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Technical Report

3rd Generation Partnership Project;

Technical Specification Group Radio Access Network;

Study on RAN-centric data collection and utilization for LTE and NR

(Release 16)

** 

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Contents

Introduction [5](#__RefHeading___Toc14821231)

1 Scope [6](#__RefHeading___Toc14821232)

2 References [6](#__RefHeading___Toc14821233)

3 Definitions of terms, symbols and abbreviations [6](#__RefHeading___Toc14821234)

3.1 Terms [6](#__RefHeading___Toc14821235)

3.2 Symbols [7](#__RefHeading___Toc14821236)

3.3 Abbreviations [7](#__RefHeading___Toc14821237)

4 General [7](#__RefHeading___Toc14821238)

5 Use cases and solutions for RAN-centric data collection and utilization [7](#__RefHeading___Toc14821239)

5.1 Capacity and Coverage Optimization [7](#__RefHeading___Toc14821240)

5.1.1 Use case description [7](#__RefHeading___Toc14821241)

5.1.2 Solution description [8](#__RefHeading___Toc14821242)

5.1.2.1 Detection of Coverage and Capacity Issues [8](#__RefHeading___Toc14821243)

5.1.2.2 Possible actions to resolve detected issues [9](#__RefHeading___Toc14821244)

5.1.3 Conclusion [10](#__RefHeading___Toc14821245)

5.2 PCI selection [10](#__RefHeading___Toc14821246)

5.2.1 Use case description [10](#__RefHeading___Toc14821247)

5.2.2 Solution description [10](#__RefHeading___Toc14821248)

5.2.3 Conclusion [11](#__RefHeading___Toc14821249)

5.3 Mobility optimization [11](#__RefHeading___Toc14821250)

5.3.1 Use case description [11](#__RefHeading___Toc14821251)

5.3.2 Solution description [12](#__RefHeading___Toc14821252)

5.3.2.1 Connection failure due to mobility [12](#__RefHeading___Toc14821253)

5.3.2.2 Inter-system Unnecessary HO [14](#__RefHeading___Toc14821254)

5.3.2.3 Inter-system HO ping-pong [15](#__RefHeading___Toc14821255)

5.3.2.4 SN change failure in case of EN-DC, NGEN-DC, NE-DC and NR-DC [15](#__RefHeading___Toc14821256)

5.3.2.5 Successful HO Report [16](#__RefHeading___Toc14821257)

5.3.3 Conclusion [17](#__RefHeading___Toc14821258)

5.4 Load Sharing and Load Balancing Optimization [17](#__RefHeading___Toc14821259)

5.4.1 Use case description [17](#__RefHeading___Toc14821260)

5.4.2 Solution description [17](#__RefHeading___Toc14821261)

5.4.3 Conclusion [18](#__RefHeading___Toc14821262)

5.5 RACH Optimization [18](#__RefHeading___Toc14821263)

5.5.1 Use case description [18](#__RefHeading___Toc14821264)

5.5.2 Solution description [19](#__RefHeading___Toc14821265)

5.5.3 Conclusion [20](#__RefHeading___Toc14821266)

5.6 Energy Saving [20](#__RefHeading___Toc14821267)

5.6.1 Use case description [20](#__RefHeading___Toc14821268)

5.6.2 Solution description [21](#__RefHeading___Toc14821269)

5.6.3 Conclusion [21](#__RefHeading___Toc14821270)

5.7 Minimization of Drive Test (MDT) Use Cases [21](#__RefHeading___Toc14821271)

5.7.1 General [21](#__RefHeading___Toc14821272)

5.7.2 Use case description [22](#__RefHeading___Toc14821273)

5.7.2.1 Use case: Coverage Optimization via MDT [22](#__RefHeading___Toc14821274)

5.7.2.2 Use case: QoS verification via MDT [22](#__RefHeading___Toc14821275)

5.7.2.3 Use case: Indoor MDT improvement [22](#__RefHeading___Toc14821276)

5.7.2.4 Use case: Sensor data collection [23](#__RefHeading___Toc14821277)

5.7.3 Solution description [23](#__RefHeading___Toc14821278)

5.7.3.1 Measurements [23](#__RefHeading___Toc14821279)

5.7.3.2 MDT procedures [23](#__RefHeading___Toc14821280)

5.7.3.3 MDT activation in split RAN [25](#__RefHeading___Toc14821281)

5.7.3.3.0 General [25](#__RefHeading___Toc14821282)

5.7.3.3.1 Signalling activation [25](#__RefHeading___Toc14821283)

5.7.3.3.2 Management activation [25](#__RefHeading___Toc14821284)

5.7.3.4 MDT reporting in split RAN [26](#__RefHeading___Toc14821285)

5.7.3.5 MDT for dual connectivity [26](#__RefHeading___Toc14821286)

5.7.4 Conclusion [26](#__RefHeading___Toc14821287)

5.8 UE energy saving [27](#__RefHeading___Toc14821288)

5.8.1 Use case description [27](#__RefHeading___Toc14821289)

5.8.2 Solution description [28](#__RefHeading___Toc14821290)

5.8.3 Conclusion [28](#__RefHeading___Toc14821291)

5.9 Active Antenna System (AAS) Optimization [28](#__RefHeading___Toc14821292)

5.9.1 Use case description [28](#__RefHeading___Toc14821293)

5.9.2 Solution description [28](#__RefHeading___Toc14821294)

5.9.3 Conclusion [28](#__RefHeading___Toc14821295)

6 Measurement quantities, events and faults for collection and utilization [28](#__RefHeading___Toc14821296)

6.1 General [28](#__RefHeading___Toc14821297)

6.2 Measurement quantities [29](#__RefHeading___Toc14821298)

6.2.1 UE originated measurements [29](#__RefHeading___Toc14821299)

6.2.2 L2 measurement quantities [29](#__RefHeading___Toc14821300)

6.2.2.0 General [29](#__RefHeading___Toc14821301)

6.2.2.1 L2 measurements in TS 28.552 [29](#__RefHeading___Toc14821302)

6.2.2.2 RAN part of packet delay measurement [32](#__RefHeading___Toc14821303)

6.2.2.2.1 UL packet delay measurement [33](#__RefHeading___Toc14821304)

6.2.2.2.2 DL packet delay measurement [33](#__RefHeading___Toc14821305)

6.2.3 L1 measurement quantities (e.g. Timing Advance in RAR) [33](#__RefHeading___Toc14821306)

6.2.4 Sensor data for UE orientation/altitude to log in addition to location [33](#__RefHeading___Toc14821307)

6.3 Events and faults [34](#__RefHeading___Toc14821308)

6.3.1 RLF and access failure information [34](#__RefHeading___Toc14821309)

6.4 Conclusion [34](#__RefHeading___Toc14821310)

7 Conclusion [34](#__RefHeading___Toc14821311)

Annex A: Change history [35](#__RefHeading___Toc14821312)

Foreword

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

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

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where:

x the first digit:

1 presented to TSG for information;

2 presented to TSG for approval;

3 or greater indicates TSG approved document under change control.

y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

z the third digit is incremented when editorial only changes have been incorporated in the document.

# Introduction

A new SI "Study on RAN-centric data collection and utilization for LTE and NR" was approved for Release 16 at the 3GPP TSG RAN #80 meeting and updated in [2]. The study aims to investigate RAN-centric Data collection and utilization for NR and LTE.

# 1 Scope

The present document provides descriptions of use cases and solutions with regard to RAN-centric data collection and utilization and analysis of these solutions.

# 2 References

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

- References are either specific (identified by date of publication, edition number, version number, etc.) or non‑specific.

- For a specific reference, subsequent revisions do not apply.

- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

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

[2] 3GPP RP-182105: "Revised SID: Study on RAN-centric data collection and utilization for LTE and NR".

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

[4] 3GPP TS 28.552: "5G performance measurements".

[5] ETSI ES 203 228: "Environmental Engineering (EE); Assessment of mobile network energy efficiency".

[6] 3GPP TS 36.331: "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification".

[7] 3GPP TR 38.913: "Study on scenarios and requirements for next generation access technologies".

[8] 3GPP TS 36.314: "Evolved Universal Terrestrial Radio Access (E-UTRA); Layer 2 - Measurements".

[9] 3GPP TS 38.463: "NG-RAN; E1 Application Protocol (E1AP)".

# 3 Definitions of terms, symbols and abbreviations

## 3.1 Terms

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

## 3.2 Symbols

Void.

## 3.3 Abbreviations

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

AAS Active Antenna System

ANR Automatic Neighbour Relationship

BFD Beam Failure Detection

BFR Beam Failure Recovery

MDT Minimization of Drive Test

MLB Mobility Load Balancing

MRO Mobility Robustness Optimization

PCI Physical Cell Identifier

RLF Radio Link Failure

RLM Radio Link Monitoring

SON Self-Optimizing Network

# 4 General

Void

# 5 Use cases and solutions for RAN-centric data collection and utilization

## 5.1 Capacity and Coverage Optimization

### 5.1.1 Use case description

Coverage and Capacity Optimization (CCO) is one of the typical operational tasks to optimize the radio access network (RAN). CCO has been identified as a key use case for SON since LTE, which aims to provide the required capacity in the targeted coverage areas and to minimize the interference and maintain an acceptable quality of service in an autonomous way. There is a trade-off between coverage and capacity optimization, capacity enhancements are usually at the expense of service coverage degradations, and vice versa. There is a need to balance and manage the trade-off between the two.

CCO allows the system to periodically adapt to the changes in traffic (i.e. load and location) and the radio environment

by automatically adjusting coverage for the cells that serve a certain area for a particular traffic situation. Due to the introduction of beam based antenna structures the set of configurable antenna and RF parameters are multi-dimensional. It is very complex to find the mapping between network configurations with target coverage and capacity performance. To make it feasible, some kind of machine learning techniques could be utilized which will leverage on the data collected in the RAN network. The collected data could be UE measurements, performance measurements, events and other monitoring information, also taking into account beamforming and massive MIMO - related information. These inputs could help the operator firstly identify the coverage and capacity problems, for instance, coverage hole, weak pilot pollution, overshoot coverage and DL and UL channel coverage mismatch and further perform the coverage and capacity optimization.

