identifies the S-NSSAI.

d) NRCellCU

6.8.1.3 Packet transmission reliability KPI in DL on N3

a) DLRelPSR_N3.

b) This KPI describes the Reliability based on Packet Success Rate(PSR) Percentage between UPF and gNB. It is used to evaluate the N3 interface reliability contribution to the total network downlink reliability. It is the percentage of GTP data PDUs which are successfully received by gNB out of the total GTP data PDUs transmitted by UPF over N3 interface. It is a measure of the DL packet delivery success i.e. PSR% over N3 interface. It is a percentage value (%). This KPI can optionally be split into KPIs per QoS level (mapped 5QI or QCI in EN-DC architecture) and per S-NSSAI.

b-1) Integer, percentage, 0-100

b-2) RATIO

c)

$$DLRelPSR\_N3 = \left[\frac{GTP.OutDataPktN3UPF - GTP.InDataPktPacketLossN3gNB}{GTP.OutDataPktN3UPF}\right] \times 100$$

where GTP.OutDataPktN3UPF, GTP.InDataPktPacketLossN3gNB are as defined in TS 28.552.

Or optionally,

$$DLRelPSR\_N3.QoS = \left[\frac{GTP.OutDataPktN3UPF.QoS - GTP.InDataPktPacketLossN3gNB.QoS}{GTP.OutDataPktN3UPF.QoS}\right] \times 100$$

where QoS identifies the target QoS quality of service class.

Or optionally,

$$DLRelPSR\_N3.SNSSAI = \left[\frac{GTP.OutDataPktN3UPF.SNSSAI - GTP.InDataPktPacketLossN3gNB.SNSSAI}{GTP.OutDataPktN3UPF.SNSSAI}\right] \times 100$$

where SNSSAI identifies the S-NSSAI.

d) UPFFunction, GNBCUUPFunction

6.8.1.4 Packet transmission reliability KPI in UL on N3

a) ULRelPSR_N3.

b) This KPI describes the Reliability based on Packet Success Rate(PSR) Percentage between gNB and UPF. It is used to evaluate the N3 interface reliability contribution to the total network uplink reliability. It is the percentage of GTP data PDUs which are successfully received by UPF out of the total GTP data PDUs transmitted by gNB over N3 interface. It is a measure of the UL packet delivery success i.e. PSR% over N3 interface. It is a percentage value (%). This KPI can optionally be split into KPIs per QoS level (mapped 5QI or QCI in EN-DC architecture) and per S-NSSAI.

b-1) Integer, percentage, 0-100

b-2) RATIO

c)

$$ULRelPSR\_N3 = \left[\frac{GTP.InDataPktN3UPF}{GTP.InDataPktN3UPF + GTP.InDataPktPacketLossN3UPF}\right] \times 100$$

where GTP.InDataPktN3UPF , GTP.InDataPktPacketLossN3UPF are as defined in TS 28.552.

Or optionally,

$$ULRelPSR\_N3.QoS = \left[\frac{GTP.InDataPktN3UPF.QoS}{GTP.InDataPktN3UPF.QoS + GTP.InDataPktPacketLossN3UPF.QoS}\right] \times 100$$

where QoS identifies the target QoS quality of service class.

Or optionally,

$$ULRelPSR\_N3.SNSSAI = \left[\frac{GTP.InDataPktN3UPF.SNSSAI}{GTP.InDataPktN3UPF.SNSSAI + GTP.InDataPktPacketLossN3UPF.SNSSAI}\right] \times 100$$

where SNSSAI identifies the S-NSSAI.

d) UPFFunction

6.8.1.5 Packet transmission reliability KPI in DL on F1-U

a) DLRelPSR_F1u.

b) This KPI describes the Reliability based on Packet Success Rate(PSR) Percentage between gNB-CU-UP and gNB-DU. It is a measure of the DL packet delivery success i.e. PSR% over F1-U interface. It provides the fraction of PDCP SDU packets that are successfully received at the gNB-DU. It is calculated as the percentage of GTP data PDU sequence numbers which are successfully received in gNB-DU out of the total GTP data PDU sequence numbers transmitted by gNB-CU-UP to gNB-DU over F1-U interface. It is a percentage value (%). This KPI can optionally be split into KPIs per QoS level (mapped 5QI or QCI in EN-DC architecture) and per S-NSSAI.

   b-1) Integer, percentage, 0-100

   b-2) RATIO

c) Below is the equation for downlink Reliability in F1 interface based on PSR percentage between gNB-CU-UP and gNB-DU.

$$DLRelPSR\_FLU = (DRB.F1UPacketSuccessRateDl) \times 100$$

Or optionally:

$$DLRelPSR\_FLU.QoS = (DRB.F1UPacketSuccessRateDl.QoS) \times 100$$

where QoS identifies the target QoS quality of service class.

Or optionally:

$$DLRelPSR\_FLU.SNSSAI = (DRB.F1UPacketSuccessRateDl.SNSSAI) \times 100$$

where SNSSAI identifies the S-NSSAI.

d) GNBCUUPFunction

6.8.1.6 Packet transmission reliability KPI in UL on F1-U

a) ULRelPSR_F1u.

b) This KPI describes the Reliability based on Packet Success Rate(PSR) Percentage between gNB-CU-UP and gNB-DU. It is a measure of the UL packet delivery success i.e. PSR% over F1-U interface. It provides the fraction of PDCP SDU packets that are successfully received at the gNB-CU-UP. It is calculated as the percentage of GTP data PDU sequence numbers which are successfully received in gNB-CU-UP out of the total GTP data PDU sequence numbers transmitted by gNB-DU over F1-U interface to gNB-CU-UP. It is a percentage value (%). This KPI can optionally be split into KPIs per QoS level (mapped 5QI or QCI in EN-DC architecture) and per S-NSSAI.

   b-1) Integer, percentage, 0-100

   b-2) RATIO

c) Below is the equation for uplink Reliability in F1 interface based on PSR percentage between gNB-CU-UP and gNB-DU.

$$ULRelPSR\_FLU = (DRB.F1PacketSuccessRateUl) \times 100$$

Or optionally:

$$ULRelPSR\_FLU.QoS = (DRB.F1PacketSuccessRateUl.QoS) \times 100$$

where QoS identifies the target QoS quality of service class.

