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Introduction

The present document is part of a TS-family covering the 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Telecommunication management; as identified below:

32.401 Performance Management (PM); Concept and requirements

52.402 Performance Management (PM); Performance measurements – GSM

32.404 Performance Management (PM); Performance measurements - Definitions and template

32.405 Performance Management (PM); Performance measurements Universal Terrestrial Radio Access Network (UTRAN)

32.406 Performance Management (PM); Performance measurements Core Network (CN) Packet Switched (PS) domain

32.407 Performance Management (PM); Performance measurements Core Network (CN) Circuit Switched (CS) domain

32.408 Performance Management (PM); Performance measurements Teleservice

32.409 Performance Management (PM); Performance measurements IP Multimedia Subsystem (IMS)

32.425 Performance Management (PM); Evolved Performance measurements Universal Terrestrial Radio Access Network (E-UTRAN)

32.426 Performance Management (PM); Evolved Packet Core (EPC)

The present document is part of a set of specifications, which describe the requirements and information model necessary for the standardised Operation, Administration and Maintenance (OA&M) of a multi-vendor E-UTRAN and EPC system.

During the lifetime of an E-UTRAN, its logical and physical configuration will undergo changes of varying degrees and frequencies in order to optimise the utilisation of the network resources. These changes will be executed through network configuration management activities and/or network engineering, see TS 32.600 [3].

Many of the activities involved in the daily operation and future network planning of an E-UTRAN require data on which to base decisions. This data refers to the load carried by the network and the grade of service offered. In order to produce this data performance measurements are executed in the NEs, which comprise the network. The data can then be transferred to an external system, e.g. an Operations System (OS) in TMN terminology, for further evaluation. The purpose of the present document is to describe the mechanisms involved in the collection of the data and the definition of the data itself.

Annex B of TS 32.404 helps in the definition of new performance measurements that can be submitted to 3GPP for potential adoption and inclusion in the present document. Annex B of TS 32.404 discusses a top-down performance measurement definition methodology that focuses on how the end-user of performance measurements can use the measurements.

1 Scope

The present document describes the measurements for E-UTRAN.

TS 32.401 [5] describes Performance Management concepts and requirements.

The present document is valid for all measurement types provided by an implementation of an E-UTRAN.

Only measurement types that are specific to E-UTRAN are defined within the present documents. Vendor specific measurement types used in E-UTRAN are not covered. Instead, these could be applied according to manufacturer's documentation.

Measurements related to "external" technologies (such as ATM or IP) as described by "external" standards bodies (e.g. ITU-T or IETF) shall only be referenced within this specification, wherever there is a need identified for the existence of such a reference.

The definition of the standard measurements is intended to result in comparability of measurement data produced in a multi-vendor network, for those measurement types that can be standardised across all vendors' implementations.

The structure of the present document is as follows:

- Header 1: Network Element (e.g. measurements related to eNodeB);
- Header 2: Measurement function (e.g. RRC connection setup related measurements);
- Header 3: Measurements.

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 and/or edition number or version number) 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 TS 32.101: "Telecommunication management; Principles and high level requirements".
- [2] 3GPP TS 32.102: "Telecommunication management; Architecture".
- [3] 3GPP TS 32.600: "Telecommunication management; Configuration Management (CM); Concept and high-level requirements".
- [4] Void.
- [5] 3GPP TS 32.401: "Telecommunication management; Performance Management (PM); Concept and requirements".
- [6] 3GPP TS 32.404: "Performance Management (PM); Performance measurements - Definitions and template".
- [7] 3GPP TS 32.762: "Evolved Universal Terrestrial Radio Access Network (E-UTRAN) Network Resource Model (NRM) Integration Reference Point (IRP): Information Service (IS)".
- [8] 3GPP TS 36.331: "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC) protocol specification".

- [9] 3GPP TS 36.413: "Evolved Universal Terrestrial Radio Access Network (E-UTRAN); S1 Application Protocol (S1AP)".
- [10] 3GPP TS 36.423: "Evolved Universal Terrestrial Radio Access Network (E-UTRAN); X2 application protocol (X2AP)".
- [11] 3GPP TS 36.314: "Evolved Universal Terrestrial Radio Access (E-UTRA); Layer 2 – Measurements".
- [12] 3GPP TS 36.300: "Evolved Universal Terrestrial Radio Access (E-UTRA); and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2".
- [13] 3GPP TS 32.450: "Telecommunication management; Key Performance Indicators (KPI) for E-UTRAN: Definitions".
- [14] 3GPP TS 36.304: "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) procedures in idle mode".
- [15] 3GPP TS 32.522: "Technical Specification Group Services and SystemAspects; Telecommunication management; Self-Organizing Networks (SON) Policy Network Resource Model (NRM) Integration Reference Point (IRP); Information Service (IS)".
- [16] 3GPP TS 36.321: "Evolved Universal Terrestrial Radio Access (E-UTRA) Medium Access Control (MAC) protocol specification".
- [17] 3GPP TS 23.272, "Circuit Switched (CS) fallback in Evolved Packet System (EPS); Stage 2".
- [18] 3GPP TS 36.331: "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification".
- [19] 3GPP TS 36.133: "Evolved Universal Terrestrial Radio Access (E-UTRA); Requirements for support of radio resource management".
- [20] ES 203 228 V1.0.0: "Environmental Engineering (EE); Assessment of mobile network energy efficiency".
- [21] ES 203 228 V1.0.0: "Environmental Engineering (EE); Assessment of mobile network energy efficiency".

3 Measurement family and abbreviations

3.1 Measurement family

The measurement names defined in the present document are all beginning with a prefix containing the measurement family name (e.g. RRC.AttConnEstab.Cause). This family name identifies all measurements which relate to a given functionality and it may be used for measurement administration (see TS 32.401 [5]).

The list of families currently used in the present document is as follows:

- DRB (measurements related to Data Radio Bearer)
- RRC (measurements related to Radio Resource Control)
- RRU (measurements related to Radio Resource Utilization)
- ERAB (measurements related to E-RAB)
- HO (measurements related to Handover)
- S1SIG (measurements related to S1 Signalling)
- SRB (measurements related to Signalling Radio Bearer)
- PAG (measurements related to Paging)
- EQPT(measurements related to Equipment)
- UECNTX(measurements related to UE CONTEXT)
- TB(measurements related to Transport Block)

- MR (measurements related to Measurement Report)

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

3G	3 rd Generation
3GPP	3G Partnership Project
BLER	Block Error Rate
CRC	Cyclic Redundancy Check
EPS	Evolved Packet System
EQPT	Equipment
E-UTRAN	Evolved UTRAN
E-RAB	E-UTRAN Radio Access Bearer
HO	Handover
PCell	Primary Cell
QoS	Quality of Service
RN	Relay Node
SCell	Secondary Cell
TB	Transport Block
UTRAN	Universal Terrestrial Radio Access Network

You can find below a list of abbreviations used within the measurement types for field E of the measurement template (see 3GPP TS 32.404 [6]).

Alloc	Allocation
AOA	Angle of Arrival
Att	Attempt(s,ed)
Conn	Connection
Ded	Dedicated
DL	Downlink
EE	Energy Efficiency
ENB	eNodeB
Err	Error
Estab	Establish (ed,ment)
Fail	Fail(ed, ure)
Freq	Frequency
Inc	Incoming
Out	Outgoing
Pkt	Packet(s)
Prep	Prepare(/Preparation)
Late	Latency
Mod	Modify(/Modification)
Nbr	Number
Rel	Release(s,d)
Res	Resource
RSRP	Reference Signal Received Power
RSRQ	Reference Signal Received Quality
Succ	Success(es,ful)
Tot	Total
UL	Uplink

4 Measurements related to eNodeB, Donor eNodeB and Relay Node

4.0 Applicability of measurements

Without particular constraint, the measurements apply to following scenarios

- 1) eNodeB serving one or more Relay Nodes.
- 2) eNodeB not serving any Relay Node
- 3) eNodeB or Relay Node supporting Carrier Aggregation
- 4) eNodeB or Relay Node not supporting Carrier Aggregation

If the specific constraint is present, which one of above scenarios the subject measurement applies to, is following the constraint.

4.1 RRC connection related measurements

4.1.1 RRC connection establishment

The three measurement types defined in the subclauses 4.1.1.1, 4.1.1.2 and 4.1.1.3 are subject to the "2 out of 3 approach".

4.1.1.1 Attempted RRC connection establishments

- a) This measurement provides the number of RRC connection establishment attempts for each establishment cause.
- b) CC
- c) Receipt of an RRCConnectionRequest message by the eNodeB/RN from the UE. Each RRCConnectionRequest message received is added to the relevant per establishment cause measurement. The possible causes are included in TS 36.331 [8]. The sum of all supported per cause measurements shall equal the total number of RRCConnectionRequest. In case only a subset of per cause measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value. The number of measurements is equal to the number of causes plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form RRC.ConnEstabAtt.*Cause* where *Cause* identifies the establishment cause.
- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switched traffic
- h) EPS
- i) One usage of this measurement is to support the coverage ratio (CR) calculation for EE coverage area determination in [21].

4.1.1.2 Successful RRC connection establishments

- a) This measurement provides the number of successful RRC establishments for each establishment cause.
- b) CC

- c) Receipt by the eNodeB/RN of an RRCConnectionSetupComplete message following a RRC connection establishment request. Each RRCConnectionSetupComplete message received is added to the relevant per establishment cause measurement. The possible causes are included in TS 36.331 [8]. The sum of all supported per cause measurements shall equal the total number of successful RRC Connection Establishments. In case only a subset of per cause measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value. The number of measurements is equal to the number of causes plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form RRC.ConnEstabSucc.*Cause* where *Cause* identifies the establishment cause.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.1.1.3 Failed RRC connection establishments

- a) This measurement provides the number of RRC establishment failures for each establishment cause.
- b) CC
- c) Transmission of an RRCConnectionReject message by the eNodeB/RN to the UE or an expected RRCConnectionSetupComplete message not received by the eNodeB/RN. Each failed RRC connection establishment is added to the relevant per establishment cause measurement. The possible causes are included in TS 36.331 [8].
The sum of all supported per cause measurements shall equal the total number of RRC connection establishment failures. In case only a subset of per cause measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value. The number of measurements is equal to the number of causes plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form RRC.ConnEstabFail.*Cause* where *Cause* identifies the establishment cause.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS
- i) One usage of this measurement is to support the coverage ratio (CR) calculation for EE coverage area determination in [21].

4.1.1.4 Failed RRC connection establishment per failure cause

- a) This measurement provides the number of failed RRC establishment per failure cause. This measurement is to support LBO target setting and evaluation, see [15]
- b) CC
- c) Transmission of an RRCConnectionReject message by the eNodeB to the UE.
Each transmitted RRCConnectionReject message caused by 'congestion' is added to the measurement cause "*Congestion*", when eNB receives an RRCConnectionRequest message and the RRC connection is not established because the eNB is going to Energy Saving mode is added to the measurement cause "*EnergySaving*" and each transmitted RRCConnectionReject message caused by the other reasons is added to measurement cause "*Unspecified*".
- d) Each measurement is an integer value.

- e) RRC.ConnEstabFaileNBCause.*Congestion*
RRC.ConnEstabFaileNBCause.*Unspecified*
RRC.ConnEstabFaileNBCause.*EnergySaving*
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS
- i) The measurement is use to count "Failed RRC connection establishment related to load" for LBO target setting and evaluation, see [15].

4.1.2 RRC connection re-establishment

The three measurement types defined in the subclause 4.1.2.n are subject to the "2 out of 3 approach".

4.1.2.1 Attempted RRC connection re-establishments

- a) This measurement provides the number of RRC connection re-establishment attempts for each re-establishment cause.
- b) CC.
- c) Receipt of an RRCCONNECTIONREESTABLISHMENTREQUEST message by the eNodeB/RN from the UE. Each RRCCONNECTIONREESTABLISHMENTREQUEST received is added to the relevant per reestablishment cause measurement. The possible causes are included in TS 36.331 [8]. The sum of all supported per cause measurements shall equal the total number of RRC connection re-establishment attempts. In case only a subset of per cause measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value. The number of measurements is equal to the number of causes plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form RRC.ConnReEstabAtt.*Cause* where *Cause* identifies the reestablishment cause.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switching.
- h) EPS

4.1.2.2 Successful RRC connection re-establishments

- a) This measurement provides the number of successful RRC connection re-establishments for each re-establishment cause.
- b) CC.
- c) Receipt by the eNodeB/RN of an RRCCONNECTIONREESTABLISHMENTCOMPLETE message following a RRC connection reestablishment request. Each RRCCONNECTIONREESTABLISHMENTCOMPLETE message received is added to the relevant per reestablishment cause measurement. The possible causes are included in TS 36.331 [8]. The sum of all supported per cause measurements shall equal the total number of successful RRC connection re-establishments. In case only a subset of per cause measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value. The number of measurements is equal to the number of causes plus a possible sum value identified by the *.sum* suffix.

- e) The measurement name has the form RRC.ConnReEstabSucc.*Cause* where *Cause* identifies the establishment cause.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switching.
- h) EPS

4.1.2.3 Failed RRC connection re-establishments

- a) This measurement provides the number of RRC re-establishment failures for each re-establishment cause.
- b) CC.
- c) Transmission of an RRCConnectionReestablishmentReject message by the eNodeB/RN to the UE or an expected RRCConnectionReestablishmentComplete message not received by the eNodeB/RN.
Each failed RRC connection re-establishment is added to the relevant per re-establishment.cause measurement. The possible causes are included in TS 36.331 [8].
The sum of all supported per cause measurements shall equal the total number of RRC connection re-establishment failures. In case only a subset of per cause measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value. The number of measurements is equal to the number of causes plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form RRC.ConnReEstabFail.*Cause* where *Cause* identifies the re-establishment.cause.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switching.
- h) EPS

4.1.3 RRC connection number

4.1.3.1 Mean number of RRC Connections

- a) This measurement provides the mean number of RRC Connections during each granularity period.
- b) SI.
- c) This measurement is obtained by sampling at a pre-defined interval, the number of RRC connections for each E-UTRAN Cell and then taking the arithmetic mean
- d) A single integer value.
- e) RRC.ConnMean
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switching.
- h) EPS

4.1.3.2 Maximum number of RRC Connections

- a) This measurement provides the maximum number of RRC Connections during each granularity period.

- b) SI.
- c) This measurement is obtained by sampling at a pre-defined interval, the number of RRC connections for each E-UTRAN cell and then taking the maximum.
- d) A single integer value.
- e) RRC.ConnMax
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switching.
- h) EPS

4.1.4 RRC connection setup time

4.1.4.1 Mean RRC connection setup time

- a) This measurement provides the mean time per establishment cause it takes to establish an RRC connection.
- b) DER (n=1).
- c) This measurement is obtained by accumulating the time intervals for every successful RRC connection establishment between the receipt of a `RRCCoNNECTIONRequest` and the corresponding `RRCCoNNECTIONSetupComplete` message by the eNodeB/RN over the granularity period. The end value of this time will then be divided by the number of successful RRC connections observed in the granularity period to give the arithmetic mean. The accumulator shall be reinitialised at the beginning of each granularity period. The measurement is split into subcounters per establishment cause, and the possible causes are included in TS 36.331 [8].
- d) Each measurement is an integer value (in milliseconds).
- e) The measurement name has the form `RRC.ConnEstabTimeMean.Cause` where *Cause* identifies the establishment cause
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switching.
- h) EPS

4.1.4.2 Maximum RRC connection setup time

- a) This measurement provides the maximum time per establishment cause it takes to establish an RRC connection.
- b) GAUGE.
- c) This measurement is obtained by monitoring the time intervals for each successful RRC connection establishment between the receipt of a `RRCCoNNECTIONRequest` and the corresponding `RRCCoNNECTIONSetupComplete` message by the eNodeB/RN over the granularity period. The high tide mark of this time will be stored in a gauge, the gauge shall be reinitialised at the beginning of each granularity period. The measurement is split into subcounters per establishment cause, and the possible causes are included in TS 36.331 [8].
- d) Each measurement is an integer value (in milliseconds).
- e) The measurement name has the form `RRC.ConnEstabTimeMax.Cause` where *Cause* identifies the establishment cause

- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switching.
- h) EPS

4.1.5 UE CONTEXT Release

4.1.5.1 Number of UE CONTEXT Release Request initiated by eNodeB/RN

- a) This measurement provides the number of UE CONTEXT Release initiated by eNB/RN for each release cause.
- b) CC.
- c) Transmission of an UE CONTEXT RELEASE REQUEST message initiated by eNodeB/RN. Each release request is to be added to the relevant cause measurement. The possible causes are defined in 36.413 [9]. The sum of all supported per causes measurements shall equal the total number of UE CONTEXT Release initiated by eNodeB/RN. In case only a subset of per cause measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value. The number of measurements is equal to the number of causes plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form UECNTX.RelReq.*Cause* where *Cause* identifies the release cause.
- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switching.
- h) EPS
- i) By differentiate the causes, this measurement is used to count 'The number of abnormal RRC connection release related to load', which can be used for LBO target calculation..

4.1.5.2 Successful UE CONTEXT Release

- a) This measurement provides the number of successful UE Context Release.
- b) CC.
- c) Sending of UE CONTEXT RELEASE COMPLETE from eNB/RN to MME/DeNB
- d) A single integer value.
- e) UEContext.RelSuccNbr.
- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switching.
- h) EPS
- i) This measurement can be used to count 'the total number of RRC connection release', which can be used for LBO target calculation.

4.1.6 Inactivity timer

4.1.6.1 Number of successful RRC connection setups in relation to the time between successful RRC connection setup and last RRC connection release

- a) This measurement provides the histogram as function of the number of successful RRC Connection setups and the time between the successful RRC Connection setup attempt and last RRC Connection release for the UE with the same S-TMSI and long inactivity timer configured.
It is not counted to the histogram in case last RRC Connection release of the UE with the same S-TMSI is caused by call drops or handover.
- b) CC.
- c) On receipt by the eNodeB of an RRCConnectionSetupComplete message from the UE. Each RRCConnectionSetupComplete message received is added to the relevant measurement per time bin for the time between the successful RRC connection setup and last RRC Connection release for the UE with the same S-TMSI.
- d) Each measurement is an integer value.
- e) The measurement name has the form *RRCCConn.Setup.TimeBin* where *TimeBin* identifies the given bin from the histogram
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switching.
- h) EPS

4.2 E-RAB related measurements

4.2.0 General

In case of carrier aggregation, for the measurements defined in this subclause, the E-RABs are only measured on the PCell.

4.2.1 E-RAB setup

4.2.1.1 Number of initial E-RABs attempted to setup

- a) This measurement provides the number of initial E-RABs attempted to setup. The measurement is split into subcounters per E-RAB QoS level (QCI).
- b) CC
- c) On receipt by the eNodeB/RN of an INITIAL CONTEXT SETUP REQUEST message, each requested E-RAB in the message is added to the relevant measurement per QCI, the possible QCIs are included in TS 36.413 [9]. The sum of all supported per QCI measurements shall equal the total number of E-RABs attempted to setup. In case only a subset of per QCI measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value. The number of measurements is equal to the number of QCIs plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form *ERAB.EstabInitAttNbr.QCI* where *QCI* identifies the E-RAB level quality of service class.
- f) EUTranCellFDD
EUTranCellTDD

- g) Valid for packet switched traffic
- h) EPS
- i) One usage of this measurement is to support the coverage ratio (CR) calculation for EE coverage area determination in [21].

