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TECHNICAL SPECIFICATION

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Contents

Foreword

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

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should indicates a recommendation to do something

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need not indicates permission not to do something

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will indicates that something is certain or expected to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

will not indicates that something is certain or expected not to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

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might not indicates a likelihood that something will not happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

In addition:

is (or any other verb in the indicative mood) indicates a statement of fact

is not (or any other negative verb in the indicative mood) indicates a statement of fact

The constructions "is" and "is not" do not indicate requirements.

1 Scope

The present document specifies concepts, use cases, requirements and solutions for the energy efficiency assessment and optimization for energy saving of 5G networks.

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

[3] ETSI ES 202 336-1 V1.2.1: "Environmental Engineering (EE); Monitoring and Control Interface for Infrastructure Equipment (Power, Cooling and Building Environment Systems used in Telecommunication Networks) Part 1: Generic Interface".

[4] ETSI ES 202 336-12 V1.1.1: "Environmental Engineering (EE); Monitoring and control interface for infrastructure equipment (power, cooling and building environment systems used in telecommunication networks); Part 12: ICT equipment power, energy and environmental parameters monitoring information model".

[5] 3GPP TS 28.550: "Management and orchestration; Performance assurance".

[6] 3GPP TS 28.531: "Management and orchestration; Provisioning".

[7] 3GPP TS 28.545: "Management and orchestration; Fault Supervision (FS)".

[8] 3GPP TS 32.432: "Telecommunication management; Performance measurement: File format definition".

[9] 3GPP TS 32.435: "Telecommunication management; Performance measurement; eXtensible Markup Language (XML) file format definition".

[10] 3GPP TS 32.436: "Telecommunication management; Performance measurement: Abstract Syntax Notation 1 (ASN.1) file format definition".

[11] 3GPP TS 28.541: "Management and orchestration; 5G Network Resource Model (NRM); Stage 2 and stage 3".

[12] 3GPP TS 38.401: "NG-RAN; Architecture description".

[13] 3GPP TS 38.300: "NR; Overall description; Stage-2".

[14] 3GPP TR 37.816: "Study on RAN-centric data collection and utilization for LTE and NR".

[15] 3GPP TS 28.552: "Management and orchestration; 5G performance measurements".

[16] 3GPP TS 28.532: "Management and orchestration; Generic management services".

[17] 3GPP TS 32.551: "Energy Saving Management (ESM); Concepts and requirements".

[18] 3GPP TS 28.554: "Management and orchestration; 5G end to end Key Performance Indicators (KPI)".

[19] ETSI GR NFV-IFA 015 V3.4.1 (2020-06): "Network Functions Virtualisation (NFV) Release 3; Management and Orchestration; Report on NFV Information Model".

[20] ETSI GR NFV 003 V1.6.1 (2021-03): "Network Functions Virtualisation (NFV); Terminology for Main Concepts in NFV".

[21] 3GPP TS 28.530: " Management and orchestration; Concepts, use cases and requirements".

[22] 3GPP TS 28.312: "Management and orchestration; Intent driven management services for mobile networks".

[23] ETSI ES 202 706-1 V1.7.1 (2022-08): "Environmental Engineering (EE); Metrics and measurement method for energy efficiency of wireless access network equipment; Part 1: Power consumption - static measurement method".

[24] 3GPP TS 28.530: " Management and orchestration; Concepts, use cases and requirements".

[25] ETSI GS NFV-IFA 027 (V4.3.1) (2022-06): "Network Functions Virtualisation (NFV) Release 4; Management and Orchestration; Performance Measurements Specification".

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

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].

Candidate cell: cell which can provide coverage when the original cell goes into energySaving state.

energySaving state: state in which a cell or network function is powered-down for energy saving purposes.

NOTE 1: In energySaving state, the cell or network function is still controllable.

NOTE 2: Void.

notEnergySaving state: state when no energy saving is in progress.

NOTE 3: Void.

ES activation: procedure to power down a cell or network function for energy saving purposes.

NOTE 4: As a result, the cell or network function goes into energySaving state.

ES deactivation: procedure to power up a cell or network function.

NOTE 5: As a result, the cell or network function goes into notEnergySaving state.

ES Probing procedure: procedure executed by an ES probing capable cell triggered by Cell Activation procedure or ES deactivation procedure.

NOTE 6: The ES probing procedure [17] assists the decision whether the cell will transfer to notEnergySaving state or remain in energySaving state.

NOTE 7: During the ES probing procedure the ES probing capable cell is not carrying traffic, while it can perform measurements and be visible to the UEs in its coverage.

compensatingForEnergySaving state: in an off-peak traffic situation, a cell is remaining powered on, e.g. taking over the coverage areas of neighbor cell in energySaving state.

ES compensation: the procedure to change a cell's configuration to remain powered on for compensating energy saving activation on other cells, e.g. by increasing a cell's coverage area. As a result, the cell is in compensatingForEnergySaving state.

Energy Efficiency (EE): ratio between performance and energy consumption.

NOTE 8: the performance may be measured based on e.g. data volume, latency, number of active users, etc..

Energy Consumption (EC): integral of power consumption over time.

NOTE 9: see [23].

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].

DV	Data Volume
EC	Energy Consumption
EE	Energy Efficiency
PEE	Power, Energy and Environmental
PNF	Physical Network Function
VNF	Virtualized Network Function

4 Concepts and overview

4.1 EE KPIs Overview

Telecommunication networks energy efficiency KPIs are defined by various SDOs / organizations and are of various natures. They can be applied to either:

- whole networks (i.e. end-to-end), or to
- sub-networks (e.g. the radio access network), or to
- single network elements, or to
- telecommunication sites, which contain network elements and site equipment.

NOTE 1: Data centers used by network operators are considered in the present document as telecommunication sites.

Moreover, EE KPIs can also be categorized according to the operator's network life cycle phase they may apply to, e.g.:

- during the Buy phase, mobile network operators may be willing to compare network elements from various vendors from an EE standpoint. Some EE KPIs and measurement methods have been specified for this purpose.
- during the Design / Build phase, mobile network operators are always faced to several design options, and may be willing to compare them from an EE standpoint. This may happen for the whole network, sub-networks and for telecom sites. For telecom sites, EE KPIs have been specified.

- during the Run phase, mobile network operators need to assess the energy efficiency of the live network, as a whole (i.e. end-to-end), or for sub-networks, or for single network elements or telecom sites. Some EE KPIs and measurement methods have also been specified for this purpose.

NOTE 2: EE KPIs in the present document are only applicable for the Run phase.

Generally, EE KPIs for network elements are expressed in terms of Data Volume divided by the Energy Consumption of the considered network elements. In the case of radio access networks, an EE KPI variant may also be used, expressed by the Coverage Area divided by the Energy Consumption of the considered network elements.

The calculation of the energy efficiency of 5G networks relies on the following principles:

- it is based on the two high-level EE KPIs defined in ETSI ES 203 228 [2]:
  - $EE_{MN,DV} = \frac{DV_{MN}}{EC_{MN}}$, and
  - $EE_{MN,CoA} = \frac{coverage\ area}{EC_{MN}}$
- $EE_{MN,DV}$ may apply to the whole 5G network whereas $EE_{MN,CoA}$ may apply only to NG-RAN;
- $EE_{MN,DV}$ requires the collection of both Data Volumes (DV) and Energy Consumption (EC) of 5G Network Functions (NF);
- In NG-RAN, DV is measured per cell;
- In 5GC, DV is measured per NF;
- EC definition and measurement method for 5G PNFs rely on ETSI ES 202 336-1 [3] and ETSI ES 202 336-12 [4];
- EC is measured by PEE parameters (cf. ETSI ES 202 336-12 [4] – Annexes A and B);
- PEE measurements requirements for all deployment scenario in NG-RAN: The 3GPP management system responsible for the management of the gNB (single or multiple vendor gNB) shall be able to collect PEE measurements data from all PNFs in the gNB, in the same way as the other PM measurements;
- When gNBCU/gNBCU-CP/gNBCU-UP energy consumption is assumed to be very small compared to gNBDU and given that, in some cases, the gNBCU/gNBCU-CP/gNBCU-UP may be virtualized, the present document only considers the energy consumed in gNBDU(s) (in case of split scenarios) and in non-split gNBs (see clause 4.2.1 of 3GPP TS 28.541 [11] and clause 6.1.1 of 3GPP TS 38.401 [12]). There might be a need for some correction in KPI between the different deployment scenarios.

NOTE 3: The vendor(s) of 2-split (gNBDU/gNBCU) or 3-split gNB/en-gNB components (gNBDU/gNBCU-CP/gNBCU-UP) may be same or different depending on the implementations.

- In the present document, it is assumed that NG-RAN is only composed of base stations with built-in sensors (see ETSI ES 202 336-12 [4] – clause 4.4.1).

Besides the parameters required to calculate the energy efficiency, e.g. DV and EC, other parameters may be used to interpret variations in energy efficiency KPI values from different networks. These parameters can be classified into demography, topography and climate classes (see ETSI ES 203 228 [2] – section 4.3), which describe the network characteristics with regard to population density, geographical conditions and climate zones. For each class of parameters, there can be subclasses, e.g. demography can be further classified into dense urban, urban, sub-urban, rural or unpopulated scenarios. For each class / subclass, the energy efficiency KPI values may be interpreted differently.

4.2 Management services

The management services required for the assessment of the energy efficiency of 5G networks are listed below:

- Performance management services (see [5] – clause 4.3):

  - Measurement job control service for NF.
  - Performance data file reporting service for NF.
  - Performance data streaming service for NF.
- Management services for network function provisioning (cf. [6] – clause 6.3):
  - Provisioning for NF.
  - Provisioning data report for NF.
- Management services for Fault Supervision (cf. [7] – clause 4.1.1):
  - Fault supervision data report service for NF.
  - Fault supervision data control service for NF.

4.3 Energy saving

4.3.1 Introduction

Operators are aiming at decreasing power consumption in 5G networks to lower their operational expense with energy saving management solutions. With the foreseen deployment of more NR base stations, e.g., small base stations with massive MIMO in high-band, energy saving becomes even more urgent and challenging.

Management of 5G networks contributes to energy saving by reducing energy consumption of 5G networks, while maintaining coverage, capacity and quality of service. The permitted impact on coverage, capacity and quality of service is determined by operator's decision.

4.3.2 Concepts

Two energy saving states can be conceptually identified for cells, NEs and NFs.