Or optionally:

$$ULRelPSR\_FLU.SNSSAI = (DRB.F1PacketSuccessRateUl.SNSSAI) \times 100$$

where SNSSAI identifies the S-NSSAI.

d) GNBCUUPFunction.

6.8.1.7 Reliability KPI in RAN with time constraint over Uplink air-interface(Uu)

a) $RelPktsTC_{UL\_Uu}$.

b) This KPI describes the packet transmission reliability considering a time constraint/delay threshold (as required for a service) in uplink over the air (Uu) interface in RAN. It is the percentage of MAC SDU packets/transport blocks that are transmitted over the air interface in uplink and successfully received within the required time constraint/delay threshold out of the total MAC SDU packets/transport blocks that are transmitted over air interface in uplink. It is a percentage value (%). This KPI can optionally be split into per QoS level (mapped 5QI or QCI in EN-DC architecture) and per S-NSSAI.

b-1) Integer, percentage, 0-100

b-2) RATIO

c) Below is the equation for Reliability KPI in RAN with a time constraint/delay threshold in UL over Uu Interface.

$$RelPktsTC_{UL\_Uu} = [DRB.AirIfDelayDistUL.Bin\_Filter \div I(T)] \times 100$$

where:

I(T) is Total number of UL MAC SDUs and is as defined in Table 4.2.1.2.2-2 in TS 38.314 [12].

DRB.AirIfDelayDistUL_Bin_Filter is as defined in TS 28.552 [6], clause 5.1.1.1.9.

d) NRCellDU

6.8.1.8 Reliability KPI in RAN with time constraint over Downlink air-interface(Uu)

a) $RelPktsTC_{DL\_Uu}$.

b) This KPI describes the packet transmission reliability considering a time constraint/delay threshold (as required for a service) in downlink over the Uu interface in RAN. It is the percentage of RLC SDU packets that are transmitted over the air interface in downlink and positively acknowledged within the required time constraint/delay threshold, out of the total RLC SDU packets transmitted over air interface in downlink. It is a percentage value (%). This KPI can optionally be split into KPIs per QoS level (mapped 5QI or QCI in EN-DC architecture) and per S-NSSAI.

b-1) Integer, percentage, 0-100

b-2) RATIO

c) Below is the equation for Reliability KPI in RAN with time constraint or delay threshold (denoted as TC) in DL over Uu Interface.

$$RelPktsTC_{DL\_Uu} = \left[(DRB.AIrIfDelayDist.Bin\_Filter) \;/\; \left(N(T, drbid) + Dloss(T, drbid)\right)\right] \times 100$$

where:

- N(T,drbid) and Dloss(T,drbid) are as defined in Table 4.2.1.5.1-2 in TS 38.314 [12].
- DRB.AirIfDelayDist_Bin_Filter is as defined in clause 5.1.1.1.2 in TS 28.552 [6].

Optionally

$$RelPktsTC_{DL\_Uu}.QoS = [(DRB.AIrIfDelayDist.Bin\_QoS) / (N(T,drbid).QoS + Dloss(T,drbid).QoS)] \times 100$$

where QoS identifies the target QoS quality of service class.

Optionally

$$RelPktsTC_{DL\_Uu}.SNSSAI = [(DRB.AIrIfDelayDist.Bin\_SNSSAI) / (N(T,drbid).SNSSAI + Dloss(T,drbid).SNSSAI)] \times 100$$

where SNSSAI identifies the S-NSSAI.

d) NRCellDU

6.8.1.9 End to end Downlink reliability KPI of URLLC Network Slice

a) $P_{URLLC,ReliabilityDL,PSR}$.

b) A packet success rate percentage (PSR%) based reliability of a network slice is a uni-directional performance characteristic of the slice. This KPI describes the end to end reliability of a URLLC network slice in downlink direction based on PSR%. It is obtained by multiplying PSR% based downlink reliability of Uu interface and N3 interface which are defined in clause 6.8.1.1 and clause 6.8.1.3 respectively. It is a percentage value (%).

b-1) Integer, percentage

b-2) RATIO

c) Below is the equation for end to end reliability of a URLLC network slice in downlink direction.

$$P_{URLLCReliabilityDL\_PSR} = PSR_{DL\_Uu} \times PSR_{DL,N3}$$

Where:

$PSR_{DL,Uu}$ is equal to DLRelPSR_Uu.SNSSAI which is as defined in clause 6.8.1.1.

$PSR_{DL,N3}$ is equal to DLRelPSR_N3.SNSSAI which is as defined in clause 6.8.1.3.

d) NetworkSlice.

6.8.1.10 End to end Uplink reliability KPI of URLLC Network Slice

a) $P_{URLLC,ReliabilityUL,PSR}$.

b) A packet success rate percentage (PSR%) based reliability of a network slice is a uni-directional performance characteristic of the slice. This KPI describes the end to end reliability of a URLLC network slice in uplink direction based on PSR%. It is obtained by multiplying PSR% based uplink reliability of Uu interface and N3 interface which are defined in clause 6.8.1.2 and clause 6.8.1.4 respectively. It is a percentage value (%).

b-1) Integer, percentage

b-2) RATIO

c) Below is the equation for end to end reliability of a URLLC network slice in uplink direction.

$$P_{URLLCReliabilityUL\_PSR} = PSR_{UL\_Uu} \times PSR_{UL,N3}$$

Where:

$PSR_{UL,Uu}$ is equal to ULRelPSR_Uu.SNSSAI which is as defined in clause 6.8.1.2.

$PSR_{UL,N3}$ is equal to ULRelPSR_N3.SNSSAI which is as defined in clause 6.8.1.4.

d) NetworkSlice.