4.2.1.2 Number of initial E-RABs successfully established

- a) This measurement provides the number of initial E-RABs successfully established. The measurement is split into subcounters per E-RAB QoS level (QCI).
- b) CC
- c) On transmission by the eNodeB/RN of an INITIAL CONTEXT SETUP RESPONSE message, each E-RAB successfully established is added to the relevant measurement per QCI, the possible QCIs are included in TS 36.413 [9]. The sum of all supported per QCI measurements shall equal the total number of E-RABs successfully setup. In case only a subset of per QCI measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value. The number of measurements is equal to the number of QCIs plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form ERAB.EstabInitSuccNbr.*QCI* where *QCI* identifies the E-RAB level quality of service class.
- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.2.1.3 Number of initial E-RABs failed to setup

- a) This measurement provides the number of initial E-RABs failed to setup. The measurement is split into subcounters per failure cause.
- b) CC
- c) On transmission by the eNodeB/RN of an INITIAL CONTEXT SETUP RESPONSE, or INITIAL CONTEXT SETUP FAILURE message, each E-RAB failed to establish is added to the relevant measurement per cause, the possible causes are included in TS 36.413 [9]. The sum of all supported per cause measurements shall equal the total number of E-RABs failed to setup. In case only a subset of per cause measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value. The number of measurements is equal to the number of causes plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form ERAB.EstabInitFailNbr.*Cause* where *Cause* identifies the cause resulting in the initial E-RAB setup failure.
- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switched traffic
- h) EPS
- i) One usage of this measurement is to support the coverage ratio (CR) calculation for EE coverage area determination in [21].

4.2.1.4 Number of additional E-RABs attempted to setup

- a) This measurement provides the number of additional E-RABs attempted to setup. The measurement is split into subcounters per E-RAB QoS level (QCI).
- b) CC.
- c) On receipt by the eNodeB/RN of an E-RAB SETUP REQUEST message, each requested E-RAB in the message is added to the relevant measurement per QCI, the possible QCIs are included in TS 36.413 [9]. The sum of all supported per QCI measurements shall equal the total number of additional E-RABs attempted to setup. In case only a subset of per QCI measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value. The number of measurements is equal to the number of QCIs plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form ERAB.EstabAddAttNbr.*QCI* where *QCI* identifies the E-RAB level quality of service class.
- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switched traffic.
- h) EPS.
- i) This measurement is to support the Accessibility KPI 'E-RAB Accessibility' defined in [13]. Another usage of this measurement is to support the coverage ratio (CR) calculation for EE coverage area determination in [21].

4.2.1.5 Number of additional E-RABs successfully established

- a) This measurement provides the number of additional E-RABs successfully established. The measurement is split into subcounters per E-RAB QoS level (QCI).
- b) CC
- c) On transmission by the eNodeB/RN of an E-RAB SETUP RESPONSE message, each E-RAB successfully established is added to the relevant measurement per QCI, the possible QCIs are included in TS 36.413 [9]. The sum of all supported per QCI measurements shall equal the total number of additional E-RABs successfully setup. In case only a subset of per QCI measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value. The number of measurements is equal to the number of QCIs plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form ERAB.EstabAddSuccNbr.*QCI* where *QCI* identifies the E-RAB level quality of service class.
- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switched traffic
- h) EPS
- i) This measurement is to support the Accessibility KPI 'E-RAB Accessibility' defined [13].

4.2.1.6 Number of additional E-RABs failed to setup

- a) This measurement provides the number of additional E-RABs failed to setup. The measurement is split into subcounters per failure cause.
- b) CC.
- c) On transmission by the eNodeB/RN of an E-RAB SETUP RESPONSE message, each E-RAB failed to establish is added to the relevant measurement per cause, the possible causes are included in TS 36.413 [9]. The sum of all

supported per cause measurements shall equal the total number of additional E-RABs failed to setup. In case only a subset of per cause measurements is supported, a sum subcounter will be provided first.

- d) Each measurement is an integer value. The number of measurements is equal to the number of causes plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form ERAB.EstabAddFailNbr.*Cause* where *Cause* identifies the cause resulting in the additional E-RAB setup failure.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic.
- h) EPS.
- i) One usage of this measurement is to support the coverage ratio (CR) calculation for EE coverage area determination in [21].

4.2.1.7 Mean E-RAB Setup time

- a) This measurement provides the mean time per QCI it takes to establish an E-RAB.
- b) DER (n=1)
- c) This measurement is obtained by accumulating the time intervals for every successfully established E-RAB between the receipt of an E-RAB SETUP REQUEST or INITIAL CONTEXT SETUP REQUEST message and the transmission of the corresponding E-RAB SETUP RESPONSE or INITIAL CONTEXT SETUP RESPONSE message by the eNodeB over the granularity period. The end value of this time will then be divided by the number of successfully established E-RABs in the granularity period to give the arithmetic mean. The accumulator shall be reinitialised at the beginning of each granularity period. The measurement is split into subcounters per QCI, and the possible QCIs are included in TS 36.413 [9].
- d) Each measurement is an integer value (in milliseconds).
- e) The measurement name has the form ERAB.EstabTimeMean.*QCI* where *QCI* identifies the E-RAB level quality of service class.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switching.
- h) EPS

4.2.1.8 Maximum E-RAB Setup time

- a) This measurement provides the maximum time per QCI it takes to establish an E-RAB.
- b) GAUGE
- c) This measurement is obtained by monitoring the time intervals for every successfully established E-RAB between the receipt of an E-RAB SETUP REQUEST or INITIAL CONTEXT SETUP REQUEST message and the transmission of the corresponding E-RAB SETUP RESPONSE or INITIAL CONTEXT SETUP RESPONSE message by the eNodeB over the granularity period. The high tide mark of this time will be stored in a gauge, the gauge shall be reinitialised at the beginning of each granularity period.. The measurement is split into subcounters per QCI, and the possible QCIs are included in TS 36.413 [9].
- d) Each measurement is an integer value (in milliseconds).
- e) The measurement name has the form ERAB.EstabTimeMax.*QCI* where *QCI* identifies the E-RAB level quality of service class.
- f) EUTranCellFDD
EUTranCellTDD

- g) Valid for packet switching.
- h) EPS

4.2.1.9 Number of E-RABs attempted to establish for incoming HOs

- a) This measurement provides the number of E-RABs attempted to establish for incoming HOs. The measurement is split into subcounters per E-RAB QoS level (QCI).
- b) CC
- c) On receipt by the eNB of a X2AP HANDOVER REQUEST or S1AP HANDOVER REQUEST message; or on transmission by the eNB of the *RRConnectionReconfiguration* message to the UE triggering the intra-eNB handover (see TS 36.331 [8]), all E-RABs of this UE (but not only the E-RABs in the message) are counted for this measurement to the target E-UTRAN cell. Each E-RAB attempted to establish is added to the relevant measurement per QCI, the possible QCIs are included in TS 36.413 [9]. The sum of all supported per QCI measurements shall equal the total number of E-RABs attempted to setup. In case only a subset of per QCI measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value. The number of measurements is equal to the number of QCIs plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form ERAB.EstabIncHoAttNbr.*QCI* where *QCI* identifies the E-RAB level quality of service class.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.2.1.10 Number of E-RABs successfully established for incoming HOs

- a) This measurement provides the number of E-RABs successfully established for incoming HOs. The measurement is split into subcounters per E-RAB QoS level (QCI).
- b) CC
- c) On transmission by the eNB of a X2AP HANDOVER REQUEST ACKNOWLEDGE or S1AP HANDOVER REQUEST ACKNOWLEDGE message, or on transmission by the eNB of the *RRConnectionReconfiguration* message to the UE triggering the intra-eNB handover (see TS 36.331 [8]) after the E-RABs in this message are successfully established in the target E-UTRAN cell. Each E-RAB successfully established is added to the relevant measurement per QCI, the possible QCIs are included in TS 36.413 [9]. The sum of all supported per QCI measurements shall equal the total number of E-RABs successfully setup. In case only a subset of per QCI measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value. The number of measurements is equal to the number of QCIs plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form ERAB.EstabIncHoSuccNbr.*QCI* where *QCI* identifies the E-RAB level quality of service class.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.2.2 E-RAB release

4.2.2.1 Number of E-RABs requested to release initiated by eNodeB/RN per QCI

- a) This measurement provides the number of E-RABs requested to release initiated by eNodeB/RN. The measurement is split into subcounters per E-RAB QoS level (QCI).
- b) CC
- c) On transmission by the eNodeB/RN of an E-RAB RELEASE INDICATION, or an UE CONTEXT RELEASE REQUEST, or a RESET message to MME or DeNB(in case of RN), each corresponding E-RAB requested to release is added to the relevant measurement per QCI, the possible QCIs are included in TS 36.413 [9]. The sum of all supported per QCI measurements shall equal the total number of E-RABs requested to release initiated by eNodeB/RN. In case only a subset of per QCI measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value. The number of measurements is equal to the number of QCIs plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form ERAB.RelEnbNbr.*QCI* where *QCI* identifies the E-RAB level quality of service class.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.2.2.2 Number of E-RABs requested to release initiated by eNodeB/RN per cause

- a) This measurement provides the number of E-RABs requested to release initiated by eNodeB/RN. The measurement is split into subcounters per cause.
- b) CC
- c) On transmission by the eNodeB/RN of an E-RAB RELEASE INDICATION, or an UE CONTEXT RELEASE REQUEST, or a RESET message to MME or DeNB(in case of RN), each corresponding E-RAB requested to release is added to the relevant measurement per cause. Possible causes are included in TS 36.413 [9].
- d) Each measurement is an integer value. The number of measurements is equal to the number of supported causes.
- e) The measurement names have the form ERAB.RelEnbNbr.*cause* where *cause* identifies the reason for the E-RABs release request initiated by eNodeB/RN.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.2.2.3 Number of E-RABs attempted to release

- a) This measurement provides the number of E-RABs attempted to release. The measurement is split into subcounters per E-RAB QoS level (QCI).
- b) CC
- c) On receipt by the eNodeB/RN of an E-RAB RELEASE COMMAND or UE CONTEXT RELEASE COMMAND or RESET message from MME/DeNB; or receipt by the eNodeB/RN of an UE CONTEXT RELEASE message from another eNodeB/DeNB or transmission by the eNodeB/RN of an E-RAB Release Indication or RESET message to MME/DeNB; or on receipt by the eNB/RN of a PATH SWITCH REQUEST ACKNOWLEDGE or PATH SWITCH REQUEST FAILED message by which some or all E-RABs in the

corresponding PATH SWITCH REQUEST need to be released; or on receipt by the eNB/RN of a *RRCConnectionReconfigurationComplete* message from the UE, indicating a successful intra-eNB/RN handover (see TS 36.331 [8]), i.e., the E-RABs in the corresponding *RRCConnectionReconfiguration* message can be released by the source EUTran cell. Each corresponding E-RAB to release is added to the relevant measurement per QCI, the possible QCIs are included in TS 36.413 [9]., the same E-RAB shall not be counted repeatedly but only one in case it appears more than one time in the same or different messages triggering this measurement. The sum of all supported per QCI measurements shall equal the total number of E-RABs attempted to release. In case only a subset of per QCI measurements is supported, a sum subcounter will be provided first.

- d) Each measurement is an integer value. The number of measurements is equal to the number of QCIs plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form ERAB.RelAttNbr.*QCI* where *QCI* identifies the E-RAB level quality of service class.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS
- i) One usage of this measurement is to support the coverage ratio (CR) calculation for EE coverage area determination in [21].

4.2.2.4 Number of E-RAB successfully released

- a) This measurement provides the number of E-RABs successfully released. The measurement is split into subcounters per E-RAB QoS level (QCI).
- b) CC
- c) On transmission by the eNodeB/RN of an E-RAB RELEASE RESPONSE or UE CONTEXT RELEASE COMPLETE, or E-RAB Release Indication or a RESET ACKNOWLEDGE to MME/DeNB; or E-RAB is released successfully by the eNB/RN after receiving PATH SWITCH REQUEST ACKNOWLEDGE or PATH SWITCH REQUEST FAILED message by which some or all E-RABs in the corresponding PATH SWITCH REQUEST are to be released; or the E-RAB is released successfully at the source EUTran cell by the eNB/RN after receiving *RRCConnectionReconfigurationComplete* message from the UE, indicating a successful intra-eNB/RN handover (see TS 36.331 [8]); or the E-RAB released successfully by source eNB/RN after receiving UE CONTEXT RELEASE from another eNB/DeNB; or on receipt by the eNB/RN of a RESET ACKNOWLEDGE message from MME/DeNB. Each corresponding E-RAB successfully released is added to the relevant measurement per QCI, the possible QCIs are included in TS 36.413 [9], the same E-RAB shall not be counted repeatedly but only one in case it appears more than one time in the same or different messages triggering this measurement. The sum of all supported per QCI measurements shall equal the total number of E-RABs fully released. In case only a subset of per QCI measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value. The number of measurements is equal to the number of QCIs plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form ERAB.RelSuccNbr.*QCI* where *QCI* identifies the E-RAB level quality of service class.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.2.2.5 Number of E-RAB failed to release

- a) This measurement provides the number of E-RAB failed to release. The measurement is split into subcounters per failure cause.
- b) CC
- c) On transmission by the eNodeB/RN of an E-RAB RELEASE RESPONSE message, each E-RAB failed to release is added to the relevant measurement per cause, the possible causes are included in TS 36.413 [9]. The sum of all supported per cause measurements shall equal the total number of E-RABs failed to release. In case only a subset of per cause measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value. The number of measurements is equal to the number of causes plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form ERAB.RelFailNbr.*Cause* where *Cause* identifies the cause resulting in the E-RAB release failure.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS
- i) One usage of this measurement is to support the coverage ratio (CR) calculation for EE coverage area determination in [21].

4.2.2.6 Number of released active E-RABs

- a) This measurement provides the number of released E-RABs that were active at the time of release. E-RABs with bursty flow are seen as being active when there is user data in the queue in any of the directions. E-RABs with continuous flow are always seen as active E-RABs in the context of this measurement. The measurement is split into subcounters per E-RAB QoS level (QCI).
- b) CC
- c) On transmission by the eNodeB/RN of an E-RAB RELEASE INDICATION message; or on transmission by the eNB/RN of an E-RAB RELEASE RESPONSE message for the E-RAB release initiated by the MME/DeNB with the exception of corresponding E-RAB RELEASE COMMAND message with 'Cause' equal to 'Normal Release' or on transmission by the eNodeB/RN of UE CONTEXT RELEASE COMPLETE for the UE context release initiated by the eNB/RN with the exception of the corresponding UE CONTEXT RELEASE REQUEST message with cause 'User inactivity', 'CSG Subscription Expiry', or any 'cause' indicating a successful CS fallback (e.g., cause 'CS Fallback triggered', 'UE Not Available for PS Service', or 'Redirection towards 1xRTT') or a successful mobility activity (e.g., cause 'Inter-RAT Redirection'); or on transmission by the eNodeB/RN of UE CONTEXT RELEASE COMPLETE message for the UE context release initiated by the MME/DeNB with the exception of the corresponding UE CONTEXT RELEASE COMMAND message with "Cause" equal to 'Normal Release' , 'detach', 'Handover Cancelled' or any 'cause' indicating a successful CS fallback (e.g., cause 'Redirection towards 1xRTT') or a successful mobility activity (e.g., cause 'Successful Handover', 'Inter-RAT Redirection' or 'S1 Intra system Handover triggered') or on receipt by the eNB of a PATH SWITCH REQUEST ACKNOWLEDGE or PATH SWITCH REQUEST FAILED message by which some or all E-RABs in the corresponding PATH SWITCH REQUEST need to be released , or on transmission of a RESET ACKNOWLEDGE message to MME/DeNB; or on receipt of a RESET ACKNOWLEDGE message from MME/DeNB, if any of the UL or DL are considered active according to the definition used for "Number of active UEs" in TS 36.314.
E-RABs with bursty flow are considered active when there is still data in the DL or UL buffer. E-RABs with continuous flow are always seen as active E-RABs in the context of this measurement. Each corresponding E-RAB to release is added to the relevant measurement per QCI.

The possible QCIs are described in TS 36.413 [9]. The sum of all supported per QCI measurements shall equal the total number of E-RABs attempted to release when the E-RAB is active according to the definition of bursty flow/continuous flow. In case only a subset of per QCI measurements is supported, a sum subcounter will be provided first.

How to define for a particular QCI if the E-RAB is of type bursty flow or continuous flow is outside the scope of this document.

- d) Each measurement is an integer value. The number of measurements is equal to the number of QCIs plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form ERAB.RelActNbr.*QCI*
where *QCI* identifies the E-RAB level quality of service class.
- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switched traffic
- h) EPS
- i) This measurement is to support the Retainability KPI 'E-RAB Retainability' defined in [13]

4.2.3 E-RAB modification

4.2.3.1 Number of E-RABs attempted to modify the QoS parameter

- a) This measurement provides the number of E-RABs attempted to modify the QoS parameter. The measurement is split into subcounters per E-RAB QoS level (QCI).
- b) CC
- c) On receipt by the eNodeB/RN of an E-RAB MODIFY REQUEST message, each E-RAB attempted to modify the QoS parameter is added to the relevant measurement per QCI, the possible QCIs are included in TS 36.413 [9]. The sum of all supported per QCI measurements shall equal the total number of E-RABs attempted to modify the QoS parameter. In case only a subset of per QCI measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value. The number of measurements is equal to the number of QCIs plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form ERAB.ModQoSAttNbr.*QCI*
where *QCI* identifies the target E-RAB level quality of service class.
- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.2.3.2 Number of E-RABs successfully modified the QoS parameter

- a) This measurement provides the number of E-RABs successfully modified the QoS parameter. The measurement is split into subcounters per E-RAB QoS level (QCI).
- b) CC
- c) On transmission by the eNodeB/RN of an E-RAB MODIFY RESPONSE message, each E-RAB successfully modified the QoS parameter is added to the relevant measurement per QCI, the possible QCIs are included in TS 36.413 [9]. The sum of all supported per QCI measurements shall equal the total number of E-RABs successfully modified the QoS parameter. In case only a subset of per QCI measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value. The number of measurements is equal to the number of QCIs plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form ERAB.ModQoS SuccNbr.*QCI*
where *QCI* identifies the target E-RAB level quality of service class.

- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.2.3.3 Number of E-RABs failed to modify the QoS parameter

- a) This measurement provides the number of E-RABs failed to be modified the QoS parameter. The measurement is split into subcounters per failure cause.
- b) CC
- c) On transmission by the eNodeB/RN of an E-RAB MODIFY RESPONSE message, each E-RAB failed to modify the QoS parameter is added to the relevant measurement per cause, the possible causes are included in TS 36.413 [9]. The sum of all supported per cause measurements shall equal the total number of E-RABs failed to modify the QoS parameter. In case only a subset of per cause measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value. The number of measurements is equal to the number of causes plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form ERAB.ModQoSFailNbr.*Cause* where *Cause* identifies the cause resulting in the E-RAB Modify failure.
- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.2.4 E-RAB activity

4.2.4.1 In-session activity time for UE

- a) This measurement provides the aggregated active session time for UEs in a cell.
- b) CC
- c) Number of session seconds aggregated for UEs in a cell.
For E-RABs with bursty flow, a UE is said to be 'in session' if any E-RAB data on a Data Radio Bearer (UL or DL) has been transferred during the last 100 ms.
For E-RABs with continuous flow, the E-RAB (and the UE) is always seen as being 'in session' in the context of this measurement, and the session time is increased from the first data transmission on the E-RAB until 100 ms after the last data transmission on the E-RAB.
- d) Each measurement is an integer value.
- e) ERAB.SessionTimeUE
- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switched traffic
- h) EPS
- i) This measurement is to support the Retainability KPI 'E-RAB Retainability' defined in [13].

4.2.4.2 In-session activity time for E-RABs

- a) This measurement provides the aggregated active session time for E-RABs in a cell. The measurement is split into subcounters per E-RAB QoS level (QCI).
- b) CC
- c) Number of 'in session' seconds aggregated for E-RABs with a certain QCI, where 'in session' has the following definitions:

- E-RABs with bursty flow is said to be 'in session' for a UE if any E-RAB data on any Data Radio Bearer (UL or DL) has been transferred during the last 100 ms for that QCI

- E-RABs with continuous flow are always seen as being 'in session' in the context of this measurement, and the session time is increased from the first data transmission on the E-RAB until 100 ms after the last data transmission on the E-RAB.