Coverage holes with unbalanced DL and UL channel coverage require consideration. The concept of RLF reporting from UE to RAN node and corresponding analysis provide the means to identify coverage holes and separate them from mobility related RLF failures, but a more detailed analysis of the root cause of a coverage hole is needed for an efficient CCO algorithm to detect UL channel coverage holes. Providing knowledge about root cause of a coverage hole by more elaborated analysis in the RAN node can trigger the right countermeasures quicker and more reliably.

Active Antenna Systems (AAS) will be deployed widely in NR as well. Therefore, dynamic coverage configuration change function similar to LTE would be supported in NR CCO.

The use cases addressed by the CCO solution for NR can be classified as follows.

**Use case 1: Coverage problems**

This use case focuses on scenarios where the coverage of reference signals is sub-optimal, leaving the UE exposed to failures or degraded performance, e.g. when a coverage hole is found or where UL/DL disparity is encountered. It is worth noticing that MRO will take care of all types of failures due to wrong mobility settings within a network with good cell planning. That implies that CCO should address cases where the root cause of the problem is due to a bad coverage planning.

**Use Case 2: Capacity problems**

Within this class some cases were found where capacity within a cell or beam is saturated, resulting in one or more UEs being subject to failures or suboptimal performance. There are a number of reasons for such event, such as high demand of services which exceeds resources available in the cell/beam or poor radio conditions affecting a large share of served UEs (for example where a large number of UEs is at cell edge, causing high interference to other UEs and consuming large amounts of resources).

It is worth noticing that MLB will take care of load distribution via mobility and that such mobility load balancing is done mainly in inter frequency scenarios, i.e. where cross cell interference is not an issue. That implies that CCO should address cases where the root cause of the problem is due to serving UEs at cell/beam edge, where the "edge" is between cells/beams utilising the same resources.

### 5.1.2 Solution description

Solutions for CCO are based on the capability to adapt cell/beam coverage to achieve better system performance. Solutions can be generalized as made of two components:

- Detection of coverage and/or capacity issue

- Action to resolve the issue

Generally, there are two types of network coverage adjustment, i.e. long term cell RF parameters tuning and short term cell coverage switching among pre-configurations. The long term cell RF parameters tuning is usually hosted by OAM and relies on UE radio measurements, e.g. RSRP, RSRQ, call drops statistics, etc which collected by MDT or performance management function.

The short term cell coverage switch is implemented by NG-RAN node. The dynamic cell coverage configuration change function will be support by exchanging the cell coverage change information between two neighbouring NG-RAN nodes, including Cell Coverage State, Cell Deployment Status Indicator, and Cell Replacing Info. The LTE mechanism can be taken as a baseline.

### 5.1.2.1 Detection of Coverage and Capacity Issues

To detect coverage and capacity issues not only information about failure cases are needed but also information about successful events. For example, a sub-optimal coverage planning between neighbour cells may not always imply that UEs handing over between these cells are subject to RLFs. Nevertheless, the handover may be suboptimal and the UE may fail RACH access in the original target beam, while succeeding it in a different beam because there is a "gap" in coverage in the mobility area.

An initial list of information that would be needed to the CCO function to detect coverage and capacity issues would be the following:

- Per source cell/beam RS measurements from UEs:

This is useful to understand the signal strength of the serving RS and to check whether the serving cell coverage is sufficiently good or not.

- Per target(s) beam/cell RS measurement from UEs:

This is useful to understand the signal strength of neighbour cells/beams, which are potential mobility targets. With this information it is possible to understand if the coverage of serving cell and that of neighbour cells have excessive/sufficient/insufficient overlap, e.g. it helps deducing if DL coverage holes are in place.

- Information on failure events associated to source and target cells, e.g. UE measurements on source and target reference signals, e.g. SSBs, at the time of failure (likely included in RLF Reports).

This information is evidence of either wrong mobility setting or of coverage issues. The CCO function should correlate this information with other UE measurements to understand whether the failure is symptom of bad coverage planning, in which case a CCO action is needed, or if the failure is purely the symptom of bad mobility setting, in which case CCO should not react and leave functions like MRO to react instead.

- Information about RACH access:

- Number of RACH attempts made by UEs per Beam/Cell ID of a serving cell and of a target cell.

The RAN configures the UE to start RACH access for a given beam starting from a pre-set transmission power level and ramping up such power at every step, in a pre-set way. By knowing the number of RACH access attempts towards a beam the CCO function also knows the transmission power used by the UE per attempt and deduces potential UL coverage issues in case RACH does not succeed.

- Information about successful/failed RACH access together with the cell/beam ID where the access was attempted.

This information is essential to understand in which beams RACH access failed/succeeded. Together with number of attempts it helps building a map of UL coverage.

- UE measurements of DL RS of the beam/cell where RACH access is attempted.

This is needed to compare DL coverage vs UL coverage for a beam for which RACH access is attempted. Comparing this information with number of RACH attempts per beam and successful/failed RACH access per beam it is possible to understand if UL/DL coverage disparities exist.

- Interference measurements on a per UE basis (RSRQ):

- This information enables the CCO function to understand if UEs are subject to excessive interference. When used together with source and target RS measurement information it allows to understand whether UEs at cell border are subject to high interference. The CCO function at the RAN is also able to correlate this information with the resources utilized to serve cell edge UEs. The CCO function is therefore able to deliberate whether there is a need for cell/beam border change in order to ease the situation of capacity utilization and interference arising from UEs being served at cell/beam edge.

- Cell load and other performance information from the target cell and the neighbour cells:

- This information enables the CCO function to determine relative capacity situation between the target and the neighbour cells and e.g. identify potential candidate cells for coverage and capacity coordination.

### 5.1.2.2 Possible actions to resolve detected issues

**Solution 1:**

Once the CCO function has a good understanding of the coverage and capacity status of the cells/beams at its hosting RAN node and possibly at neighbouring nodes, the CCO function can trigger a corrective action to address such issue.

For the disaggregated gNB scenario, the gNB-CU should provide relevant information to the gNB-DU, leaving to the gNB-DU freedom to address such problem.

UL coverage optimization based on SUL may be supported by UE reporting of random-access (RA) attempts on SUL and NUL carriers. This may detect mismatch between rsrp-ThresholdSSB-SUL threshold and the actual SUL/NUL radio coverage, and the UE may report this to the network in order to re-configure the rsrp-ThresholdSSB-SUL threshold for better selection of SUL and NUL carriers by the UE.

An inter RAN node signalling solution to coordinate changes of coverage amongst RAN nodes should be specified. For that, an index based solution such as the one in LTE could be adopted, or in general a solution based on RAN nodes learning the coverage configuration of neighbour nodes and adapting accordingly.

**Solution 2:**

In case that the CCO function is hosted at OAM, the OAM can trigger a corrective action to address the CCO issue.

### 5.1.3 Conclusion

RAN3 has concluded the analysis of the CCO function and agreed that solutions in line with the description in the above clause can be moved to normative phase.

## 5.2 PCI selection

### 5.2.1 Use case description

Physical Cell Identifier (PCI) is assigned to each cell to help UE distinguish wireless signals of different cells. The selection of PCI is one of the first use cases that have been introduced in SON, in order to ensure that PCI collision does not happen or are minimized. In LTE, the eNB base the selection of its PCI either on a centralized or distributed PCI assignment algorithm. The centralized assignment works in a way that the eNB selects the specific PCI value sent to it by the OAM as its PCI, while the distributed PCI assignment is that the eNB selects a PCI value randomly from the restricted list of PCIs.

In NR, ultra-dense network is the key technology to meet the demand of future mobile data traffic, and there will be coexistence of macro cell in lower frequency and small cells in higher frequency (mmwave) in a certain area. For the sake of improving energy efficiency, those small cells may switch to sleep mode at any time. Those various cell changes will lead to serious challenges in PCI allocation and selection.

In NR, the PCI selection function should be applicable for split gNB architecture.

The study on the solutions for PCI selection in NR could focus on:

1) Definition of the information/data required to support PCI conflict discovery and selection.

2) Functionalities and procedures to support PCI selection, e.g. report by UE or exchange over the X2/Xn/F1 interface

3) PCI confusion resolution, without using CGI reading functionality (ANR).

Solutions of PCI selection in LTE and the mechanisms that have been specified in NR Rel-15 specification should be the baseline. There is a need to first evaluate whether the existing mechanisms is sufficient for PCI selection on NR.

### 5.2.2 Solution description

The NG-RAN node (non-split) bases the selection of its PCI either on a centralized or distributed PCI assignment algorithm.

In the split gNB architecture, there are several options for the PCI selection. A non-exhaustive list of possible option is reported below. Details about which option will be selected for normative specification will be provided during work item phase.

**Case 1: centralized PCI selection, OAM assigns a single PCI to each NR cell**

In this case, the OAM configures a single PCI value for NR cells in the DU. The DU sends the PCI of each serving cell to the CU during the F1 setup procedure.

- Option 1a: CU detects PCI conflict and indicates to OAM via DU. OAM assigns a new PCI.

In option 1, when the CU detects PCI conflict between NR cells within a DU or between neighbouring gNBs, it sends the PCI conflict indication to the DU. The DU reports the PCI conflict to the OAM. After that, the OAM will allocate a new PCI value for the DU.

- Option 1b: CU detects PCI conflict and indicates to OAM directly. OAM assigns a new PCI.

When the CU detects the PCI conflict between NR cells within a DU or between neighbouring gNBs, it sends the PCI conflict to OAM directly. And the OAM will allocate a new PCI value for the cell having PCI conflict and configure it to the DU.

**Case 2: Distributed PCI selection, OAM configures a list of PCIs to each NR cell**

In this case, the OAM signals a list of PCIs for each cell to the DU, and DU selects one from the list for each NR cell. The DU sends the selected PCI of each serving cell to the CU during F1 setup.

- Option 2a: CU detects PCI conflict and indicates to DU. DU reassigns a new PCI.

When the CU detects the PCI conflict, it sends the PCI conflict indication to the DU. In addition, the CU sends the PCIs of cells neighbouring to the cell subject to PCI update to the DU, or allowed PCIs, or non-allowed PCIs to the DU. The DU may restrict the PCI list considering the information suggested by CU. Based that, the DU reselects a new PCI value from the remaining list of the PCIs.