6.9 Void

6.10 Void

6.11 Availability KPI

6.11.1 Cell Availability KPI

a) $CellAvailAvg_{TimeCU}$

b) This KPI describes the Average availability of cells in a gNB-CU for providing services to UEs. Cell availability is the time duration for which an active cell in a gNB-CU stays "In-Service". This KPI provides "average availability time duration per cell" in a gNB-CU.

  b-1) Integer, time duration (second)

  b-2) MEAN

c) It is obtained by summing all measurements of OEU.CellInServiceTotal.NCGI (as defined in TS 28.552 [6] clause 5.1.4.1.1) for all the gNB-DUs GNB-DU CONFIGURATION UPDATE messages in a gNB-CU and then dividing the result by Ncell where Ncell is the total number of active cells (NR CGIs) present in Cells Status List in GNB-DU CONFIGURATION UPDATE messages of all the gNB-DUs in a gNB-CU as explained in TS 38.473 [16] clause 9.2.1.7.

d) GNBCUCPFunction

6.11.2 Radio access network availability KPI

a) $NwAvailAvg_{TimeRAN}$

b) This KPI describes the Average availability of a network in terms of cells availability for providing services to UEs. Cell availability is the time duration for which an active cell in a network stays "In-Service". This KPI provides "average availability time duration per cell" of an entire RAN sub-network.

  b-1) Integer, time duration (second)

  b-2) MEAN

c) It is obtained by summing all measurements of $CellAvailAvg_{TimeCU}$ and then dividing the result by Ncu where Ncu is the total number of gNB-CUs present in the RAN network.

d) SubNetwork

Annex A (informative): Use cases for end to end KPIs

A.1 Use case for end-to-end latency measurements of 5G network-related KPI

The end-to-end latency is an important performance parameter for operating 5G network. In some scenarios (e.g. uRLLC), if end-to-end latency is insufficient, the 5G network customer cannot obtain guaranteed network performance provided by the network operator. So it is necessary to define end-to-end latency of network related measurement to evaluate whether the end-to-end latency that network customer requested has been satisfied. A procedure is invoked by network management system and is used:

- to update the CSMF/NSMF with the end-to-end latency parameter for monitoring;
- to inform the network customer/network operator the end-to-end latency;
- to make CSMF/NSMF aware if the end-to-end latency can meet network customer's service requirement.

If high end-to-end latency are measured, it is also of benefit to pinpoint where in the chain from application to UE that the latency occurs.

A.2 Use case for number of registered subscribers of single network-slice related KPI

Number (mean and max) of registered subscribers of single network slice can be used to describe the amount of subscribers that are successfully registered, it can reflect the usage of network slice. It is useful to evaluate accessibility performance provided by one single network slice which may trigger the lifecycle management of the network slice, this kind of KPI is valuable especially when network functions (e.g. AMF) are shared between different network slice. This KPI is focusing on both network and user view.

A.3 Use case for upstream/downstream throughput for one-single-network-slice-related KPI

Measuring throughput is useful to evaluate system load of end to end network slice. If the throughput of the specific network slice cannot meet the performance requirement, some actions need to be performed to the network slice e.g. reconfiguration, capacity relocation. So it is necessary to define the IP throughput for one single network slice. This KPI is focusing on network and user view.

A.4 Use case for mean PDU sessions number in network slice

It is necessary to evaluate the mean or maximum PDU session or MA PDU session number in the network slice to indicate system load level. For example, if the mean or maximum value of the PDU sessions or MA PDU session is high, the system capacity may need to be expanded. This KPI is focusing on network view.

A.5 Use case for virtualised resource utilization of network-slice-related KPI

It is necessary to evaluate the current utilization of virtualised resources (e.g. memory and storage utilization) that a network slice is occupied. If the utilization is larger or smaller than the threshold, maybe some scale in/out operations will be made by the management system. This KPI is focusing on network and user view.

A.6 Use case for 5GS registration success rate of one single-network-slice-related KPI

It is necessary to evaluate accessibility performance provided by 5GS. 5GS registration for a UE is important when they have registered to the network slice. If users or subscribers cannot register to the network slice, they cannot access any network services in the network slice. This KPI is focusing on network view.

A.7 Use case for RAN UE throughput-related KPI

The UE perceived throughput in NG-RAN is an important performance parameter for operating 5G network. If the UE throughput of the NR cell cannot meet the performance requirement, some actions need to be performed to the network, e.g. reconfiguration or capacity increase. So it is necessary to define UE throughput KPI to evaluate whether the end-users are satisfied. The KPI covers volume large enough to make the throughput measurement relevant, i.e. excluding data volume of the last or only slot.

The UE throughput KPI covers also E-UTRA-NR Dual Connectivity (EN-DC) [19] scenarios. Then the gNB is "connected" towards the EPC, and not towards 5GC.

It is proposed to allow UE throughput KPI split into KPIs per QoS level based on mapped 5QI (or QCI in case of EN-DC architecture).

When network slicing is supported by the NG-RAN, multiple network slices may be supported. The UL and DL UE throughput for each network slice is then of importance to the operator to pinpoint a specific performance problem.

A.8 Use case for QoS flow retainability-related KPI

QoS flow is the key and limited resource for 5GS to deliver services. The release of the QoS flow needs to be monitored. QoS flow retainability is a key performance indicator of how often an end-user abnormally losing a QoS flow during the time the QoS flow is used. This key performance indicator is of great importance to estimate the end users' experiences.

A.9 Use case for DRB accessibility-related KPIs

In providing services to end-users, the first step is to get access to the service. First after access to the service has been performed, the service can be used.

The service provided by NG-RAN is the DRB. For the DRB to be successfully setup it is also necessary to setup an RRC connection and an NG signalling connection.

If an end user cannot access a service, it is hard to charge for the service. Also, if it happens often that an end-user cannot access the provided service, the end-user might change wireless subscription provider, i.e. loss of income for the network operator. Hence, to have a good accessibility of the services is important from a business point of view.

The DRB accessibility KPIs require the following 5 measurements:

- DRB connection setup success rate.

- DRB setup success rate.

The success rate for RRC connection setup and for NG signalling connection setup shall exclude setups with establishment cause mo-Signalling, since these phases/procedures occur when there is no request to setup a DRB.