The possible QCIs are described in TS 36.413 [9]. The sum of all supported per QCI measurements shall equal the total session seconds. In case only a subset of per QCI measurements is supported, a sum subcounter will be provided first.

How to decide for a particular QCI if the E-RAB is of type continuous flow is outside the scope of this document.

- d) Each measurement is an integer value. The number of measurements is equal to the number of QCIs plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form *ERAB.SessionTimeQCI.QCI* where *QCI* identifies the E-RAB level quality of service class.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS
- i) This measurement is to support the Retainability KPI 'E-RAB Retainability' defined in [13].

4.2.5 E-RAB number

4.2.5.1 Average Number of simultaneous E-RABs.

- a) This measurement provides the average number of simultaneous E-RABs. The measurement is split into subcounters per E-RAB QoS level (QCI).
- b) SI.
- c) This measurement is obtained by sampling at a pre-defined interval, the number of simultaneous E-RABs and then taking the arithmetic mean. The measurement is split into subcounters per QCI, and the possible QCIs are included in TS 36.413 [9]. In case only a subset of per QCI measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value. The number of measurements is equal to the number of QCIs plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form *ERAB.UsageNbrMean.QCI* where *QCI* identifies the E-RAB level quality of service class.
- f) EUTranCellFDD
EUTranCellTDD

- g) Valid for packet switching.
- h) EPS

4.2.5.2 Maximum Number of simultaneous E-RABs.

- a) This measurement provides the maximum number of simultaneous E-RABs. The measurement is split into subcounters per E-RAB QoS level (QCI).
- b) SI.
- c) This measurement is obtained by sampling at a pre-defined interval, the number of simultaneous E-RABs and then taking the maximum. The measurement is split into subcounters per QCI, and the possible QCIs are included in TS 36.413 [9]. In case only a subset of per QCI measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value. The number of measurements is equal to the number of QCIs plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form *ERAB.UsageNbrMax.QCI* where *QCI* identifies the E-RAB level quality of service class.
- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switching.
- h) EPS

4.3 Handover related measurements

4.3.1 Intra-RAT Handovers

4.3.1.1 Intra-eNB/RN Handover related measurements

4.3.1.1.1 Attempted outgoing intra-eNB/RN handovers per handover cause

- a) This measurement provides the number of attempted outgoing intra-eNB/RN handovers per handover cause.
- b) CC.
- c) Transmission of the *RRCConnectionReconfiguration* message by the eNB/RN to the UE triggering the intra-eNB/RN handover (see TS 36.331 [8]). Each *RRCConnectionReconfiguration* message transmitted is added to the relevant per handover cause measurement, the possible causes are included in TS 36.413 [9]. The sum of all supported per cause measurements shall equal the total number of outgoing intra-eNB/RN handover events. In case only a subset of per cause measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value. The number of measurements is equal to the number of causes supported plus a possible sum value identified by the *.sum* suffix.
- e) *HO.IntraEnbOutAtt.Cause*
where *Cause* identifies the cause for handover.
- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.3.1.1.2 Successful outgoing intra-eNB/RN handovers per handover cause

- a) This measurement provides the number of successful outgoing intra-eNB/RN handovers per handover cause.
- b) CC.
- c) Receipt of a RRC message *RRCConnectionReconfigurationComplete* sent from the UE to the target (=source) eNB/RN, indicating a successful outgoing intra-eNB/RN handover (see TS 36.331 [8]). Each *RRCConnectionReconfigurationComplete* message transmitted is added to the relevant per handover cause measurement, the possible causes are included in TS 36.413 [9].
The sum of all supported per cause measurements shall equal the total number of outgoing intra-eNB/RN handover events. In case only a subset of per cause measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value. The number of measurements is equal to the number of causes supported plus a possible sum value identified by the .sum suffix
- e) HO.IntraEnbOutSucc.Cause
where *Cause* identifies the cause for handover.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.3.1.1.3 Attempted outgoing intra-DeNB handover preparations from DeNB cell to RN per handover cause

- a) This measurement provides the number of attempted outgoing intra-DeNB handover preparations from DeNB cell to RN per handover cause; this measurement is only applicable to DeNB.
- b) CC.
- c) Transmission of the X2AP message HANOVER REQUEST from the DeNB to RN (see TS 36.423[10]), indicating the attempt of an outgoing intra-DeNB handover preparation from DeNB cell to RN, the forwarded X2AP message HANOVER REQUEST for the handover from another RN, eNB or DeNB to the RN is exclusive, the measurement is only incremented by one for one handover in case the X2AP message HANOVER REQUEST are sent to multiple RNs. Each attempted outgoing intra-DeNB handover preparation from DeNB cell to RN is added to the relevant per handover cause measurement, the possible causes are included in TS 36.413 [9]. The sum of all supported per cause measurements shall equal the total number of attempted outgoing intra-DeNB handover preparations from DeNB cell to RN. In case only a subset of per cause measurements is supported, a sum subcounter will be provided first.
- d) A single integer value.
- e) HO.IntraDenbOutPrepToRnAtt.Cause
where *Cause* identifies the cause for handover
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.3.1.1.4 Attempted outgoing intra-DeNB handover executions from DeNB cell to RN per handover cause

- a) This measurement provides the number of attempted outgoing intra-eNB handovers from DeNB cell to RN per handover cause; this measurement is only applicable to DeNB.
- b) CC.

- c) Transmission of the *RRC ConnectionReconfiguration* message to UE triggering the handover from the DeNB to the RN, indicating the attempt of an outgoing intra-eNB handover from DeNB cell to RN (see TS 36.331 [8]). Each *RRCConnectionReconfiguration* message transmitted is added to the relevant per handover cause measurement, the possible causes are included in TS 36.413 [9]. The sum of all supported per cause measurements shall equal the total number of attempted outgoing intra-eNB handovers from DeNB cell to RN. In case only a subset of per cause measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value. The number of measurements is equal to the number of causes supported plus a possible sum value identified by the .sum suffix.
- e) *HO.IntraDenbOutToRnAtt.Cause*
where *Cause* identifies the cause for handover
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.3.1.1.5 Successful outgoing intra-DeNB handover executions from DeNB cell to RN per handover cause

- a) This measurement provides the number of successful outgoing intra-DeNB handovers from DeNB cell to RN per handover cause; this measurement is only applicable to DeNB.
- b) CC.
- c) Receipt by the source DeNB of X2AP message UE CONTEXT RELEASE from the RN following a successful handover (see TS 36.423[10]), the forwarded X2AP message UE CONTEXT RELEASE for the handover from another RN, eNB or DeNB to the RN is exclusive. Each outgoing intra-DeNB handover from DeNB cell to RN is added to the relevant per handover cause measurement, the possible causes are included in TS 36.413 [9]. The sum of all supported per cause measurements shall equal the total number of successful outgoing intra-eNB handovers from DeNB cell to RN. In case only a subset of per cause measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value. The number of measurements is equal to the number of causes supported plus a possible sum value identified by the .sum suffix.
- e) *HO.IntraDenbOutToRnSucc.Cause*
where *Cause* identifies the cause for handover.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.3.1.2 Inter-eNB Handover related measurements

4.3.1.2.1 Attempted outgoing inter-eNB handover preparations

- a) This measurement provides the number of attempted outgoing inter-eNB handover preparations, the forwarded handovers for RN in DeNB are exclusive.
- b) CC.
- c) Transmission of the X2AP message HANDOVER REQUEST from the source eNB to the target eNB (see TS 36.423[10]), indicating the attempt of an outgoing inter-eNB handover preparation or on transmission of S1AP message HANDOVER REQUIRED to the MME (see TS 36.413 [9]), the forwarded X2AP message HANDOVER REQUEST and S1AP message HANDOVER REQUIRED for RN in DeNB are exclusive.
- d) A single integer value.

- e) HO.InterEnbOutPrepAtt
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.3.1.2.2 Attempted outgoing inter-eNB handover executions per handover cause

- a) This measurement provides the number of attempted outgoing inter-eNB handovers per handover cause.
- b) CC.
- c) Transmission of the *RRC ConnectionReconfiguration* message to UE triggering the handover from the source eNB to the target eNB, indicating the attempt of an outgoing inter-eNB handover (see TS 36.331 [8]).
The sum of all supported per cause measurements shall equal the total number of outgoing inter-eNB handover event. Each *RRC ConnectionReconfiguration* message transmitted is added to the relevant per handover cause measurement, the possible causes are included in TS 36.413 [9]. In case only a subset of per cause measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value. The number of measurements is equal to the number of causes supported plus a possible sum value identified by the .sum suffix.
- e) HO.InterEnbOutAtt.*Cause*
where *Cause* identifies the cause for handover
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.3.1.2.3 Successful outgoing inter-eNB handover executions per handover cause

- a) This measurement provides the number of successful outgoing inter-eNB handovers per handover cause, the forwarded handovers for RN in DeNB are exclusive.
- b) CC.
- c) Receipt at the source eNB of UE CONTEXT RELEASE [10] over the X2 from the target eNB following a successful handover, or if handover is performed via S1, receipt of UE CONTEXT RELEASE COMMAND [9] at the source eNB following a successful handover, the forwarded X2AP UE CONTEXT RELEASE message and S1AP UE CONTEXT RELEASE COMMAND message for RN in DeNB are exclusive. Each X2AP UE CONTEXT RELEASE message or S1AP UE CONTEXT RELEASE COMMAND message received and counted is added to the relevant per handover cause measurement, the possible causes are included in TS 36.413 [9].
The sum of all supported per cause measurements shall equal the total number of outgoing inter-eNB handover events. In case only a subset of per cause measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value. The number of measurements is equal to the number of causes supported plus a possible sum value identified by the .sum suffix.
- e) HO.InterEnbOutSucc.*Cause*
where *Cause* identifies the cause for handover.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.3.1.3 Handover measurements on neighbour cell basis

4.3.1.3.1 Attempted outgoing handovers per handover cause

- a) This measurement provides the number of attempted outgoing handovers per handover cause and LTE target cell specific.
- b) CC.
- c) Transmission of the *RRCConnection reconfiguration* message to UE triggering the intra-RAT handover (see TS 36.331 [8]). Each *RRCConnectionReconfiguration* message transmitted is added to the relevant per handover cause measurement, the possible causes are included in TS 36.413 [9]. In case of CA, this attempted handover is only added to the neighbour cell relation from the source EUTRAN cell, through which the *RRCConnectionReconfiguration* message is sent to the UE, to the target EUTRAN cell appointed in the 'MobilityControlInfo' IE of the *RRCConnectionReconfiguration message*.
The sum of all supported per cause measurements shall equal the total number of outgoing handover events. In case only a subset of per cause measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value. The number of measurements is equal to the number of causes supported plus a possible sum value identified by the .sum suffix.
- e) HO.OutAttTarget.Cause
where *Cause* identifies the cause for handover
- f) EUTranRelation
- g) Valid for packet switched traffic
- h) EPS

4.3.1.3.2 Successful outgoing handovers per handover cause

- a) This measurement provides the number of successful outgoing handovers per handover cause and LTE target cell specific.
- b) CC.
- c) Receipt of a RRC message *RRCConnectionReconfigurationComplete* sent from the UE to the target (=source) eNB, indicating a successful outgoing intra-eNB handover (see TS 36.331 [8]), or receipt at the source eNB of UE CONTEXT RELEASE [10] over the X2 from the target eNB following a successful inter-eNB handover, or if handover is performed via S1, receipt of UE CONTEXT RELEASE COMMAND[9] at the source eNB following a successful inter-eNB handover. Each *RRCConnectionReconfigurationComplete*, X2AP UE CONTEXT RELEASE message or S1AP UE CONTEXT RELEASE COMMAND message received is added to the relevant per handover cause measurement, the possible causes are included in TS 36.413 [9]. In case of CA, this successful handover is only added to same the neighbour cell relation that the corresponding attempted handover is counted at (i.e., the same neighbour cell relation that the measurement defined in subclause 4.3.1.3.1 is counted at). The sum of all supported per cause measurements shall equal the total number of outgoing intra-RAT handover events. In case only a subset of per cause measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value. The number of measurements is equal to the number of causes supported plus a possible sum value identified by the .sum suffix.
- e) HO.OutSuccTarget.Cause
where *Cause* identifies the cause for handover.
- f) EUTranRelation
- g) Valid for packet switched traffic
- h) EPS

4.3.1.3.3 Number of handover failures related with MRO

- a) This measurement provides the number of outgoing handover related events that fail related with MRO. Handover related events include normal successful handovers and all failure events by which a UE in RRC connected state changes its serving cell without following a normal handover. Different MRO failure cases are found in [12]. The measurement includes separate counters for the number of handover failures classified as 'too early', 'too late' and 'to wrong cell'. The measurement for the too late handover is split to subcounters indicating the threshold of the serving cell itself was not crossed and the threshold of the neighbour cell was not crossed in UE measurements before handover in case the handover is triggered by more than one threshold of the measurement report triggering events, the subcounters are only needed if more than one threshold of the measurement report triggering events is used and using single or multiple thresholds is vendor specific.
- b) CC
- c) The measurements of too early handovers, too late handovers and to wrong cell handovers are obtained respectively by accumulating the number of failure events related to handover which are identified by the eNB according to the definitions in TS 36.300 [12].

Besides being added to the measurement of total too late handovers, each too late handover (identified by the eNB according to the definitions in TS 36.300 [12]) is also added to the relevant subcounter indicating the threshold of the serving cell itself configured in the measurement report triggering events (see 36.331 [18]) was not crossed or the threshold of the neighbour cell configured in the measurement report triggering events was not crossed if more than one threshold triggering a measurement report is configured to the UEs for the involved neighbour relation and the following UE measurement results are available for both cells involved in the too late handover

- rsrpResult of 'measResultLastServCell' and
- rsrpResult of the subject neighbour cell in 'measResultNeighCells'

in

a) the 'RLF report' IE in the received RRC message 'UEInformationResponse' (see 36.331 [18]), in case both cells involved in the too late handover belong to the same eNB,

or

b) the 'UE RLF Report Container' IE in the received X2 message 'RLF Indication', in case the cells involved in the too late handover belong to different eNBs.

The uncrossed threshold (of the serving itself and the neighbour) is identified by comparing the UE measurement results above with the configured thresholds (adding the corresponding hysteresis, see 36.331 [18]) of the measurement report triggering events,

- if the threshold of the serving cell itself was not crossed, the observed too late handover is then added to the subcounter (HO.OutFail.TooLateOwnNotCrossed) indicating the threshold of the serving cell was not crossed
- if the threshold of the neighbor cell itself was not crossed, the observed too late handover is then added to the subcounter (HO.OutFail.TooLateNeighborNotCrossed) indicating the threshold of the neighbour cell was not crossed
- if the thresholds of both the serving cell itself and the neighbour cell were not crossed, then this too late handover is added to both subcounters (HO.OutFail.TooLateOwnNotCrossed and HO.OutFail.TooLateNeighborNotCrossed) indicating the threshold of serving cell itself was not crossed and the threshold of the neighbour cell was not crossed
- if no threshold was not crossed, then this handover is only added to the measurement of total too late handovers but not to the subcounter indicating the threshold of the serving cell itself was not crossed or the threshold of the neighbour cell was not crossed.

If only one threshold triggering the measurement report is configured to the UEs for the involved neighbour relation or the UE measurements above are not available, the observed too late handover is only added to the measurement of total too late handovers but not to the subcounter indicating the threshold of the serving cell itself was not crossed or the threshold of the neighbour cell was not crossed.

- d) Each measurement is an integer value.
- e) The measurements are named

HO.OutFail.TooEarly

HO.OutFail.TooLate

Which indicates the total number of too late handovers identified by the eNB according to the definitions in TS 36.300 [12].

HO.OutFail.TooLateOwnNotCrossed

Which indicates the number of too late handovers for which the threshold of the serving cell itself was not crossed.

HO.OutFail.TooLateNeighborNotCrossed

Which indicates the number of too late handovers for which the threshold of the neighbor cell was not crossed.

HO.OutFail.ToWrongCell

Which indicates the number of 'handover to wrong cell' cases on the NR (NR A→B in Annex A.13) towards the target cell (see 36.300 [12]). It is up to the eNodeB to decide whether or not the HO parameters of this NR are problematic in the 'handover to wrong cell' case.

HO.OutFail.HwcReestablish

Which indicates the number of 'handover to wrong cell' cases on the NR (NR A→C in Annex A.13) towards the cell with which the UE attempts to re-establish the radio link connection (see 36.300 [12]). It is up to the eNodeB to decide whether or not the HO parameters of this NR are problematic in the 'handover to wrong cell' case.

- f) EUTranRelation
- g) Valid for packet switched traffic
- h) EPS

4.3.1.4 Intra- / Inter-frequency Handover related measurements

4.3.1.4.1 Attempted outgoing intra-frequency handovers

- a) This measurement provides the number of attempted outgoing intra-frequency handovers.
- b) CC.
- c) Transmission of the *RRCConnectionReconfiguration* message by the eNB/RN to UE triggering the handover, indicating the attempt of an outgoing intra-frequency handover (see TS 36.331 [8]).
- d) A single integer value.
- e) HO.IntraFreqOutAtt.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.3.1.4.2 Successful outgoing intra-frequency handovers

- a) This measurement provides the number of successful outgoing intra-frequency handovers.
- b) CC.
- c) Receipt of a RRC message *RRCConnectionReconfigurationComplete* sent from the UE to the target (=source) eNB/RN, indicating a successful outgoing intra-eNB/RN intra-frequency handover (see TS 36.331 [8]), or receipt at the source eNB/RN of UE CONTEXT RELEASE [10] over the X2 from the target eNB or DeNB following a successful inter-eNB intra-frequency handover, or if handover is performed via S1, receipt of UE CONTEXT RELEASE COMMAND[9] at the source eNB following a successful inter-eNB intra-frequency handover.
- d) A single integer value.
- e) HO.IntraFreqOutSucc
- f) EUTranCellFDD
EUTranCellTDD

- g) Valid for packet switched traffic
- h) EPS

4.3.1.4.3 Attempted outgoing inter-frequency handovers – gap-assisted measurement

- a) This measurement provides the number of attempted outgoing inter-frequency handovers, when measurement gaps are used [12].
- b) CC.
- c) Transmission of the *RRCConnectionReconfiguration* message by the eNB/RN to UE triggering the handover, indicating the attempt of an outgoing inter-frequency handover when measurement gaps are used (see TS 36.331 [8]).
- d) A single integer value.
- e) HO.InterFreqMeasGapOutAtt
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.3.1.4.4 Successful outgoing inter-frequency handovers – gap-assisted measurement

- a) This measurement provides the number of successful outgoing inter-frequency handovers, when measurement gaps are used [12].
- b) CC.
- c) Receipt of a RRC message *RRCConnectionReconfigurationComplete* sent from the UE to the target (=source) eNB/RN, indicating a successful outgoing intra-eNB/RN inter-frequency handover when measurement gaps are used (see TS 36.331 [8]), or receipt at the source eNB/RN of UE CONTEXT RELEASE [10] over the X2 from the target eNB or DeNB following a successful inter-frequency handover when measurement gaps are used, or if handover is performed via S1, receipt of UE CONTEXT RELEASE COMMAND[9] at the source eNB following a successful inter-frequency handover when measurement gaps are used.
- d) A single integer value.
- e) HO.InterFreqMeasGapOutSucc
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.3.1.4.5 Attempted outgoing inter-frequency handovers – non gap-assisted measurement

- a) This measurement provides the number of attempted outgoing inter-frequency handovers, when measurement gaps are not used [12].
- b) CC.
- c) Transmission of the *RRCConnectionReconfiguration* message by the eNB/RN to UE triggering the handover, indicating the attempt of an outgoing inter-frequency handover when measurement gaps are not used (see TS 36.331 [8]).
- d) A single integer value.
- e) HO.InterFreqNoMeasGapOutAtt

- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.3.1.4.6 Successful outgoing inter-frequency handovers – non gap-assisted measurement

- a) This measurement provides the number of successful outgoing inter-frequency handovers, when measurement gaps are not used [12].
- b) CC.
- c) Receipt of a RRC message *RRCConnectionReconfigurationComplete* sent from the UE to the target (=source) eNB/RN, indicating a successful outgoing intra-eNB/RN inter-frequency handover when measurement gaps are not used (see TS 36.331 [8]), or receipt at the source eNB/RN of UE CONTEXT RELEASE [10] over the X2 from the target eNB or from DeNB following a successful inter-frequency handover when measurement gaps are not used, or if handover is performed via S1, receipt of UE CONTEXT RELEASE COMMAND[9] at the source eNB following a successful inter-frequency handover when measurement gaps are not used.
- d) A single integer value.
- e) HO.InterFreqNoMeasGapOutSucc
- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.3.1.5 Handover related measurements for DRX / non-DRX

4.3.1.5.1 Attempted outgoing handovers with DRX

- a) This measurement provides the number of attempted outgoing handovers, when DRX is used (for DRX see [12]).
- b) CC.
- c) Transmission of the *RRCConnectionReconfiguration* message to UE triggering the handover, indicating the attempt of an outgoing handover when DRX is used (see TS 36.331 [8]).
- d) A single integer value.
- e) HO.DrxOutAtt
- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.3.1.5.2 Successful outgoing handovers with DRX

- a) This measurement provides the number of successful outgoing handovers, when DRX is used (for DRX see [12]).
- b) CC.
- c) Receipt of a RRC message *RRCConnectionReconfigurationComplete* sent from the UE to the target (=source) eNB, indicating a successful outgoing intra-eNB handover when DRX is used (see TS 36.331 [8]), or receipt at

the source eNB of UE CONTEXT RELEASE [10] over the X2 from the target eNB following a successful handover when DRX is used, or if handover is performed via S1, receipt of UE CONTEXT RELEASE COMMAND[9] at the source eNB following a successful handover when DRX is used.