- Option 2b: CU detects PCI conflict and reassigns a new PCI.

When the CU detects the PCI conflict, the CU will select a new PCI value from the remaining list of the PCIs reported from the DU, and send the new PCI value to the DU in the gNB-CU configuration update procedure. This option needs the gNB-DU report the PCI list of each NR cell to the gNB-CU during F1 setup.

### 5.2.3 Conclusion

The following features and solutions are recommended to be specified for NR PCI selection function as part of a Rel.16 RAN-centric DCU WI:

- Centralized PCI assignment and distributed PCI assignment for non-split gNB and split gNB.

- The solution down-selection for split gNB case will be decided in normative phase.

## 5.3 Mobility optimization

### 5.3.1 Use case description

In LTE, Mobility Robustness Optimization (MRO) aims at detecting and enabling correction of following problems, which will deteriorate user experience and waste network resources:

- Connection failure due to intra-LTE or inter-RAT mobility;

- Unnecessary HO to another RAT (too early IRAT HO with no radio link failure);

- Inter-RAT ping-pong.

For connection failure due to intra-LTE or inter-RAT mobility, three kinds of failures were identified: too late HO, too early HO and HO to a wrong cell. The detection of the events is enabled by the RLF Indication and HO Report procedures. By analysing the report from UE and network side information, HO related parameters could be adjusted to resolve the detected problems.

For unnecessary HO to another RAT, the RAN node in the other RAT, may instruct the UE to continue to evaluate the received measurement reports with the coverage/quality condition received during the inter-RAT HO preparation phase and decide if an inter-RAT unnecessary HO report should be sent to the RAN node in the source RAT.

For inter-RAT ping-pong, the statistics regarding ping-pong occurrence may be based on evaluation of the UE History Information IE in the HANDOVER REQUIRED message. If the evaluation indicates a potential ping-pong case and the source eNB of the 1st inter-RAT handover is different than the target eNB of the 2nd inter-RAT handover, the target eNB may use the HANDOVER REPORT message to indicate the occurrence of potential ping-pong cases to the source eNB.

For NR, mobility optimization solution should also be introduced to detect and resolve the above problems. LTE should be taken as the baseline. Intra-system (5GS) intra/inter-RAT mobility and inter-system (5GS) inter-RAT mobility should be studied in the SI. Since new network architectures, e.g. MR-DC, CU-DU split, CP-UP separation and some new features, e.g. BWP, beam, etc, are introduced in NR, enhancements on the procedures and measurements are needed. For instance:

1) New information or measurement is defined and collected, e.g. besides cell level measurements, related beam IDs and beam measurements, as well as SUL information are also included in the RLF report, and/or HO Report.

2) Enhancement to F1/Xn/X2 to support mobility enhancement in CU/DU architecture, MR-DC.

### 5.3.2 Solution description

#### 5.3.2.1 Connection failure due to mobility

**1) Connection failure due to intra-system mobility**

**Failure event definition:**

- [Intra-system Too Late Handover] An RLF occurs after the UE has stayed for a long period of time in the cell; the UE attempts to re-establish the radio link connection in a different cell.

- [Intra-system Too Early Handover] An RLF occurs shortly after a successful handover from a source cell to a target cell or a handover failure occurs during the handover procedure; the UE attempts to re-establish the radio link connection in the source cell.

- Intra-system Handover to Wrong Cell] An RLF occurs shortly after a successful handover from a source cell to a target cell or a handover failure occurs during the handover procedure; the UE attempts to re-establish the radio link connection in a cell other than the source cell and the target cell.

**Detection mechanism:**

- [Intra-system Too Late Handover]  
There is no recent handover for the UE prior to the connection failure i.e. the UE reported timer is absent or larger than the configured threshold, e.g. Tstore\_UE\_cntxt.

- [Intra-system Too Early Handover]  
There is a recent handover for the UE prior to the connection failure i.e. the UE reported timer is smaller than the configured threshold, e.g. Tstore\_UE\_cntxt, and the first re-establishment attempt cell/the cell UE attempts to re-connect is the cell that served the UE at the last handover initialization.

- [Intra-system Handover to Wrong Cell]

There is a recent handover for the UE prior to the connection failure i.e. the UE reported timer is smaller than the configured threshold, e.g. Tstore\_UE\_cntxt, and the first re-establishment attempt cell/the cell UE attempts to re-connect is neither the cell that served the UE at the last handover initialization nor the cell that served the UE where the RLF happened or the cell that the handover was initialized toward.

**Impact to Xn interface:**

- Failure Indication message which is used to provide UE RLF Report from the NG-RAN node that collects the UE report to the last serving node.

- HO Report message which is used to indicate the failure events in case of too early HO or handover to wrong cell.

**Impact to NG interface:**

In case the UE re-connects to a cell that has no Xn interface with the last serving NG-RAN node, the UE RLF Report could also be transferred in NG interface via NG-RAN Node Configuration update message.

**Impact to UE:**

To support MRO for NR, UE RLF report should also be supported in NR. The following information should be included in UE RLF Report:

- The CGI of the last cell that served the UE (in case of RLF) or the target of the handover (in case of handover failure).

- The CGI of the cell towards which the UE wants to initiate re-establishment attempt.

- The CGI of the cell that served the UE at the last handover initialization.

- Time elapsed since the last handover initialization until the RRC connection failure.

- An indication whether the RRC connection failure was due to RLF or handover failure.

- C-RNTI allocated for the UE in the last serving cell.

- RLF trigger of the last RLF that was detected.

- Time elapsed from the RRC connection failure till RLF Report signalling.

- Handover type i.e. intra-system or inter-system handover should be included in both E-UTRAN and NR UE RLF Report.

- The radio measurements and measurements configurations. These can be listed as follow (subject to RAN2 checking):

- Information related to the Radio-link monitoring (RLM) on serving cell (where the RLF is detected) and on target cell (in case of handover failure)

- Beam measurements on RLM related resources i.e. measurement on reference signals (RS) such as:

- SSB

- CSI-RS

Measurements to be logged may be RSRP, RSRQ, SINR, Qout, Qin, etc.

- Information related to the beam failure detection (BFD) on serving cell (where the RLF is detected) and on target cell (in case of handover failure)

- Beam measurements on BFD related resources i.e. measurement on reference signals (RS) such as:

- SSB

- CSI-RS

Measurements to be logged may be at least RSRP, RSRQ, SINR, Qout, Qin, etc.

Note that BFD and RLM resources may be different from each other.

- Information related to the beam failure recovery (BFR) on the serving cell where the RLF happened and on target cell (in case of handover failure) including:

- Measurements performed on the list of the candidate beam-resources configured for BFR reason.

- Measurement on signals that were "not" listed in the candidate beam-resources list while the UE detects such signals with a quality above a certain beam suitability threshold.

- There measured signals can include:

- SSB

- CSI-RS

Measurements to be logged may be at least RSRP, RSRQ, SINR.

- Information on RRM measurements per beam on a serving cell (where RLF is detected) and on target cell (in case of handover failure)

- Beam level measurement for cell quality derivation

- Beam level measurement on at least one neighbour cell for cell quality derivation

- Beam level measurement on a cell the UE selects and performs reestablishment after RLF

- Measurement can be done on different RS types such as:

- SSB

- CSI-RS

- TRS, DMRS or any combination of these signals

- RACH related information:

- beam identity where RACH access was attempted during handover

- Number of RACH attempts for each RACH access attempt

- Logging sensor data, including UE orientation/altitude to log in addition to location, speed and heading (e.g. digital compass, gyroscope as well as barometer, etc.).

- UE speed state (low, mid, high) detected by UE as part of speed-based scaling procedure.

To support MRO between gNB and ng-eNB, UE RLF Report could be provided via different RAT, i.e.NR RLF Report could be included in E-UTRAN UE ULInformationResponse message. Similarly, E-UTRAN RLF Report could also be included in NR ULInformationResponse message.

**2) Connection failure due to inter-system mobility**

**Failure events definition**

- [Inter-system/ Too Late Handover] An RLF occurs after the UE has stayed in a E-UTRAN cell which connects with 5GC for a long period of time; the UE attempts to re-establish to an E-UTRAN cell which connects with EPC.

- [Inter-system/ Too Early Handover] An RLF occurs shortly after a successful handover from a E-UTRAN cell which connects with EPC to a target cell in a E-UTRAN cell which connects with 5GC; the UE attempts to re-establish to the source cell or to another E-UTRAN cell which connects with EPC.

**Detection mechanism**

- [Too Late Inter-system Handover]  
The connection failure occurs while being connected to an NG-RAN cell, and there is no recent handover for the UE prior to the connection failure i.e. the UE reported timer is absent or larger than the configured threshold, e.g. Tstore\_UE\_cntxt, and the first cell where the UE attempts to re-connect/re-establish is a E-UTRAN cell which connect with EPC.

- [Too Early Inter-system Handover]  
The connection failure occurs while being connected to an NG-RAN cell, and there is a recent inter-system handover for the UE prior to the connection failure i.e. the UE reported timer is smaller than the configured threshold, e.g. Tstore\_UE\_cntxt, and the first cell where the UE attempts to re-connect/re-establish and the cell that served the UE at the last handover initialization are both E-UTRAN cell which connect with EPC.

**Impact to NG interface:**

- To support the above too early inter-system handover detections, the NG-RAN node receiving the RLF INDICATION message may inform the E-UTRAN node over NG.

- The NG-RAN node receiving the RLF report could forward the report to the NG-RAN node that served the UE before the connection failure via Xn or NG interface.

#### 5.3.2.2 Inter-system Unnecessary HO

**Failure events definition**

UE is handed over from NG-RAN to other system (e.g. UTRAN) even though quality of the NG-RAN coverage was sufficient for the service used by the UE. The handover may therefore be considered as unnecessary HO to another system (too early Inter-system HO without connection failure)

**Detection mechanism**

To be able to detect the Unnecessary HO to another system, an NG-RAN may choose to put additional coverage and quality condition information into the HANDOVER REQUIRED message in the Handover Preparation procedure when an inter-system HO from NG-RAN to another system occurs. The RAN node in the other system, upon receiving this additional coverage and quality information, may instruct the UE to continue measuring the source system (NG-RAN) during a period of time, while being connected to another system (e.g. E-UTRAN), and send periodic or single measurement reports to the other system (e.g. E-UTRAN). When the period of time indicated by the source system (NG-RAN) expires, the RAN node in the other system (e.g. E-UTRAN), may evaluate the received measurement reports with the coverage/quality condition received during the inter-system HO procedure and decide if an inter-system unnecessary HO report should be sent to the RAN node in the source RAT (NG-RAN).

