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Contents

Foreword

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

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  - 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.

In the present document, certain modal verbs have the following meanings:

shall indicates a mandatory requirement to do something

shall not indicates an interdiction (prohibition) to do something

The constructions "shall" and "shall not" are confined to the context of normative provisions, and do not appear in Technical Reports.

The constructions "must" and "must not" are not used as substitutes for "shall" and "shall not". Their use is avoided insofar as possible, and they are not used in a normative context except in a direct citation from an external, referenced, non-3GPP document, or so as to maintain continuity of style when extending or modifying the provisions of such a referenced document.

should indicates a recommendation to do something

should not indicates a recommendation not to do something

may indicates permission to do something

need not indicates permission not to do something

The construction "may not" is ambiguous and is not used in normative elements. The unambiguous constructions "might not" or "shall not" are used instead, depending upon the meaning intended.

can indicates that something is possible

cannot indicates that something is impossible

The constructions "can" and "cannot" shall not to be used as substitutes for "may" and "need not".

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

might indicates a likelihood that something will happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

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".

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 some functions of a cell or a network element or network function are powered-down.

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

NOTE 2: This is the state when the traffic goes below a certain threshold.

notEnergySaving state: state when no energy saving in progress.

NOTE 3: This is the state when the traffic goes above a certain threshold.

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

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

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

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

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.

- EC definition and measurement method for 5G VNFs are not in the scope of 3GPP;
- In the present document, it is assumed that NG-RAN is only composed of base stations with built-in sensors (cf. ETSI ES 202 336-12 [4] – clause 4.4.1).

4.2 Management services

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

- Performance management services (cf. [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.

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]).

The energy saving consists of two scenarios where the capacity booster cell - gNB is fully or partially overlaid by the candidate cell(s).

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

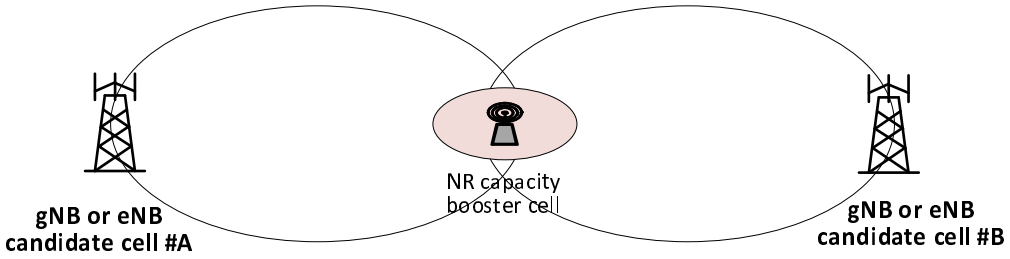

Figure 5.1.3.2.1-1: NR capacity booster cell partially overlaid by candidate cells

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 distributed energy saving where the energy saving decision is made in the NR cells with MnS producer(s) assist to provide relevant information, or 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.

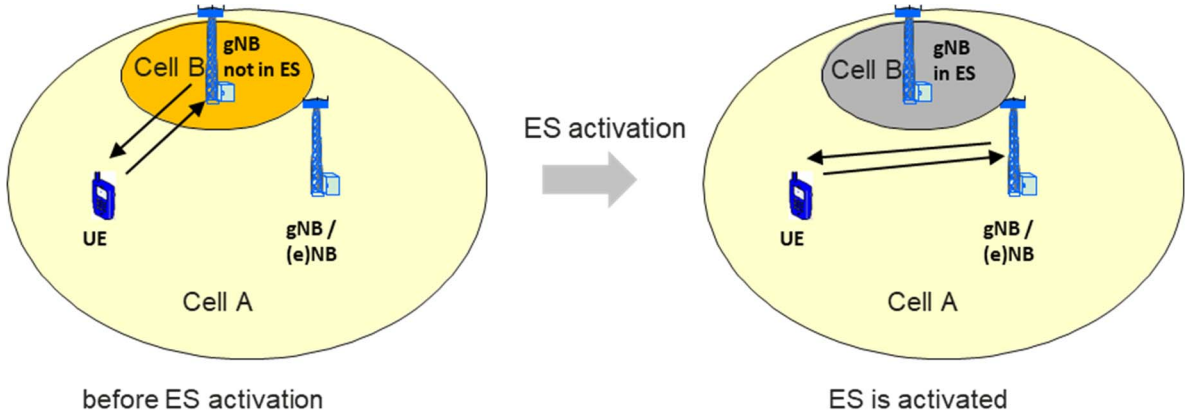

Figure 5.1.3.3-1: gNB capacity booster cell fully overlaid by candidate cell(s)

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.