Conceptually, a cell or a network element or network function may be on one of these two states with respect to energy saving:

- notEnergySaving state
- energySaving state

Based on the above energy saving states, a full energy saving solution includes two elementary procedures:

- Energy saving activation (change from notEnergySaving state to energySaving state)
- Energy saving deactivation (change from energySaving state to notEnergySaving state)

When a cell is in energy saving state it may need candidate cells to pick up the load. However a cell in energySaving state should not cause coverage holes or create undue load on the surrounding cells. All traffic on that cell is expected to be drained to other overlaid/umbrella candidate cells before the cell moves to energySaving state.

Similarly, when a network element or network function is in energy saving state it may need candidate network elements or network functions to pick up the load. For example, during off-peak traffic periods, one or more edge UPFs in energySaving state should not cause undue load on the other UPFs, all remaining traffic on those edge UPFs is expected to be redirected to other UPFs before the edge UPFs move into energySaving state.

A cell in energySaving state is not considered as a cell outage or a fault condition. No alarms should be raised for any condition that is a consequence of a subject cell or network element or network function moving into energySaving state.

5 Specification level requirements

5.1 Use cases

5.1.1 Data Volume (DV) collection

5.1.1.1 Applicability

The use cases for Data Volume measurement control, data file reporting and streaming in the following clauses 5.1.1.x are valid for all 5GS network functions.

5.1.1.2 DV measurement control

Use cases specified in [5] – clause 5.1.1.1 ("NF measurement job control service") – apply for measurement job control of Data Volume.

Depending on scenarios, NF measurement job control services may not exist. In such a case, the NF measurement control of DV may be achieved as specified in [6] – clause 5.1.18 ("Configuration of a 3GPP NF instance").

Traceability: REQ-DVMCS-FUN-001, REQ-DVMCS-FUN-002, REQ-DVMCS-FUN-003, REQ-DVMCS-FUN-004, REQ-DVMCS-FUN-005, REQ-PEEMCS-FUN-006.

5.1.1.3 DV measurement data file reporting

Use cases specified in [5] – clause 5.1.1.2 – apply for Data Volume measurement data file reporting, in compliance with [8], [9], [10].

Traceability: REQ-DVFRS-FUN-010, REQ-DVFRS-FUN-011.

5.1.1.4 DV measurement data streaming

Use cases specified in [5] – clause 5.1.1.3 – apply for Data Volume measurement data streaming.

Traceability: REQ-DVDS-FUN-020.

5.1.2 Power, Energy and Environmental (PEE) measurement collection

5.1.2.1 Applicability

The requirements for PEE measurement control, data file reporting and streaming, fault supervision and configuration management in the following clauses 5.1.2.x are only valid for 5GS physical network functions.

5.1.2.2 PEE measurement control

Use cases specified in [5] – clause 5.1.1.1 ("NF measurement job control service") – apply for measurement job control of PEE parameters.

Depending on scenarios, NF measurement job control services may not exist. In such a case, the NF measurement control of PEE parameters may be achieved as specified in [6] – clause 5.1.18 ("Configuration of a 3GPP NF instance").

Traceability: REQ-PEEMCS-FUN-001, REQ-PEEMCS-FUN-002, REQ-PEEMCS-FUN-003, REQ-PEEMCS-FUN-004, REQ-PEEMCS-FUN-005.

5.1.2.3 PEE measurement data file reporting

Use cases specified in [5] – clause 5.1.1.2 – apply for PEE measurement data file reporting, in compliance with [8], [9], [10].

Traceability: REQ-PEEFRS-FUN-010, REQ-PEEFRS-FUN-011.

5.1.2.4 PEE measurement data streaming

Use cases specified in [5] – clause 5.1.1.3 – apply for PEE measurement data streaming.

Traceability: REQ-PEEDS-FUN-020.

5.1.2.5 PEE fault supervision

Use cases specified in [7] – clause 5.1.13 ("Report alarm notifications of NF instance") – apply for PEE fault supervision.

Traceability: REQ-PEEFSS-FUN-020.

5.1.2.6 PEE configuration management

Use cases specified in [6] – clause 5.1.18 - apply for PEE configuration management.

Traceability: REQ-PEECMS-FUN-030, REQ-PEECMS-FUN-031.

5.1.3 Energy saving use cases

5.1.3.1 General

The objective of energy saving is to lower OPEX for mobile operators, through the reduction of power consumption in the mobile networks that is becoming more urgent and challenging, as there are much more network elements in NR (e.g., small cells with massive MIMO in higher frequency bands) than those used in LTE (TR 37.816 [14], TS 38.300 [13]). One typical scenario of energy saving is to switch off capacity boosters when the traffic demand is low, and re-activated them on a need basis (see clause 5.6 in TR 37.816 [14]).

For NG-RAN, the energy saving consists of two scenarios where the capacity booster cell - gNB is fully or partially overlaid by the candidate cell(s). For 5GC, the energy saving consists of scenario where some UPFs deployed at the edge of 5GC network may be switched off during off-peak traffic time.

5.1.3.2 Capacity booster cell partially overlaid by candidate cell(s)

5.1.3.2.1 Introduction

Figure 5.1.3.2.1-1 shows that a NR capacity booster cell is partially overlaid by the gNB or eNB candidate cell(s). There can be two cases of energy saving:

- Intra-RAT energy saving if the candidate cell is a gNB
- Inter-RAT energy saving if the candidate cell is an eNB

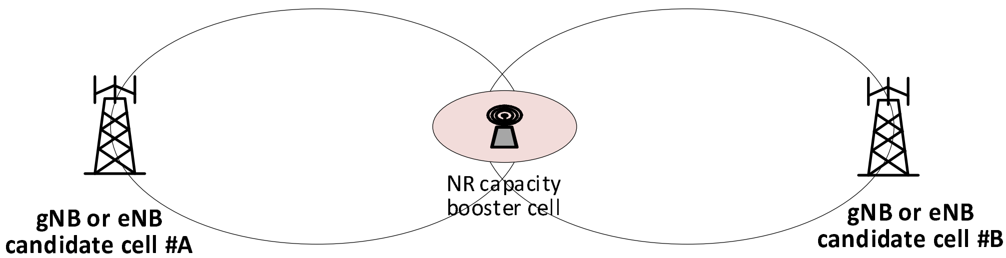

Figure 5.1.3.2.1-1: NR capacity booster cell partially overlaid by candidate cells

Traceability: REQ-ESCOL-FUN-1, REQ-ESCOL-FUN-2, REQ-ESCOL-FUN-3, REQ-ESCOL-FUN-4, REQ-ESCOL-FUN-5, REQ-ESCOL-FUN-6, REQ-ESCOL-FUN-7.

5.1.3.2.2 Intra-RAT energy saving

Intra-RAT energy saving focuses on a scenario where the gNB candidate cells provides the coverage for the NR capacity booster cells that is switched off. Intra-RAT energy saving (ES) consists of distributed energy saving where the energy saving decision is made in the NR cells with MnS producer(s) assist to provide relevant information, such as policies, and centralized energy saving where the energy saving decision is made in MnS producer (see clause 15.4 in TS 38.300 [13]).

For the distributed energy saving, the NR capacity booster cell may decide to enter the energy saving mode when it detects that its traffic load is below certain threshold, and its coverage can be provided by the candidate cells. However, the NR capacity booster cell can be switched off only after the handover actions to off-load its traffic to the candidate cells is completed (see clause 15.4.2 in TS 38.300 [13]). The candidate cell decides to re-activate the NR capacity booster cell when it detects additional capacity is needed (see clause 15.4.2 in TS 38.300 [13]).

For the centralized energy saving, MnS producer collects the traffic load performance measurements from the NR capacity booster cell and candidate cells, and may request a NR capacity booster cell to enter the energy saving mode when its traffic is below certain threshold. The NR capacity booster may initiate handover actions to off-load the traffic to the neighbouring cells (see clause 15.4.2 in TS 38.300 [13]) prior to entering into the energy saving mode.

5.1.3.2.3 Inter-RAT energy saving

Inter-RAT energy saving focuses on a scenario where the LTE eNB provides basic coverage, with the gNB providing the capacity booster that can be switched off, based on its own cell load information or by MnS producer(s). The LTE eNB is allowed to activate the dormant capacity booster NR cell (see clause 5.6 in TR 37.816 [14]).

Inter-RAT energy saving consists of centralized energy saving where the energy saving decision is made in MnS producer. The inter-RAT energy saving is almost the same as the intra-RAT energy with the exception that the candidate cells are eNB.

5.1.3.3 Capacity booster cell fully overlaid by candidate cell(s)

An NG-RAN node, which connects with 5GC to provide boost capacity, may enter into energySaving state if there is radio coverage by other radio systems – be another NG-RAN node or an entity of another radio access technology - for the whole coverage area of the NG-RAN node in question, see figure 5.1.3.3-1 for gNB capacity booster cell fully overlaid by candidate cell(s) case.

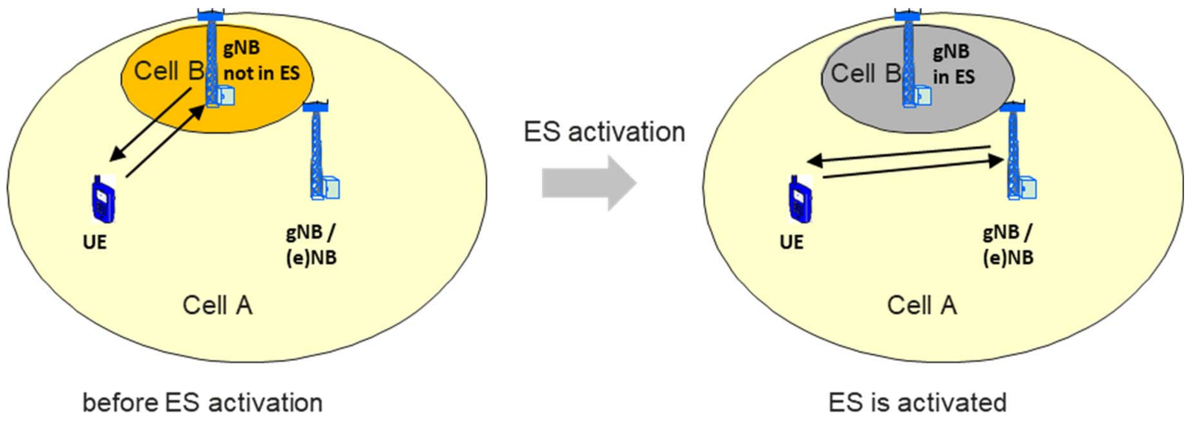

Figure 5.1.3.3-1: gNB capacity booster cell fully overlaid by candidate cell(s)

This use case applies both for Intra- and Inter-RAT Energy Saving.