- d) A single integer value.
- e) HO.DrxOutSucc
- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.3.1.5.3 Attempted outgoing handovers non-DRX

- a) This measurement provides the number of attempted outgoing handovers, when DRX is not used (for DRX see [12]).
- b) CC.
- c) Transmission of the *RRCConnectionReconfiguration* message to UE triggering the handover, indicating the attempt of an outgoing handover when DRX is not used (see TS 36.331 [8]).
- d) A single integer value.
- e) HO.NoDrxOutAtt.
- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.3.1.5.4 Successful outgoing handovers non-DRX

- a) This measurement provides the number of successful outgoing handovers, when DRX is not used (for DRX see [12]).
- b) CC.
- c) Receipt of a RRC message *RRCConnectionReconfigurationComplete* sent from the UE to the target (=source) eNB, indicating a successful outgoing intra-eNB handover when DRX is not used (see TS 36.331 [8]) when DRX is not used, or receipt at the source eNB of UE CONTEXT RELEASE [10] over the X2 from the target eNB following a successful handover when DRX is not used, or if handover is performed via S1, receipt of UE CONTEXT RELEASE COMMAND[9] at the source eNB following a successful handover when DRX is not used.
- d) A single integer value.
- e) HO.NoDrxOutSucc
- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.3.1.6 Handover to cells outside the RN related measurements

4.3.1.6.1 Attempted preparations of outgoing handovers to the cells outside the RN

- a) This measurement provides the number of attempted preparations of outgoing handovers to the cells outside the RN.
- b) CC.
- c) Transmission of the X2AP message HANOVER REQUEST by the RN to the DeNB (see TS 36.423[10]), indicating the attempt of an outgoing handover preparation to the cells outside the RN.
- d) A single integer value.
- e) HO.OutRNOOutPrepAtt
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.3.1.6.2 Attempted executions of outgoing handover to the cells outside the RN per handover cause

- a) This measurement provides the number of attempted executions of outgoing handovers to the cells outside the RN per handover cause.
- b) CC.
- c) Transmission of the *RRC ConnectionReconfiguration* message by the RN to UE triggering the handover from the RN to the cell outside the RN, indicating the attempt of an outgoing handover to the cell outside the RN (see TS 36.331 [8]).
The sum of all supported per cause measurements shall equal the total number of attempted executions of outgoing handovers to the cell outside the RN. Each *RRC ConnectionReconfiguration* message transmitted is added to the relevant per handover cause measurement, the possible causes are included in TS 36.413 [9]. In case only a subset of per cause measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value. The number of measurements is equal to the number of causes supported plus a possible sum value identified by the .sum suffix.
- e) HO.OutRNOOutAtt.*Cause*
where *Cause* identifies the cause for handover
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.3.1.6.3 Successful executions of outgoing handover to the cells outside the RN per handover cause

- a) This measurement provides the number of successful executions of outgoing handovers to the cells outside the RN per handover cause.
- b) CC.
- c) Receipt at the RN of UE CONTEXT RELEASE [10] over the X2 from the DeNB following a successful handover. Each X2AP UE CONTEXT RELEASE message received is added to the relevant per handover cause measurement, the possible causes are included in TS 36.413 [9].
The sum of all supported per cause measurements shall equal the total number of executions of outgoing

handovers to the cells outside the RN. In case only a subset of per cause measurements is supported, a sum subcounter will be provided first.

- d) Each measurement is an integer value. The number of measurements is equal to the number of causes supported plus a possible sum value identified by the .sum suffix.
- e) HO.InterRNOOutSucc.Cause
where *Cause* identifies the cause for handover.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.3.1.7 Handover triggering measurements

4.3.1.7.1 Average quality of the serving cell when HO is triggered

- a) This measurement provides the average quality of the serving cell reported in the UE measurement reports that triggered HO. The average is computed over all measurement reports that triggered HO received during the measurement granularity period. Separate measurement is produced for each measurement quantity {RSRP, RSRQ}.
- b) DER (n=1)
- c) For each UtranRelation, this measurement is obtained by accumulating the value (linear value converted from dbm unit) of the quality of the serving (source) cell (RSRP and RSRQ) in the UE measurement report causing HO on the UtranRelation, and dividing the accumulated value by the number of HO occurrence on the UtranRelation at the end of granularity period, and converting the value back to dbm unit from linear value. Separate measurement is provided for RSRP and for RSRQ.
- d) Each measurement is a single integer value in dBm (RSRP) or dB (RSRQ)
- e) HO.SrcCellQual.RSRP
HO.SrcCellQual.RSRQ
- f) EUTranRelation
- g) Valid for packet switched traffic
- h) EPS

4.3.1.7.2 Average quality of the neighboring cell when HO is triggered

- a) This measurement provides the average quality of the neighbor cell that triggered HO (target HO cell) reported in the UE measurement reports. The average is computed over all measurement reports that triggered HO during the measurement granularity period. Separate measurement is produced for each measurement quantity {RSRP, RSRQ}.
- b) DER (n=1)
- c) For each UtranRelation, this measurement is obtained by accumulating the value (linear value converted from dbm unit) of the quality of neighbor (target) cell (RSRP, RSRQ) in the UE measurement report causing HO to the subject neighbor (target) cell on the UtranRelation, and dividing the accumulated value by the number of HO occurrence on the UtranRelation at the end of granularity period, and converting the value back to dbm unit from linear value. Separate measurement is provided for RSRP and for RSRQ.
- d) Each measurement is a single integer value in dBm (RSRP) or dB (RSRQ)
- e) HO.TrgtCellQual.RSRP
HO.TrgtCellQual.RSRQ

- f) EUTranRelation
- g) Valid for packet switched traffic
- h) EPS

4.3.2 Inter-RAT Handovers

4.3.2.1 Measurements related to inter-RAT Handovers – target cell of 3GPP and non-3GPP network technology

4.3.2.1.1 Attempted outgoing inter-RAT handovers per handover cause

- a) This measurement provides the number of attempted outgoing inter-RAT handovers per cause and target cell specific.
- b) CC.
- c) Transmission of the *MobilityFromEUTRACommand* message or the *HandoverFromEUTRAPreparationRequest* message from the serving eNB/RN to the UE indicating the attempt of an outgoing handover from EUTRAN to UTRAN or to GERAN or to CDMA2000 (see TS 36.331 [8]). Each *MobilityFromEUTRACommand* message or *HandoverFromEUTRAPreparationRequest* message transmitted is added to the relevant per handover cause measurement, the possible causes are included in TS 36.413 [9].
The sum of all supported per cause measurements shall equal the total number of outgoing inter-RAT handover events. In case only a subset of per cause measurements is supported, a sum subcounter will be provided first. All IRAT handovers to the neighbouring cells in non-eUTRAN networks are measured.
- d) Each measurement is an integer value. The number of measurements is equal to the number of causes supported plus a possible sum value identified by the *.sum* suffix.
- e) *HO.IartOutAtt.Cause*
where *Cause* identifies the cause for handover
- f) EUTranCellFDD
EUTranCellTDD
GSMRelation
UTRANRelation
CDMA2000Relation
- g) Valid for packet switched traffic
- h) EPS

4.3.2.1.2 Successful outgoing inter-RAT handovers per handover cause

- a) This measurement provides the number of successful outgoing inter-RAT handovers per cause target cell specific.
- b) CC.
- c) Receipt of a S1AP message UE CONTEXT RELEASE COMMAND sent from the MME/DeNB to the source eNB, indicating a successful IRAT handover (see TS 36.413 [9]). Each UE CONTEXT RELEASE COMMAND message received is added to the relevant per handover cause measurement, the possible causes are included in TS 36.413 [9].
The sum of all supported per cause measurements shall equal the total number of outgoing inter-RAT handover events. In case only a subset of per cause measurements is supported, a sum subcounter will be provided first. All IRAT handovers to the neighbouring cells in non-eUTRAN are measured.
- d) Each measurement is an integer value. The number of measurements is equal to the number of causes supported plus a possible sum value identified by the *.sum* suffix.
- e) *HO.IartOutSucc.Cause*
where *Cause* indicating the cause for handover.

- f) EUTranCellFDD
EUTranCellTDD
GSMRelation
UTRANRelation
CDMA2000Relation
- g) Valid for packet switched traffic
- h) EPS

4.3.2.1.3 Number of outgoing unnecessary handovers related with inter-RAT MRO

- a) This measurement provides the number of outgoing unnecessary handovers to another RAT from E-UTRAN related with inter-RAT MRO.
- b) CC
- c) The measurement is obtained by accumulating the number of outgoing unnecessary handovers to another RAT from E-UTRAN according to the definitions in TS 36.300 [12] and TS 36.413[9].
- d) A single integer value.
- e) HO.IratOutUnnecessaryFromEutran
- f) GSMRelation
UTRANRelation
CDMA2000Relation
- g) Valid for packet switched traffic
- h) EPS
- i) This measurement is to support the PM for inter-RAT MRO defined in TS 32.522[15].

4.4 Cell level radio bearer QoS related measurements

4.4.1 Cell PDCP SDU bit-rate

4.4.1.1 Average DL cell PDCP SDU bit-rate

- a) This measurement provides the average cell bit-rate of PDCP SDUs on the downlink. This represents the ingress rate of user plane traffic to the eNodeB/RN (via X2 or S1). The measurement is split into subcounters per E-RAB QoS level (QCI).
- b) CC
- c) This measurement is obtained by accumulating the number of bits entering the eNodeB/RN, and then dividing the sum by the measurement period. The measurement is performed at the PDCP SDU level. PDCP SDUs that are forwarded over the X2/S1 to another eNodeB during handover shall be deducted from the bit count – if this results in a negative bit count the bit count shall be set to zero. Separate counters are maintained for each QCI. The sum of all supported per QCI measurements shall equal the total DL cell PDCP SDU bit-rate. In case only a subset of per QCI measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value representing the bit-rate measured in kb/s. The number of measurements is equal to the number of QCIs plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form DRB.PdcpSduBitrateDl.QCI where *QCI* identifies the E-RAB level quality of service class.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic

- h) EPS
- i) One usage of this measurement is to support the performance indicator DV_{MN} for EE evaluation in [20].

4.4.1.2 Average UL cell PDCP SDU bit-rate

- a) This measurement provides the average cell bit-rate of PDCP SDUs on the uplink. This represents successful transmissions of user plane traffic; control signalling and retransmissions are excluded from this measure. The measurement is split into subcounters per E-RAB QoS level (QCI).
- b) CC
- c) This measurement is obtained by accumulating the number of bits leaving the eNodeB/RN on the X2 or S1 interface, and then dividing the sum by the measurement period. The measurement is performed at the PDCP SDU level. PDCP SDUs that were not received over the air interface in the cell (but were forwarded from another eNodeB during handover) are excluded from the count. Separate counters are maintained for each QCI. The sum of all supported per QCI measurements shall equal the total UL cell PDCP SDU bit-rate. In case only a subset of per QCI measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value representing the bit-rate measured in kb/s. The number of measurements is equal to the number of QCIs plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form DRB.PdcpSduBitrateUl.QCI where *QCI* identifies the E-RAB level quality of service class.
- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switched traffic
- h) EPS
- i) One usage of this measurement is to support the performance indicator DV_{MN} for EE evaluation in [20].

4.4.1.3 Maximum DL cell PDCP SDU bit-rate

- a) This measurement provides the maximum cell bit-rate of PDCP SDUs on the downlink. This represents the maximum ingress rate of user plane traffic to the eNodeB/RN (via X2 or S1). This is a sum counter measured across all QCIs.
- b) SI
- c) This measurement is obtained by sampling at pre-defined intervals the DL cell PDCP SDU bit-rate summed across all QCIs (see clause 4.4.1.1), and then taking the arithmetic maximum of these samples.
- d) A single integer value representing the maximum bit-rate measured in kb/s.
- e) DRB.PdcpSduBitrateDlMax
- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.4.1.4 Maximum UL cell PDCP SDU bit-rate

- a) This measurement provides the maximum cell bit-rate of PDCP SDUs measured on the uplink. This represents successful transmissions of user plane traffic; control signalling and retransmissions are excluded from this measure. This is a sum counter measured across all QCIs.
- b) SI

- c) The measurement is obtained by sampling at pre-defined intervals the UL cell PDCP SDU bit-rate summed across all QCI (see clause 4.4.1.2), and then taking the arithmetic maximum of these samples.
- d) A single integer value representing the maximum bit-rate measured in kb/s.
- e) DRB.PdcpSduBitrateUIMax
- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.4.1.5 Average DL cell control plane PDCP SDU bit-rate

- i) This measurement provides the average cell bit-rate of control plane PDCP SDUs on the downlink.
- j) CC.
- k) This measurement is obtained by accumulating the number of received control plane PDCP SDU bits by the eNodeB/RN, including the control plane PDCP SDU bits received from S1 and RRC SAP, and then dividing the sum by the measurement period.
- l) An single integer value in kb/s.
- m) SRB.PdcpSduBitrateDL
- n) EUTRANCellFDD
EUTRANCellTDD
- o) Valid for packet switching.
- p) EPS

4.4.1.6 Average UL cell control plane PDCP SDU bit-rate

- a) This measurement provides the average cell bit-rate of control plane PDCP SDUs on the uplink. This represents successful transmissions of control plane traffic;
- b) CC.
- c) This measurement is obtained by accumulating the number of transmitted uplink control plane PDCP SDU bits by the eNodeB/RN, and then dividing the sum by the measurement period.
- d) An single integer value in kb/s.
- e) SRB.PdcpSduBitrateUL
- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switching.
- h) EPS

4.4.2 Active UEs

4.4.2.1 Average number of active UEs on the DL

- a) This measurement provides the average number of UEs that have DTCH data queued on the downlink. The measurement is split into subcounters per E-RAB QoS level (QCI). For an eNodeB serving one or more RNs, the measurement refers to the number of active UEs connected directly to the eNodeB, excluding RNs. The measurement is also applicable to RNs.

- b) SI
- c) This measurement is obtained according to the definition in 3GPP TS 36.314 [11]. Separate counters are maintained for each QCI.
- d) Each measurement is an integer value. The number of measurements is equal to the number of QCIs plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form
DRB.UEActiveDL.*QCI*
where *QCI* identifies the E-RAB level quality of service class.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.4.2.2 Average number of active UEs on the UL

- a) This measurement provides the average number of UEs that have DTCH data queued on the uplink. The measurement is split into subcounters per E-RAB QoS level (QCI). For an eNodeB serving one or more RNs, the measurement refers to the number of active UEs connected directly to the eNodeB, excluding RNs. The measurement is also applicable to RNs.
- b) SI
- c) This measurement is obtained according to the definition in 3GPP TS 36.314 [11]. Separate counters are maintained for each QCI.
- d) Each measurement is an integer value. The number of measurements is equal to the number of QCIs plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form
DRB.UEActiveUL.*QCI*
where *QCI* identifies the E-RAB level quality of service class.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.4.3 Packet Delay and Drop Rate

4.4.3.1 Average DL PDCP SDU delay

- a) This measurement provides the average (arithmetic mean) PDCP SDU delay on the downlink. The measurement is split into subcounters per E-RAB QoS level (QCI). If there is one or more RNs served in a cell, for that cell the eNodeB performs each measurement separately for packets transmitted between the eNodeB and UEs and for packets transmitted between the E-UTRAN and RNs. The measurement is also applicable to RNs.
- b) DER (n=1)
- c) This measurement is obtained according to the definition in 3GPP TS 36.314 [11].
- d) Each measurement is an integer value representing the mean delay in ms. The number of measurements is equal to the number of QCIs plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form
DRB.PdcpSduDelayDL.*QCI*, which indicates the PDCP SDU delay between the eNodeB (or RN) and UE

DRB.PdcpSduDelayDIRN.*QCI*, which indicates the PDCP SDU delay between the E-UTRAN and RN.
where *QCI* identifies the E-RAB level quality of service class.

- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.4.3.2 DL PDCP SDU drop rate

- a) This measurement provides the fraction of IP packets (PDCP SDUs) which are dropped on the downlink. Only user-plane traffic (DTCH) is considered. A dropped packet is one whose context is removed from the eNodeB/RN without any part of it having been transmitted on the air interface. Packets discarded during handover are excluded from the count. The measurement is split into subcounters per E-RAB QoS level (*QCI*).
- b) SI
- c) This measurement is obtained according to the definition in 3GPP TS 36.314 [11]. Separate counters are maintained for each *QCI*. In case only a subset of per *QCI* measurements is supported, a drop rate subcounter calculated across all *QCIs* will be provided first.
- d) Each measurement is an integer value representing the drop rate multiplied by 1E6. The number of measurements is equal to the number of *QCIs* plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form DRB.PdcpSduDropRateDL.*QCI*
where *QCI* identifies the target E-RAB level quality of service class.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.4.4 Packet loss rate

4.4.4.1 DL PDCP SDU air interface loss rate

- a) This measurement provides the fraction of IP packets (PDCP SDUs) which are lost (not successfully transmitted) on the downlink air interface. Only user-plane traffic (DTCH) is considered. A lost packet is one whose context is removed from the eNodeB/RN after an attempt has been made to transmit part or all of the packet on the air interface but the whole packet has not been successfully transmitted. The measurement is split into subcounters per E-RAB QoS level (*QCI*). The packets transmitted between the eNodeB (or RN) and UEs and the packets transmitted between E-UTRAN and RN are counted separately. The measurement is also applicable to RNs.
- b) SI
- c) This measurement is obtained according to the definition in 3GPP TS 36.314 [11]. Separate counters are maintained for each *QCI*. In case only a subset of per *QCI* measurements is supported, a loss rate subcounter calculated across all *QCIs* will be provided first.
- d) Each measurement is an integer value representing the air interface loss rate multiplied by 1E6. The number of measurements is equal to the number of *QCIs* plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form
DRB.PdcpSduAirLossRateDL.*QCI*, which indicates the DL PDCP SDU air interface loss rate between the eNodeB (or RN) and UE

DRB.PdcpSduAirLossRateDIRN.*QCI*, which indicates the DL PDCP SDU air interface loss rate between the E-UTRAN and RN.
where *QCI* identifies the target E-RAB level quality of service class.

- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.4.4.2 UL PDCP SDU loss rate

- a) This measurement provides the fraction of IP packets (PDCP SDUs) which are lost (not successfully received) on the uplink. Only user-plane traffic (DTCH) and only PDCP SDUs that have entered PDCP (and given a PDCP sequence number) are considered. The measurement is split into subcounters per E-RAB QoS level (QCI). The packets transmitted between the eNodeB and UEs and the packets transmitted between E-UTRAN and RN are counted separately. The measurement is also applicable to RNs.
- b) SI
- c) This measurement is obtained according to the definition in 3GPP TS 36.314 [11]. Separate counters are maintained for each QCI. In case only a subset of per QCI measurements is supported, a loss rate subcounter calculated across all QCIs will be provided first.
- d) Each measurement is an integer value representing the loss rate multiplied by 1E6. The number of measurements is equal to the number of QCIs plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form DRB.PdcpSduLossRateUl.QCI, which indicates the UL PDCP SDU loss rate between the eNodeB (or RN) and UE
DRB.PdcpSduLossRateUIRN.QCI, which indicates the UL PDCP SDU loss rate between the E-UTRAN and RN. where QCI identifies the target E-RAB level quality of service class.
- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.4.5 IP Latency measurements

4.4.5.1 IP Latency in DL, E-RAB level

- a) This measurement provides IP Latency in DL on E-RAB level.
- b) CC
- c) This measurement is obtained by the following formula for E-RABs

$$\frac{\text{LatTime}}{\text{LatSample}}$$

LatTime is obtained by accumulating the time T for E-RABs

$$T = t_{\text{first part of data volume transmitted}} - t_{\text{data received}} \quad [ms]$$

The sample of 'T' is made for the new arrived IP data block (PDCP SDU) when there is no other prior data to be transmitted to the same UE in the eNodeB/RN.

LatSample is obtained by accumulating the number of Latency samples taken on the E-RAB level

The measurement is split into subcounters per E-RAB QoS level (QCI).

- d) Each measurement is an integer value representing the time in ms. The number of measurements is equal to the number of QCIs.

- e) The measurement name has the form DRB.IpLateDl.QCI
where QCI identifies the E-RAB level quality of service class.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS
- i) This measurement is to support the Integrity KPI 'E-UTRAN IP Latency' defined in [13]

4.4.6 IP Throughput measurements

4.4.6.1 IP Throughput in DL

- a) This measurement provides IP throughput in downlink. For an eNodeB serving one or more RNs, packets transmitted between the E-UTRAN and RNs are excluded, i.e., only packets transmitted between the eNodeB (or RN) and UEs are counted. The measurement is also applicable to RN.
- b) DER(N=1)
- c) This measurement is obtained according to the following formula based on the 'ThpVolDl' and 'ThpTimeDl' defined for the 'Scheduled IP Throughput in DL' in 3GPP TS 36.314 [11] for each QCI.

$$\text{If } \sum_{UEs} \sum \text{ThpTimeDl} > 0, \frac{\sum_{UEs} \sum \text{ThpVolDl}}{\sum_{UEs} \sum \text{ThpTimeDl}} \times 1000 [\text{kbits/s}]$$

$$\text{If } \sum_{UEs} \sum \text{ThpTimeDl} = 0, 0 [\text{kbits/s}]$$

- d) Each measurement is a real value representing the throughput in kbits/s. The number of measurements is equal to the number of QCIs.
- e) The measurement name has the form
DRB.IPThpDl.QCI
where QCI identifies the E-RAB level quality of service class.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS
- i) This measurement is to support the Integrity KPI 'E-UTRAN IP Throughput' defined in [13].

4.4.6.2 IP Throughput in UL

- a) This measurement provides IP throughput in uplink. For an eNodeB serving one or more RNs, packets transmitted between the E-UTRAN and RNs are excluded, i.e., only packets transmitted between the eNodeB (or RN) and UEs are counted. The measurement is also applicable to RN
- b) DER(N=1)

- c) This measurement is obtained according to the following formula based on the 'ThpVolUl' and 'ThpTimeUl' defined for the 'Scheduled IP Throughput inUL' in 3GPP TS 36.314 [11] for each QCI.

$$\text{If } \sum_{UEs} \sum \text{ThpTimeUl} > 0, \frac{\sum_{UEs} \sum \text{ThpVolUl}}{\sum_{UEs} \sum \text{ThpTimeUl}} \times 1000 [\text{kbits} / \text{s}]$$

$$\text{If } \sum_{UEs} \sum \text{ThpTimeUl} = 0, 0 [\text{kbits} / \text{s}]$$

- d) Each measurement is a real value representing the volume in kbits. The number of measurements is equal to the number of QCIs.
- e) The measurement name has the form
DRB.IPThpUl.QCI
where QCI identifies the E-RAB level quality of service class.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS
- i) This measurement is to support the Integrity KPI 'E-UTRAN IP Throughput' defined in [13].

4.5 Radio resource utilization related measurements

4.5.1 DL PRB Usage for traffic

- a) This measurement provides the usage (in percentage) of physical resource blocks (PRBs) on the downlink for DTCH traffic. The measurement is split into subcounters per E-RAB QoS level (QCI). If there is one or more RNs served in a cell, for that cell the eNodeB performs PRB usage measurements separately for all traffic (including transmissions to/from RNs and UEs directly connected to the eNodeB) and for RN traffic. The measurement is also applicable to RNs.
- b) SI
- c) This measurement is obtained according to the definition in 3GPP TS 36.314 [11]. Separate counters are maintained for each QCI. The sum of all supported per QCI measurements shall equal the total PRB usage for DTCH. In case only a subset of per QCI measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value from 0 to 100. The number of measurements is equal to the number of QCIs plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form
RRU.PrbDl.QCI, which indicates the DL PRB Usage for all traffic
RRU.PrbDIRN.QCI, which indicates the DL PRB Usage for the RN traffic
where QCI identifies the E-RAB level quality of service class.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.5.2 UL PRB Usage for traffic

- a) This measurement provides the usage (in percentage) of physical resource blocks (PRBs) on the uplink for DTCH traffic. The measurement is split into subcounters per E-RAB QoS level (QCI). If there is one or more RNs served in a cell, for that cell the eNodeB performs PRB usage measurements separately for all traffic

(including transmissions to/from RNs and UEs directly connected to the eNodeB) and for RN traffic. The measurement is also applicable to RNs.

- b) SI
- c) This measurement is obtained according to the definition in 3GPP TS 36.314 [11]. Separate counters are maintained for each QCI. The sum of all supported per QCI measurements shall equal the total PRB usage for DTCH. In case only a subset of per QCI measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value from 0 to 100. The number of measurements is equal to the number of QCIs plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form
RRU.PrbUl.QCI, which indicates the UL PRB Usage for all traffic
RRU.PrbUlRN.QCI, which indicates the UL PRB Usage for the RN traffic
where QCI identifies the E-RAB level quality of service class.
- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.5.3 DL Total PRB Usage

- a) This measurement provides the total usage (in percentage) of physical resource blocks (PRBs) on the downlink for any purpose. If there is one or more RNs served in a cell, for that cell the eNodeB performs PRB usage measurements separately for all traffic (including transmissions to/from RNs and UEs directly connected to the eNodeB) and for RN traffic. The measurement is also applicable to RNs.
- b) SI
- c) This measurement is obtained according to the definition in 3GPP TS 36.314 [11].
- d) A single integer value from 0 to 100.
- e) RRU.PrbTotDL, which indicates the DL PRB Usage for all traffic
RRU.PrbTotDLRN, which indicates the DL PRB Usage for the RN traffic
- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.5.4 UL Total PRB Usage

- a) This measurement provides the total usage (in percentage) of physical resource blocks (PRBs) on the uplink for any purpose. If there is one or more RNs served in a cell, for that cell the eNodeB performs PRB usage measurements separately for all traffic (including transmissions to/from RNs and UEs directly connected to the eNodeB) and for RN traffic. The measurement is also applicable to RNs.
- b) SI
- c) This measurement is obtained according to the definition in 3GPP TS 36.314 [11].
- d) A single integer value from 0 to 100.
- e) RRU.PrbTotUL, which indicates the UL PRB Usage for all traffic
RRU.PrbTotULRN, which indicates the UL PRB Usage for the RN traffic
- f) EUTRANCellFDD
EUTRANCellTDD

- g) Valid for packet switched traffic
- h) EPS

4.5.5 RACH Usage

4.5.5.1 Mean number of RACH preambles received

- a) This measurement provides the mean number of RACH preambles received in a cell in one second. Separate counts are provided for dedicated preambles, randomly chosen preambles in group A (aka 'low range') and randomly chosen preambles in group B (aka 'high range').
- b) Gauge
- c) This measurement is obtained according to the definition in 36.314 [11].
- d) Each measurement is an integer value.
- e) RRU.RachPreambleDedMean
RRU.RachPreambleAMean
RRU.RachPreambleBMean
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.5.5.2 Distribution of RACH preambles sent

- a) This measurement provides the distribution of number of RACH preambles sent by the UE as reported by the UEs inside the *UEInformationResponse* message
- b) CC
- c) This measurement is obtained by incrementing the measurement bin corresponding to the value of IE *numberOfPreamblesSent-r9* ([8] clause 6.2.2) reported by UE inside *UEInformationResponse* message. The measurement is incremented each time a *UEInformationResponse* message containing *rach-Report-r9* IE is received.
- d) Each measurement is an integer value.
- e) RRU.RachPreambleDist.BinX
where BinX represents the bin.
Note: Number of bins and the range for each bin is left to implementation.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.5.5.3 Distribution of RACH access delay

- a) This measurement provides the distribution of number of the time before UEs in a cell achieve a successful attach. The RACH access delay is the time from when a UE sends its first Random Access Preamble until the UE receives the Random Access Response.
- b) CC

- c) This measurement is obtained by incrementing the measurement bin corresponding to the access delay experienced by the UE. The access delay is calculated based upon the value of IE *numberOfPreamblesSent* and IE *contentionDetected* reported by UE inside *UEInformationResponse* message ([8] clause 6.2.2). The measurement is incremented each time a *UEInformationResponse* message containing *rach-Report-r9* IE is received.
- d) Each measurement is an integer value.
- e) RRU.RachAccessDelayDist.BinX
where BinX represents the bin.
Note: Number of bins and the range for each bin is left to implementation.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.5.5.4 Percentage of contentious RACH attempts

- a) This measurement provides the percentage of *UEInformationResponse* messages received within the measurement granularity interval with *contentionDetected* IE set to TRUE.
- b) SI
- c) When *UEInformationResponse* message ([8] clause 6.2.1) containing *rachReport-r9* IE is received the measurement is updated.
- d) Percentage
- e) RRU.RachContentionReported
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.5.5.5 Number of UE RACH reports received

- a) This measurement provides the number of *UEInformationResponse* messages received within the measurement granularity interval containing *rachReport-r9* IE.
- b) CC
- c) When *UEInformationResponse* message ([8] clause 6.2.1) containing *rachReport-r9* IE is received the measurement is incremented by one.
- d) Single integer value
- e) RRU.RachReportCount
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.5.5.6 Percentage of time when all dedicated RACH preambles are used

- a) This measurement provides the percentage of time when all dedicated RACH preambles are assigned to UEs.

- b) SI
- c) During each measurement granularity interval the percentage of time during which all dedicated RACH preambles were assigned to UEs is computed.
- d) Percentage
- e) RRU.RachDedicatedPreamblesAssigned
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.5.6 Cell Unavailable Time

- a) This measurement provides the length of time the cell has been unavailable for each cause.
- b) DER (n=1)
- c) This measurement is obtained by accumulating the time periods when the cell is unavailable per cause. The possible cause could be 'manual intervention', 'fault' and 'energy saving'. The sum of all supported per cause measurements shall equal the total time periods of cell unavailability. In case only a subset of per cause measurements is supported, a sum subcounter will be provided first.
- d) Each measurement is an integer value (in seconds). The number of measurements is equal to the number of supported causes plus a possible sum value identified by the *.sum* suffix.
- e) The measurement name has the form RRU.CellUnavailableTime.cause.

Where *cause* identifies the cause resulting in cell unavailable.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS
- i) This measurement is to support KPI 'E-UTRAN Cell Availability' defined in [13].

4.5.7 TB related measurements

4.5.7.1 Total Number of DL TBs

- a) This measurement provides the total number of TBs transmitted on the downlink in a cell. HARQ retransmissions are excluded from this measurement.
- b) CC
- c) On transmission by the eNodeB/RNof TB to UE during the period of measurement. (see 36.321 [16])
- d) A single integer value.
- e) TB.TotNbrDl
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.5.7.2 Error Number of DL TBs

- a) This measurement provides the number of faulty TBs transmitted on the downlink in a cell. HARQ retransmissions are excluded from this measurement.
- b) CC
- c) On receipt by the eNodeB/RN of a NACK from UE which indicates a faulty reception of TB by UE during the period of measurement. (see 36.321 [16])
- d) A single integer value.
- e) TB.ErrNbrDl
- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.5.7.3 Total Number of UL TBs

- a) This measurement provides the total number of TBs on the uplink in a cell. HARQ retransmissions are excluded from this measurement.
- b) CC
- c) On receipt by the eNodeB/RN of TB from UE during the period of measurement. (see 36.321 [16])
- d) A single integer value.
- e) TB.TotNbrUl
- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.5.7.4 Error Number of UL TBs

- a) This measurement provides the number of faulty TBs on the uplink in a cell. HARQ retransmissions are excluded from this measurement.
- b) CC
- c) On receipt by the eNodeB/RN of a TB on which CRC fails from UE during the period of measurement. (see 36.321 [16])
- d) A single integer value.
- e) TB.ErrNbrUl
- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.5.8 Power utilization measurements

4.5.8.1 Maximum carrier transmit power

- a) This measurement provides the maximum carrier transmit power in the measurement granularity interval.
- b) SI
- c) This measurement is obtained by retaining the maximum value of the total carrier power transmitted in the cell within the measurement granularity period. The power includes all radio power transmitted, included common channels, traffic channels, control channels. The value is expressed in dBm.
- d) Float in dBm.
- e) CARR.MaxTxPwr
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switching.
- h) EPS

4.5.8.2 Mean carrier transmit power

- a) This measurement provides the mean carrier transmit power in the measurement granularity interval.
- b) SI
- c) This measurement is obtained by computing the mean value of the total carrier power transmitted in the cell within the measurement granularity period. The power includes all radio power transmitted, included common channels, traffic channels, control channels. The value is expressed in dBm.
- d) Float in dBm.
- e) CARR.AvgTxPwr
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switching.
- h) EPS

4.5.9 PRB Full Utilisation

4.5.9.1 DL PRB full utilisation

- a) This measurement provides the percentage of time during which all available PRBs for traffic on the downlink have been assigned.
- b) SI
- c) This measurement represents the percentage of time during the measurement granularity interval during which all available PRBs for downlink traffic have been assigned to UEs.
- d) A single integer value from 0 to 100.
- e) RRU.PrbCongestionDI
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic

h) EPS

4.5.9.2 UL PRB full utilisation

- a) This measurement provides the percentage of time during which all available PRBs for traffic on the uplink have been assigned.
- b) SI
- c) This measurement represents the percentage of time during the measurement granularity interval during which all available PRBs for uplink traffic have been assigned to UEs.
- d) A single integer value from 0 to 100.
- e) RRU.PrbCongestionUl
- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.6 UE-associated logical S1-connection related measurements

4.6.1 UE-associated logical S1-connection establishment

4.6.1.1 Attempted UE-associated logical S1-connection establishment from eNB to MME

- a) This measurement provides the number of attempted UE-associated logical S1-connection establishments from eNB to MME.
- b) CC
- c) Transmission of an INITIAL UE MESSAGE by the eNodeB to the MME (See 36.413 [9]).
- d) A single integer value.
- e) S1SIG.ConnEstabAtt
- f) EUTRANCellFDD
EUTRANCellTDD
- g) Valid for packet switched traffic
- h) EPS
- i) This measurement is to support the Accessibility KPI 'E-RAB Accessibility' defined in [13].

4.6.1.2 Successful UE-associated logical S1-connection establishment from eNB to MME

- a) This measurement provides the number of successful UE-associated logical S1-connection establishments from eNB to MME.
- b) CC
- c) On receipt by the eNB of first message from MME which succeeds INITIAL UE MESSAGE message on a UE-associated logical S1-connection (See 36.413 [9]).
- d) A single integer value.

- e) S1SIG.ConnEstabSucc
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS
- i) This measurement is to support the Accessibility KPI 'E-RAB Accessibility' defined in [13]

4.7 Paging related measurements

4.7.1 Paging Performance

4.7.1.1 Number of paging records discarded at the eNodeB/RN

- a) This measurement provides the number of paging records that are discarded at the eNB/RN for paging occasions in each cell.
- b) CC
- c) Reception of a S1AP PAGING message from MME/DeNB, see TS 36.413[9], with UE identity which satisfies the following formulae from TS 36.304 [14].
$$X = (T \text{ div } N) * (\text{UE_ID mod } N)$$
$$Y = \text{floor}(\text{UE_ID}/N) \text{ mod } N_s$$

AND the maximum number of paging records that can be queued for each paging occasion has been reached.
- d) A single integer value.
- e) PAG.DiscardedNbr
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic.
- h) EPS

4.7.1.2 Number of paging records received by the eNodeB/RN

- a) This measurement provides the number of paging records that are received by the eNB/RN for paging occasions in each cell.
- b) CC
- c) Reception of a S1AP PAGING message from MME/DeNB, see TS 36.413[9].
- d) A single integer value.
- e) PAG.ReceivedNbr
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic.

- h) EPS

4.8 Measurements related to equipment resources

4.8.1 eNodeB/RN processor usage

4.8.1.1 Mean processor usage

- a) This measurement provides the mean usage of each key processor during the granularity period. Each equipment may have more than one key processor, how to identify key processor is vendor specific.
- b) SI.
- c) This measurement is obtained by sampling at a pre-defined interval the usage of the processor and then taking the arithmetic mean for each key processor.
- d) Each measurement is an integer value (Unit: %).
- e) EQPT.MeanProcessorUsage.ProcessorID
where *ProcessorID* identifies the key processor of this equipment, the format of *ProcessorID* is vendor specific.
- f) ManagedElement.
- g) Valid for packet switched traffic.
- h) EPS.

4.8.1.2 Peak processor usage

- a) This measurement provides the peak usage of each key processor during the granularity period. Each equipment may have more than one key processor, how to identify key processor is vendor specific.
- b) SI.
- c) This measurement is obtained by sampling at a pre-defined interval the usage of the processor and then taking the maximum for each key processor.
- d) Each measurement is an integer value (Unit: %).
- e) EQPT.PeakProcessorUsage.ProcessorID
where *ProcessorID* identifies the key processor of this equipment, the format of *ProcessorID* is vendor specific.
- f) ManagedElement.
- g) Valid for packet switched traffic.
- h) EPS.

4.9 Common LAs of overlapping RAT"s coverage

4.9.1 Number of incoming IRAT mobility events per LA

- a) This measurement provides the number of incoming IRAT mobility events per E-UTRAN cell. This measurement is split into subcounters per LA.
- b) CC.
- c) On receipt by the eNB from UE of an RRCConnectionSetupComplete message in which the most significant bit of the 'mmeqi' in 'RegisteredMME' IE is '0' (see TS 36.331 [8]). Each RRCConnectionSetupComplete message received is added to the relevant per LAI measurement. This definition is only applicable to the EUTRAN cells of which the adjacent (including overlaid) RAT is set the most significant bit of the <LAC> with zero.