**Impact to NG/S1 interface:**

An inter-system unnecessary HO report should be sent from LTE system to the NR system.

#### 5.3.2.3 Inter-system HO ping-pong

**Failure events definition**

A UE is handed over from a cell in a source system (e.g. NG-RAN) to a cell in a target system different from the source system (e.g. E-UTRAN), then within a predefined limited time the UE is handed over back to a cell in the source system, while the coverage of the source system was sufficient for the service used by the UE. The event may occur more than once.

**Detection mechanism**

The statistics regarding ping-pong occurrence may be based on evaluation of the *UE History Information* IE in the HANDOVER REQUIRED message. If the evaluation indicates a potential ping-pong case and the source NG-RAN node of the 1st inter-system handover is different than the target NG-RAN node of the 2nd inter-system handover, the target NG-RAN node may use the HANDOVER REPORT message to indicate the occurrence of potential ping-pong cases to the source NG-RAN node.

**Impact to Xn interface:**

HO Report message which is used to indicate the inter-system ping-pong event.

#### 5.3.2.4 SN change failure in case of EN-DC, NGEN-DC, NE-DC and NR-DC

In case of MR-DC, e.g. EN-DC, NGEN-DC, NE-DC and NR-DC, the SN can be configured with SRB3, and can trigger the SN change autonomously. According to the specification TS 37.340 [3], the SCG failure includes multiple causes of SCG RLF, SN change failure, SCG configuration failure, SCG RRC integrity check failure, etc. i.e. the SN change failure can be detected by the UE as one kind of SCG failure. During the period of SN change, the UE may suffer SN change failure due to inappropriate parameter setting of the triggering condition, e.g. too late SN change, too early SN change and wrong SN change (to another SN).

SN change-related failures can be categorized as follows:

- Failures due to too late SN change triggering: an SCG failure occurs after the UE has stayed for a long period of time in the cell of the SN; the MN makes decisions for UE, making UE to establish the radio link connection in a different SN.

- Failures due to too early SN change triggering: an SCG failure occurs shortly after a successful SN change from a source SN to a target SN or a SN change failure occurs during the SN change procedure; the MN makes decisions for UE, making UE to re-establish the radio link connection in the source SN.

- Failures due to change to wrong SN triggering: an SCG failure occurs shortly after a successful SN change from a source SN to a target SN or a SN change failure occurs during the SN change procedure; the MN makes decisions for UE, making UE to establish the radio link connection in a SN other than the source SN or target SN.

The detection solution enabled by the RLF Indication and HO Report procedures can be reused, the corresponding messages may be signalled between the MN and SN, and/or among the involved SNs.

- In case of MN trigger SN change, MN can obtain the SCG failure information from UE directly when SCG RLF occurs.

- In case of SN trigger SN change, MN should inform the SN about the SN change failure to help SN adjust SN change related measurement event thresholds.

#### 5.3.2.5 Successful HO Report

The MRO function in NR could be enhanced to provide a more robust mobility via reporting failure events observed during successful handovers. A solution to this problem is to configure the UE to compile a report associated to a successful handover comprising a set of measurements collected during the handover phase, i.e. measurement at the handover trigger, measurement at the end of handover execution or measurement after handover execution. The UE could be configured with triggering conditions to compile the Successful Handover Report, hence the report would be triggered only if the conditions are met. This limits UE reporting to relevant cases, such as underlying issues detected by RLM, or BFD detected upon a successful handover event.

The availability of a Successful Handover Report may be indicated by the Handover Complete message (*RRCReconfigurationComplete*) transmitted from UE to target NG-RAN node over RRC. The target NG-RAN node may fetch information of a successful handover report via UE Information Request/Response mechanism. In addition, the target NG-RAN node could then forward the Successful Handover Report to the source NR-RAN node to indicate failures experienced during a successful handover event.

The information contained in the successful handover report may comprise:

- RLM related information

- RLM related timers (e.g. T310, T312)

- Measurements of reference signals used for RLM in terms of RSRP, RSRQ, SINR

- RLC retransmission counter

- Beam failure detection (BFD) related information

- Detection indicators and counters (e.g. Qin and Qout indications)

- Measurements of reference signals used in BFD in terms of RSRP, RSRQ, SINR

- Handover related information

- Measurements of the configured reference signals at the time of successful handover

- SSB beam measurements

- CSI-RS measurements

- Handover related timers (e.g. T304)

- Measurement period indication, i.e. measurements are collected at handover trigger, at the end of handover execution or just after handover execution

Upon reception of a Successful HO Report, the receiving node is able to analyse whether its mobility configuration needs adjustment. Such adjustments may result in changes of mobility configurations, such as changes of RLM configurations or changes of mobility thresholds between the source and the target. In addition, target NG RAN node, in the performed handover, may further optimize the dedicated RACH-beam resources based on the beam measurements reported upon successful handovers.

### 5.3.3 Conclusion

RAN3 has studied the mobility optimization function and has converged to the solution principles and description outlined above. RAN3 has concluded its study on mobility optimization and determined that the mobility optimization feature can be moved to normative phase. The details of the solution parts involving UE behaviour remain pending to RAN2 analysis.

The SN change failure optimization in case of EN-DC and MR-DC is concluded to be specified in the normative phase of this function.

## 5.4 Load Sharing and Load Balancing Optimization

### 5.4.1 Use case description

The objective of load sharing and load balancing is to distribute cell load evenly among cells or to transfer part of the traffic from congested cell, or to offload users from one cell or carrier or RAT to achieve network energy saving, This can be done by means of optimization of cell reselection/handover parameters and handover actions. The automation of such optimization can provide high quality user experience, while simultaneously improving the system capacity and also to minimize human intervention in the network management and optimization tasks.

Compared to LTE, NR new features, e.g. CU/DU split and CP-UP separation architecture, network slicing, and EN-DC/MR-DC should be considered in the load sharing and load balancing optimization in NR. Study on load sharing and balancing across DUs within one gNB is needed (load management over F1), as well as load sharing and balancing across CU-UPs within one gNB (E1 load management). It should be studied whether slicing level metrics e.g. slice level radio resource utilization and slice availability also need to be taken into account for the reselection/handover parameters and handover action optimization.

Both intra-RAT and inter-RAT load balancing scenarios should be supported. LTE is the baseline, studies for NR will focus on:

1) Definition of the data required the load sharing and load balancing;

2) Functionalities and actions required to support the load sharing and load balancing, e.g. load reporting architecture, adapting handover and/or reselection configuration.

### 5.4.2 Solution description

There are possible solutions that enable load management over X2, Xn, F1 and E1 interfaces. On X2 and Xn, the reported information should contain at least cell level load (e.g. resource utilization). Likewise, similar information is required from the gNB-DU to gNB-CU over F1 in case of disaggregated architecture. For E1, load information should also be provided from the gNB-CU-UP to the gNB-CU-CP.

Furthermore, which procedure (i.e. new, reuse of existing one) and the periodicity (i.e. periodic reporting, event-triggered) needs to be considered.

And indicative summary of the load related information discussed during the study phase is summarized in Table 5.4.2-1. More discussions may be needed during normative phase to specify the details of the metrics reported below.

Table 5.4.2-1: Load Related Information

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Load Category | Load Related Information | X2 | Xn | F1 | E1 |
| Cell Level | Composite Available Capacity (CAC) | X | X | X |  |
| Cell Level | Cell Level Load (DL/UL/SUL) | X | X | X |  |
| Cell Level | Cell Level Load per Slice |  | X | X |  |
| Cell Level | Cell Level Load per Band | X | X | X | X |
| Cell Level | PRB Usage for SUL | X | X | X |  |
| Cell Level | Number of RRC Connections | X | X |  |  |
| Beam Level | PRB Usage for SSBs | X | X | X |  |
| Beam Level | Composite Available Capacity (CAC) per SSB Beam | X | X | X |  |
| Hardware Level | HW Load Indicator | X | X | X | X |
| Hardware Level | CU-CP Hardware Load | X | X |  |  |
| Hardware Level | CU-UP Hardware Load | X | X |  | X |
| Hardware Level | CU Hardware Load (CU-CP+CU-UP) | X | X |  |  |
| Hardware Level | CU-UP (Hardware) Load per Slice |  |  |  | X |
| Hardware Level | CU-UP Max Number of DRB Supported |  |  |  | X |
| Hardware Level | DU Hardware Load |  |  | X |  |
| Hardware Level | DU DRB Capacity |  |  | X |  |
| Transport Level | TNL Load Indicator | X | X | X | X |

### 5.4.3 Conclusion

Load sharing and load balancing functions over X2, Xn, F1 and E1 interfaces should be specified in Release 16 normative phase. At least the following load related information should be specified. Whether the reporting mechanism supports both periodic and event-triggered procedures is for further decision during normative phase.

- Composite Available Capacity per cell (DL/UL), reported via X2, Xn and F1 interfaces

- Cell Level Load (DL/UL/SUL) reported via X2, Xn, and F1 interfaces

- TNL Load reported via X2, Xn, F1, and E1 interfaces

Further refinement on the above metrics, as well as an evaluation on whether these metrics are sufficient for the correct functioning of the load management function and whether they should be complemented with additional enhancements should take place during Release 16 normative phase.

Likewise, introduction of additional load information over X2, Xn, F1 and E1 interfaces is seen as potential enhancement on several areas and may be considered for specification in Release 16. Details to be further discussed during normative phase:

- Beam level load indication

- Hardware load related information

- Per slice/band level reporting

- For EN-DC case, the EN-DC X2 interface are enhanced to support load information report from SgNB to MeNB

## 5.5 RACH Optimization

### 5.5.1 Use case description

The RACH configuration has critical impacts on user experience and overall network performance. The RACH collision probability, and therefore access setup delays, data resuming delays from the UL unsynchronized state, handover delays, transition delays from RRC\_INACTIVE, and beam failure recovery delays are all affected by the RACH settings. In addition, performing RACH on the most suitable downlink beam is also important and will avoid unnecessary power ramping and failed RACH attempts. This is beneficial both for the network as well as for the attempting device; it allows to avoid unnecessary interference in the network and, also, reduce the experienced delay and UE energy consumption. In NR, a new feature allows UE to change RACH resource during a RACH procedure, which lead to more complex behaviour.