The KPIs are available per mapped 5QI and per S-NSSAI, and assist the network operator with information about the accessibility provided to their 5G network customers.

A.10 Use case for mobility KPIs

When a service is used it is important that it is not interrupted or aborted. One of the fault cases in a radio system for this is handovers/mobility.

If a mobility KPI is not considered OK, then the network operator can investigate which steps that are required to improve the mobility towards their services.

These KPIs can be used for observing the impact on end-users of mobility in NG-RAN and towards other system.

A.11 Use case for DRB retainability related KPI

DRB is the key and limited resource for 5GS to deliver services. Once a QoS flow reaches a gNB it will trigger setup of a new DRB or it will be mapped to an existing DRB. The decision on how to map QoS flows into new or existing DRBs is taken at the CU-CP. CU-CP also defines one set of QoS parameters (one 5QI) for the DRB. If a QoS flow is mapped to an existing DRB, the packets belonging to that QoS flow are not treated with the 5QI of the QoS flow, but they are treated with the mapped 5QI of the DRB.

The release of the DRB needs to be monitored, so that abnormal releases while the UE is considered in an active transfer shall be logged. DRB retainability is a key performance indicator of how often an end-user abnormally loses a DRB during the time the DRB is actively used. This key performance indicator is of great important to estimate the end users' experiences. DRBs with bursty flow are considered active if any data (UL or DL) has been transferred during the last 100 ms. DRBs with continuous flow are seen as active DRBs in the context of this measurement as long as the UE is in RRC connected state. A particular DRB is defined to be of type continuous flow if the mapped 5QI is any of {1, 2, 65, 66}.

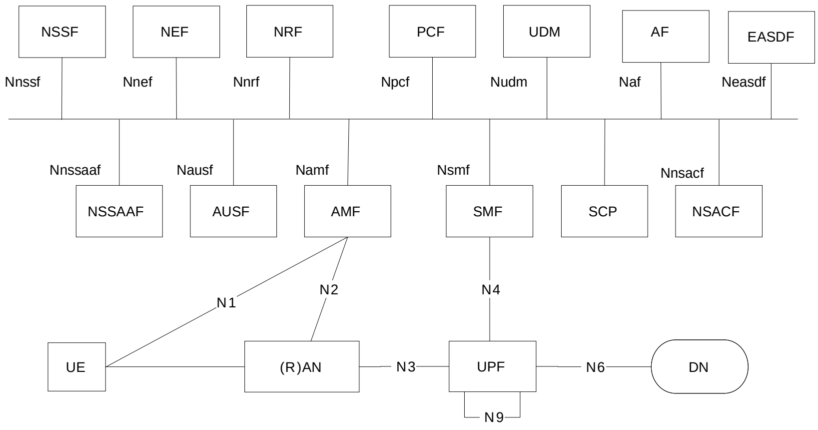
The key performance indicator shall monitor the DRB retainability for each used mapped 5QI value, as well as for the used S-NSSAI(s). DRBs used in 3GPP EN-DC architecture shall not be covered by this KPI. For the case when a DRB have multiple QoS flows mapped and active, when a QoS flow is released it will not be counted as a DRB release (DRB still active) in this KPI.

A.12 Use case for PDU session establishment success rate of one network slice (S-NSSAI) related KPI

It is necessary to evaluate accessibility performance provided by 5GS. PDU session and MA PDU session Establishment for a UE is important when it has registered to the network slice. If users or subscribers cannot establish PDU sessions or MA PDU sessions in slice instance, they cannot access any network services in the network slice. This KPI is focusing on network view.

A.13 Use case for integrated downlink latency in RAN

Following figure captured in clause 4.2.3, 3GPP TS 23.501[7] illustrates the 5G system architecture. The end to end downlink latency should be measured from Data Network to UE, of which the latency from RAN to UE is an important part for the latency of this section is closely related to NG-RAN.



The integrated downlink latency in RAN is a key performance parameter for evaluating the packet delay in RAN for QoS monitoring. This KPI is also an important part of the end-to-end network latency for SLA assurance.

A.14 Use case for PDU session Establishment success rate of one single-network-slice instance-related KPI

It is necessary to evaluate PDU session establishment time, it can be used to analyse the network service difference between different RAN locations in one area, which can be used for management area division. This KPI is focusing on network view.

A.15 Use case for QoS flow retainability-related KPI

QoS Flow is the key and limited resource for 5GS to deliver services. The release of the QoS flow needs to be monitored. QoS Flow drop ratio is a key performance indicator of how often an end-user is abnormally losing a bearer. This key performance indicator is of great importance to estimate the end users' experiences.

The KPI shall be available per QoS group.

From QoS perspective it is important to focus also on call duration as in some cases wrong quality perceived by the end user is not fully reflected by drop ratio nor retainability KPI. Typical case is when due to poor radio conditions the end user redials (the call was terminated normally) to the same party to secure the quality. But in this case the drop ratio KPI will not show any degradation. Secondly, although the call is dropped the end user may or may not redial depending on dropped call duration compared to the case when the call would be normally released. It is therefore highly recommended to monitor distribution of duration of normally and abnormally released calls.

A.16 Use case for 5G Energy Efficiency (EE) KPI

Assessment of Energy Efficiency in network is very important for operators willing to control their OPEX and, in particular, their network energy OPEX.

5G energy efficiency can be addressed from various perspectives:

- NG-RAN.
- 5GC.

Mobile Network data Energy Efficiency ($EE_{MN,DV}$) is the ratio between the performance indicator (DV_{MN}) and the energy consumption (EC_{MN}) when assessed during the same time frame, see ETSI ES 203 228 [8] clause 3.1 and clause 5.3.

$$EE_{MN,DV} = \frac{DV_{MN}}{EC_{MN}}$$

where: $EE_{MN,DV}$ is expressed in bit/J.

Assessment of $EE_{MN,DV}$ needs the collection of both Data Volumes (DV) and Energy Consumption (EC) of 5G Network Functions (NF). How this EE KPI can be applied to NG-RAN or 5GC is specified in clause 4.1 of TS 28.310 [9].