- d) Each measurement is an integer value.
- e) `RRC.IratIncMobility.LAI`
where *LAI* identifies the LAI of the RAT's coverage the UE comes from.
- f) `EUtranCellFDD`
`EUtranCellTDD`
- g) Valid for packet switched traffic
- h) EPS

4.10 RF Measurements

4.10.1 CQI Distribution

4.10.1.0 General

In CA, in case the CQI of SCell is reported to PCell via PUCCH, the CQI is counted to the reported SCell (but not to the PCell).

4.10.1.1 Wideband CQI distribution

- a) This measurement provides the distribution of the Wideband CQI (Channel Quality Indicator) reported by UEs in the cell.
- b) CC.
- c) This measurement is obtained by incrementing the appropriate measurement bin when a wideband CQI value is reported by a UE in the cell. When spatial multiplexing is used, CQI for both code words should be considered.
- d) A single integer value.
- e) `CARR.WBCQIDist.BinX`
where X represents the CQI value (0 to 15).
- f) `EUtranCellFDD`
`EUtranCellTDD`
- g) Valid for packet switching.
- h) EPS

4.10.1.2 Average sub-band CQI

- a) This measurement provides the average value of the sub-band CQI (Channel Quality Indicator) reported by UEs in the cell.

A subband is a set of k contiguous PRBs where k is a function of system bandwidth. Note the last subband in set S may have fewer than k contiguous PRBs depending on N_{RB}^{DL} . The number of subbands for system

bandwidth given by N_{RB}^{DL} is defined by $N = \lceil N_{RB}^{DL} / k \rceil$. The subbands shall be indexed in the order of increasing frequency and non-increasing sizes starting at the lowest frequency.

- b) CC
- c) This measurement is obtained by computing the average value of the sub-band CQI reported by UEs in the cell within the measurement granularity period. One value is produced for each sub-band. The number of sub-bands depends on the bandwidth used, as specified in [18]. When spatial multiplexing is used, CQI for both code words should be considered.
- d) Float value.

- e) $CARR.AvgSubCQI.SubbandX$
where $SubbandX$ represents the sub-band index, as specified in [18].
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switching.
- h) EPS

4.10.2 Timing Advance Distribution

- a) This measurement provides the distribution of the Timing Advance (T_A) values transmitted by the eNB to UEs in the cell.
- b) CC.
- c) This measurement is obtained by incrementing the appropriate measurement bin when a Timing Advance Command is sent to a UE in the cell. For Timing Advance Command see [16] clause 6.1.3.5.
- d) A single integer value.
- e) $CARR.TADist.BinX$
where X represents the T_A value (0 to 63).
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switching.
- h) EPS

4.11 SCell scheduling related measurements in CA

4.11.0 Introduction

The three measurement types defined in the subclauses 4.11.1, 4.11.2 and 4.11.3 are subject to the "2 out of 3 approach".

4.11.1 Attempted PUCCH allocations for SCell scheduling in Carrier Aggregation

- a) This measurement provides the number of attempted PUCCH allocations in the PCell for SCell scheduling in Carrier Aggregation. This measurement is split into subcounters for the PUCCH format 3 and PUCCH format 1b/wcs.
- b) CC
- c) On allocation of PUCCH resources in the Pcell for Scell scheduling in Carrier Aggregation.
- d) Each measurement is an integer value.
- e) $DRB.PucchAllocNbrAtt.PUCCHFormat$
where $PUCCHFormat$ identifies the PUCCH format, which is either 'format3' or 'format1b/wcs'.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.11.2 Successful PUCCH allocations for SCell scheduling in Carrier Aggregation

- a) This measurement provides the number of successful PUCCH allocations in the PCell for SCell scheduling in Carrier Aggregation. This measurement is split into subcounters for the PUCCH format 3 and PUCCH format 1bwcs.
- b) CC
- c) On the success of a SCell scheduling in Carrier Aggregation.
- d) Each measurement is an integer value.
- e) DRB.PucchAllocNbrSucc.*PUCCHFormat*
where *PUCCHFormat* identifies the PUCCH format, which is either 'format3' or 'format1bwcs'.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

4.11.3 Failed PUCCH allocations for SCell scheduling in Carrier Aggregation

- a) This measurement provides the number of failed PUCCH allocations in the PCell for SCell scheduling in Carrier Aggregation. This measurement is split into subcounters for the PUCCH format 3 and PUCCH format 1bwcs.
- b) CC
- c) On the failure of a SCell scheduling due to lack of PUCCH resources in the PCell for Carrier Aggregation.
- d) Each measurement is an integer value.
- e) DRB.PucchAllocNbrFail.*PUCCHFormat*
where *PUCCHFormat* identifies the PUCCH format, which is either 'format3' or 'format1bwcs'.
- f) EUTranCellFDD
EUTranCellTDD
- g) Valid for packet switched traffic
- h) EPS

5 Measurements related to Relay Node

5.1 DeNB Reconfiguration related measurements

5.1.1 RN Reconfiguration

5.1.1.1 Number of RNReconfiguration attempts

- a) This measurement provides the number of RNReconfiguration attempts sent by DeNB.
- b) CC
- c) On transmission by the DeNB of a RNReconfiguration message to RN. Each RNReconfiguration message received is added to the relevant measurement. The message is included in 3GPP TS 36.331 [8].
- d) Each measurement is an integer value.
- e) The measurement name has the form RRC.RNReconAttNbr.
- f) DeNBCapability
- g) Valid for packet switched traffic
- h) EPS

5.1.1.2 Number of RNReconfiguration Completed

- a) This measurement provides the number of RNReconfiguration completed received by DeNB
- b) CC
- c) On receipt by the DeNB of a RNReconfigurationComplete message from RN. Each RNReconfigurationComplete message received is added to the relevant measurement. The message is included in 3GPP TS 36.331 [8].
- d) Each measurement is an integer value.
- e) The measurement name has the form RRC.RNReconCmptNbr
- f) DeNBCapability
- g) Valid for packet switched traffic
- h) EPS

6 Measurements related to Measurement Report

6.1 RSRP related measurements

- a) This measurement provides a bin distribution (histogram) of the periodical E-UTRAN RSRP measurements received from all of UEs in the measured E-UTRAN cell. To collect this measurement, the eNodeB needs to trigger the periodical UE measurement reports towards all of the UEs in the measured E-UTRAN cell.
- b) CC

- c) Receipt by the eNodeB from the UE of *MeasurementReport* message indicating a periodical UE measurement report where IE *MeasResults* field includes *rsrpResult*. The event triggered *MeasurementReport* messages are excluded. This measurement shall be increased for each reported value RSRP_LEV (See in 3GPP TS 36.331 [18]). For every one or two or 17 or 20 RSRP_LEV(s) a separate measurement is defined. (See in 3GPP TS 36.133 [19])
- d) Each measurement is an integer value.
- e) MR.Rsrp.y . y is an integer from 00 to 47.
Note:
00 of y indicates from RSRP_LEV_00 to RSRP_LEV_LEV_20, namely $RSRP < -120\text{dBm}$,
01 of y indicates RSRP_LEV_21 and RSRP_LEV_25, namely $-120 \leq RSRP < -115\text{dBm}$,
02 of y indicates RSRP_LEV_26, namely $-115 \leq RSRP < -114\text{dBm}$,
03 of y indicates RSRP_LEV_27, namely $-114 \leq RSRP < -113\text{dBm}$
...
36 of y indicates RSRP_LEV_60, namely $-81 \leq RSRP < -80\text{dBm}$,
37 of y indicates RSRP_LEV_61, RSRP_LEV_62, namely $-80 \leq RSRP < -78\text{dBm}$,
38 of y indicates RSRP_LEV_63, RSRP_LEV_64, namely $-78 \leq RSRP < -76\text{dBm}$,
...
46 of y indicates from RSRP_LEV_79 to RSRP_LEV_80, namely $-62 \leq RSRP < -60\text{dBm}$,
47 of y indicates from RSRP_LEV_81 to RSRP_LEV_97, namely $-60\text{dBm} \leq RSRP$. (See in 3GPP TS36.133 [19])
- f) EUTranCellTDD
EUTranCellFDD
- g) Valid for packet switched traffic.
- h) EPS

6.2 RSRQ related measurements

- a) This measurement provides a bin distribution (histogram) of the periodical E-UTRAN RSRQ measurements received from all of UEs in the measured E-UTRAN cell. To collect this measurement, the eNodeB needs to trigger the periodical UE measurement reports towards all of the UEs in the measured E-UTRAN cell.
- b) CC
- c) Receipt by the eNodeB from the UE of *MeasurementReport* message indicating a periodical UE measurement report where IE *MeasResults* field includes *rsrqResult*. The event triggered *MeasurementReport* messages are excluded. This measurement shall be increased for each reported value RSRQ_LEV (See in 3GPP TS 36.331 [18]). For every one or two RSRQ_LEV(s) a separate measurement is defined. (See in 3GPP TS 36.133 [19])
- d) Each measurement is an integer value.
- e) MR. Rsrq.y . y is an integer from 00 to 17.
Note:
00 of y indicates RSRQ_00, namely $RSRQ < -19.5\text{dB}$,
01 of y indicates RSRQ_01 and RSRQ_02, namely $-19.5 \leq RSRQ < -18.5\text{dB}$,
02 of y indicates RSRQ_03 and RSRQ_04, namely $-18.5 \leq RSRQ < -17.5\text{dB}$,
...
16 of y indicates RSRQ_31 and RSRQ_32, namely $-4.5 \leq RSRQ < -3.5\text{dB}$,
17 of y indicates RSRQ_33 and RSRQ_34, namely $-3.5\text{dB} \leq RSRQ$,
(See in 3GPP TS36.133 [19])
- f) EUTranCellTDD
EUTranCellFDD
- g) Valid for packet switched traffic.
- h) EPS

6.3 UE power headroom related measurements

- a) This measurement provides a bin distribution (histogram) of the periodical E-UTRAN UE power headroom measurements received from all of UEs in the measured E-UTRAN cell. To collect this measurement, the eNodeB needs to trigger the periodical UE measurement reports towards all of the UEs in the measured E-UTRAN cell.
- b) CC
- c) Receipt by the eNodeB from the UE of Power Headroom Report message indicating a periodical UE measurement POWER_HEADROOM report. This measurement shall be increased for each reported value POWER_HEADROOM (See in 3GPP TS 36.321 [16]). For every one POWER_HEADROOM (s) a separate measurement is defined. (See in 3GPP TS 36.133 [19]).
- d) Each measurement is an integer value.
- e) MR.PowerHeadRoom.y . y is an integer from 00 to 63.
Note:
00 of y indicates POWER_HEADROOM_00, namely $-23 \leq PH < -22$,
01 of y indicates POWER_HEADROOM_01, namely $-22 \leq PH < -21$,
...
63 of y indicates POWER_HEADROOM_63, namely $PH \geq 40$. (See in 3GPP TS36.133 [19])
- f) EUTranCellTDD
EUTranCellFDD
- g) Valid for packet switched traffic.
- h) EPS

6.4 UE Rx – Tx time difference related measurements

- a) This measurement provides a bin distribution (histogram) of the periodical E-UTRAN UE Rx–Tx time difference measurements received from all of UEs in the measured E-UTRAN cell. To collect this measurement, the eNodeB needs to trigger the periodical UE measurement reports towards all of the UEs in the measured E-UTRAN cell.
- b) CC
- c) Receipt by the eNodeB from the UE of *MeasurementReport* message indicating a periodical UE measurement report where IE *MeasResults* field includes *ue-RxTxTimeDiffResult*. The event triggered *MeasurementReport* messages are excluded. This measurement shall be increased for each reported value RX-TX_TIME_DIFFERENCE (See in 3GPP TS 36.331 [18]). For every 5 or 20 or 100 or 524 RX-TX_TIME_DIFFERENCEs a separate measurement is defined. (See in 3GPP TS 36.133 [19])
- d) Each measurement is an integer value.
- e) MR.RxTxTimeDiff.y y is an integer from 00 to 47
Note:
00 of y indicates from RX-TX_TIME_DIFFERENCE_0000 to RX-TX_TIME_DIFFERENCE_0004, namely $0 \text{ Ts} \leq \text{TUE Rx-Tx} < 10 \text{ Ts}$,
...
19 of y indicates from RX-TX_TIME_DIFFERENCE_0095 to RX-TX_TIME_DIFFERENCE_0099, namely $190 \text{ Ts} \leq \text{TUE Rx-Tx} < 200 \text{ Ts}$,
20 of y indicates from RX-TX_TIME_DIFFERENCE_0100 to RX-TX_TIME_DIFFERENCE_0119, namely $200 \text{ Ts} \leq \text{TUE Rx-Tx} < 240 \text{ Ts}$,
...
39 of y indicates from RX-TX_TIME_DIFFERENCE_0480 to RX-TX_TIME_DIFFERENCE_0499, namely $960 \text{ Ts} \leq \text{TUE Rx-Tx} < 1000 \text{ Ts}$,
40 of y indicates from RX-TX_TIME_DIFFERENCE_0500 to RX-TX_TIME_DIFFERENCE_0599, namely $1000 \text{ Ts} \leq \text{TUE Rx-Tx} < 1200 \text{ Ts}$,
...

44 of y indicates from RX-TX_TIME_DIFFERENCE_0900 to RX-TX_TIME_DIFFERENCE_0999, namely $1800T_s \leq \text{TUE RX-TX} < 2000 T_s$,
 45 of y indicates from RX-TX_TIME_DIFFERENCE_1000 to RX-TX_TIME_DIFFERENCE_1523, namely $2000T_s \leq \text{TUE RX-TX} < 3048 T_s$,
 46 of y indicates from RX-TX_TIME_DIFFERENCE_1524 to RX-TX_TIME_DIFFERENCE_2047, namely $3048 T_s \leq \text{TUE RX-TX} < 4096 T_s$,
 47 of y indicates from RX-TX_TIME_DIFFERENCE_2048 to RX-TX_TIME_DIFFERENCE_4095, namely $4096 T_s \leq \text{TUE RX-TX}$
 (See in 3GPP TS36.133[20])

- f) EUTRANCellTDD
EUTRANCellFDD
- g) Valid for packet switched traffic.
- h) EPS

6.5 AOA related measurements

- a) This measurement provides a bin distribution (histogram) of the periodical E-UTRAN AOA measurements received from all of UEs in the measured E-UTRAN cell. To collect this measurement, the eNodeB needs to trigger the periodical UE measurement reports towards all of the UEs in the measured E-UTRAN cell.
- b) CC
- c) Receipt by the eNodeB from the UE of *MeasurementReport* message indicating a periodical UE measurement report where IE *MeasResults* field includes *aoaResult*. The event triggered *MeasurementReport* messages are excluded. This measurement shall be increased for each reported value AOA_ANGLE (See in 3GPP TS 36.331 [18]). For every 5 AOA_ANGLE (s) a separate measurement is defined. (See in 3GPP TS 36.133 [19])
 Note: antenna deployment.
 Note: this measurement is only valid for eNodeB with antenna array.
- d) Each measurement is an integer value.
- e) MR.EUTRANAOA.y y is an integer from 00 to 71.
 Note:
 00 of y indicates from AOA_ANGLE_000 to AOA_ANGLE_009, namely $0 \leq \text{AOA_ANGLE} < 5$ degree,
 ...
 71 of y indicates from AOA_ANGLE_710 to AOA_ANGLE_719, namely $355 \leq \text{AOA_ANGLE} < 360$ degree. (See in 3GPP TS36.133 [19])
- f) EUTRANCellTDD, EUTRANCellFDD
- g) Valid for packet switched traffic.
- h) EPS

Annex A (informative): Use cases for performance measurements definition

This annex provides the concrete use cases for the E-UTRAN performance measurements defined in clause 4.

Without particular constraint, the following use cases defined for eNodeB apply to following scenarios

- 1) eNodeB serving one or more Relay Nodes
- 2) eNodeB without serving any Relay Node
- 3) eNodeB or Relay Node supporting Carrier Aggregation
- 4) eNodeB or Relay Node not supporting Carrier Aggregation

If the specific constraint is present, which one of the above scenarios the subject use case applies to, is following the constraint.

A.1 Monitor of call(/session) setup performance

Call(/session) setup is one of most important step to start delivering services by the networks to users.

The success or failure of a call(/session) setup directly impacts the quality level for delivering the service by the networks, and also the feeling of the end user. So the success or failure of call(/session) setup needs be monitored, this can be achieved by the calculation of call setup success rate which gives a direct view to evaluate the call setup performance, and the analysis of the specific reason causing the failure to find out the problem and ascertain the solutions.

In addition, the time duration of the call(/session) setup need to be monitored as it impacts the end user experience, and by comparison with operator"s benchmark requirements, the optimization may be required according the performance.

And due to different priority and tolerance for different service type with different OoS level in the networks, the monitor needs to be opened on each service type and OoS level.

To complete the call(/session) setup procedure, E-UTRAN is mainly responsible for the establishment of radio and S1 signaling connection and service bearer by the RRC connection establishment (See 3GPP TS 36.331[8]), RRC connection reestablishment after RRC connection dropped due to some reasons like radio link failure or handover failure etc (See 3GPP TS 36.331[8]) E-RAB setup (See 3GPP TS 36.413[9]) and Initial UE Context Setup (See 3GPP TS 36.413[9]) procedure.

To support the monitor of success or failure of the call(/session) setup, the performance measurements related to RRC connection establishment (See 3GPP TS 36.331[8]), RRC connection reestablishment (See 3GPP TS 36.331[8]) procedure, and the performance measurements related to E-RAB setup (See 3GPP TS 36.413[9]) and Initial UE Context Setup (See 3GPP TS 36.413[9]) procedure for each QoS level are required To support the monitor of time duration of setup call(/session) setup, the performance measurements related to RRC connection setup time and E-RAB setup time are required.

A.2 Monitor of E-RAB release

E-RAB is the key and limited resource for E-UTRAN to deliver services. The release of the E-RAB needs to be monitored as:

- an abnormal release of the E-RAB will cause the call(/session) drop, which directly impacts the QoS delivered by the networks, and the satisfaction degree of the end user;
- a successfully released E-RAB can be used to setup other requested calls(/sessions). The E-RAB failed to be released will still occupy the limited resource and hence it can not be used to admit other requested calls(/sessions).

From a retainability measurement aspect, E-RABs do not need to be released because they are inactive, they can be kept to give fast access when new data arrives.

To define (from an E-RAB release measurement point of view) if an E-RAB is considered active or not, the E-RABs can be divided into two groups:

- a. Continuous flow, E-RABs that are always considered active, i.e. independent of if there is ongoing traffic or not at the moment. Examples: VoIP sessions, Real-time sessions, Live streaming sessions.
- b. Bursty flow, E-RABs that are only considered active when there is data in UL/DL buffer.
Example: Web sessions.

How to decide for a particular QCI if the E-RAB is of type bursty flow or continuous flow is outside the scope of this document.

The specific reason causing the abnormal and failed release of the E-RAB is required in order to find out the problem and ascertain the solutions. And due to different priority and tolerance for different service type with different OoS level in the networks, the monitor needs to be opened on each service type with OoS level.

The E-RAB can be released by E-RAB Release procedure (See 3GPP TS 36.413[9]) , UE Context Release procedure (See 3GPP TS 36.413[9] and 3GPP TS 36.423[10]) procedure, Reset procedure(See 3GPP TS 36.413[9]) either initiated by eNodeB or MM, Path Switch procedure (See 3GPP TS 36.413[9]) and Intra-eNB HO procedure (See 3GPP TS 36.331[8])E.

So performance measurements related to E-RAB Release (See 3GPP TS 36.413[9]) and UE Context Release (See 3GPP TS 36.413[9]) procedure for each service type with QoS level are necessary to support the monitor of E-RAB release.