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.

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: FFS.

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.

5.3 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

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]:

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

For different gNB scenarios, the two following performance measurements may be used as the DV_{MN}:

- **For split-gNBs scenario:**

  1) DL PDCP SDU Data Volume per interface (cf. clause 5.1.3.6.2.3 of TS 28.552 [15]): This measurement provides the Data Volume (amount of PDCP SDU bits) in the downlink delivered from GNB-CU-UP to GNB-DU (F1-U interface), to external gNB-CU-UP (Xn-U interface) and to external eNB (X2-U interface). The measurement is calculated per QoS level (mapped 5QI or QCI in NR option 3) and per S-NSSAI, and reported per Interface (F1-U, Xn-U, X2-U);

  2) UL PDCP SDU Data Volume per interface (cf. clause 5.1.3.6.2.4 of TS 28.552 [15]): This measurement provides the Data Volume (amount of PDCP SDU bits) in the uplink delivered to GNB-CU-UP from GNB-DU (F1-U interface), from external gNB-CU-UP (Xn-U interface) and from external eNB (X2-U interface). The measurement is calculated per QoS level (mapped 5QI or QCI in NR option 3) and per S-NSSAI, and reported per Interface (F1-U, Xn-U, X2-U);

- **For non-split gNBs scenario:**

  1) DL Cell PDCP SDU Data Volume (cf. clause 5.1.2.1.1.1 of TS 28.552 [15]): This measurement provides the Data Volume (amount of PDCP SDU bits) in the downlink delivered to PDCP layer. The measurement is calculated per PLMN ID and per QoS level (mapped 5QI) and per S-NSSAI;

  2) UL Cell PDCP SDU Data Volume (cf. clause 5.1.2.1.2.1 of TS 28.552 [15]): This measurement provides the Data Volume (amount of PDCP SDU bits) in the uplink delivered from PDCP layer to higher layers. The measurement is calculated per PLMN ID and per QoS level (mapped 5QI) and per S-NSSAI;

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.

6.2 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 set by operators.

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), 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)
    - 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)
- 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.
    - 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

Figure 6.2.2.1.1-1 depicts a procedure that describes how MnS producer of Centralized ES management can activate the ES function.

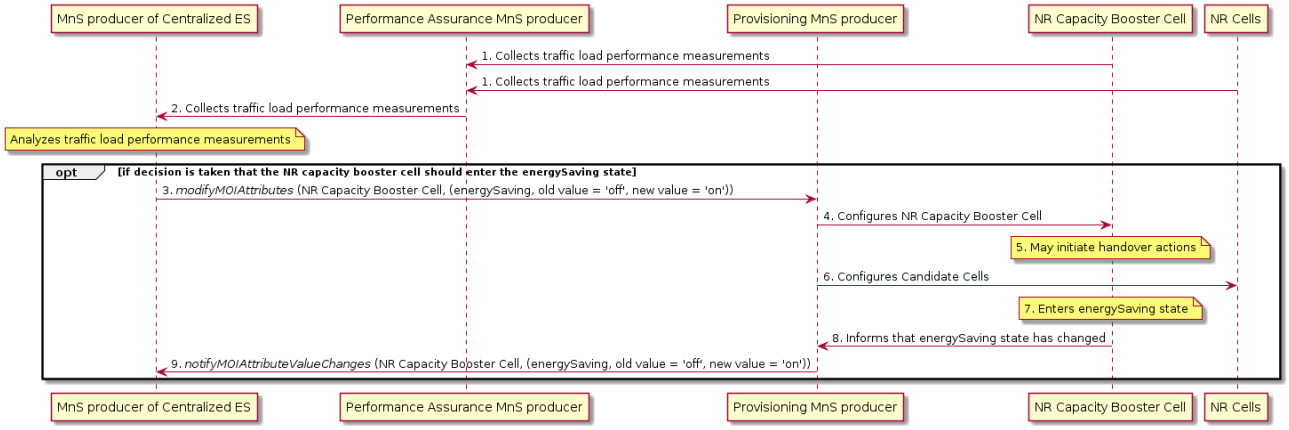

Figure 6.2.2.1.1-1: Centralized energy saving activationIt is assumed that all relevant MOIs have been created.

Energy saving activation:

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

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

The MnS producer for 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 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 Centralized ES management can deactivate the ES function.