Inter-frequency Intra-RAT gNB Coverage

Two gNB cells (Cell A, Cell B) with separate frequency bands cover the same geographical area. Cell B has a smaller size than Cell A and is covered totally by Cell A. Generally, Cell A is deployed to provide continuous coverage of the area, while Cell B increases the capacity of the special sub-areas, such as hot spots. The ES activation procedure in the coverage of Cell B (ES area) may be triggered in case that light traffic in Cell B is detected. Cell B ES activation may also be triggered when the traffic of ES area (measured by candidate Cell A) resumes to a high level. A Cell B capable of ES probing can execute the ES probing procedure and based on Cell B measurements the centralized or distributed ES management can decide if the Cell B needs to be activated and take portion of the traffic from Cell A.

Inter-RAT gNB Coverage

Two IRAT cells (Cell A, Cell B) cover the same geographical area. gNB Cell B is totally covered by inter-RAT Cell A (such as legacy system UMTS or LTE). Cell A is deployed to provide continuous coverage of basic eMBB services in the area, while Cell B enhances the capability of the area to support eMBB services with high data rate or URLLC services. The ES activation in the coverage of Cell B (ES area) may be triggered in case that no eMBB services with high data rate or URLLC traffic in Cell B is detected or load threshold for going into energySaving state is reached. Cell B ES deactivation may be triggered when the eMBB services with high data rate or URLLC service request in ES area is restarted again or load threshold for going out of energySaving state (i.e. going into notEnergySaving state) is reached. A Cell B capable of ES probing can execute the ES probing procedure and based on Cell B measurements the centralized or distributed ES management can decide if the Cell B needs to be activated and take portion of the traffic from Cell A.

Different scenarios of gNB capacity booster cell fully overlaid by candidate cell(s) are listed in below table 5.1.3.3-1.

Table 5.1.3.3-1: Different scenarios of gNB capacity booster cell fully overlaid by candidate cell(s)

Scenario	Capacity booster	Coverage provider	Scenario
1	gNB	eNB	Inter-RAT ES
2	gNB	gNB	Intra-RAT ES
3	gNB	eNB and gNB	Intra-RAT ES, Inter-RAT ES
4	gNB	NB	Inter-RAT ES
5	gNB	eNB and NB	Inter-RAT ES

Traceability: REQ-ESCOL-FUN-1, REQ-ESCOL-FUN-2, REQ-ESCOL-FUN-3, REQ-ESCOL-FUN-4, REQ-ESCOL-FUN-5, REQ-ESCOL-FUN-6, REQ-ESCOL-FUN-7.

5.1.3.4 Switch off edge UPFs during off-peak traffic hours

To meet service demands, e.g. in terms of latency, the Network Operator (NOP) decided to deploy some UPFs at the edge of 5GC network, i.e. closer to low latency demanding service users than if they were deployed in its central core network.

During off-peak periods and depending on service users' profile, observed behaviour and habits, the NOP may decide that some of these edge UPFs are no longer justified. For example, at night, in some locations where no user paying for low latency services is connected, the remaining traffic (not demanding low latency) can be redirected from the edge UPFs to central UPFs. The NOP may then decide to:

- redirect the remaining traffic to and from these edge UPFs to existing central UPFs, and
- decommission these edge UPFs, or scale them in/down, or any other action enabling to achieve energy saving, depending on e.g. whether these UPFs are virtualized or not.

The decommissioning of edge UPFs can be done e.g. by administratively putting them out of service so that they can't carry any more traffic, either with immediate effect or only when no more users are using these UPFs.

The NOP may decide at any time to come back to the initial situation.

Traceability: REQ-SOUPF-FUN-1, REQ-SOUPF-FUN-2.

5.1.4 Energy saving compensation activation and deactivation procedures

5.1.4.1 Introduction

The MnS producer for Domain-centralized ES or the distributed ES function, that makes a decision for the NR capacity booster cell to enter or exit energySaving state, should be able to initiate energy saving compensation activation and/or deactivation on one or multiple cells.

5.1.4.2 Description

For the energy saving use cases (defined in clause 5.1.3), when a NR capacity booster cell enters energySaving state, then the candidate cell(s) may transition to:

- compensatingForEnergySaving.

Correspondingly, the use cases support the following procedures:

- Energy saving compensation activation: the procedure to increase the coverage area for the candidate cell(s).

- Energy saving compensation deactivation: the procedure to decrease a previously increased coverage area.

Traceability: REQ-ESCOL-FUN-1, REQ-ESCOL-FUN-2, REQ-ESCOL-FUN-3, REQ-ESCOL-FUN-4.

5.1.5 Intent driven RAN energy saving

Operators are aiming at decreasing power consumption in 5G networks to lower their operational expense with energy saving management solutions. Introducing the intent driven approach for energy saving can enable the 3GPP management system to analyse and select the optimal energy saving management solutions to achieve the optimal balance between the energy saving effect and service experience by utilizing some intelligent mechanisms. As TS 28.312 [22] described, an intent focuses more on describing the "What" needs to be achieved but less on "How" that outcomes should be achieved, which not only relieves the burden of the consumer knowing implementation details but also leaves room to allow the 3GPP management system to explore alternative options and find optimal solutions.

The detailed use case for intent containing an expectation for RAN energy saving is described in clause 5.1.7.1 in TS 28.312[22].

5.2 Requirements

5.2.1 Requirements for Data Volume (DV) measurement

5.2.1.1 Applicability

The requirements for Data Volume measurement control, data file reporting and streaming in the following clauses 5.2.1.x are valid for all 5GS network functions.

5.2.1.2 Requirements for DV measurement control

REQ-DVMCS-FUN-001: The management service producer responsible for DV measurement control shall have the capability allowing its authorized consumer to request starting the collection of DV measurement data of NF(s).

REQ-DVMCS-FUN-002: The management service producer responsible for DV measurement control shall have the capability allowing its authorized consumer to indicate the reporting method, granularity period, reporting period, etc. for DV measurement data of NF(s).

REQ-DVMCS-FUN-003: The management service producer responsible for DV measurement control shall have the capability to generate the DV measurement data of NF(s) according to the request of the consumer.

REQ-DVMCS-FUN-004: The management service producer responsible for DV measurement control shall have the capability allowing its authorized consumer to request stopping the collection of DV measurement data of NF(s).

REQ-DVMCS-FUN-005: The management service producer responsible for DV measurement control shall have the capability allowing its authorized consumer to query the information about the ongoing collection of DV measurement data of NF(s).

5.2.1.3 Requirements for DV measurement data file reporting

REQ-DVFRS-FUN-010: The management service producer responsible for DV performance data file reporting shall have the capability to send the notification about DV performance data (of NF(s)) file ready to its authorized consumer.

REQ-DVFRS-FUN-011: The management service producer responsible for DV performance data file reporting shall have the capability to allow its authorized consumer to fetch the DV performance data (of NF(s)) file.

5.2.1.4 Requirements for DV measurement data streaming service

REQ-DVDS-FUN-020: The management service producer responsible for DV performance data streaming shall have the capability to send the stream containing DV performance data (of NF(s)) to its authorized consumer.

5.2.2 Requirements for Power, Energy and Environmental (PEE) measurement

5.2.2.1 Applicability

The requirements for PEE measurement control, data file reporting and streaming, fault supervision and configuration management in the following clauses 5.2.2.x are only valid for 5GS physical network functions.

5.2.2.2 Requirements for PEE measurement control

REQ-PEEMCS-FUN-001: The management service producer responsible for PEE measurement control shall have the capability allowing its authorized consumer to request starting the collection of PEE measurement data of NF(s).

REQ-PEEMCS-FUN-002: The management service producer responsible for PEE measurement control shall have the capability allowing its authorized consumer to indicate the reporting method, granularity period, reporting period, etc. for PEE measurement data of NF(s).

REQ-PEEMCS-FUN-003: The management service producer responsible for PEE measurement control shall have the capability to generate the PEE measurement data of NF(s) according to the request of the consumer.

REQ-PEEMCS-FUN-004: The management service producer responsible for PEE measurement control shall have the capability allowing its authorized consumer to request stopping the collection of PEE measurement data of NF(s).

REQ-PEEMCS-FUN-005: The management service producer responsible for PEE measurement control shall have the capability allowing its authorized consumer to query the information about the ongoing collection of PEE measurement data of NF(s).

REQ-PEEMCS-FUN-006: The management service producer responsible for PEE measurement control shall have the capability collecting the PEE measurement data of PNF(s) in gNB according to the request of the consumer.

5.2.2.3 Requirements for PEE measurement data file reporting

REQ-PEEFRS-FUN-010: The management service producer responsible for PEE performance data file reporting shall have the capability to send the notification about PEE performance data (of NF(s)) file ready to its authorized consumer.

REQ-PEEFRS-FUN-011: The management service producer responsible for PEE performance data file reporting shall have the capability to allow its authorized consumer to fetch the PEE performance data (of NF(s)) file.

5.2.2.4 Requirements for PEE measurement data streaming

REQ-PEEDS-FUN-020: The management service producer responsible for PEE performance data streaming shall have the capability to send the stream containing PEE performance data (of NF(s)) to its authorized consumer

5.2.2.5 Requirements for PEE fault supervision

REQ-PEEFSS-FUN-020: The management service producer responsible for PEE fault supervision shall have the capability allowing its authorized consumer to be notified in case of PEE related alarms.

5.2.2.6 Requirements for PEE configuration management

REQ-PEECMS-FUN-030: The management service producer responsible for PEE configuration management shall have the capability allowing its authorized consumer to modify configurable PEE related parameters.

REQ-PEECMS-FUN-031: The management service producer responsible for PEE configuration management shall have the capability allowing its authorized consumer to be notified in case of PEE related configuration changes.

5.2.3 Requirements for energy saving

5.2.3.1 Requirements for capacity booster cell overlaid by candidate cell(s)

REQ-ESCOL-FUN-1: The management service producer responsible for energy saving should have the capability allowing its authorized consumer to configure the cell overlaid relations, and energy saving policies, and to enable or disable the function for a NR capacity booster cell to enter energy saving mode.