The setting of RACH parameters depends on a multitude of factors, e.g.:

- the uplink inter-cell interference from the Physical Uplink Shared Channel (PUSCH),

- RACH load (call arrival rate, HO rate, tracking area update, RRC\_Inactive transition rate, the request for Other SI, the beam failure recovery, traffic pattern and population under the cell coverage as it affects the UL synchronization states and hence the need to use random access),

- uplink (SUL) and supplementary uplink (SUL) imbalances,

- PUSCH load,

- the cubic metric of the preambles allocated to a cell,

- whether the cell is in high-speed mode or not,

- uplink (UL) and downlink (DL) imbalances.

The targets of RACH optimization are indicated as follows:

- Minimize access delays for the UEs under the coverage of popular SSBs

- Minimize the delays for the UEs to request the other SIs

- Minimize the imbalance of UEs access delays on uplink (UL) and supplementary uplink (SUL) channel

- Minimize the beam failure recovery delays for the UEs in RRC\_Connected.

- Minimize the failed/unnecessary RACH attempts on RACH resource before success.

Consequently, the RACH optimization function will attempt to automatically set several parameters related to the performance of RACH.

Automatic RACH parameter settings can be enabled by collecting the RACH report from UE and by PRACH parameters exchange between gNBs. The mechanism and content of information report/exchange for RACH optimization in LTE could be the baseline whereas taking NR new features. e.g. beam, SUL, etc into account.

### 5.5.2 Solution description

The setting of RACH parameters that can be optimized are:

- RACH configuration (resource unit allocation);

- RACH preamble split (among dedicated, group A, group B);

- RACH backoff parameter value;

- RACH transmission power control parameters.

As a minimum, RACH optimization is realized by UE providing RACH related information report to the NG RAN node, and by exchange of PRACH configuration of normal UL carrier and SUL carrier between NG RAN node.

For CU-DU architecture, gNB-DU should be allowed to report its RACH configuration per cell to the gNB-CU, and the gNB-CU should be allowed to signal the RACH configuration per served cell to neighbouring NG RAN nodes. This allows NG-RAN nodes to identify whether RACH configurations of neighbouring cells are optimized or whether changes are needed in order to achieve a better RACH coordination between neighbouring cells.

Upon receiving the polling message requesting RACH report, e.g. UE Information Request message, from the NG RAN node (potentially gNB-CU of the current serving cell), UE reports RACH information within a UE Information Response message. The gNB-CU and gNB-DU take into account the RACH report and other node information, to achieve an optimized RACH configuration.

The contents of the RACH information report comprises of the following (further check by RAN2 is needed):

- Indexes of the SSBs and number of RACH preambles sent on each tried SSB listed in chronological order of attempts

- The frequency (NR ARFCN) of tried SSBs

- The beam quality of each tried SSB (i.e. beam level measurement during RACH attempts such as BRSRP, BRSRQ, BSINR)

- Indication whether the selected SSB is above or below the rsrp-ThresholdSSB threshold

- Elapsed time from the last measurement prior to the beam selection time

- Number of RACH preambles sent on SUL

- Number of RACH preambles sent on NUL

- Total number of fallbacks between Contention Based RACH Access (CBRA) and Contention Free RACH Access (CFRA)Contention detection indication

The above RACH information report should also applied to the SN node for MR-DC case.

### 5.5.3 Conclusion

The following features and solutions are recommended to be specified for NR RACH optimization as part of a potential Rel.16 RAN-centric DCU WI:

- RACH optimization is supported by UE reported information and by PRACH parameters exchange over Xn between gNBs and F1 between gNB-CU and gNB-DU.

- UE RACH report (contents needs further check by RAN2 in normative phase).

- The PRACH parameters of normal UL carrier and SUL carrier are exchanged over Xn separately.

## 5.6 Energy Saving

### 5.6.1 Use case description

Mobile operators are increasingly aiming at decreasing power consumption in mobile networks to lower their operational expense (OPEX) with energy saving solutions. With the foreseen deployment of more number of network elements in NR, e.g. small base stations with massive MIMO in high-band, energy saving becomes even more urgent and challenging. Energy saving can be achieved through radiated power optimization on air interface (transmission power optimization and lean carrier design), enhanced hardware supporting different sleep mode and coordinated power optimization among different cells. One of the typical energy saving scenario is that capacity boosters are deployed under the umbrella of cells providing basic coverage, the capacity booster can be switched off when its capacity is no longer needed and to be re-activated on a need basis.

In Rel-15 NR WI, some functionality of energy saving has been supported, including cell activation/deactivation over Xn/X2/F1 interface, and peer eNB/gNB are informed by en-gNB/gNB owning the concerned cell about the activation/deactivation actions. In addition to that, NR new features, e.g. sparser RS and SS signals, URLLC, CU/DU architecture and MR-DC should be studied and their need assessed in the energy saving solutions in NR. Furthermore, to support more efficient 4G and 5G synergy, inter-system inter-RAT energy saving solutions should also be studied based on the use cases described as below.

The following use cases for R16 energy saving should be studied:

1) Inter-system inter-RAT energy saving

Scenario a) The gNB connects with 5GC to provide boost capacity, the LTE eNB connects with EPC to provide basic coverage. The NR capacity booster cells may be switched off. The LTE eNB is allowed to activate the dormant capacity booster NR cell.

2) Energy Efficiency of base stations

To calculate the energy efficiency of base stations, ETSI ES 203 228 ("Environmental Engineering (EE); Assessment of mobile network energy efficiency") defines the following high-level EE KPI:



In which Mobile Network data Energy Efficiency (EEMN,DV) is the ratio between the performance indicator (i.e. Data Volume DVMN) and the energy consumption (ECMN).

3GPP SA5 with ETSI TC EE have identified the list of existing 3GPP performance measurements to be used, per pre-5G radio access technology (GERAN, UTRAN, E-UTRAN), for the calculation of the EE KPI. It should be studied how to achieve the same measures for NG-RAN. .

### 5.6.2 Solution description

There is no further solution needed for intra-system energy saving.

1) Inter-RAT Inter-system energy saving solution:

The solution builds upon the possibility for the NG-RAN node owning a capacity booster cell to autonomously decide to switch-off such cell to dormant state and possibility for the eNB node owning non-capacity boosting cells to request an inter-system cell re-activation over the S1/NG interface.

The NR capacity booster cell can autonomously switch-off by the NG-RAN node based on its own cell load information or by O&M. The NG-RAN node indicates the switch-off action to the eNB over NG interface and S1 interface.

The eNB providing basic coverage may request a NR cell re-activation based on its own cell load information or neighbour cell load information, the switch-on decision may also be taken by O&M. The eNB requests a NR cell re-activation towards the NG-RAN node over the S1 interface and NG interface.

2) Energy Efficiency of base stations:

Data volume per site could be calculated by using the PDCP PDU data volume Measurement defined in TS 28.552, clause 5.1.3.6.1. These measurements calculate the UL and DL PDCP data volume for a gNB-CU-UP.

If it can be assumed that a site is served by one CU-UP, then these measurements could already provide the desired statistics to calculate the energy per bit per site.

When looking at future cases it could be plausible to assume that one CU-UP may serve gNB-DUs at different sites. In this case the measurements in TS 28.552 could be taken as reference to define new measurements, taken at gNB-DU, and measuring the PDCP data throughput incoming to and outgoing from a gNB-DU

### 5.6.3 Conclusion

Intra-system energy saving was completed in R15.

The following features and solutions are recommended to be specified for Energy Saving as part of a Rel.16 RAN-centric DCU WI:

- Inter-RAT Inter-system energy saving solution

- Solution for calculation of data volumes for the calculation of energy efficiency for a base station

## 5.7 Minimization of Drive Test (MDT) Use Cases

### 5.7.1 General

The general principles and requirements guiding the definition of functions for Minimization of drive tests are the following:

**MDT mode**

There are two modes for the MDT measurements: Logged MDT and Immediate MDT. There are also cases of measurement collection not specified as either immediate or logged MDT, such as Accessibility measurements. Logged MDT is supported by RRC\_INACTIVE and RRC\_IDLE UE state. LTE MDT measurements/failures consists the baseline for NR MDT. Apply the Logged MDT configuration, logged measurements and reporting procedures to RRC\_INACTIVE state.

**TRACE**

Management based and signaling based trace procedure in LTE can be reused in NG-RAN MDT. From RAN2 perspective both Management-based MDT & Signaling-based MDT can be either Logged MDT or Immediate MDT. For Signaling-based MDT in NR, the user consent is required as in LTE.

**Measurement quantities**

For Immediate MDT, the measurement quantities should consider both cell-level RSRP/RSRQ/SINR and BRSRP/BRSRQ/BSINR. For logged MDT, best beam index (SSB index) of the camped cell is supported as part of the logged MDT report.

**UE Measurements**

In order to limit the impact on UE power consumption and processing, the UE measurement logging will reply on the measurements that are available in R15 NR and existing in LTE MDT as baseline.

### 5.7.2 Use case description

#### 5.7.2.1 Use case: Coverage Optimization via MDT

The MDT data reported from UEs and the RAN may be used to monitor and detect coverage problems in the network. Coverage optimization use cases in LTE are the baseline for NR.

Some examples of use cases of coverage problem monitoring and detection are described in the following:

**-** Coverage hole

- Weak coverage

- Pilot Pollution

- Overshoot coverage

- Coverage mapping

- UL coverage

- Cell boundary mapping

#### 5.7.2.2 Use case: QoS verification via MDT

The MDT data reported from UEs and the RAN may be used to verify Quality of Service, assess user experience from RAN perspective, and to assist network capacity extension. QoS verification use cases in LTE are the baseline for NR.

Use cases are described in the following:

- Traffic Location: MDT functionality to obtain information of where data traffic is transferred within a cell.