Before the network operator takes any action to save network energy OPEX, the network operator needs to know the energy efficiency of its 5G network.

This KPI needs to be used for observing the impact of NG-RAN on data energy efficiency of 5G access networks.

- Network slices.

In a Network Slice as a Service (NSaaS) model, a Network Slice Customer (NSC) may ask to its Network Slice Provider (NSP) a network slice with certain characteristics, among which the expected EE of the network slice. It is therefore required that a standardized definition of EE KPIs exists, per type of network slice, and that such EE KPIs can be measured and delivered by Network Slice Providers.

Most of the EE KPIs (i.e. NG-RAN EE KPI and 5GC EE KPI) only consider the aspect of data volume, but not other network performance aspects. For example, two RAN base stations can have similar EE evaluation results using the EE KPI based on DV, but the RAN UE throughput or cell availability of these two serving base stations can be very different.

To enhance the EE KPIs to be more comprehensive in different network scenarios, it is needed to also consider other KPIs for EE evaluation.

A.17 Use case for PFCP session established success rate of one network and one network slice instance-related KPI

It is necessary to evaluate the PFCP session established success rate of one network and one network slice instance-related KPI. It can be used to analyse the quality for the N4 interface connection between different vendor's SMF and UPF related to one network or one network slice. The KPI is very useful for the industry customer's Park area and N4 interface decoupling deployment for operators. And this KPI is mainly focusing on network view.

A.18 Use case for end-to-end reliability measurements of 5G network-related KPI

The end-to-end reliability is an important performance parameter for operating 5G network. In some scenarios (e.g. uRLLC), if end-to-end reliability is insufficient, the 5G network customer cannot obtain guaranteed network performance provided by the network operator. So it is necessary to assess end-to-end reliability of network utilizing the packet delivery success rate measurements defined in clauses 6.8.1.1, 6.8.1.3,6.8.1.2, 6.8.1.4 and also clauses 6.8.1.5 and 6.8.1.6 if its split gNB. The same can be used to determine the end to end reliability of a slice.

The reliability KPIs with time constraint defined in clauses 6.8.1.7 and 6.8.1.8 can be used in delay critical scenario to provide the reliability performance of URLLC service to 5G network consumers. For example, delay threshold or time constraint can be configured as vendor or operator specific, e.g., required latency or survival time.

A.19 Use case for average UE achievable air-interface efficiency

The average UE achievable air-interface efficiency could provide operators with the channel status considering both channel rank and quality simultaneously. It can help operators to evaluate the overall channel state and the efficiency of the cell when Massive MIMO is enabled. There are several CQI tables defined in TS 38.214[14], the KPI can be calculated by using all the CQI tables or some of CQI tables with the same BLER value.

A.20 Use case for 5G VN group measurements related KPIs

It is necessary to evaluate the end-to-end network KPIs on 5G VN group level to evaluate the performance of 5G LAN-type services for provided consistence of group UE experience. The 5G VN group measurements KPIs require the follow measurements:

- The 5G VN internal group status, calculated by group member registration/de-registration success rate of 5G VN group, internal Group ID identifies a 5G VN group communication, as specified in TS 23.501 [7].

- The 5G VN internal group session establishment success rate, calculated by the PDU session establishment success rate related to a 5G VN group, internal Group ID identifies a 5G VN group communication, as specified in TS 23.501 [7].

- The duration of 5G VN internal group communication, counted by the sum of duration of individual PDU sessions within the 5G VN group communication, internal Group ID identifies a 5G VN group communication, as specified in TS 23.501 [7].

To monitor the status of 5G VN Group, 5G VN Group level session establishment success rate and the duration of 5G VN group communication can assist the network operator with information about the 5G LAN-type services provided to their 5G network customers. These KPIs are focusing on network view.

A.21 Use case for air interface average efficiency based on MCS for NRCellDU

The air interface average efficiency KPI based on MCS could provide operators with the channel status and efficiency considering spatial multiplexing under both SU MIMO and MU MIMO scenarios when Massive MIMO is enabled. The MCS distribution can be performed separately in uplink and downlink, so the corresponding KPIs can also evaluate the performance of air interface separately. There are several MCS tables defined in TS 38.214 [14] both for uplink and downlink, the KPIs can be calculated by using all the MCS tables or some of MCS tables with the same BLER value.

A.22 Use case for throughput KPI at NgU interface for a Network Slice

This KPI represents the downstream and upstream throughput on the NgU interface (i.e. RAN end of N3 interface) for a particular network slice. Measuring and assuring this KPI is important for RAN slice subnet MnS producer, for both performance assurance (e.g., making this KPI available to RAN slice subnet MnS consumer), and capacity planning (e.g., optimize the capacity of gNB / gNB-CU-UP taking part in the slice).

A.23 Use case for NSOEU related KPIs

To monitor and control its distribution grid, the DSO uses thousands of 3GPP compatible UEs. These UEs are spread across a wide geographical area, just like the distribution grid the UEs support. The DSO uses the UEs to provide connectivity to the monitor and control infrastructure of the distribution grid. This infrastructure has very high availability service requirements. To fulfil these requirements, highly available communication is required. To achieve this highly available communication, the DSO monitors performance of communications services they use. If and when the DSO deems it necessary, the DSO proactively activates additional communication services. See more details in TS 28.318 [17].

Subject to mobile network operator policy, regulatory requirements and contractual obligations, 3GPP management system allows the DSO to request collection and reporting of NSOEU related KPIs:

- Cell availability.
- Radio access network availability.

A.24 Use case for GTP capacity related KPIs

The KPIs in clause 6.3 are defined for the NWDAF to produce QoS sustainability analytics.

As described in TS 23.288, the consumer of QoS Sustainability analytics may request NWDAF analytics information regarding the QoS change statistics for an Analytics target period in the past in a certain area or the likelihood of a QoS change for an Analytics target period in the future in a certain area. To improve QoS Sustainability analytics, the NWDAF may additionally collect GTP metrics. These key performance indicators are of great importance to assist NWDAF in evaluating more accurate QoS sustainability analysis.