A.3 Monitor of E-RAB level QoS modification

When an E-RAB has been established, the QoS it experiences in the E-UTRAN is dependent upon the E-RAB level QoS parameters established for the bearer, together with settings of other bearers established in the same cell. If the QoS experienced by a bearer does not meet the expected performance, or the resource need be reassigned for other bearers, the E-RAB level QoS may be adjusted (typically with a knock-on effect onto other bearers).

So the modification of E-RAB level QoS parameters needs to be monitored, and due to different priority and tolerance for different service type with different OoS level in the networks, the monitor needs to be opened on each target service type with OoS level.

The E-RAB level QoS can be modified by E-RAB Modify procedure (see 3GPP TS 36.413[9]), in which the MME entity instructs the eNodeB to change one or more QoS parameters on an E-RAB using the E-RAB MODIFY REQUEST message. The eNodeB typically makes the adjustments as instructed (and adjusts the RRM applied to the bearer appropriately) but in some circumstances the bearer modification can fail. The eNodeB returns an E-RAB MODIFY RESPONSE message that tells the MME whether the modification was successful or not – for an unsuccessful modification a cause value is included. It is important for OAM to measure the failure rate of the bearer modifications, this information can be used, for example, to make adjustments to OAM CM settings.

A.4 Overview handover related Use Cases

Use Case	PM KPI / elementary object
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<p>Continuous Network Supervision: Supervision of overall handover performance. It is essential in network operations to follow the success rate of various handover. Low handover success rate will impact user experience, therefore it is important to define measurements to follow handover success rate.</p>	<ul style="list-style-type: none"> - outgoing Intra RAT HO Success Rate (cell) *1 - outgoing Inter RAT HO Success Rate (cell) *1 - outgoing Inter System HO Success Rate (cell) *1 *3 - outgoing Intra Frequency HO Success Rate (cell) *1 - outgoing Inter Frequency HO Success Rate (cell) *1 - outgoing Intra eNB/RN HO Success Rate (cell) *2 *2.1 - outgoing Inter eNB HO Success Rate (cell) *2 *2.2 - outgoing HO to the cells outside the RN <p>*1: It is expected that the HO success rate may vary depending on the respective scenarios : intra-RAT, inter-RAT, inter System, intra frequency, inter frequency</p> <p>*2: it is expected that the HO success rate may vary depending on the used external interfaces</p> <p>*2.1: For the intra-DeNB handover, the handover from a DeNB cell to an RN under the same DeNB shall be counted separately as the handover happens between E-UTRAN and RN.</p> <p>*2.2: For the handover from the DeNB to another eNB/DeNB, the forwarded handovers for RN in the source DeNB shall not be counted as these handovers are controlled by RN so cannot directly reflect DeNB handover performance.</p> <p>*3: inter system : LTE- non 3GPP HO</p>
<p>Continuous Network Supervision: Supervision of the signal strength when handovers are triggered. This information is useful for evaluating the customer experience (e.g. throughput) at the cell edge and during handover as well for network planning purposes (e.g. signal strength at the cell edge).</p> <p>Troubleshooting: detect a "bad" configuration/neighbor in a particular direction by analyzing abnormal measurement report causing HO.</p>	<p>Signal strength of the serving and neighbouring cell reported by the UE in handover triggering measurement reports in EUTranRelation..</p>
<p>Troubleshooting: Detection of bad handover relation. The first use case provides the overall performance of handover success rate on E-UTRAN cell level, but it is essential to get a knowledge between which cell pairs the handover success rate is low. Therefore it is important to know the success rate on neighbor cell relation basis.</p>	<ul style="list-style-type: none"> - HO Success Rate (neighbourcell)
<p>Troubleshooting: Reason for started handover</p> <p>To go for further analysis of handover failures, it is essential to know what causes the handovers. For this we need to know the success rate of handovers per HO reason.</p>	<ul style="list-style-type: none"> - outgoing HO Success Rate per HO reason (neighbor cell) *4 <p>*4 different results expected e.g. emergency or normal HO</p>
<p>Troubleshooting: Reason for failed handover. To go for further detailed analysis for handover failure it is important to know what the reason for handover failure was, or whether the handover was assisted by measurement gaps or was with DRX.</p>	<ul style="list-style-type: none"> - outgoing HO Failure Distribution Rate (cell+neighbourcell) - HO Path Switching Failure Distribution Rate (cell or Interface) - HO Failure Rate DRX / Non DRX (cell) *5 - Inter frequency HO Failure Rate Meas gap assisted / not assisted (cell) *5

<p>It is also important to know if measurement gaps and DRX are helping in handover procedure or not. (i.e. what is the handover failure rate if measurement gaps are switched on. Measurement gaps and DRX can cause more load and battery consumption to the UE, therefore if these are not causing any changes in handover failure rate, operators may not use them)</p>	<p>*5: measurement only on cell basis and not per neighbourcell due to amount of counters as mentioned above.</p>
<p>Network Planning: Traffic flow analysis or Network Planning: Handover traffic optimization</p>	<p>- outgoing Intra RAT HO Success Rate (neighbour cell) - outgoing Inter RAT HO Success Rate (cell) - outgoing Inter System HO Success Rate (cell)</p>

A.5 Monitor of cell level QoS and radio resource utilisation

In an E-UTRAN cell the quality of service achieved is directly influenced by a number of factors, including:

- Loading of users on the cell
- Traffic loading and characteristics
- UE locations and mobility
- RRM policies
 - Scheduling
 - congestion control
 - admission control
 - layer 2 protocol configuration
- Mapping of traffic to QCI
- Setting of QoS parameters other than the QCI.

It is very important to be able to monitor the QoS to determine whether the combined effect of these policies, algorithms and external factors is satisfactory. Unsatisfactory QoS may be rectified by adjusting policies and RRM settings, for instance.

Cell bit-rate

A fundamental measure of QoS is the throughput (data rate) of the cell. The total cell throughput measured across all radio bearers gives an indication of the loading and activity in the cell. Adding a per QCI counter allows the loading on the different QCIs to be measured. For example, if QCI 1 is used exclusively for VoIP then the loading of conversational speech can be directly determined. Finally, the maximum throughput can indicate to the operator whether there is enough capacity in the network; for example, is the backhaul sufficient. Separate counters should be configured on the downlink and uplink. Complexity may be reduced by performing the counters at layer 3, giving the ingress bit-rate to the eNB on the downlink and the egress bit-rate from the eNB on the uplink.

Cell throughput includes both User Plane data and Control Plane data. To support the User Plane data, necessary Control Plane data also need to be transmitted. This Control Plane data although required, will not be perceived (felt) by the User. The total cell throughput helps to evaluate the usage of bandwidth and radio resource.

Operators ideally want to see the Control Plane data as small as possible when compared to the User Plane data without compromising on the service.

Hence it is important to monitor the total cell throughput as well as how much is occupied by Control Plane Data.

Number of actives UEs

It is also of interest to determine how many users are enjoying the throughput numbers determined for each QCI. Therefore, we may count the number of users that are active for each QCI – here active users have data queued pending transmission. A simple division of the throughput (data rate) of a QCI by the number of active users on the QCI indicates the throughput per user on the QCI. For example, taking QCI 1 this metric could indicate the typical codec rate being employed in the cell. Alternatively, for QCI 9 supporting low priority TCP-based traffic it can indicate the typical bandwidth pipe size for a user when he has data to send / receive.

DL packet delay

Latency is of prime concern for some services, particularly conversational services like speech and instant messaging. A counter is added to measure the mean delay for IP packets incurred within the eNodeB. Separate counters are provided per QCI which are particularly useful when the QCI is used by very few services and the packet sizes vary little. It is only practical to measure packet delays on the downlink.

In case of the eNodeB serving one or more RN, the packet delay includes both the internal processing delay at eNB) and UE/RN as well as the packet transferring delay on the radio link. As RN UE's packets need to be transferred via between E-UTRAN and RN while packets for UEs directly connected to eNB need to pass through only Uu interface, packet delay optimization mechanism may be different for RN UEs and eNB UEs. Therefore it is beneficial to have measurements on packet delay separately for packets transmitted between the eNodeB and UEs and for packets transmitted between the E-UTRAN and RNs.

DL packet drop rate

When a cell is heavily loaded congestion can take place. When congestion is not severe, the impact is typically the incurrance of additional delay for non-GBR radio bearers. However, when congestion is severe the eNodeB may be forced to discard packets. It is important for the operator to have visibility of packet discard so that corrective action can be instigated (for example, by adjusting admission control settings in the network). It is only practical to measure packet discards on the downlink. Packet discards on handover should not be included in the count.

PRB Usage

The resource utilisation, measured in terms of physical resource blocks (PRBs), is a useful measure of whether a cell is lightly loaded or not. Loading is a key input to network capacity planning and load balancing. Furthermore, when resource utilisation per QCI is reported the distribution of resources between different services can be estimated.

For a RN that requires subframe configuration, the RN can only be scheduled by the eNodeB within subframes configured for RN, while macro UE can be scheduled in any subframe. Therefore in certain scenario it may be possible that the PRB usage is different for the subframe configured for the RN and for any other subframe. For example, in case there are many RNs in the network and only a few UEs connected directly to the eNodeB, it may happen that the PRB usage in the subframe configured for RN is quite high, while the subframes used for UEs is low. Therefore it is beneficial to measure the PRB usage separately for RN and the total PRB usage. The total PRB usage includes the PRB usage for RN traffic and UE traffic, while the RN PRB usage includes only PRB usage for RN traffic.

Resource Full Utilisation

Resource congestion is a critical situation in the network that needs to be monitored closely in order to be assessed and addressed immediately (e.g. by expanding related resources). Measurements reflecting the time during which the resources are fully used are needed to properly assess the congestion. Congestion affects PRB so appropriate congestion measurements are needed.

Transport Resource Usage

Transport resource utilisation provides information on the overall traffic of an eNodeB with the rest of the network, together with information on the traffic of the individual cells it gives the ability to localise bottlenecks. On the other hand it is a key input for planning of timely expansion of transport (backhaul) resources in the network provides . Measurements enabling to track the transport resource utilisation are therefore useful.

Hardware Resource Usage

Hardware resource utilisation provides information on the overall load of an eNodeB, together with the information on the individual loads – it gives the ability to localise bottlenecks. On the other hand it is a key input for planning of timely expansion of hardware resources in the network. Measurements enabling to track the hardware resource utilisation are therefore useful.

Downlink Air interface packet loss rate

The downlink air interface packet loss can be directly compared with the PELR value of a QCI to see if the packet loss (over the air interface) aspect of quality of service is being met within the cell (see [12] for more details on PELR). On the downlink this measurement can be added to the congestion losses (see DL packet drop rate) to determine the total packet loss rate at the eNodeB. Consequently, the downlink useful bit-rate can be estimated by scaling the measurement of the downlink PDCP ingress bit-rate by $(1 - \text{DL packet drop rate}) (1 - \text{air interface packet loss rate})$.

In case of RN deployment the communication between the E-UTRAN and RN is going through the air interface. It is possible that the radio conditions are bad, which can lead also to high packet loss rate, which can contribute also whether the packet loss aspect of the quality of service is met or not. Therefore it is beneficial to have separate packet loss rate measurement for RN traffic and for the traffic connected directly to the eNodeB.

Uplink packet loss rate

The uplink air interface packet loss rate (per QCI) can be compared directly with the PELR defined for that QCI. An estimate of the uplink air interface packet loss may be provided by the 'Uplink PDCP SDU loss rate'. This uplink measurement is based on PDCP sequence numbers and cannot precisely measure the air interface losses. Any packets discarded by the UE within the protocol stack (i.e. at layer 2) are also counted since they will have been given a PDCP sequence number. Discards at layer 3 are not counted.

In case of RN deployment the communication between the E-UTRAN and RN is going through the air interface. It is possible that the radio conditions are bad, which can lead also to high packet loss rate, which can contribute also whether the packet loss aspect of the quality of service is met or not. Therefore it is beneficial to have separate packet loss rate measurement for RN traffic and for the traffic connected directly to the eNodeB.

RACH Usage

The RACH plays a vital role in the following procedures:

- Initial access from RRC_IDLE;
- Initial access after radio link failure;
- Handover requiring random access procedure;
- DL data arrival during RRC_CONNECTED requiring random access procedure;
- UL data arrival during RRC_CONNECTED requiring random access procedure;

Furthermore, the random access procedure takes two distinct forms:

- Contention based using a randomly selected preamble (applicable to all five events);
- Non-contention based using a dedicated preamble (applicable to only handover and DL data arrival).

In the use-case of RACH configuration optimization, received Random Access Preambles and a contention indicator are signalled across an OAM interface.

Monitoring of the preamble usage in a cell allows the operator to determine if the resources allocated to the RACH by the eNodeB are appropriate for the number of random access attempts. If the resources are underutilised then the operator may reconfigure the eNodeB (via CM) to allocate less resource to RACH thereby freeing up resource for other uplink transmissions. Alternatively, if the resources are heavily utilised then this is indicative of RACH congestion leading to increased latency for the procedures listed above. To this effect, measurements directly reflecting RACH congestion experienced by the eNodeB and by the UEs are useful.

The eNodeB can partition the RACH resource between dedicated preambles, randomly selected preambles in group A and randomly selected preambles in group B. This partitioning can be evaluated when usage measurements are made on each set separately.

To further monitor and analyze the latency of the procedures listed above created at the RACH level, the measurement of the number of RACH preambles sent per RACH attempt is useful.

RACH optimisation function optimises RACH related configurations to achieve minimizing of access delays and random access collision probability for all the UEs. eNB may request the UEs to report the number of attempts to access the network (numberOfPreamblesSent in TS 36.331 [8]). Based on the attempting number of random access of all the UEs, the eNB can know the distribution of RACH preambles sent by UEs and calculate the access probability (AP) of a cell accurately. The eNB may also request the UEs to report contention detected while attempting to access the network (contentionDetected in TS 36.331 [8]). Based on the estimated time per random access and the estimated contention level in the network, the eNB can estimate the access delay probability (ADP) of a cell.

A.6 Monitor of the number of connected users

The number of the connected users in each cell is valuable information for operators to know how many users are connecting to E-UTRAN per cell basis. This kind of information can help operator to tune the admission control parameters for the cell and to do load balancing between cells to ensure that the target percentage or number of users admitted achieve the target QoS.

A.7 Monitoring of interference situation

In the LTE radio technology interference has to be coordinated on the basis uplink and downlink i.e. in a coordinated usage of the UL resources (Physical Resource Blocks, PRBs) and DL Transmitted Power, which lead to improve SIR and corresponding throughput. These are achieved by means of mechanisms employing channel quality indicators in support of scheduling/radio resource allocation functions.

These RRM functions in the eNB require the setting of frequency / power restrictions and preferences for the resource usage in the different cells. Setting and updating these parameters is the task of a network optimisation (done by operator or automatically by SON).

Use cases for the related interference measurements are e.g. optimisation of ICIC related RRM functionality, the detection of long distance interferer and the interference due to spurious emissions of neighbour cells. The later case is assumed only in high load scenarios or insufficient ICIC functionality due to the fact that ICIC functionality would minimise interference autonomously if sufficient bandwidth is available.

The necessary measurements to identify and analyse the interference situation as input for optimisation tasks has to be defined.

A.8 Monitor of ARQ and HARQ performance

Reliable Packet Delivery is one of the important Performance factor for a better User experience. HARQ retransmissions at the MAC layer ensure reliable packet delivery

In addition, RLC can be configured to operate in acknowledged mode for those applications that need very low packet drops and can tolerate a slightly higher delay from RLC retransmissions.

If a MAC PDU is not delivered, HARQ takes care of retransmitting (upto a maximum configurable number). If all the retransmissions fail at MAC layer, and if RLC is configured to operate in acknowledged mode, RLC's ARQ mechanism will take care of any residual packet errors.

It is important to

- a) maintain the block error rate or packet error rate within tolerable limits
- b) ensure that HARQ retransmissions take care of most packet errors, instead of relying on RLC layer retransmissions (which would increase the delay).

So, it is important to monitor the performance of these schemes.

ARQ Performance if viewed at QCI level can help in monitoring the distribution for each of the services.

HARQ Performance if viewed at MCS (Modulation Coded Scheme) can help in monitoring the MCS Performance also.

A.9 Monitoring of RF performance

RF Performance reflects the cell loading levels and abnormal conditions.

In the Downlink, Power Resources are managed by the EUTRAN Cell(RAN).

More Power Resources may help in increasing the Capacity of the System. Hence, there the power resources could be effectively used to optimize the Capacity of the System.

Hence there is a need to keep monitoring the Power Resource Utilization in % and also in absolute terms.

Monitoring of the quality of RF signal in the cell is useful for the purpose of NW planning and overall service quality assessment. Measurements of Channel Quality Indicator (CQI) reported by UEs is a useful metric reflecting RF signal quality and service quality.

Timing advance measurements reflect the distance of the UE from the cell antenna. This information reflects the optimality of the cell antenna location with respect to the cell traffic and is useful in the NW planning process.

Monitoring interference, both uplink and downlink, is an important aspect of monitoring RF performance. For this purpose, monitoring of UL interference power is useful.

Interference signals in a number of different ways, including frequency, frequency band, direction of interfering signals, etc. can also be classified by System internal interference and External interference. By efficient frequency planning and careful

Selection of base station locations, the impact of interference signal can be effectively controlled within an acceptable scope. uplink interference disturbs the base station receiver. Once the base station receiver is compromised, it leads to receiving code errors for the whole base station and the site's entire service area is degraded including its network and service. Of course, customer satisfaction is negatively impacted. So it is very useful to monitor uplink interference of communication system to do network optimization.

A.10 Monitor of paging performance

In EUTRAN, Paging is under the control of the MME. When the MME wants to page a UE it has to page it in all cells that belong to the TA(s) to which the UE is registered.

The paging load per cell is an important measure for the operator as it allows the operator to properly dimension the resources for paging in the E-UTRAN Cell .

At an E-UTRAN Cell it makes sense to measure the number of discarded paging messages if this is due to some problem in the eNodeB, such as paging occasion overflow. In that scenario the periodicity of paging occasions can be reconfigured in order to ensure that all paging messages are transmitted by the eNodeB in the first available paging occasion, thereby avoiding paging delays and extended call setup delay.

Operators need to know when such an event occurs, in order to identify if the problem is at the E-UTRAN cell level or not.

In addition to discarded paging records measurement, it is important to know total paging records received so that discarded paging records ratio can be derived.

Total number of paging records received is important in the sense that, it may be fine if the discarded paging records are high if discarded paging records ratio is small. On the other hand, it may be problematic if discarded paging records are low, if discarded paging records ratio turn out to be high.

A.11 Use case of eNodeB processor usage

When network is very busy, for example on important holiday or emergency events happened, the traffic of one eNodeB is very heavy. So eNodeB processor usage measurements are very important to indicate eNodeB processor load capability. If eNodeB processor usage is too high, operator must take action to avoid network paralysis.

A.12 Monitor of simultaneous E-RABs

E-RAB is one of the EUTRAN Cell resources which are limited in number.

Hence along with the E-RAB Setup Success Rate, there is a need to keep monitoring the simultaneous E-RABs and having them at QCI level can help in learning the service distribution in time periods.

Average / Maximum simultaneous E-RABs, can help to know the average / maximum utilization of the resources in time periods, thereby helping to do necessary resource capacity engineering.

A.13 Monitoring of Mobility Robustness Optimization (MRO)

The following measurement is defined specifically to monitor the performance of handover optimisation:

- Number of handover failures for MRO.

The measurement examines 'handover related events' in which the serving cell of a RRC connected UE is changed. Handover related events are either normal successful handovers, or they are failures. Different failure modes are possible and the measurement provides counts for the occurrences of the failure modes related with MRO, 'too early', 'too late' and 'to wrong cell'. The detailed definitions of these modes are captured in [12]. The counters provide visibility of the mix of failure problems that the handover optimisation function is tackling.