- User QoS Experience: MDT functionality to assess the QoS experience for a specific UE together with location information.

#### 5.7.2.3 Use case: Indoor MDT improvement

The WLAN/Bluetooth measurement can be collected to improve positioning accuracy for indoor MDT. WLAN/Bluetooth measurement use cases of LTE are the baseline of NR.

#### 5.7.2.4 Use case: Sensor data collection

In addition to location and time information, UE orientation in a global coordinate system can be collected in MDT if the information is available. No additional measurement is required. Further details are in clause 5.7.3.2.

### 5.7.3 Solution description

#### 5.7.3.1 Measurements

The following measurements should be supported for MDT performance

- DL signal quantities measurement results for the serving cell and for intra-frequency/Inter-frequency/inter-RAT neighbour cells (logged MDT and immediate MDT)

- PHR (immediate MDT)

- Received Interference Power measurement (immediate MDT)

- Data Volume measurement separately for DL and UL (immediate MDT)

- Scheduled IP Throughput for MDT measurement separately for DL and UL (immediate MDT)

- Packet Delay measurement separately for DL and UL (immediate MDT)

- Packet loss rate measurement separately for DL and UL (immediate MDT)

- RSSI measurement by UE (logged MDT and immediate MDT, for WLAN/Bluetooth measurement)

- RTT measurement by UE (logged MDT and immediate MDT, for WLAN measurement)

#### 5.7.3.2 MDT procedures

The procedures of LTE MDT are the baseline of NR MDT.

- For immediate MDT: The network can collect data with/without the UE involvement in RRC\_CONNECTED. For example, the UE can report measurements to the RAN via periodical or event-triggered ways.

- For logged MDT: the network sends logged measurement configuration to the UE in connected mode, and then the UE collects measurements in RRC\_IDLE/INACTIVE. Upon UE restarting the RRC connection, the UE firstly sends available indicator(s) to the network, and then the network can command the UE to send the measurements:

- The release operation for logged measurement configuration in the INACTIVE UE is realized only by configuration replacement when the configuration is overwritten or by configuration clearance (due to logging duration expiry).

- For Logged MDT measurement collection for RRC INACTIVE UEs, the actual process of logging within the UE, takes place in RRC INACTIVE and continued in RRC IDLE.

- The logged measurement stored in UE during RRC INACTIVE and IDLE are kept for a given common period before they are deleted as in LTE MDT.

- MDT measurement reporting from RRC INACTIVE and IDLE is preceded by logs availability indicator to indicate logs availability.

- The best beam index (SSB index) of the camped cell is supported as part of the logged MDT report.

- Beam RSRP/RSRQ of the best beam of camped cell could be included in logged MDT report.

- Include the 'number of good beams' associated to the cells within the range (which is configured by network for cell reselection) of the R value of the highest ranked cell as part of the beam level measurements in the logged MDT report.

- The out-of-coverage detection and logging in NR can be configured to be independent of the periodical DL pilot strength logged measurements.

- For MDT in NR, UE can be configured to only perform the logging for out-of-coverage detection, i.e. UE is not required to log the DL pilot strength measurements if the configuration is only out-of-coverage detection.

- A new indicator is introduced per logged measurement information entry in order to informing of detection of any cell selection state as in Rel-15 LTE MDT.

- For RLF report and accessibility measurements, UE logs these measurements without the need for prior configuration by the network. Upon UE entering connected state, the UE firstly sends available indicator(s) to the network, and then the network can command the UE to send the measurements. The mechanisms of LTE RLF (Radio Link Failure) and CEF (Connection Establishment Failure) reporting are taken as baseline for 5G NR. The information included in LTE RLF and CEF reporting is taken as baseline for 5G NR.

- The use cases of NR accessibility measurements includes:

- The UE fails to send RRCSetupRequest, i.e. when timer T300 expires.

- The UE fails to send RRCResumeRequest/RRCResumeRequest1, i.e. when timer T319 expires.

- To address Coverage Optimization use case, RLF report and accessibility measurements are enhanced with:

- NR RLF Report can indicate the information that enable to differentiate DL and UL availability after RLF occurrence. NR RLF report is extended with a flag, where at least "no suitable cell is found" is indicated. There is no additional UE measurement requirement for this. When to set the flag can be discussed in WI phase.

- NR CEF Report is enhanced with further information elements expressing the number of failed connection setup attempts after RLF at least including the number and available location information. NR CEF Report is extended with "Number of connection failures per cell" field. The UE counts the number of CEFs that it has experienced within the last 48 hours.

- RACH failure information, if available, should be included in both RLF report and CEF report. Attempted SSB index can be indicated as part of RACH failure information.

- Include SSB related information consisting of SSB index and number of preambles sent for each tried SSB in the RACH information report.

- SS Block index, CSI-RS index for both of serving and neighbouring cells could be included in the NR RLF report.

- The mechanism of RRC resume failure reporting takes CEF reporting as baseline.

- The information included in the NR RRC resume failure reporting takes the information included in the 5G NR CEF reporting as baseline.

- CSI-RS index and the corresponding number of preambles sent for each tried beam carrying CSI-RS index can be included in the NR RLF report, if it is RACH procedure failure leading to the RLF.

- SSB index of the downlink beams of both serving cell and neighbour cells, and SUL/NUL carrier information can be included in the NR CEF reporting.

- for WLAN/Bluetooth measurement collection: procedure for LTE WLAN/Bluetooth measurement collection is taken as baseline. The procedure baseline in TS 36.331 [6] includes:

- Supporting WLAN/Bluetooth measurement collection for logged MDT, immediate MDT, RLF report and accessibility measurements.

- Supporting WLAN and Bluetooth name list configuration in order to only collect the measurements of operator deployed WLAN and Bluetooth.

- Supporting reporting WLAN ID, RSSI, RTT for WLAN measurements and reporting Bluetooth address, RSSI for Bluetooth measurement.

- For MDT continuity:

- Logged MDT continuity could span PLMNs within MDT PLMN list in NR.

- Logged MDT configurations and logging should be suspended if the validity time is not expired upon the change of RATs and systems, e.g. when cell reselection to/from NR. Different system mentioned here means different core networks.

- Signalling based immediate MDT could be propagated across PLMNs within MDT PLMN list in NR.

- Signalling based immediate MDT continuity could not be propagated across RATs, e.g. when handover to/from NR.

- In addition to location and time information, following sensor information can be collected if available:

- The uncompensated barometric pressure measurement if available can be included in the MDT report.

- NR MDT measurements can be tagged with information fields informing the network about UE speed.

- NR MDT measurements can be tagged with information fields informing the network about UE orientation in a global coordinate system.

- In Rel-16, UE includes the GNSS location information for Logged MDT, DL signal quantities measurement of Immediate MDT, RLF report, accessibility measurement and out-of-coverage logging, if the GNSS location information is available when the measurement was taken for the UEs with the GNSS receiver.

#### 5.7.3.3 MDT activation in split RAN

##### 5.7.3.3.0 General

Note: The solutions in this clause are pending progress in RAN2 and further discussions are needed in RAN3 in normative phase.

##### 5.7.3.3.1 Signalling activation

If the MDT measurement is initiated by the AMF, the AMF sends MDT measurement request to the CU-CP. The CU-CP may further decide which DU or which CU-UP to perform the MDT measurement. For some measurement, the CU-CP may need to split the measurement into different measurements performed in different nodes.



Figure 5.7.3.3.1-1: Signalling MDT Activation in split RAN

##### 5.7.3.3.2 Management activation

If the MDT measurement is initiated by the EM, the EM sends MDT measurement activation to the CU-CP. The CU-CP may further decide which DU or which CU-UP to perform the MDT measurement. For some measurement, the CU-CP may need to split the measurement into different measurements performed in different nodes.



Figure 5.7.3.3.2-1: Management MDT Activation in split RAN

#### 5.7.3.4 MDT reporting in split RAN

Void

#### 5.7.3.5 MDT for dual connectivity

- Immediate MDT configurations are supported for DC scenario.

- Logged MDT configurations can come from SN node in DC scenario.

- The existing MDT framework is the baseline for the SCG cells related MDT configuration.

- The triggers for MDT measurements associated to MCG and SCG are separate.

- MN-SN coordination is required for MDT measurements' configuration and reporting in DC framework.

- If SRB3 is not configured, SN related measurements are transmitted to MN via SRB1/2 and then forwarded to SN.

- If SRB3 is configured, MN related measurements are transmitted to MN via SRB1/2, SN related measurements are transmitted to SN via SRB3

### 5.7.4 Conclusion

This chapter of technical report presents the results of a study on MDT for NR. Multiple use cases for MDT have been identified, including coverage optimization, QoS verification via MDT, indoor MDT improvement and sensor data collection.

To address these use cases, logged MDT, immediate MDT and accessibility measurements for NR are recommended for normative work.

Several measurements are recommended to be supported for NR MDT, including DL signal quantities measurement results, PHR, Received interference power measurement, data volume measurement, scheduled IP throughput, packet delay measurement, packet loss rate measurement, RSSI and RTT for WLAN and Bluetooth.

The procedures for immediate MDT, logged MDT and accessibility measurements described in the present document are recommended to be specified. The procedures of LTE MDT are the baseline for NR. Several new procedures for NR should also be specified, including procedures for RRC INACTIVE, beam related measurements, RLF reporting, CEF reporting, WLAN/Bluetooth measurement collection, MDT continuity, sensor/GNSS location information collection and MDT configuration for DC scenario.

## 5.8 UE energy saving

### 5.8.1 Use case description

High-end mobile devices with 5G modem are expected to feature advanced components e.g. display, processors, graphic engine, etc. Added up, these render power management to be very challenging. In other words, power efficiency is critical for every single component, in particular for the modem itself, regardless of the power source used (e.g. battery capacity and technology).

Battery lifetime is an important criterion directly affecting user experience – no matter how good the other performance aspects of a device may be, if its battery lifetime is poor, user experience will be greatly impacted. To ensure a smooth migration from 4G to 5G, the battery lifetime should thus be, under similar criteria, on par or better using 5G than 4G.

Therefore, network and UE vendors have a common interest in ensuring that the 5G NR ecosystem is able to maximize battery lifetime for all its users in all conditions. This means network and UE ought to cooperate to ensure lower baseline power and maintain better efficiency with all data rates, as shown below.