REQ-ESCOL-FUN-2: The management service producer responsible for energy saving should have the capability to send notifications to the authorized consumer to indicate the energy saving mode has been activated or deactivated in the NR capacity booster cell.

REQ-ESCOL-FUN-3: The management service producer responsible for energy saving should have the capability allowing its authorized consumer to collect the traffic load performance measurements of NR capacity booster and candidate cells.

REQ-ESCOL-FUN-4: The management service producer responsible for energy saving should have the capability allowing its authorized consumer to request the NR capacity booster cell to enter the energy saving mode.

REQ-ESCOL-FUN-5: The management service producer responsible for energy saving should have the capability allowing its authorized consumer to deactivate the energy saving mode of a NR capacity booster cell.

REQ-ESCOL-FUN-6: The management service producer responsible for energy saving should have the capability allowing its authorized consumer to configure one or more related cells as the candidate cells to take over the coverage when the original NR capacity booster cell is going into energy saving mode.

REQ-ESCOL-FUN-7: The management service producer responsible for energy saving should have the capability allowing its authorized consumer to request the NR capacity booster cell to leave the energy saving mode.

5.2.3.2 Requirements for switch off edge UPFs during off-peak hours

REQ-SOUPF-FUN-1: The management service producer responsible for energy saving should have the capability allowing its authorized consumer to collect the traffic load performance measurements of its edge UPFs.

REQ-SOUPF-FUN-2: The management service producer responsible for energy saving should have the capability allowing its authorized consumer to administratively prohibit selected edge UPFs from performing services for its users, either with immediate effect or only when no more users are using these UPFs.

5.2.3.3 Requirements for energy saving compensation activation and deactivation procedures

REQ-ESCOL-FUN-1: The Domain-centralized ES shall support the procedure to initiate energy saving compensation activation to one or multiple cells.

REQ-ESCOL-FUN-2: The Domain-centralized ES shall support the procedure to initiate energy saving compensation deactivation to one or multiple cells.

REQ-ESCOL-FUN-3: The distributed ES function shall support the procedure to initiate energy saving compensation activation to one or multiple cells.

REQ-ESCOL-FUN-4: The distributed ES function shall support the procedure to initiate energy saving compensation deactivation to one or multiple cells.

5.2.4 Requirements for Intent driven RAN energy saving

The requirements for intent containing an expectation for RAN energy saving are defined in clause 5.1.7.2 in TS 28.312 [22].

5.3 Actor roles

Consumers of management services involved in use cases and requirements - see clauses 5.1 and 5.2.

5.4 Telecommunication resources

The telecommunication resources include network function management functions and/or the managed network functions.

6 Solutions for energy efficiency

6.1 Solutions for assessment of mobile network data energy efficiency

6.1.1 Energy efficiency of NG-RAN

Assessment of NG-RAN data EE is based on the high-level mobile network data EE KPI defined in clause 3.1 and clause 5.3 of ETSI ES 203 228 [2]:

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

NG-RAN data EE KPI is is obtained by the data volume divided by Energy Consumption (EC) of the considered network elements. The KPI is defined for both non-split and split gNB scenarios. This KPI is defined in clause 6.7.1 of TS 28.554 [18].The following PEE (Power, Energy and Environmental) measurement may be used as the EC_{MN}:

- PNF Energy consumption (cf. clause 5.1.1.19.3 of TS 28.552 [15]): This measurement provides the energy consumed (in kilowatt-hours) by the subject gNB.

6.1.2 Energy efficiency of network slices

6.1.2.1 Introduction

Assessment of the energy efficiency of 5G network slices is based on KPIs defined in TS 28.554 [18] clause 6.7.2.

The Generic network slice Energy Efficiency KPI is defined as the ratio between the performance of network slice to the Energy Consumption of the network slice. The KPI for Energy Consumption of the network slice is defined in TS 28.554 [18] clause 6.7.3.3.

The energy efficiency of 5G network slice is defined for each slice type as follows:

1) Energy efficiency of eMBB network slice, with the following variants:

- Energy efficiency of eMBB network slice, where the KPI is obtained by the sum of UL and DL data volumes at N3 interface(s) of the network slice, divided by the energy consumption of the network slice. This KPI is defined in TS 28.554 [18] clause 6.7.2.2.

- Energy efficiency of eMBB network slice – RAN-based, where the performance of the network slice is is obtained by summing up UL and DL data volumes at F1-U, Xn-U and X2-U interface(s) of gNBs, on a per S-NSSAI basis, divided by energy consumption of the RAN-only network slice. This KPI is defined in TS 28.554 [18] clause 6.7.2.2a.

2) Energy efficiency of URLLC network slice, with the following variants:

- Energy efficiency of URLLC network slice based on latency of the network slice, where the KPI is obtained by the inverse of the average end-to-end User Plane (UP) latency of the network slice divided by the energy consumption of the network slice. This KPI is defined in TS 28.554 [18] clause 6.7.2.3.2.

- Based on both latency and data volume of the network slice, where the KPI is obtained by the product of the sum of the weighted UL and DL traffic data volumes at N3 interface(s) or N9 interface of the PSA UPF of the network slice multiplied by the inverse of the end-to-end User Plane (UP) latency of the network slice, divided by the energy consumption of the network slice. This KPI is defined in TS 28.554 [18] clause 6.7.2.3.3.

3) Energy efficiency of MIoT network slice, with the following variants:

- Based on the number of registered subscribers of the network slice, where the KPI is obtained by the maximum number of registered subscribers to the network slice divided by the energy consumption of the network slice. This KPI is defined in TS 28.554 [18] clause 6.7.2.4.1.

- Based on the number of active UEs in the network slice, where the KPI is obtained by the mean number of active UEs of the network slice divided by the energy consumption of the network slice. This KPI is defined in TS 28.554 [18] clause 6.7.2.4.2.

6.1.2.2 Void

6.1.2.3 Void

6.1.2.4 Void

6.1.2.5 Void

6.2 Solutions for energy saving

6.2.1 Overview

For the scenarios where the capacity booster cell is fully or partially overlaid by the candidate cell(s), the key of energy saving solution is that 3GPP management system or NG-RAN node owning the capacity booster cell has the capability to autonomously decide to deactivate such capacity booster cell to lower energy consumption (in energySaving state) or activate the capacity booster cell in energySaving state back to notEnergySaving state due to the increasing traffic above the threshold. The cell activation/deactivation decision is typically based on the load information of the related cells and the energy saving policies (e.g. service related information as one kind of energy saving policies) set by operators.

The service related information may include service characteristic information and/or tenant information of service.

The service characteristic information may include service type information, service name information, and service priority information.

- The service type information indicates the type of service that is being provided via traffic carried by cells under observation, it can be decided by operator's policy, for example, one kind of service type may be eMBB, URLLC, mIoT, or V2X etc, or another kind of service type may be voice, video, industrial control, web browsing, or autonomous driving;
- The service name may be human-readable name according to operator's policy;
- The service priority information may be, for example, high priority, medium priority, or low priority.

The tenant information of service may include tenant type information, tenant name information, tenant priority information

- The tenant type may be, for example, Business to Consumer (B2C) tenant, Business to Business (B2B) tenant, Business to Household (B2H) tenant, Business to Business to Everything (B2B2X) tenant;

- The tenant name may be human-readable name according to operator's policy;

- The tenant priority information may be, for example, high priority, medium priority, or low priority.

The service related information can be obtained from UEs, 5GC NFs (such as UPFs or SMFs) or operators' information provisioned in 3GPP management system.

Based on the load information of the related cells and the service related information of the the area under consideration, 3GPP management system decides ES actions for the corresponding cells. 3GPP management system may use different weight values for the factors that can influence the ES actions - load information of the related cells and the service related information of the analysis area.

NOTE: How the weight values are assigned by the operator is not subject to standardization.

ES activation procedure and ES deactivation procedure may be initiated in different ways as below:

- Centralized ES solution
  - Consumer of centralized MnS for ES requests the producer to configure ES procedure trigger points (e.g. cell traffic load crossing threshold, service characteristic information or tenant information of service), monitoring the traffic situation of capacity booster cells and candidate cells.
  - Consumer of centralized MnS for ES requests the producer to instruct the capacity booster cells to move from notEnergySaving state into energySaving state (e.g. according to some traffic performance measurements which cross below some load thresholds and service characteristic information or tenant information of service)
  - Consumer of centralized MnS for ES requests the producer to instruct the capacity booster cells to move from energySaving state into notEnergySaving state (e.g. according to some traffic performance measurements which cross above some load thresholds and service characteristic information or tenant information of service)
- Distributed ES solution
  - NF provisioning MnS consumer requests the producer to set policies and conditions when these policies/conditions are met, the capacity booster cells will move from notEnergySaving state into energySaving state. Examples for policies/conditions are: A time period, during which energy saving is or not allowed; load thresholds to be considered for energy saving decisions; which of the RATs should be considered with priority in Inter-RAT scenario; service characteristic information or tenant information of service.
  - Based on these policies/conditions and further information - e.g. the operational status of the candidate cell to take over the coverage- the NG-RAN node controls the energy saving procedures (ES activation procedure and ES deactivation procedure) in the network nodes. The network operator is informed about configuration changes which are triggered by the NG-RAN nodes. For example, the gNB owning the capacity booster cells moves itself to/from energySaving state autonomously and sends notifications of configuration changes to operator.

6.2.2 Centralized energy saving solution

6.2.2.1 Procedures

6.2.2.1.1 Energy saving activation

NOTE: The centralized energy saving solution in clause 6.2.2 is Domain-Centralized ES solution because the scope of the centralized ES solution is for NR only.

Figure 6.2.2.1.1-1 depicts a procedure that describes how MnS producer of Domain Centralized SON ES management makes the NR capacity booster cell enter the energySaving state.