In 'handover to wrong cell' case, an RLF occurs shortly after a successful handover from a source cell (cell A in Figure A.13-1) to a target cell (cell B in Figure A.13-1) or a HOF occurs during the handover procedure; the UE attempts to re-establish the radio link connection in a cell (Cell C in Figure A.13-1) other than the source cell and the target cell. (See 36.300 [12]).

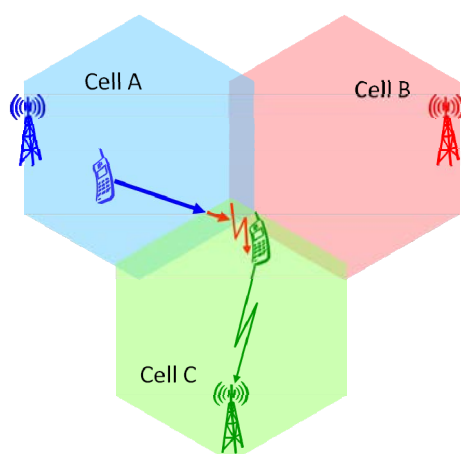


Figure A.13-1 Handover to wrong cell case

For the 'handover to wrong cell' case ($A \rightarrow B \rightarrow C$) above-mentioned, the handover parameters on Neighbour Relation $A \rightarrow B$, Neighbour Relation $A \rightarrow C$ or both may be problematic and need to be corrected. So the performance measurements for both Neighbour Relation $A \rightarrow B$ and Neighbour Relation $A \rightarrow C$ are needed for problem detection.

In addition to event-based (i.e. reactive) optimization of handover performance, a pro-active optimization is possible by monitoring the dynamics of handover triggering from UE measurement reports.

A.14 Monitor of BLER performance

The TB Error Rate in UL/DL can directly reflect the BLER, and has an influence on MCS selection and user throughput. It can be helpful to estimate the performance of radio resource management like radio resource scheduling in transport layer and be helpful in trouble shooting. Furthermore, they should be taken into account to optimize the system performance. To obtain TB Error Rate by calculating, the number of total and error TBs transmitted in a cell should be monitored.

A.15 Monitoring of common LAs of overlapping target RAT's coverage

For CS fallback in EPS, as defined in section 5.1A of 3GPP TS 23.272 [17], the fallback procedure is likely to be faster if the network can allocate a Location Area to the UE that is the LA of the overlapping target RAT's coverage. For this situation, the MME should avoid allocating TAI lists that span multiple Location Areas of the target RAT, this can be achieved by:

- configuring the E-UTRAN cell's TAI to align the LA boundary of the target RAT;
- the MME being configured to know which TAIs are within which LA; and
- the MME using the TAI of the current E-UTRAN cell to derive the LAI.

Also as specified in section 4.3.4 of 3GPP TS 23.272 [17], to facilitate the alignment of TA boundaries with LA boundaries, the E-UTRAN can gather statistics (from the inbound inter-RAT mobility events of all UEs) of the most common LAs indicated in the RRC signalling.

From such measurements per E-UTRAN cell basis, operators 1) can know the common LA(s) of the overlapping target RAT's coverage for each TA, which is useful to configure the TAI list within which LA boundary to MME, operators can also 2) detect the case that TA spans multiple LAs if different most common LA(s) is/are reported from the E-UTRAN cells in the same TA, operators may take actions to rectify it if needed.

A.16 Monitoring of Energy Saving

Beside monitoring of the energy consumption it is also important to differentiate if the cell unavailability or the failure of the RRC connection establishment happens because of Energy Saving as Energy Saving Management feature is by the Operator on purpose. Therefore such failures should be distinguishable from other network failures, therefore should be counted separately. With the separate cell unavailability counter due to Energy Saving makes it possible to deduct the cell downtime due to Energy Savings from the total cell outage.

A.17 Monitoring of RNReconfiguration

The purpose of RNReconfiguration related procedure is to configure/reconfigure the RN subframe configuration and/or to update the system information relevant for the RN in RRC_CONNECTED.

The system information and subframe configuration is very important for RN, but the RN does not need to apply the system information acquisition and change monitoring procedures, if configured with an RN subframe configuration. Upon change of any system information relevant to an RN, E-UTRAN provides the system information blocks containing the relevant system information to RNs with an RN subframe configuration via dedicated signalling using the *RNReconfiguration* message. This dedicated signalling replaces any stored system information acquired through the system information acquisition procedure.

Because the RN is semi-duplex, to avoid the transmission conflict between access link (between UE and RN) and backhaul link (between RN and DeNB), the subframe of RN is semi-statically assigned (see TR 36.814) and the configuration information is included in the RNReconfiguration message.

During the RN operation, failures of backhaul link will cause unsuccessful RN reconfiguration. In that case, RN will not get any response from DeNB. The defined performance counter will help to compute how many response messages are missing. Depending on this result, operators could easily make network planning to consider fix or optimize the backhaul link quality.

A.18 Monitoring of E-RAB setup for incoming HOs

The E-RAB needs to be established in the target cell during HO, the success or failure of E-RAB establishment in the target cell during HO results in if the services beared on the E-RABs can continue or not after HO, thus whether or not the E-RAB can be successfully established for incoming HO impacts the user experience.

The unsuccessful setup of E-RABs with different QCI could lead to different user experience, thus the E-RAB setup for incoming HOs needs to be monitored per QCI.

A.19 Use case of RSRP

E-UTRAN RSRP measurement is important for analyzing coverage probability and coverage balance of downlink. From the distribution of this measurement, the general coverage information can be learned. So that coverage hole can be found more easily by driving test. Much more measurement values with small granularity are necessary to analyze coverage probability for specific area, such as from ratio of the number of RSRP that is larger than or equal to threshold to the total number of it, So it is necessary to define RSRP measurement.

According to optimization experience and the transmission bandwidth requirement reduced, several granularity of this measurement is proposed. For $-120 \text{ dBm} \leq \text{RSRP} < -115 \text{ dBm}$, the granularity is 5dB, for $-115 \text{ dBm} \leq \text{RSRP} < -80 \text{ dBm}$, the granularity is 1dB, and for $-80 \text{ dBm} \leq \text{RSRP} < -60 \text{ dBm}$, the granularity is 2dB.

The measurement period should be preconfigured by EMS.

A.20 Use case of RSRQ

E-UTRAN RSRQ measurement can be used to calculate signal quality distribution. According to signal quality distribution and other measurements like AOA, UE Rx-Tx time difference, the general signal quality information of cells can be learned, so that interference heavy area can be found more easily by driving test. Also it can be used to evaluate user satisfaction to some extent. So it is necessary to define the RSRQ measurements.

In order to reduce the transmission bandwidth requirement, according to network optimization experience, 1dB granularity of measurement is enough.

A.21 Use case of UE power headroom

E-UTRAN UE power headroom measurement is important for analyzing UE power distribution, to learn whether the uplink signal strength can be increased or not. So it is very useful to do trouble shooting of coverage hole and coverage balance for uplink. It is also used to evaluate the power control performance and increase UE power headroom as possible with QoS is guaranteed for the purpose of energy saving. These questions are determined by the ratio of the number of larger or less than threshold to the total number of it and the threshold is configurable.

According to network optimization experience, the granularity of measurement 1dB is enough to do trouble shooting of coverage hole and evaluation of power control.

A.22 Use case of UE Rx–Tx time difference related measurements

UE Rx – Tx time difference measurement can be used to calculate distance distribution between UE and serving eNodeB. It is useful to analyze traffic distribution in geographic area and to do trouble shooting of extending coverage and blind coverage spot. The probability of extending coverage and blind coverage should be analyzed by the ratio of the number of UE Rx – Tx time difference that is larger than or equal to threshold to the total number of it. Threshold is configurable according to the cases to be analyzed, Cases includes dense urban area macro cell, suburban area macro cell and rural area cell. So it is necessary to define the UE Rx–Tx time difference related measurements.

For TDD mode, propagation distance of 1Ts is nearly 9.77m. According to optimization experience, several granularity of this measurement is proposed. Minimize granularity of 10Ts is enough to analyze distance distribution for near base station, namely UE Rx–Tx time difference is less than 200Ts. For UE Rx–Tx time difference is larger than 200Ts and less than 1000Ts, the corresponding propagation distance is from 1953m to 9766m, the granularity of 40Ts is enough to do trouble shooting of extending coverage. For UE Rx–Tx time difference is larger than 1000Ts and less than 2000Ts, the granularity is 200Ts. And for UE Rx–Tx time difference is larger than 2000Ts and less than 4096Ts, the granularity is 1048Ts.

A.23 Use case of AOA

E-UTRAN AOA value measurement can be used to calculate UE's direction distribution of coverage to optimize network coverage together with other measurements like RSRP, UE Rx-Tx time difference etc. So it is necessary to define E-UTRAN AOA value measurement.

According to network optimization experience, 5 degrees granularity of measurement is enough.

A.24 Monitoring of SCell scheduling on PUCCH in Carrier Aggregation

In the deployment scenarios for carrier aggregation as depicted in 3GPP 36.300 [12], the number of possible SCell per PCell can be multiple and not fixed. So the PUCCH resource for the SCell scheduling needs to be properly allocated, because:

- Over-dimensioned PUCCH causes high overhead and results in reduced UL throughput is (in general UL is not used efficiently);
- Under-dimensioned PUCCH will result in reduced DL throughput (if no PUCCH format 1bCS or format 3 ACK/NACK resource is available, PDSCH cannot be allocated by the PDCCH for the SCell(s) and the UE cannot be allocated resources on its SCell(s)).

Thus, the SCell scheduling success/blocking rate on PUCCH needs to be monitored for evaluation of control channel usage in CA. When needed OAM can also provide the guidance or take action to the eNB to optimize the PUCCH dimension for CA.

A.25 Evaluation of long inactivity timer

The services from the point of view the time between the newly successful RRC connection setup and the last RRC Connection Release can be divided into the two groups. First group is build from the services the time is quite long (tens of minutes or hours) while for the second group it is tens of seconds. Typical example of the service from the first group can be VoLTE call with a common characteristic that data transmission is accumulated into the time period the call is active without any long interruptions and sufficiently long period between the two consequent calls from the same UE. A second type of service can be web browsing with a common characteristic that data transmission is accumulated into the smaller time periods the service is active i.e. with long interruptions between data transmissions.

In the past operators had only option to set the inactivity timer commonly for all kind of services. This may lead to the situation that for the services from the first group UE had to spend ineffectively longer time in RRC Connected state which had negative impact on UE's battery live. On the other hand for the services from the second group the inactivity timer setting can be insufficient which then may lead to significant increase of the UE movements from RRC Idle to RRC Connected state.

Operators shall therefore accurately tune the inactivity timers to avoid some bottlenecks in the RRC Connection setup on one side and prolongation of the UE's battery life on the second side. Especially regarding the services where long inactivity timer applies operator needs to have an option to estimate how intended prolongation of the long inactivity timer is going to decrease the number of RRC Connection Setups on one side and prolong the UEs' state in RRC Connected state on second side, using the "Number of successful RRC connection setups in relation to the time between successful RRC connection setup and last RRC connection release".

Annex B (informative): Change history

Change history								
Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Cat	Old	New
Mar 2009	SP-43	SP-090143	--	--	Presentation to SA for information and approval	--	1.0.0	8.0.0
Jun 2009	SP-44	SP-090408	002	--	Add missing E-UTRAN measurement for paging discards at the eNodeB - Align with 36.304 and 32.426	F	8.0.0	8.1.0
Jun 2009	SP-44	SP-090290	001	--	Addition of eNodeB processor usage related measurements	B	8.1.0	9.0.0
Sep 2009	SP-45	SP-090542	004	--	Correction on the IP latency and additional SAE Bearers setup measurements	A	9.0.0	9.1.0
Sep 2009	SP-45	SP-090542	006	--	Alignment of PRB usage related measurements with 36.314	A	9.0.0	9.1.0
Sep 2009	SP-45	SP-090627	007	--	Add SAE Bearer number related measurements	B	9.0.0	9.1.0
Mar 2010	SP-47	SP-100035	010	--	Add RRC connection release as a PM counter	F	9.1.0	9.2.0
Mar 2010	SP-47	SP-100035	011	--	Introduction of handover failure PM counters for handover optimisation	F	9.1.0	9.2.0
Mar 2010	SP-47	SP-100035	012	--	Add a PM counter of RRC connection establishments per failure cause	F	9.1.0	9.2.0
Mar 2010	SP-47	SP-100036	008	--	Incorrect section numbering	D	9.2.0	10.0.0
Mar 2010	SP-47	SP-100036	009	--	Add TB related measurements	B	9.2.0	10.0.0
Jun 2010	SP-48	SP-100264	013	--	Editorial changes to clause References	D	10.0.0	10.1.0
Jun 2010	SP-48	SP-100259	022	--	Correct L3 messages in measurement definitions	A	10.0.0	10.1.0
Jun 2010	SP-48	SP-100412	018	--	Add IP Throughput measurements	A	10.0.0	10.1.0
Jun 2010	SP-48	SP-100262	015	--	Missing Measurement related to common LAs to support faster CS fallback in EPS	A	10.0.0	10.1.0
Jun 2010	SP-48	SP-100262	019	--	Add the missing reference of causes in HO measurements	A	10.0.0	10.1.0
Sep 2010	SP-49	SP-100488	023	--	Correction of intra-RAT HO measurements	A	10.1.0	10.2.0
Sep 2010	SP-49	SP-100489	024	--	Modification of E-RAB release related measurements	C	10.1.0	10.2.0
Sep 2010	SP-49	SP-100489	025	--	Addition of measurements for pagings received	B	10.1.0	10.2.0
Sep 2010	SP-49	SP-100493	026	--	Modifying RRC establishment failure and Cellunavailability measurements due to Energy Saving	C	10.1.0	10.2.0
Dec 2010	SP-50	SP-100878	030	1	Correcting L3 messages and cleanup	A	10.2.0	10.3.0
Mar 2011	SP-51	SP-110095	031	1	Apply the RRC connection setup related measurements to RN	B	10.3.0	10.4.0
Mar 2011	SP-51	SP-110095	032	2	Apply the RRC connection reestablishment related measurements to RN	B	10.3.0	10.4.0
Mar 2011	SP-51	SP-110095	033	1	Apply the E-RAB setup related measurements to RN	B	10.3.0	10.4.0
Mar 2011	SP-51	SP-110095	034	2	Apply the abnormal E-RAB release related measurements to RN	B	10.3.0	10.4.0
Mar 2011	SP-51	SP-110095	035	1	Addition of HO related measurements to RN	B	10.3.0	10.4.0
Mar 2011	SP-51	SP-110095	036	1	Apply the eNB measurements to DeNB as well	C	10.3.0	10.4.0
Mar 2011	SP-51	SP-110095	044	1	Adding measurements on power utilization	B	10.3.0	10.4.0
Mar 2011	SP-51	SP-110093	048	-	Change counter for RACH usage from 'Cumulative Counter' to 'Gauge'	A	10.3.0	10.4.0
Mar 2011	SP-51	SP-110095	053	1	Add measurements for maximum PRB usage	B	10.3.0	10.4.0
Mar 2011	SP-51	SP-110095	054	1	Add measurements for radio coverage	B	10.3.0	10.4.0
Mar 2011	SP-51	SP-110095	055	9	Add measurements for radio coverage, handover triggering, RACH performance	B	10.3.0	10.4.0
Mar 2011	SP-51	SP-	058	1	Add RRC connection setup and UE context release related	B	10.3.0	10.4.0

		110095			measurements of RN			
Mar 2011	SP-51	SP-110095	059	1	Add E-RAB release and modification related measurements of RN	B	10.3.0	10.4.0
Mar 2011	SP-51	SP-110095	060	-	Add inter-RAT HO related measurements of RN	B	10.3.0	10.4.0
Mar 2011	SP-51	SP-110095	061	-	Add cell level radio bearer QoS related measurements of RN	B	10.3.0	10.4.0
Mar 2011	SP-51	SP-110095	062	-	Add Radio resource utilization related measurements of RN	B	10.3.0	10.4.0
Mar 2011	SP-51	SP-110095	063	-	Add paging related measurements of RN	B	10.3.0	10.4.0
Mar 2011	SP-51	SP-110095	064	-	Add equipment resources related measurements of RN	B	10.3.0	10.4.0
Mar 2011	SP-51	SP-110095	065	2	Adding separate counters for Un link and Uu link L2 measurements in DeNB.	B	10.3.0	10.4.0
Mar 2011	SP-51	SP-110095	066	2	Add RNReconfiguration related measurements to DeNB - Align with RAN2 TS 36.331	B	10.3.0	10.4.0
Mar 2011	SP-51	SP-110098	067	1	Introduction of PM counters on distribution of RACH preambles sent	B	10.3.0	10.4.0
Mar 2011	SP-51	SP-110095	068	1	Add HO to RN in intro-eNB HO measurements	B	10.3.0	10.4.0
Mar 2011	SP-51	SP-110095	069	1	Exclude HOs from RN in inter-eNB HO measurements	C	10.3.0	10.4.0
Mar 2011	SP-51	SP-110094	071	2	Correct CSFB measurements to exclude inapplicable scenarios	A	10.3.0	10.4.0
May 2011	SP-52	SP-110287	074	-	Correct measurement of released active E-RABs	A	10.4.0	10.5.0
May 2011	SP-52	SP-110285	077	2	Remove the inconsistency with RAN wrt RNs	F	10.4.0	10.5.0
May 2011	SP-52	SP-110288	079	-	Correction of HO measurements names at EUTRAN level	A	10.4.0	10.5.0
Sep 2011	SP-53	SP-110634	081	2	Add missing measurements for unnecessary HOs for Inter-RAT MRO	B	10.5.0	11.0.0
Dec 2011	SP-54	SP-110707	0089	1	Distinguish trigger in MRO measurements of too late handovers	B	11.0.0	11.1.0
March 2012	SP-55	SP-120043	0093	-	Correction of E-RAB release related measurements	A	11.1.0	11.2.0
June 2012	SP-56	SP-120355	0106	1	Include path switch and HO in E-RAB release measurements	A	11.2.0	11.3.0
June 2012	SP-56	SP-120356	0109	--	Correction of IP throughput measurements	A	11.2.0	11.3.0
June 2012	SP-56	SP-120358	0110	2	Correction of E-RAB activity measurements used by Retainability KPI	F	11.2.0	11.3.0
June 2012	SP-56	SP-120358	0111	1	Add number of E-RABs by incoming HOs	B	11.2.0	11.3.0
Dec-2012	SP-58	SP-120790	0083	5	Statement for handover related measurements in CA	B	11.3.0	11.4.0
		SP-120790	0090	3	Add statement about applicability of measurements to CA	B		
		SP-120790	0094	3	Statement for CQI related measurements in CA	B		
		SP-120790	0114	3	Clarify measured object for E-RAB related measurements for CA	B		
June-2013	SP-60	SP-130268	0130	1	Addition of RSRP related measurements	B	11.4.0	12.0.0
			0131	1	Addition of RSRQ related measurements	B		
			0132	1	Addition of UE Power Headroom related measurements	B		
			0133	1	Addition of UE Rx-Tx time difference related measurements	B		
			0134	1	Addition of AOA related measurements	B		
Dec-2014	SP-66	SP-140799	0155	2	Add measurements on PUCCH usage in CA	B	12.0.0	13.0.0
Mar 2015	SP-67	SP-150061	0156	1	Enhance the HWC counters in MRO	B	13.0.0	13.1.0
Jun 2015	SP-68	SP-150314	0148	1	Add usage of measurements for EE	C	13.1.0	13.2.0
			0157	1	Add usage of measurements supporting EE coverage KPI	C		
Sep 2015	SP-69	SP-150415	0159	2	Add measurements on inactivity timer	B	13.2.0	13.3.0

History

Document history		
V13.3.0	March 2016	Publication