Figure 5.8.1-1: UE power variation with data rate

3GPP has started an effort, i.e. power saving SI, to achieve this target. From the study, as shown on Figure 5.8.1-2, for different traffic types, roughly less than 36 % of the total power consumption occurs in sleep state (~RRC\_Idle mode). Said otherwise, reducing the power consumption in RRC\_Connected mode is the primary target. As the UE behavior in RRC\_Connected mode is controlled by the network, the joint role of the UE and the network to reduce power consumption in this state is clear.

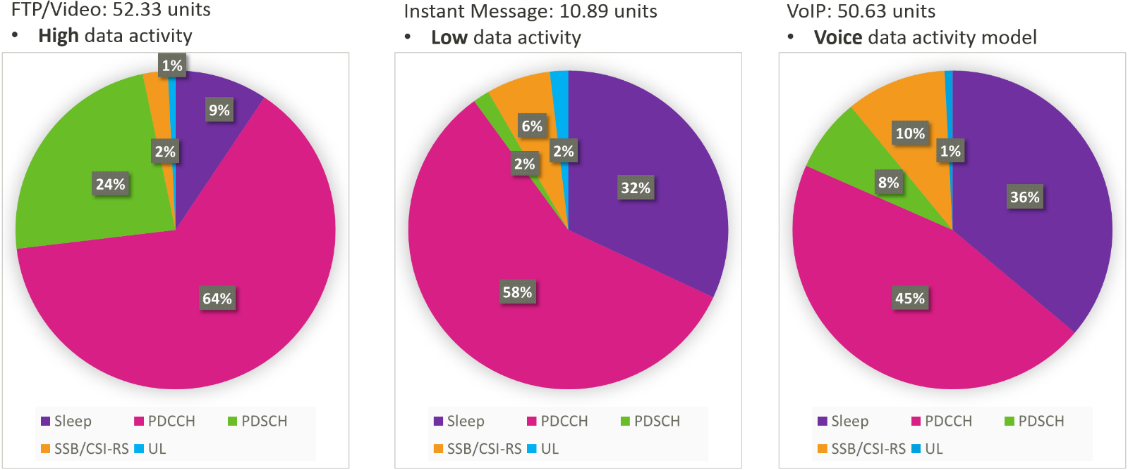


Figure 5.8.1-2: Power consumption distribution for different traffic models

For 5G/NR design UE energy efficiency is listed as one of the key performance indicators in 3GPP TR 38.913.

UE energy efficiency, which means the capability of a UE to sustain much better mobile broadband data rate while minimizing the UE modem energy consumption both qualitative and quantitative KPIs are required. Although only a qualitative KPI is captured now, it is also specified that based on the study, more detailed quantitative assessment can be performed.

Although it is possible to measure power consumption of a UE directly, such direct measurement is vendor dependent, i.e. only represent the power consumption of a specific UE model, and it can only represent UE part of the power saving efforts. There is a need for a UE energy efficiency (UE EE) measurement to represent the network part of the power saving efforts, which can be used for network optimization. R1 power consumption model agreed in TR 38.840 can be used as a baseline for such vendor-independent UE energy efficiency measurement. For network optimization, a reliable quantitative KPI UE energy efficiency (UE EE) should be consistent across UE vendors.

The objective of this use case is to measure the network performance on UE energy efficiency through RAN data collection, therefore, the effect of power saving features can be objectively reflected, which in the end leads to network and UE to work together to maximize UE battery lifetime and enhance user experience.

### 5.8.2 Solution description

Void

### 5.8.3 Conclusion

Void

## 5.9 Active Antenna System (AAS) Optimization

### 5.9.1 Use case description

Active Antenna System (AAS) is a key component of 5G radio access networks, and, through the exploitation of a beam-centric design, it enables extensive usage of beamforming techniques. Monitoring the radiated power of Downlink Control Channels in total and per beam allows operators to in-depth monitoring of radiation power emission requirement fulfilments.

RAN2 agreed to define the following NR measurements for the use case of Active Antenna System optimization:

1) Total NG-RAN Transmit Power for Control Channels (i.e. SSB/PDCCH/…)

2) NG-RAN Transmit Power per Beam for Control Channels (i.e. SSB/PDCCH/…)

NOTE: The power measurements are conditioned to the approval from RAN1 and RAN4.

### 5.9.2 Solution description

Void

### 5.9.3 Conclusion

Void

# 6 Measurement quantities, events and faults for collection and utilization

## 6.1 General

Void

## 6.2 Measurement quantities

### 6.2.1 UE originated measurements

Void

### 6.2.2 L2 measurement quantities

#### 6.2.2.0 General

The following measurements are to be introduced to NR:

- Received Random Access Preambles

- Number of users for RRC\_CONNECTED

- Number of users for RRC\_INACTIVE

For the following measurements, SA5 defined measurements are to be used instead of measurements defined in TS 36.314 [8]:

- 4.1.1 PRB usage

- 4.1.4 Packet Delay

- 4.1.5 Data loss

- 4.1.6 Scheduled IP Throughput

- 4.1.7 Scheduled IP Throughput for MDT

- 4.1.8 Data Volume

- 4.1.11 Distribution of scheduled IP throughput

It is not precluded that RAN2 introduce new or alternative measurements.

#### 6.2.2.1 L2 measurements in TS 28.552

RAN2 and RAN3 have analysed SA5 requirements for "Performance measurements for gNB" defined in TS 28.552 [4], and came to the following conclusion:

Table 6.2.2.1-1: Analysis on performance measurements for gNB in TS 28.552

| Clause | Title | Use case description | Views from RAN2 and RAN3 |
| --- | --- | --- | --- |
| 5.1.1 | Performance measurements valid for all gNB deployment scenarios |  | Measurements in this clause of TS 28.552 refer to the NRCellCU or NRCellDU Measurement Object Classes, while RAN3 has not defined gNB-CU and gNB-DU for non-split gNB deployment scenario. |
| 5.1.1.1 | Packet Delay | The average time it takes to get a response back on a HARQ transmission in the DL | Feasible from RAN2 point of view  Feasible from RAN3 point of view |
| 5.1.1.2 | Radio resource utilization | The total usage (in percentage), or distribution of usage.  - DL total PRB usage  - UL total PRB usage  - distribution of DL usage  - distribution of UL usage | Feasible from RAN2 point of view  Feasible from RAN3 point of view |
| 5.1.1.3 | UE throughput | UE throughput/volume:  - Average DL UE throughput in gNB  - Distribution of DL UE throughput in gNB  - Average UL UE throughput in gNB  - Distribution of UL UE throughput in gNB  - Volume of unrestricted DL UE data in gNB  - Volume of unrestricted UL UE data in gNB | Feasible from RAN2 point of view  Feasible from RAN3 point of view |
| 5.1.1.4 | RRC connection number | The mean number of users in RRC connected mode  - mean number of RRC conn  - max number of RRC conn | Feasible from RAN2 point of view  Feasible from RAN3 point of view |
| 5.1.1.5 | PDU Session Management | There are the following use cases:  - Number of PDU Sessions requested to setup  - Number of PDU Sessions successfully setup  - Number of PDU Sessions failed to setup | Suggest RAN3 to check the feasibility  Feasible from RAN3 point of view.  However, RAN3 thinks that these measurements need to also consider the PDU session to setup and failed to setup in the Initial Context Setup procedure. |
| 5.1.1.6 | Mobility Management | Measurements related to inter-gNB handovers | Suggest RAN3 to check the feasibility  Feasible from RAN3 point of view |
| 5.1.1.7 | TB related Measurements | TB related measurements | Feasible from RAN2 point of view  Feasible from RAN3 point of view |
| 5.1.1.8 | PDU session modifications | Measurements related to PDU session modifications | Suggest RAN3 to check the feasibility  Out of RAN3 scope. |
| 5.1.1.9 | PDU session releases | Measurements related to PDU session releases | Suggest RAN3 to check the feasibility  Out of RAN3 scope. |
| 5.1.1.10 | DRB Setup Management | There are the following use cases:  - Number of DRBs attempted to setup  - Number of DRBs successfully setup | Suggest RAN3 to check the feasibility  The trigger for the measurement on Number of DRB Successfully setup measurement in TS 28.522 seems badly defined. The following condition is not the main condition for successful DRB setup, although it is an essential part of the overall DRB setup process: *On transmission of INITIAL CONTEXT SETUP RESPONSE, PDU SESSION RESOURCE SETUP RESPONSE message containing the "PDU Session Resource Setup Response List" IE (see 3GPP TS 38.413 [18]) or by the PDU SESSION RESOURCE MODIFY REQUEST message from the gNB to the AMF.*  The main condition for successful DRB setup is listed later in the text, namely: *On receipt of RRCReconfigurationComplete message by the gNB to the UE, as the response to the transmitted RRCReconfiguration message that contains the DRBs to add.*  RAN3 asks SA5 to revise the triggering condition by taking the above comments into account. |
| 5.1.2 | Measurements related to end-to-end 5G network and network slicing | No measurements in this clause |  |
| 5.1.3 | Performance measurements valid for split gNB deployment scenario |  |  |
| 5.1.3.1 | Packet Loss Rate | The fraction of PDCP SDU packets which are not successfully received at gNB-CU-UP.  - UL packet loss rate  - UL F1-U packet loss rate  - DL F1-U packet loss rate | UL Packet loss rate with measurements maintained per gNB-CU-UP or per gNB-DU (termination point left to gNB implementation) is Feasible from RAN2 point of view.  Suggest RAN3 to check the feasibility  Feasible from RAN3 point of view.  Note 5 |
| 5.1.3.2 | Packet drop rate | The fraction of PDCP SDU packets which are dropped on DL.  - DL PDCP SDU Drop rate in gNB-CU-UP  - DL Packet Drop Rate in gNB-DU | Feasible from RAN2 point of view with understanding that measurements maintained per gNB-CU-UP or per gNB-DU  Feasible from RAN3 point of view.  Note 5 |
| 5.1.3.3 | Packet delay | There are the following use cases:  - average delay DL in CU-UP  - average delay on F1-U  - average delay DL in gNB-DU | Feasible from RAN2 point of view, with understanding that measurements maintained per gNB-CU-UP or per gNB-DU  Suggest RAN3 to check the feasibility  Feasible from RAN3 point of view, with the understanding that "NG-U ingress IP termination" should be read as "F1-U ingress IP termination".  Note 5 |
| 5.1.3.4 | IP latency measurements | IP latency DL in gNB-DU | Suggest RAN3 to check the feasibility  Feasible from RAN3 point of view  Note 5 |
| 5.1.3.5 | UE context release | There are the following use cases:  - UE context release request (gNB-DU initiated)  - Number of UE context release request (gNB-CU initiated) | Suggest RAN3 to check the feasibility  Feasible from RAN3 point of view |
| 5.1.3.6 | PDCP data volume measurements | There are the following use cases:  - PDCP PDU data volume Measurement  - PDCP SDU data volume Measurement | Feasible from RAN2 point of view  Feasible from RAN3 point of view  Note 5 |

Note 1: It is noted that the current table is based on TS 28.552 v16.0.0, and there may be more measurements due to SA5 progresses.