A.25 Use case for the PDU Session Establishment Requests and Rejects related KPIs

The PDU Session Establishment Requests and Rejects KPIs are useful for performance assurance to characterize PDU session establishment success rate for scenarios where a handover happens from non 3GPP access to 3GPP access links with a pre-established PDU Session.

A.26 Use case for reliability KPI in RAN with time constraint over Downlink and Uplink air-interface

Reliability KPI based on time constraint in DL and UL over Uu interface in a 5G network as defined in clauses 6.8.1.8 and 6.8.1.7 is important to be calculated specially for delay critical URLLC services. It would help in troubleshooting any delay related issue in RAN side for the ongoing URLLC service. It enables operators to track the performance of a URLLC service and the delay values of each packet can be used for analysing and troubleshooting. This may include enabling/disabling or configuring/de-configuring the URLLC service-impacting RAN features or may involve actions like re-configuring time constraint/delay threshold values if not set correctly already.

A.27 Use case for the Connected Mode RRM Relaxation Usage rate KPI

The Connected Mode RRM Relaxation Usage rate KPI is useful to assess how often do UEs that fulfil conditions to enter connected mode rrm relaxation state stay in such a state or exit it.

A.28 Use case for the Extended DRX Negotiation Success Rate KPI

The Extended DRX Negotiation Success Rate KPI is useful to assess the proper usage of eDRX feature as well as to support informed resource dimensioning and planning on the AMF side for performance assurance purposes.

A.29 Use case for high load ratio based on PRB usage distribution for NRCellDU

The high load ratio based on PRB usage distribution could provide operators with a more accurate measure of utilization rate and resource load by using the second or milisecond-level PRB usage data. In transient overload scenarios (e.g., high-speed rail or subway systems), the high load caused by massive user access and bursty traffic typically lasts only seconds—specifically when trains pass through a cell, while traffic volume remains extremely low during other periods. This KPI can help operators identify the actual high load ratio when these shot-duration, high-impact events occur. The KPI can be used either independently or alongside other KPIs to support network expansion decisions.

Annex B (informative): Change history

Change history							
Date	Meeting	TDoc	CR	Rev	Cat	Subject/Comment	New version
2018-09	SA#81					Upgrade to change control version	15.0.0
2018-09	SA#81					EditHelp fix	15.0.1
2018-12	SA#82	SP-181041	0001	-	F	Align title with TS database	15.1.0
2019-03	SA#83	SP-190122	0005	2	F	Update KPI subscribers of single network slice instance through UDM	15.2.0
2019-03	SA#83	SP-190122	0011	2	F	Update definition of mean number of PDU sessions KPI	15.2.0
2019-03	SA#83	SP-190111	0007	1	B	Add KPI of QoS flow Retainability	16.0.0
2019-03	SA#83	SP-190111	0009	1	B	Add DRB Accessibility KPI and Use Case	16.0.0
2019-06	SA#84	SP-190371	0013	-	B	Add KPI for NG-RAN Handover Success Rate	16.1.0
2019-06	SA#84	SP-190375	0015	1	A	Correction of Throughput KPI	16.1.0
2019-09	SA#85	SP-190747	0016	2	B	Add KPI for DRB Retainability	16.2.0
2019-09	SA#85	SP-190747	0017	3	B	Add a new KPI definition of PDU session Establishment Success Rate of one network slice (S-NSSAI)	16.2.0
2019-09	SA#85	SP-190751	0020	-	A	Correction on kbits abbreviation	16.2.0
2019-09	SA#85	SP-190747	0021	1	F	Correction of Flow Retainability KPI	16.2.0
2019-09	SA#85	SP-190747	0022	1	F	Correction of DRB Accessibility KPI	16.2.0
2019-09	SA#85	SP-190748	0024	2	A	Correct the title of KPI	16.2.0
2019-09	SA#85	SP-190747	0025	1	B	Add definition of integrated downlink latency in RAN	16.2.0
2019-09	SA#85	SP-190747	0028	2	B	Add a new KPI definition of Inter-gNB handover Execution time of one single network slice	16.2.0
2019-09	SA#85	SP-190747	0029	2	B	Add a new KPI definition of PDU session Establishment Time of one single network slice	16.2.0
2019-09	SA#85	SP-190747	0030	2	B	Add new specification requirement related to extended 5QI 1 QoS Flow Retainability monitoring	16.2.0
2019-12	SA#86	SP-191165	0032	1	B	Add 5G Energy Efficiency KPI	16.3.0
2019-12	SA#86	SP-191149	0033	1	B	Add a new KPI definition of Mean number of successful periodic registration updates of Single Network Slice	16.3.0
2019-12	SA#86	SP-191149	0034	1	B	Add a new description of KPI that related to successful rate of mobility registration updates of Single Network Slice	16.3.0
2019-12	SA#86	SP-191150	0036	1	F	Update the template of KPI definition for TS 28.554	16.3.0
2020-03	SA#87E	SP-200163	0038	1	F	Update KPI definitions to align with the new template	16.4.0
2020-03	SA#87E	SP-200162	0039	-	F	Correction of equation color	16.4.0
2020-07	SA#88-e	SP-200502	0044	1	F	Correction of Downlink latency in gNB-DU KPI	16.5.0
2020-07	SA#88-e	SP-200502	0045	-	F	Removal of the KPI named KPI categories	16.5.0
2020-07	SA#88-e	SP-200502	0046	-	F	Update of KPI template	16.5.0
2020-07	SA#88-e	SP-200503	0049	1	B	Add KPI on e2e UL delay for network slice	16.5.0
2020-07	SA#88-e	SP-200503	0050	1	B	Add KPI on e2e DL delay for network slice	16.5.0
2020-07	SA#88-e	SP-200503	0051	1	B	Add KPIs for UL packet delay in NG-RAN	16.5.0
2020-07	SA#88-e	SP-200503	0052	1	B	Correction of Integrated downlink delay in RAN KPI	16.5.0
2020-07	SA#88-e	SP-200485	0053	1	F	Cleanup based on refined slice definitions	16.5.0
2020-09	SA#89e	SP-200751	0054	1	F	Fixing KPIs	16.6.0
2020-09	SA#89e	SP-200738	0056	-	F	Correction of RAN UE throughput KPI	16.6.0
2020-09	SA#89e	SP-200747	0057	1	B	Additional KPI Definition for Max Subscriber and PDU Session	17.0.0
2020-12	SA#90e	SP-201059	0061	1	A	Correct UDM e2e KPI	17.1.0
2020-12	SA#90e	SP-201061	0064	-	A	Editorial Correction of TS 28.554	17.1.0
2020-12	SA#90e	SP-201054	0068	-	A	Correction and alignment of Retainability KPIs definitions	17.1.0
2020-12	SA#90e	SP-201054	0069	-	A	Add missing KPI for inter system Handover success rate	17.1.0
2020-12	SA#90e	SP-201062	0071	1	B	Add EE KPI definitions for network slices	17.1.0
2020-12	SA#90e					Correction of style of clause from CR0071	17.1.1
2021-03	SA#91e	SP-210157	0074	-	B	CHO measurements KPI	17.2.0
2021-03	SA#91e	SP-210150	0077	-	A	Update retainability KPIs to consider abnormal releases in RRC connected state	17.2.0
2021-06	SA#92e	SP-210412	0075	2	B	Update the Accessibility KPI to cover DRB access via RRC Resume	17.3.0
2021-06	SA#92e	SP-210412	0078	1	B	Definition of the Total DRB Accessibility KPI .	17.3.0
2021-06	SA#92e	SP-210578	0079	1	B	Update on energy efficiency of URLLC network slice	17.3.0
2021-06	SA#92e	SP-210578	0080	1	B	Add Energy Consumption KPI pour 5G NF and 5G CN	17.3.0
2021-06	SA#92e	SP-210578	0081	1	B	Add EE KPI for eMBB network slice based on RAN measurements	17.3.0
2021-09	SA#93e	SP-210869	0082	-	B	Add estimated VNF, VNFC and virtual compute resource instance Energy Consumption KPI	17.4.0
2021-09	SA#93e	SP-210869	0083	1	C	Update the EE KPI for the URLLC network slice	17.4.0
2021-09	SA#93e	SP-210872	0084	-	B	Add Mean&Maximum CM-Connected subscribers of network slice through AMF	17.4.0
2021-09	SA#93e	SP-210872	0085	-	B	Add PFCP session established success rate of one network and one network slice	17.4.0
2021-12	SA#94e	SP-211459	0086	1	B	Add definition of ECns	17.5.0
2021-12	SA#94e	SP-211459	0087	1	B	Add Energy Consumption KPI for NG-RAN	17.5.0
2021-12	SA#94e	SP-211459	0088	1	B	Add definition of 5GC energy efficiency (EE) KPI	17.5.0