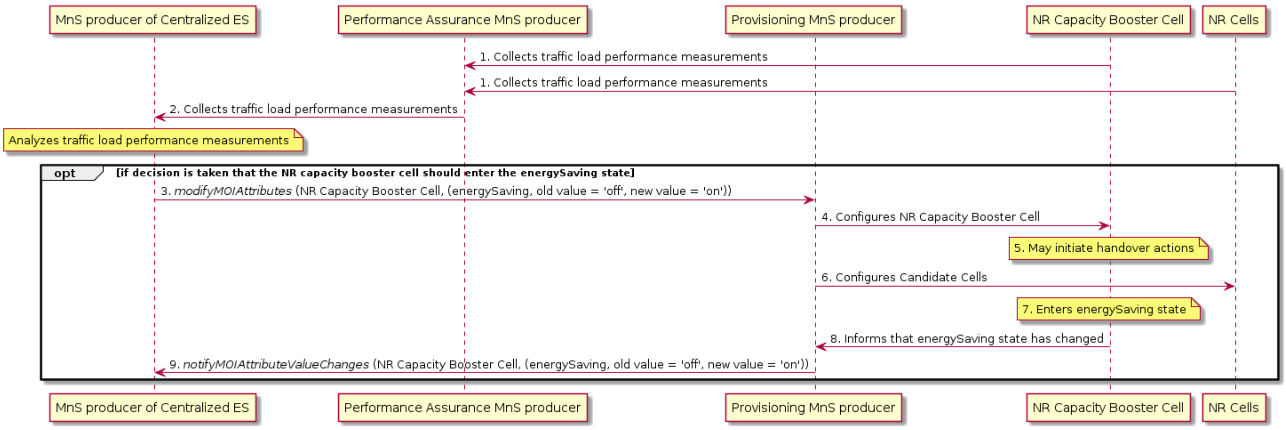

Figure 6.2.2.1.1-1: Centralized energy saving activation

It is assumed that all relevant MOIs have been created.

Energy saving activation:

The MnS producer for Domain-centralized ES collects the traffic load performance measurements from the NR capacity booster cell and candidate cells.

The MnS producer for Domain-centralized ES analyzes the traffic load performance measurements and decides that the NR capacity booster cell should enter the energySaving state.

The MnS producer for Domain-centralized ES consumes the management service for NF provisioning with *modifyMOIAttributes* operation to request the NR capacity booster cell to enter the energySaving state.

The NR capacity booster cell may initiate handover actions to off-load the traffic to the neighbour cells (see clause 15.4.2 in TS 38.300 [13]), prior to entering into the energySaving state, and then change to the energySaving state, leading to a `notifyMOIAttributeValueChanges` being sent to the MnS producer for Domain-centralized ES that the NR capacity booster cell has entered the energySaving state.

6.2.2.1.2 Energy saving deactivation

Figure 6.2.2.1.2-1 depicts a procedure that describes how MnS producer of Domain-Centralized ES management makes the NR capacity booster cell leave the energySaving state.

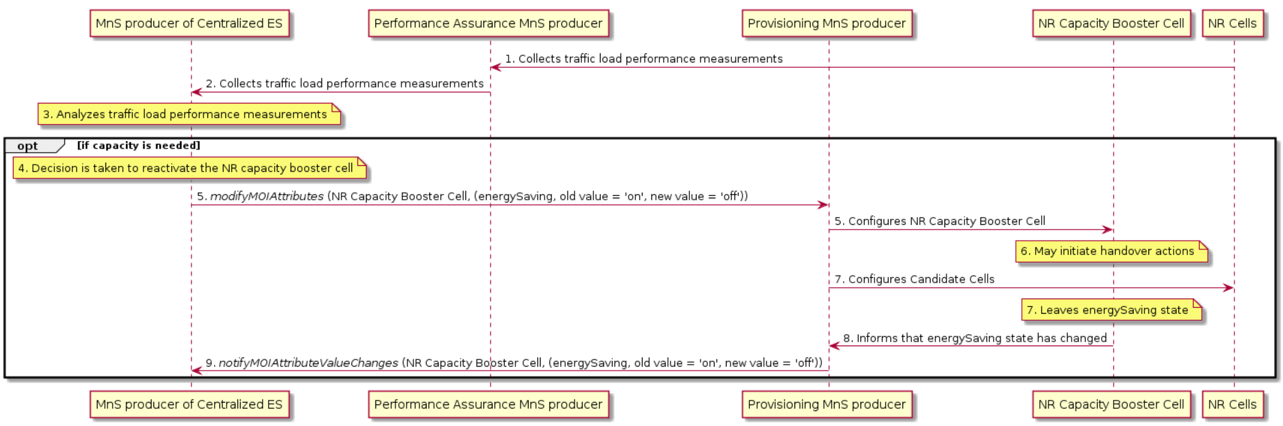

Figure 6.2.2.1.2-1: Centralized energy saving deactivation

Energy saving deactivation:

The MnS producer for Domain-centralized ES collects the traffic load performance measurements from the candidate cells.

The MnS producer for Domain-centralized ES decides to re-activate the NR capacity booster cell if it detects that the capacity is needed (see clause 15.4.2 in TS 38.300 [13]).

The MnS producer for Domain-centralized ES consumes the management service for NF provisioning with *modifyMOIAttributes* operation to re-activate the NR capacity booster cell, and changes to the notEnergySaving state, leading to a `notifyMOIAttributeValueChanges` being sent to the consumer to indicate that the NR capacity booster cell has been re-activated.

6.2.2.2 Management services

6.2.2.2.1 MnS component type A

MnS Component Type A	Note
Operations defined in clause 11.1.1 of TS 28.532 [16]: - `createMOI` - `getMOIAttributes` - `modifyMOIAttributes` - `deleteMOI`	Supported by the Provisioning MnS for NF, as defined in TS 28.531 [6].
Notifications defined in clause 11.1.1 of TS 28.532 [16]: - `notifyMOICreation` - `notifyMOIAttributeValueChanges` - `notifyMOIDeletion` - `notifyMOIChanges`	Supported by the Provisioning MnS for NF, as defined in TS 28.531 [6].

6.2.2.2.2 MnS Component Type B

6.2.2.2.2.1 Objective and targets

The objective of ES is to automatically set parameters so as to maximize NG-RAN data energy efficiency - see Table 6.2.2.1.2.1-1.

Table 6.2.2.1.2.1-1. Energy Saving targets

Targets	Definition	Legal Values
NG-RAN data Energy Efficiency	Data Volume (DV) divided by Energy Consumption (EC) of the considered network elements.	In bit/J.

6.2.2.2.2.2 Control information

The parameters in `CESManagementFunction` IOC, which is defined in TS 28.541 [11], are used to control the Domain-SON ES functionality.

6.2.2.2.3 MnS Component Type C

6.2.2.2.3.1 Parameters to be optimized

This is out of the scope of the present document.

6.2.2.2.3.2 Performance measurements

Performance measurements related to Domain-centralized SON ES are captured in Table 6.2.2.2.3.2-1:

Table 6.2.2.2.3.2-1. Energy saving management related performance measurements

Performance measurements	Description	Related targets
DRB.PdcpSduVolumeDL_Filter	Data Volume (amount of PDCP SDU bits) in the downlink delivered to PDCP layer – see clause 5.1.2.1.1.1 of TS 28.552 [15], per configured PLMN ID and per QoS level (mapped 5QI) and per S-NSSAI. In case of non-split gNBs.	NG-RAN data Energy Efficiency
DRB.PdcpSduVolumeUL_Filter	Data Volume (amount of PDCP SDU bits) in the uplink delivered from PDCP layer to higher layers – see clause 5.1.2.1.2.1 of TS 28.552 [15], per configured PLMN ID and per QoS level (mapped 5QI) and per S-NSSAI. In case of non-split gNBs.	NG-RAN data Energy Efficiency
DL Cell PDCP SDU Data Volume on X2 Interface	Data Volume (amount of PDCP SDU bits) in the downlink delivered on X2 interface in DC-scenarios – see clause 5.1.2.1.1.2 of TS 28.552 [15], per PLMN ID and per QoS level (mapped 5QI or QCI in NR option 3). In case of non-split gNBs.	NG-RAN data Energy Efficiency
DL Cell PDCP SDU Data Volume on Xn Interface	Data Volume (amount of PDCP SDU bits) in the downlink delivered on Xn interface in DC-scenarios scenarios – see clause 5.1.2.1.1.3 of TS 28.552 [15], per PLMN ID and per QoS level (mapped 5QI) and per S-NSSAI. In case of non-split gNBs.	NG-RAN data Energy Efficiency
UL Cell PDCP SDU Data Volume on X2 Interface	Data Volume (amount of PDCP SDU bits) in the uplink delivered on X2 interface in NSA scenarios – see clause 5.1.2.1.2.2 of TS 28.552 [15], per PLMN ID and per QoS level (mapped 5QI or QCI in NR option 3). In case of non-split gNBs.	NG-RAN data Energy Efficiency
UL Cell PDCP SDU Data Volume on Xn Interface	Data Volume (amount of PDCP SDU bits) in the uplink delivered on Xn interface in SA scenarios – see clause 5.1.2.1.2.3 of TS 28.552 [15], per PLMN ID and per QoS level (mapped 5QI) and per S-NSSAI. In case of non-split gNBs.	NG-RAN data Energy Efficiency
DRB.F1uPdcpSduVolumeDL_Filter	Data Volume (amount of PDCP SDU bits) in the downlink delivered from GNB-CU-UP to GNB-DU (F1-U interface) – see clause 5.1.3.6.2.3 of TS 28.552 [15], per PLMN ID and per QoS level (mapped 5QI) and per S-NSSAI. In case of split gNBs	NG-RAN data Energy Efficiency
DRB.XnuPdcpSduVolumeDL_Filter	Data Volume (amount of PDCP SDU bits) in the downlink delivered from GNB-CU-UP to external gNB-CU-UP (Xn-U interface) – see clause 5.1.3.6.2.3 of TS 28.552 [15], per PLMN ID and per QoS level (mapped 5QI) and per S-NSSAI. In case of split gNBs	NG-RAN data Energy Efficiency
DRB.X2uPdcpSduVolumeDL_Filter	Data Volume (amount of PDCP SDU bits) in the downlink delivered from GNB-CU-UP to external eNB (X2-U interface) – see clause 5.1.3.6.2.3 of TS 28.552 [15], per PLMN ID and per QoS level (mapped 5QI). In case of split gNBs.	NG-RAN data Energy Efficiency
DRB.F1uPdcpSduVolumeUL_Filter	Data Volume (amount of PDCP SDU bits) in the uplink delivered to GNB-CU-UP from GNB-DU (F1-U interface) – see clause 5.1.3.6.2.4 of TS 28.552 [15], per PLMN ID and per QoS level (mapped 5QI) and per S-NSSAI. In case of split gNBs	NG-RAN data Energy Efficiency
DRB.XnuPdcpSduVolumeUL_Filter	Data Volume (amount of PDCP SDU bits) in the uplink delivered to GNB-CU-UP from external gNB-CU-UP (Xn-U interface) – see clause 5.1.3.6.2.4 of TS 28.552 [15], per PLMN ID and per QoS level (mapped 5QI) and per S-NSSAI. In case of split gNBs	NG-RAN data Energy Efficiency

DRB.X2uPdcpSduVolumeUL_Filter	Data Volume (amount of PDCP SDU bits) in the uplink delivered to GNB-CU-UP from external eNB (X2-U interface) – see clause 5.1.3.6.2.4 of TS 28.552 [15], per PLMN ID and per QoS level (mapped 5QI). In case of split gNBs.	NG-RAN data Energy Efficiency
PNF Energy consumption	Energy consumed – see clause 5.1.1.19.3 of TS 28.552 [15]	NG-RAN data Energy Efficiency

6.2.3 Distributed energy saving solution

6.2.3.0 Management service components used for Distributed SON ES solution

The MnS components used for Distributed SON ES solution are listed in the following clauses 6.2.3.1.1, 6.2.3.1.2 and 6.2.3.1.3.