Note 2: The table starts with the reference to clause 5.1.1 "Performance measurements valid for all gNB deployments". Given the generic approach that RAN2 has no insight into F1 (and its termination points), measurements feasibility by RAN2 has not been made for all possible deployments (e.g. but with the assumption that measurements are maintained per gNB, or gNB-CU or per gNB-DU).

Note 3: Currently, for some measurements defined in TS 28.552, they are defined per mapped 5QI level (a single 5QI mapped to a DRB). From RAN2 point of view, mapping between 5QI and DRB in NR might be many to one, so there may be alternative ways to do the measurement, e.g. perform measurements by DRB level. RAN2 understanding is that all QoS flows mapped to one DRB get the same QoS treatment.

Note 4: RAN3 clarifies that the definition of "Mapped 5QI" in TS 28.552 is in line with RAN3 specifications. Namely, there is a one to one relation between the 5QI assigned to a DRB to be setup (i.e. Mapped 5QI) and the DRB itself. However, there could be many QoS flows, each with individual QoS Flow Level QoS Parameters (including one 5QI), mapped to one DRB.

Note 5: The "UL PDCP SDU Loss Rate", the "UL F1-U Packet Loss Rate", the "DL PDCP SDU Drop rate in gNB-CU-UP", the "Average delay DL in CU-UP", the "Average delay on F1-U", the "DL PDCP PDU Data Volume", the "UL PDCP PDU Data Volume", the "DL PDCP SDU Data Volume" and the "UL PDCP SDU Data Volume" require collection on a per mapped 5QI by the gNB-CU-UP. The latter is not possible according to the current version of TS 38.463, due to the mapped 5QI not being signalled from gNB-CU-CP to gNB-CU-UP. However, RAN3 has agreed to include such information in opportune signalling from gNB-CU-CP to gNB-CU-UP in next meeting, hence RAN3 concludes that these measurements can be considered feasible for Release 15 gNB-CU-UPs.

Note 6: For RRC connection number, RAN2 common understanding is that it is not part of L1/L2 measurement.

#### 6.2.2.2 RAN part of packet delay measurement

Packet delay includes RAN part of delay and CN part of delay. This study only covers RAN part of the packet delay.

The RAN part of DL and UL packet delay is measured by gNB and UE at DRB level, respectively. In reporting to TCE, the delay may be provided to QoS flow level by gNB with the assumption that all QoS flows mapped to one DRB get the same QoS treatment.

#### 6.2.2.2.1 UL packet delay measurement



Figure 6.2.2.2.1-1: RAN part of UL delay

As shown in figure 6.2.2.2.1-1, RAN part (T2-T1) of the UL delay is defined as the delay from packet entering the UE's PDCP upper SAP to leaving gNB's PDCP upper SAP. It can be separated into D1 and D2:

- D1 is the PDCP queuing delay in the UE, including the delay from packet arrival at PDCP upper SAP until the UL grant to transmit the packet is available, which has included the delay the UE gets resources granted (from sending SR/RACH to getting first grant). D1 is invisible to the network and should be measured by the UE.

- D2 is the rest of the delay, including HARQ (re)transmission delay, RLC delay, F1 delay\* and PDCP re-ordering delay in gNB. Separate measurement associated to over-the-air delay in UL will be introduced, and it is defined as the average time between the time of sending the successful HARQ feedback to the time of scheduling grant in UL for the UE.

Note: The measurements "average delay DL in CU-UP" and "average delay on F1-U" in the Table 6.2.2.1-1 could be used.

The RAN part of UL delay is measured by the following mechanism:

- UE measures D1 and reports the average of D1 to gNB in RRC;

- gNB measures the D2 and derives UL delay as D1+D2.

#### 6.2.2.2.2 DL packet delay measurement

RAN part of the DL delay is measured by gNB by DRB level. For arrival of packets the reference point is PDCP upper SAP. For successful reception the reference point is MAC lower SAP. It includes average delay in DL (e.g. average delay in CU-UP, average delay on F1-U and average delay DL in gNB-DU)\*. The delay may be converted to QoS flow level by gNB with the assumption that all QoS flows mapped to one DRB get the same QoS treatment.

Note: The measurements "average delay DL in CU-UP" and "average delay on F1-U" in the Table 6.2.2.1-1 could be used.

### 6.2.3 L1 measurement quantities (e.g. Timing Advance in RAR)

Void

### 6.2.4 Sensor data for UE orientation/altitude to log in addition to location

Void

## 6.3 Events and faults

### 6.3.1 RLF and access failure information

Void

## 6.4 Conclusion

The feasibility of L2 measurements in TS 28.552 have been checked in TR 37.816. The following feasible L2 measurements are recommended to be supported in NR in context of RAN-centric data collection:

- PRB usage

- Packet Delay

- Data loss

- Scheduled IP Throughput

- Scheduled IP Throughput for MDT

- Data Volume

- Distribution of scheduled IP throughput

for which the definitions in TS 28.552 apply.

In addition, new definitions for RAN part of packet delay measurement, alternative end user throughput measurement, received random access preambles, number of UEs should be introduced in NR. It is not precluded that RAN2 introduce new or alternative measurements.

# 7 Conclusion

RAN3 conclusions

The following SON features are recommended by RAN3 to be specified in normative phase:

- Capacity and Coverage Optimization

- PCI Selection

- Mobility Optimization

- Load Sharing and Load Balancing Optimization

- RACH Optimization

- Energy Saving

Recommendations for each feature are described in the dedicated conclusion section for each use case.

RAN2 conclusions

MDT and L2 measurements are recommended by RAN2 to be specified in normative phase, detailed recommendations are described in the dedicated section for MDT and measurements.

Annex A:  
Change history

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Change history** | | | | | | | |
| **Date** | **Meeting** | **Tdoc** | **CR** | **Rev** | **Cat** | **Subject/Comment** | **New version** |
| 2018-10-8 | RAN3 #101bis | R3-186031 |  |  |  | First Skeleton provided | 0.0.0 |
| 2018-10-11 | RAN3 #101bis | R3-186226 |  |  |  | Skeleton revised | 0.0.1 |
| 2018-10-13 | RAN3 #101bis | R3-186264 |  |  |  | Agreed TR skeleton | 0.0.2 |
| 2018-10-26 | RAN3 #101bis | R3-186268 |  |  |  | Included agreed TP in R3-186227 | 0.1.0 |
| 2019-03-28 | RAN3 #103 |  |  |  |  | Included agreed TP in R3-191064 | 0.2.0 |
| 2019-04-25 | RAN3 #103bis and RAN2 #105bis | R3-192188 |  |  |  | Included agreed TPs in R3-192130, R3-192136, R3-192180, R3-192181, R2-1904830, R2-1904321, R2-1905197, R2-1905229 | 0.3.0 |
| 2019-5-22 | RAN3#104 and RAN2 #106 | R3-193283 |  |  |  | Included agreed TPs in R2-1905924, R2-1908147, R2-1907694, R2-1908143, R2-1908145, R2-1908162, R2-1908148, [R3-192544](../../../../../../../CMRI%20work/2019%20projects/3GPP/RAN3%20%23104/RAN3_104_agenda_with_Tdocs20190517_EOM/Inbox/R3-192544.zip), R3-193185, [R3-193184](../../../../../../../CMRI%20work/2019%20projects/3GPP/RAN3%20%23104/RAN3_104_agenda_with_Tdocs20190517_EOM/Docs/R3-193184.zip), [R3-193186](../../../../../../../CMRI%20work/2019%20projects/3GPP/RAN3%20%23104/RAN3_104_agenda_with_Tdocs20190517_EOM/Docs/R3-193186.zip), [R3-193187](../../../../../../../CMRI%20work/2019%20projects/3GPP/RAN3%20%23104/RAN3_104_agenda_with_Tdocs20190517_EOM/Inbox/R3-193281.zip), [R3-193188](../../../../../../../CMRI%20work/2019%20projects/3GPP/RAN3%20%23104/RAN3_104_agenda_with_Tdocs20190517_EOM/Docs/R3-193188.zip), [R3-193189](../../../../../../../CMRI%20work/2019%20projects/3GPP/RAN3%20%23104/RAN3_104_agenda_with_Tdocs20190517_EOM/Docs/R3-193189.zip), [R3-193190](../../../../../../../CMRI%20work/2019%20projects/3GPP/RAN3%20%23104/RAN3_104_agenda_with_Tdocs20190517_EOM/Docs/R3-193190.zip), [R3-193247](../../../../../../../CMRI%20work/2019%20projects/3GPP/RAN3%20%23104/RAN3_104_agenda_with_Tdocs20190517_EOM/Docs/R3-193247.zip), [R3-193246](../../../../../../../CMRI%20work/2019%20projects/3GPP/RAN3%20%23104/RAN3_104_agenda_with_Tdocs20190517_EOM/Docs/R3-193246.zip), [R3-193249](../../../../../../../CMRI%20work/2019%20projects/3GPP/RAN3%20%23104/RAN3_104_agenda_with_Tdocs20190517_EOM/Docs/R3-193249.zip) | 0.4.0 |
| 2019-06 | RAN #84 |  |  |  |  | Version for one-step approval | 1.0.0 |
| 2019-07 | RAN #84 |  |  |  |  | TR is approved by RAN plenary | 16.0.0 |