2022-03	SA#95e	SP-220172	0091	-	A	Editorial clean up of mobilty KPIs HO success rate	17.6.0
2022-03	SA#95e	SP-220172	0092	1	B	Add KPI for HO success rate for all handover types	17.6.0
2022-03	SA#95e	SP-220180	0093	-	B	Define Reliability KPI in 5G Network	17.6.0
2022-06	SA#96	SP-220515	0095	-	A	Update formula of PDU session establishment success rate	17.7.0
2022-09	SA#97e	SP-220853	0097	-	A	Correct wrong measurement names in KPI definition	17.8.0
2022-09	SA#97e	SP-220850	0098	1	F	Correct 5G energy consumption definitions	17.8.0
2022-09	SA#97e	SP-220850	0099	1	F	Updating Packet transmission reliability KPI in DL on N3	17.8.0
2022-09	SA#97e	SP-221183	0105	2	B	Add KPI on average air-interface efficiency achievable per UE within the observed NRCellDU	18.0.0
2023-03	SA#99	SP-230194	0109	-	A	Correct error in estimated VNFC energy consumption	18.1.0
2023-03	SA#99	SP-230200	0114	-	A	Correction of integrity KPIs	18.1.0
2023-06	SA#100	SP-230663	0117	1	B	Add a use case for 5G VN group measurements related KPIs	18.2.0
2023-06	SA#100	SP-230663	0118	1	B	Add Accessibility KPIs for 5G VN group measurements	18.2.0
2023-06	SA#100	SP-230647	0122	-	A	Correction of accessibility and integrity KPI	18.2.0
2023-09	SA#101	SP-230939	0127	1	A	Rel-18 CR TS 28.554 Correct reference and fix void section	18.3.0
2023-09	SA#101	SP-230939	0131	-	F	Rel-18 CR for TS28.554 editorial Correction	18.3.0
2023-09	SA#101	SP-230952	0132	1	B	Adding additional virtual resources usage to estimate VNF energy consumption	18.3.0
2023-09	SA#101	SP-230974	0138	1	B	New KPIs for Inactive and Idle Mode Paging Accessibility	18.3.0
2023-09	SA#101	SP-230937	0140	1	B	Rel-18 CR 28.554 Add Accessibility KPIs for 5G VN group measurements	18.3.0
2023-09	SA#101	SP-230937	0141	1	B	Rel-18 CR 28.554 Add Integrity KPIs for 5G VN group measurements	18.3.0
2023-09	SA#101	SP-230937	0142	1	B	Rel-18 CR 28.554 Add Utilization KPIs for 5G VN group measurements	18.3.0
2023-09	SA#101					Correction of editorials	18.3.1
2023-12	SA#102	SP-231483	0146	1	C	Rel-18 CR TS 28.554 Adapt the Downlink delay in NG-RAN and gNB-DU to support cases for NTN	18.4.0
2023-12	SA#102	SP-231484	0147	1	B	Rel-18 CR 28.554 Add new KPI on air-interface efficiency based on MCS	18.4.0
2023-12	SA#102	SP-231451	0159	-	A	Rel-18 CR TS 28.554 Correction Utilization KPI definition of PDU session establishment time of network slice	18.4.0
2024-03	SA#103	SP-240188	0165	-	F	Rel-18 CR TS 28.554 Correct the reference information in the end-to-end reliability description in A18 – MCC: could not be implemented due to clash with CR 0167.	18.5.0
2024-03	SA#103	SP-240166	0167	-	A	Rel-18 CR TS 28.554 Correction of Wrong Clause Indexes – MCC: could not be implemented due to clash with CR 0165.	18.5.0
2024-03	SA#103	SP-240176	0168	1	B	Rel-18 CR TS 28.554 Add KPIs for NSOEU	18.5.0
2024-03	SA#103	SP-240188	0169	1	B	Rel-18 CR TS 28.554 Add the KPI of DL Packet transmission reliability on F1-U	18.5.0
2024-03	SA#103	SP-240188	0170	1	B	Rel-18 CR TS 28.554 Add the KPI of UL Packet transmission reliability on F1-U	18.5.0
2024-03	SA#103	SP-240180	0174	1	B	Rel-18 CR TS 28.554 Throughput KPI for Network Slice at gNB	18.5.0
2024-06	SA#104	SP-240818	0180	1	F	Rel-18 CR 28.554 Update KPIs on "UL/DL capacity GTP" and "UL/DL available capacity GTP"	18.6.0
2024-06	SA#104	SP-240812	0184	-	A	Rel-18 CR 28.554 Correction of downlink latency in gNB-DU	18.6.0
2024-06	SA#104	SP-240818	0191	1	F	Rel-18 CR TS 28.554 name update as per measurement family name	18.6.0
2024-06	SA#104	SP-240833	0193	1	F	Rel-18 CR TS 28.554 Correction to NSOEU KPI	18.6.0
2024-06	SA#104	SP-240818	0194	1	F	Rel-18 CR TS 28.554 add Use cases of GTP capacity related KPIs	18.6.0
2024-06	SA#104	SP-240816	0187	1	B	Rel-19 CR TS 28.554 Reliability KPI in RAN with time constraint over Uplink air-interface	19.0.0
2024-06	SA#104	SP-240816	0189	1	B	Rel-19 CR TS 28.554 Reliability KPI in RAN with time constraint over Downlink air-interface	19.0.0
2024-06	SA#104	SP-240816	0192	1	B	New KPIs for PDU Establishment Accessibility	19.0.0
2024-09	SA#105	SP-241171	0201	1	A	Rel-19 CR TS 28.554 update the use of EN-DC architecture	19.1.0
2024-09	SA#105	SP-241180	0202	-	B	Rel-19 CR TS 28.554 Add the KPIs of mean and maximum MA PDU session number for ATSSS	19.1.0
2024-09	SA#105	SP-241180	0203	1	B	Rel-19 CR TS 28.554 Add a new KPI definition of MA PDU session Establishment Success Rate of network slice	19.1.0
2024-09	SA#105	SP-241180	0204	1	B	Rel-19 CR TS 28.554 Add use case for reliability KPI in RAN with time constranit	19.1.0
2024-09	SA#105	SP-241180	0205	-	B	Rel-19 CR TS 28.554 End to end downlink and end to end uplink reliability KPIs of URLLC Network Slice	19.1.0
2024-09	SA#105	SP-241180	0206	1	B	Rel-19 CR TS 28.554 Use case for informative Annex A	19.1.0
2024-12	SA#106	SP-241648	0210	1	B	New KPIs for Connected Mode RRM Relaxation Usage rate	19.2.0
2024-12	SA#106	SP-241648	0211	1	B	New KPIs for Extended DRX Negotiation Success Rate	19.2.0
2024-12	SA#106	SP-241648	0212	-	B	Rel-19 CR 28.554 Update mobility KPI for LTM	19.2.0
2025-03	SA#107	SP-250166	0215	1	C	Rel-19 CR TS 28.554 Update the reference for reliability related KPIs	19.3.0
2025-06	SA#108	SP-250559	0217	1	F	Correct the description of maximum number of PDU sessions of network slice	19.4.0