6.2.3.1 Management services

6.2.3.1.1 MnS component type A

MnS Component Type A	Note
Operations defined in clause 11.1.1 of TS 28.532 [16]: - createMOI - getMOIAttributes - modifyMOIAttributes - deleteMOI	Supported by the Provisioning MnS for NF, as defined in TS 28.531 [6].
Notifications defined in clause 11.1.1 of TS 28.532 [16]: - notifyMOICreation - notifyMOIAttributeValueChanges - notifyMOIDeletion - notifyMOIChanges	Supported by the Provisioning MnS for NF, as defined in TS 28.531 [6].

6.2.3.1.2 MnS Component Type B

6.2.3.1.2.1 Objective and targets

The objective of ES is to automatically set parameters so as to maximize NG-RAN data energy efficiency - see Table 6.2.3.1.2.1-1.

Table 6.2.3.1.2.1-1. Energy Saving targets

Targets	Definition	Legal Values
NG-RAN data Energy Efficiency	Data Volume (DV) divided by Energy Consumption (EC) of the considered network elements.	In bit/J.

6.2.3.1.2.2 Control information

The parameters in `DESManagementFunction` IOC, which is defined in TS 28.541 [11], are used to control the Distributed SON ES functionality.

6.2.3.1.3 MnS Component Type C

6.2.3.1.3.1 Parameters to be optimized

This is out of the scope of the present document.

6.2.3.1.3.2 Performance measurements

Performance measurements related to Distributed SON ES are captured in Table 6.2.3.1.3.2-1:

Table 6.2.3.1.3.2-1. Energy saving management related performance measurements

Performance measurements	Description	Related targets
DRB.PdcpSduVolumeDL_Filter	Data Volume (amount of PDCP SDU bits) in the downlink delivered to PDCP layer – see clause 5.1.2.1.1.1 of TS 28.552 [15], per configured PLMN ID and per QoS level (mapped 5QI) and per S-NSSAI. In case of non-split gNBs.	NG-RAN data Energy Efficiency
DRB.PdcpSduVolumeUL_Filter	Data Volume (amount of PDCP SDU bits) in the uplink delivered from PDCP layer to higher layers – see clause 5.1.2.1.2.1 of TS 28.552 [15], per configured PLMN ID and per QoS level (mapped 5QI) and per S-NSSAI. In case of non-split gNBs.	NG-RAN data Energy Efficiency
DL Cell PDCP SDU Data Volume on X2 Interface	Data Volume (amount of PDCP SDU bits) in the downlink delivered on X2 interface in DC-scenarios – see clause 5.1.2.1.1.2 of TS 28.552 [15], per PLMN ID and per QoS level (mapped 5QI or QCI in NR option 3). In case of non-split gNBs.	NG-RAN data Energy Efficiency
DL Cell PDCP SDU Data Volume on Xn Interface	Data Volume (amount of PDCP SDU bits) in the downlink delivered on Xn interface in DC-scenarios scenarios – see clause 5.1.2.1.1.3 of TS 28.552 [15], per PLMN ID and per QoS level (mapped 5QI) and per S-NSSAI. In case of non-split gNBs.	NG-RAN data Energy Efficiency
UL Cell PDCP SDU Data Volume on X2 Interface	Data Volume (amount of PDCP SDU bits) in the uplink delivered on X2 interface in NSA scenarios – see clause 5.1.2.1.2.2 of TS 28.552 [15], per PLMN ID and per QoS level (mapped 5QI or QCI in NR option 3). In case of non-split gNBs.	NG-RAN data Energy Efficiency
UL Cell PDCP SDU Data Volume on Xn Interface	Data Volume (amount of PDCP SDU bits) in the uplink delivered on Xn interface in SA scenarios – see clause 5.1.2.1.2.3 of TS 28.552 [15], per PLMN ID and per QoS level (mapped 5QI) and per S-NSSAI. In case of non-split gNBs.	NG-RAN data Energy Efficiency
DRB.F1uPdcpSduVolumeDL_Filter	Data Volume (amount of PDCP SDU bits) in the downlink delivered from GNB-CU-UP to GNB-DU (F1-U interface) – see clause 5.1.3.6.2.3 of TS 28.552 [15], per PLMN ID and per QoS level (mapped 5QI) and per S-NSSAI. In case of split gNBs	NG-RAN data Energy Efficiency
DRB.XnuPdcpSduVolumeDL_Filter	Data Volume (amount of PDCP SDU bits) in the downlink delivered from GNB-CU-UP to external gNB-CU-UP (Xn-U interface) – see clause 5.1.3.6.2.3 of TS 28.552 [15], per PLMN ID and per QoS level (mapped 5QI) and per S-NSSAI. In case of split gNBs	NG-RAN data Energy Efficiency
DRB.X2uPdcpSduVolumeDL_Filter	Data Volume (amount of PDCP SDU bits) in the downlink delivered from GNB-CU-UP to external eNB (X2-U interface) – see clause 5.1.3.6.2.3 of TS 28.552 [15], per PLMN ID and per QoS level (mapped 5QI). In case of split gNBs.	NG-RAN data Energy Efficiency
DRB.F1uPdcpSduVolumeUL_Filter	Data Volume (amount of PDCP SDU bits) in the uplink delivered to GNB-CU-UP from GNB-DU (F1-U interface) – see clause 5.1.3.6.2.4 of TS 28.552 [15], per PLMN ID and per QoS level (mapped 5QI) and per S-NSSAI. In case of split gNBs	NG-RAN data Energy Efficiency
DRB.XnuPdcpSduVolumeUL_Filter	Data Volume (amount of PDCP SDU bits) in the uplink delivered to GNB-CU-UP from external gNB-CU-UP (Xn-U interface) – see clause 5.1.3.6.2.4 of TS 28.552 [15], per PLMN ID and per QoS level (mapped 5QI) and per S-NSSAI. In case of split gNBs	NG-RAN data Energy Efficiency

DRB.X2uPdcpSduVolumeUL_Filter	Data Volume (amount of PDCP SDU bits) in the uplink delivered to GNB-CU-UP from external eNB (X2-U interface) – see clause 5.1.3.6.2.4 of TS 28.552 [15], per PLMN ID and per QoS level (mapped 5QI). In case of split gNBs.	NG-RAN data Energy Efficiency
PNF Energy consumption	Energy consumed – see clause 5.1.1.19.3 of TS 28.552 [15]	NG-RAN data Energy Efficiency

6.2.3.2 Procedures

6.2.3.2.1 Energy saving activation

Figure 6.2.3.2.1-1 depicts a procedure that describes how MnS producer of Distributed ES management makes the NR capacity booster cell enter the energySaving state.

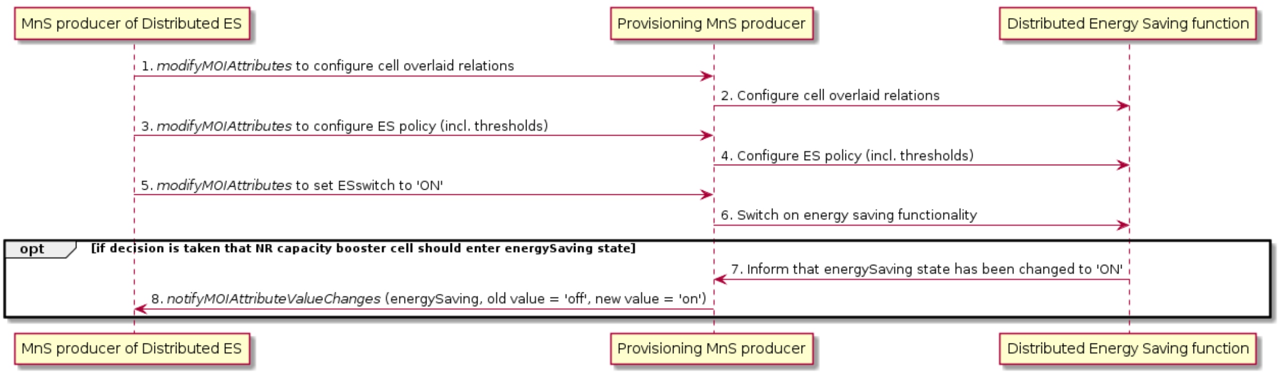

Figure 6.2.3.2.1-1: Distributed energy saving activation

It is assumed that all relevant MOIs have been created.

Energy saving activation:

The MnS producer for distributed ES management consumes the management service for NF provisioning with *modifyMOIAttributes* operation to:

- Configure the cell overlaid relations for NR capacity booster cells, and macro cells as candidate cells
- Configure the ES policy that includes the thresholds for the energy saving activation and deactivation for NR capacity booster cells and candidate cells
- Enable the distribute energy saving function for intra-RAT or inter-RAT.

NOTE: Void

The distributed ES function makes decision for the NR capacity booster cell to enter the energySaving state based on the cell traffic load information (see clause 15.4.2 in TS 38.300 [13]).

The distributed ES function changes to the energySaving state, leading to a `notifyMOIAttributeValueChanges` (see clause 5.1.9 in TS 28.532 [16]) being sent to the MnS producer for distributed ES management to indicate the NR capacity booster has entered the energySaving state.

6.2.3.2.2 Energy saving deactivation

Figure 6.2.3.2.2-1 depicts a procedure that describes how Distributed ES function makes the NR capacity booster cell leave the energySaving state.

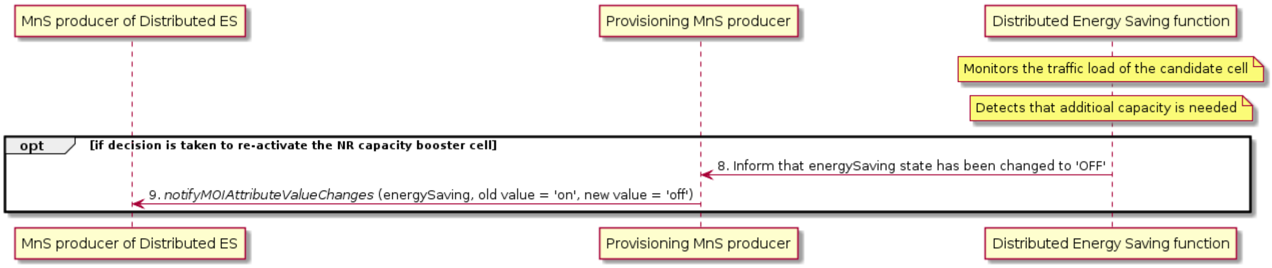

Figure 6.2.3.2.2-1: Distributed energy saving deactivation

Energy saving deactivation:

The distributed ES function monitors the traffic load of candidate cell, and decides to re-activate the NR capacity booster cell when it detects that additional capacity is needed (see clause 15.4.2 in TS 38.300 [13]).

The distributed ES function changes to the notEnergySaving state, leading to a `notifyMOIAttributeValueChanges` being sent to the MnS producer for distributed ES management to indicate the NR capacity booster has been re-activated.

6.3 Solutions for energy consumption

6.3.1 Solution for energy consumption of PNFs

TS 28.552 [15] clause 5.1.1.19 defines measurements for the Energy Consumption (EC) of Physical Network Functions (PNF), associated to corresponding ManagedElement IOC instances.

The method for collecting these measurements is described in ETSI ES 202 336-12 [4].

6.3.2 Solution for energy consumption of VNF/VNFCs

6.3.2.1 Introduction

In case of Network Functions (NF) composed of Virtualized Network Functions (VNF) running on a Network Function Virtualization Infrastructure (NFVI), it is expected to be able to measure the energy consumption of each VNF separately. However, in a NFVI, the finest grain at which Energy Consumption can be measured is the NFVI Node, making it impossible to measure the energy consumed by each and every VNF separately given that a) a VNF can run on more than one NFVI node and b) a NFVI node can support more than one VNF. Therefore, this clause describes a solution for estimating the energy consumption of VNFs.

ETSI GR NFV-IFA 015 [19] states that:

- a VNF is composed of 1-to-many VNF Component(s) (VNFC) – see diagram below.
- a VNFC runs over a single VirtualisationContainer – see diagram below.

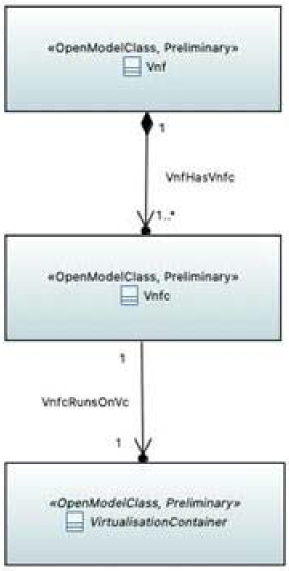

Figure 3.2.1-1: VNF-VNFC-Virtualisation Container relationship

where a Virtualisation Container is defined in ETSI GR NFV 003 [20] as follows:

"

partition of a compute node that provides an isolated virtualised computation environment.

NOTE: Examples of virtualisation container includes virtual machine and OS container.

".

Hence, a Virtualisation Container runs on a single NFVI Compute Node. A NFVI Compute Node may support 1-to-many Virtualisation Container(s).

To estimate the Energy Consumption of VNF / VNFCs, it is assumed that:

- Pre-condition #1: there exists a Management Function (MF) in charge of estimating the energy consumption of the VNFs.

- Pre-condition #2: this MF knows on which NFVI node(s), the VNF/VNFC instances run;

- Pre-condition #3: NFVI nodes are equipped with embedded or external sensors (see ETSI ES 202 336-12).

6.3.2.2 Solution for VM-based VNF/VNFCs

6.3.2.2.1 Solution based on vCPU usage of virtual compute resources

The procedure for estimating the energy consumption of VNF/VNFCs based on the vCPU usage of underlying virtual compute resources is as follows:

1. The MF in charge of estimating the energy consumption of VNFs collects Power, Energy and Environmental (PEE) measurements from NFVI nodes (see clause 6.3.1), during a given period of time. The procedure described here is independent from whether the NFVI nodes are equipped with embedded sensors or external sensors;

2. The MF subscribes to PM notifications towards the VNFM, so as to receive notifications about the vCPU mean usage of selected VNF/VNFC instances (see ETSI GS NFV IFA 008 [14] clause 7.4.4) for a given period of time (same observation period as in 1);

3. The MF requests the VNFM to create a PM job to collect the vCPU usage of selected VNF/VNFC instances (see ETSI GS NFV IFA 008 [14] clause 7.4.2);

4. The VNFM subscribes to PM notifications towards the VIM, so as to receive notifications about the vCPU usage of the virtual compute instances on which each VNF/VNFC instance runs (see ETSI GS NFV IFA 006 [20] clause 7.7.5);

5. The VNFM requests the VIM to create a PM job to collect the vCPU usage of the virtual compute instances on which each VNF/VNFC instance runs and whose IDs are provided as input parameters of the CreatePMJob request (see ETSI GS NFV IFA 006 [20] clause 7.7.2);

6. The VIM gets, at pre-defined intervals, the process utilization compute metric values from all CPU Cores of the NFVI (see ETSI NFV TST 008 [14] – clause 6.6). Whether the VIM gets this data in pull mode or in push mode is out of scope of the present document;

7. The VIM aggregates them per virtual compute resource and calculates their arithmetic mean per virtual compute resource; this per virtual compute resource arithmetic mean of process utilization compute metric values is called VCpuUsageMean (see ETSI GS NFV IFA 027 clause 7.1.2);

8. The VIM notifies the VNFM about VCpuUsageMean measurement(s) for the virtual compute instance(s) (see ETSI GS NFV IFA 006 [20] clause 7.7.6);

9. The VNFM maps the received VCpuUsageMean measurement(s) from virtual compute instances to the VNF/VNFC instance(s);

10. The VNFM generates the measurement for the subject VNF/VNFC instances by assigning the value of the multiple VCpuUsageMean measurements received (see ETSI GS NFV IFA 027 [18] clause 7.2.2);

11. The VNFM notifies the Management Function in charge of estimating the 5GC NF EC, about the average VCpuUsageMean of each virtual compute instance used by the VNF/VNFC instance(s) which constitute the NF (see ETSI GS NFV IFA 008 [14] clause 7.4.5);

12. NF energy consumption can be now estimated as follows:

   - The energy consumed by the NF is the sum of the energy consumed by all its constituent VNF/VNFC instances.
   - For each VNF/VNFC instance, its estimated energy consumption is a proportion of the NFVI node energy consumption on which it runs.
   - This proportion is equal to the vCPU mean usage of the VNF/VNFC instance relatively to the sum of the vCPU mean usage of all VNF/VNFC instances running on the same NFVI node.

6.4 Solution for intent driven RAN energy saving

The MnS component Type A for Intent driven MnS for RAN energy saving solution is defined in clause 6.1 in TS 28.312 [22].

The MnS component Type B for intent driven MnS for RAN energy saving solution is defined in clause 6.2 in TS 28.312 [22], including Information model definition for Intent and RadioNetworkExpectation.

The guidelines for using RadioNetworkExpectation for Intent driven MnS for RAN energy saving is described in clause 8 in TS 28.312 [22].

YAML document example for intent containing an expectation on RAN energy saving is described in Annex D.5 in TS 28.312 [22].

7 Roles involved in EE KPI building

7.1 Introduction

Building EE KPIs requires collecting measurements of various types (performance measurements, energy consumption), possibly from various entities (network elements / network functions, virtualization infrastructure, servers, etc.). These entities may be under the responsibility of various stakeholders.

Roles defined in TS 28.530 [21] clause 4.8 may be involved for the collection of measurements and the calculation of EE KPIs. In all use cases, the Network Operator (NOP) is involved. When additional roles are involved, interactions are needed between them.

Typical scenarios / use cases include (non-exhaustive list):- when all entities from which measurements are collected are non-virtualized;

- when part or all of the entities from which measurements are collected are virtualized;

- when all entities from which measurements are collected are under the responsibility of the Network Operator;

- when a part of the entities from which measurements are collected are under the responsibility of the Network Operator, while other parts are under the responsibility of other roles.

The above scenarios / use cases are not mutually exclusive.

Example scenarios are described in Annex B.