2025-06	SA#108	SP-250559	0223	1	D	Rel-19 CR TS 28.554 Clause 6.7.3.1 minor editorials	19.4.0
2025-06	SA#108	SP-250557	0225	1	A	Rel-19 CR TS 28.554 Clause 6.7.3.1 KPI name correction	19.4.0
2025-06	SA#108	SP-250555	0231	1	A	Rel-19 CR TS 28.554 Update the KPI definitions template	19.4.0
2025-06	SA#108	SP-250530	0232	1	B	Rel-19 CR TS 28.554 Add multi-dimensional energy efficiency use case	19.4.0
2025-06	SA#108	SP-250530	0233	2	B	Rel-19 CR TS 28.554 Add EE KPIs evaluated from network availability performance dimension	19.4.0
2025-06	SA#108	SP-250530	0234	2	B	Rel-19 CR TS 28.554 Add EE KPIs evaluated from network quality performance dimension	19.4.0
2025-06	SA#108	SP-250530	0235		B	Rel-19 CR TS 28.554 Add the measurement of carbon emission related KPIs for gNB	19.4.0
2025-06	SA#108					MCC: Add some missing SP numbers	19.4.1
2025-09	SA#109	SP-251085	0237	-	F	Rel-19 CR TS 28.554 Corrections on KPI template	19.5.0
2025-09	SA#109	SP-251100	0239	1	B	Rel-19 CR TS 28.554 Add NG-RAN estimated carbon emission KPI	19.5.0
2025-09	SA#109	SP-251085	0240	1	B	Rel-19 CR 28.554 Add new KPI for high loads evaluation based on PRB usage distribution	19.5.0
2025-09	SA#109	SP-251078	0243	1	B	Rel-19 CR TS 28.554 Update the unit and type of the KPI	19.5.0
2025-09	SA#109	SP-251078	0244	1	F	Rel-19 CR TS 28.554 Change the structure of clauses 6.9 and 6.10	19.5.0
2025-09	SA#109	SP-251085	0247	1	D	Rel-19 CR TS 28.554 Editorial Corrections for Retainability KPI Definition	19.5.0
2025-11	SA#109					MCC correction to enable equation correction on MS Word.	19.5.1

History

Document history		
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