Annex A (informative): Plant UML source code

A.1 Distributed energy saving activation

```
@startuml

title Distributed energy saving activation Diagram

participant "MnS producer of Distributed ES" as MnSProdDSON
participant "Provisioning MnS producer" as MnSProdProv
participant "Distributed Energy Saving function" as DESFunction

MnSProdProv <- MnSProdDSON: 1. <i>modifyMOIAttributes</i> to configure cell overlaid relations
DESFunction <- MnSProdProv: 2. Configure cell overlaid relations
MnSProdProv <- MnSProdDSON: 3. <i>modifyMOIAttributes</i> to configure ES policy (incl. thresholds)
DESFunction <- MnSProdProv: 4. Configure ES policy (incl. thresholds)
MnSProdProv <- MnSProdDSON: 5. <i>modifyMOIAttributes</i> to set ESswitch to 'ON'
DESFunction <- MnSProdProv: 6. Switch on energy saving functionality

opt if decision is taken that NR capacity booster cell should enter energySaving state

DESFunction -> MnSProdProv: 7. Inform that energySaving state has been changed to 'ON'
MnSProdProv -> MnSProdDSON: 8. <i>notifyMOIAttributeValueChanges</i> (energySaving, old value =
'off', new value = 'on')
end

@enduml
```

A.2 Distributed energy saving deactivation

```
@startuml

title Distributed energy saving deactivation Diagram

participant "MnS producer of Distributed ES" as MnSProdDSON
participant "Provisioning MnS producer" as MnSProdProv
participant "Distributed Energy Saving function" as DESFunction

note over DESFunction: Monitors the traffic load of the candidate cell
note over DESFunction: Detects that additioal capacity is needed

opt if decision is taken to re-activate the NR capacity booster cell

DESFunction -> MnSProdProv: 8. Inform that energySaving state has been changed to 'OFF'
MnSProdProv -> MnSProdDSON: 9. <i>notifyMOIAttributeValueChanges</i> (energySaving, old value =
'on', new value = 'off')
end

@enduml
```

A.3 Centralized energy saving activation

```
@startuml

title Centralized energy saving activation Diagram

participant "MnS producer of Centralized ES" as MnSProdCSON
participant "Performance Assurance MnS producer" as MnSProdPA
participant "Provisioning MnS producer" as MnSProdProv
participant "NR Capacity Booster Cell" as NRCapacityBCell
participant "NR Cells" as NRCandidateCells

MnSProdPA <- NRCapacityBCell: 1. Collects traffic load performance measurements
MnSProdPA <- NRCandidateCells: 1. Collects traffic load performance measurements
```

```
MnSProdPA -> MnSProdCSON: 2. Collects traffic load performance measurements
note over MnSProdCSON: Analyzes traffic load performance measurements

opt if decision is taken that the NR capacity booster cell should enter the energySaving state
MnSProdCSON -> MnSProdProv: 3. <i>modifyMOIAttributes</i> (NR Capacity Booster Cell, (energySaving,
old value = 'off', new value = 'on'))
MnSProdProv -> NRCapacityBCell: 4. Configures NR Capacity Booster Cell
note over NRCapacityBCell: 5. May initiate handover actions
MnSProdProv -> NRCandidateCells: 6. Configures Candidate Cells
note over NRCapacityBCell: 7. Enters energySaving state
NRCapacityBCell -> MnSProdProv: 8. Informs that energySaving state has changed
MnSProdProv -> MnSProdCSON: 9. <i>notifyMOIAttributeValueChanges</i> (NR Capacity Booster Cell,
(energySaving, old value = 'off', new value = 'on'))
end

@enduml
```

A.4 Centralized energy saving deactivation

```
@startuml

title Centralized energy saving deactivation Diagram

participant "MnS producer of Centralized ES" as MnSProdCSON
participant "Performance Assurance MnS producer" as MnSProdPA
participant "Provisioning MnS producer" as MnSProdProv
participant "NR Capacity Booster Cell" as NRCapacityBCell
participant "NR Cells" as NRCandidateCells

MnSProdPA <- NRCandidateCells: 1. Collects traffic load performance measurements
MnSProdPA -> MnSProdCSON: 2. Collects traffic load performance measurements
note over MnSProdCSON: 3. Analyzes traffic load performance measurements

opt if capacity is needed
note over MnSProdCSON: 4. Decision is taken to reactivate the NR capacity booster cell
MnSProdCSON -> MnSProdProv: 5. <i>modifyMOIAttributes</i> (NR Capacity Booster Cell, (energySaving,
old value = 'on', new value = 'off'))
MnSProdProv -> NRCapacityBCell: 5. Configures NR Capacity Booster Cell
note over NRCapacityBCell: 6. May initiate handover actions
MnSProdProv -> NRCandidateCells: 7. Configures Candidate Cells
note over NRCapacityBCell: 7. Leaves energySaving state
NRCapacityBCell -> MnSProdProv: 8. Informs that energySaving state has changed
MnSProdProv -> MnSProdCSON: 9. <i>notifyMOIAttributeValueChanges</i> (NR Capacity Booster Cell,
(energySaving, old value = 'on', new value = 'off'))
end

@enduml
```

Annex B (Informative): Example scenarios

B.1 Example scenario #1 – non-virtualized RAN

In this scenario,

- Company-A operates their radio access network (playing thus the role of NOP);
- Company-A’s radio access network is not shared;
- all Managed Elements (ME) on which measurements are collected for the purpose of EE KPI building are built on Physical Network Functions (PNF), i.e. none are virtualized;
- all Company-A’s MEs are deployed in its own premises.

In this scenario, Company-A:

1) collects required performance measurements from their RAN MEs. These performance measurements include those used as numerator of EE KPIs defined in TS 28.554 [18] clause 6.7, e.g. performance measurements related to traffic data volumes, number of registered subscribers, etc.
2) collects PEE (Power, Energy and Environmental) parameters from their MEs. Depending on whether Network Elements (NE) are equipped with embedded sensors or external sensors, Company-A may use an OA&M channel (in case of embedded sensor) or a dedicated channel (in case of external sensor) to collect PEE parameters.
3) build EE KPIs using:
    a) performance measurements (cf. item 1 above) as numerator of the KPIs; and
    b) PEE parameters (cf. item 2 above) as denominator of the KPIs.

B.2 Example scenario #2 – Virtualized 5GC on telco cloud

In this scenario:

- Company-B operates their 5G core network (playing thus the role of NOP);
- 5G core network functions are all virtualized and deployed on a telco cloud infrastructure owned and managed by Company-B (playing thus the role of VISP);
- the telco cloud infrastructure is deployed on Company-B’s own data center (Company-B playing thus the role of DCSP).

In this scenario, Company-B:

1) as NOP: collects required performance measurements from 5GC NFs via OA&M. These performance measurements include those used as numerator of EE KPIs defined in TS 28.554 [18] clause 6.7, e.g. performance measurements related to traffic data volumes, number of registered subscribers, etc.
2) as VISP: collects performance measurements related to VNF/VNFCs which compose the 5GC NFs, e.g. vCPU usage, vDisk usage, etc. defined in ETSI GS NFV-IFA 027 [25] clause 7;

3) as DCSP: collects PEE (Power, Energy and Environmental) parameters related to NFVI nodes on which the VNF/VNFCs supporting the 5GC NFs run. These PEE parameters are defined in TS 28.552 [15] clause 5.1.1.19 and collected according to the method defined in ETSI ES 202 336-12 [26];

4) builds EE KPIs using:

   a) performance measurements (cf. item 1 above) as numerator of the KPIs; and

   b) performance measurements related to VNF/VNFCs which compose the 5GC NFs (cf. item 2 above) and PEE parameters (cf. item 3 above) as denominator of the KPIs;

NOTE: NOP, VISP and DCSP are role names defined in TS 28.530 [] clause 4.8.

Annex C (informative): Change history

Change history							
Date	**Meeting**	**TDoc**	**CR**	**Rev**	**Cat**	**Subject/Comment**	**New version**
2020-03	SA#87-e	SP-200198				Presented for approval	2.0.0
2020-03	SA#87-e					Upgrade to change control version	16.0.0
2020-06	SA#88-e	SP-200496	0001	1	F	Update on D-SON ES solution management service	16.1.0
2020-09	SA#89-e	SP-200734	0002	-	F	Add missing requirements traceability for energy saving use cases	16.2.0
2020-12	SA#90e	SP-201047	0003	-	F	Correction on general descriptions of centralized energy saving activation and deactivation	16.3.0
2020-12	SA#90e	SP-201047	0004	-	F	Corrections on distributed ES solution	16.3.0
2020-12	SA#90e	SP-201047	0005	-	F	Correction on general descriptions of distributed energy saving activation and deactivation	16.3.0
2020-12	SA#90e	SP-201047	0007	-	F	Remove the distributed scenario from the inter-RAT energy saving use case	16.3.0
2021-03	SA#91e	SP-210143	0009	1	F	Introducing the ES probing procedure	16.4.0
2021-03	SA#91e	SP-210142	0008	1	B	Add introductory text to EE KPIs for network slices	17.0.0
2021-03	SA#91e	SP-210142	0010	1	B	Add use case and requirements for switching off UPFs deployed at the edge of the network during off-peak hours to achieve energy savings.	17.0.0
2021-06	SA#92e	SP-210578	0011	1	B	Update on energy efficiency of URLLC network slice	17.1.0
2021-06	SA#92e	SP-210408	0015	-	A	Update on energy saving management services	17.1.0
2021-06	SA#92e	SP-210578	0016	1	B	Update of the EE KPIs Overview	17.1.0
2021-09	SA#93e	SP-210869	0017	-	F	Update on the solutions for energy efficiency	17.2.0
2021-12	SA#94e	SP-211459	0018	1	C	Update clause 6.2 for energy saving	17.3.0
2021-12	SA#94e	SP-211460	0020	1	A	Update energy saving solution	17.3.0
2022-09	SA#97e	SP-220850	0021	1	F	Solutions to calculate the energy consumption of PNF/VNF/VNFCs	17.4.0
2022-12	SA#98e	SP-221174	0022	2	B	Add Energy Saving compensation procedure	18.0.0
2023-03	SA#99	SP-230194	0024	-	A	Correct latency-based URLLC EE KPI unit	18.1.0
2023-03	SA#99	SP-230194	0026	-	A	Correct measurement used for eMBB and URLLC EE KPIs	18.1.0
2023-03	SA#99	SP-230243	0027	1	C	Adding traceablity for ES compensation activation and deactivation procedures	18.1.0
2023-06	SA#100	SP-230651	0033	1	F	Several editorial Corrections	18.2.0
2023-09	SA#101	SP-230940	0030	1	A	Update NG-RAN data EE KPI definition with reference to TS 28.554	18.3.0
2023-09	SA#101	SP-230944	0032	1	A	Remove redundant Network Slice EE KPI definition	18.3.0
2023-09	SA#101	SP-230952	0034	1	B	Introduce clause on roles involved in EE KPI building	18.3.0
2023-12	SA#102	SP-231465	0037	1	F	Rel-18 CR 28.310 Update on energy saving for UPFs	18.4.0
2023-12	SA#102	SP-231475	0038	1	B	Rel-18 CR TS 28.310 Add reference to TS 28.312 for intent driven approach for RAN energy saving use case	18.4.0
2023-12	SA#102	SP-231465	0039	2	B	Add definitions	18.4.0
2023-12	SA#102	SP-231465	0040	1	B	Describe example scenarios involving multiple roles in EE KPI building	18.4.0
2024-06	SA#104	SP-240812	0048	-	A	Rel-18 CR TS 28.310 Update energy saving terms	18.5.0

History

Document history		
V18.4.0	May 2024	Publication
V18.5.0	July 2024	Publication