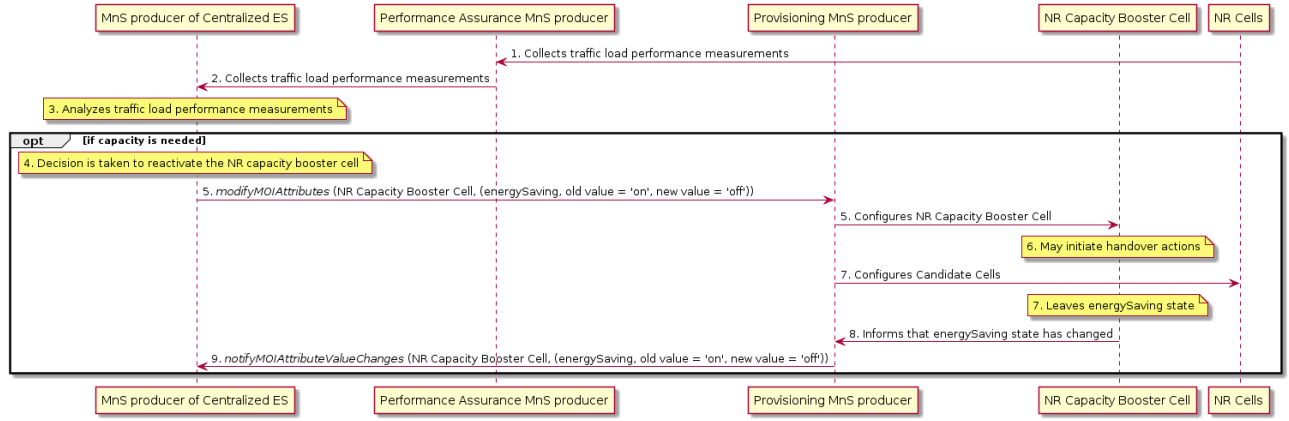

Figure 6.2.2.1.2-1: Centralized energy saving deactivation

Energy saving deactivation:

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

The MnS producer for 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 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.

6.2.3 Distributed energy saving solution

6.2.3.0 Management service components used for D-SON ES solution

The MnS components used for D-SON (Distributed SON or Domain-Centralized) ES solution are listed in the following clauses.

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` - `notifyMOIAttributeValueChange` - `notifyMOIDeletion`	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 D-SON (Distributed SON or Domain-Centralized) 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 energy saving 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.	
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.	
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 split gNBs.	
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 split gNBs.	
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 split gNBs.	
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 split gNBs.	
PNF Energy consumption	Energy consumed – see clause 5.1.1.19.3 of TS 28.552	

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 can activate the Distributed ES function.

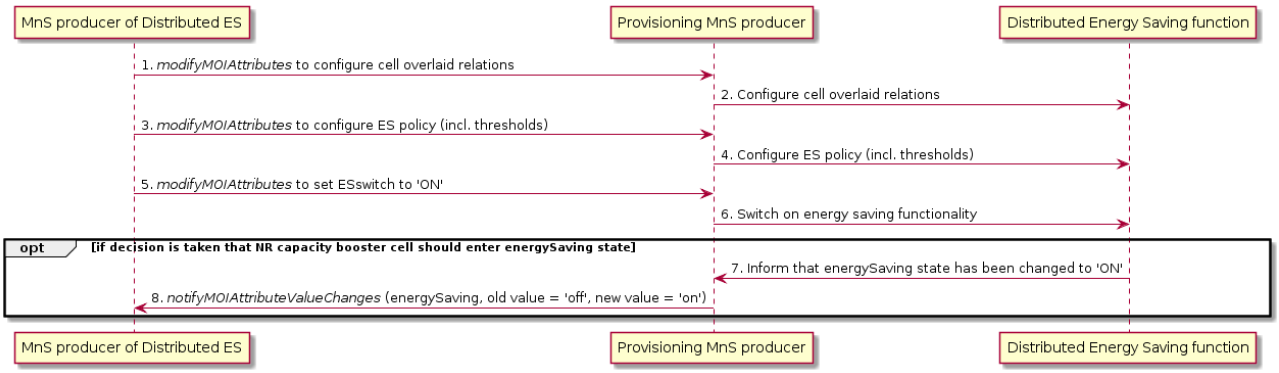

Figure 6.2.3.2.1-1: Distributed energy saving activation

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: NRM may need to be enhanced to support cell overlaid relations, ES policy, and ES control. This is FFS.

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 MnS producer of Distributed ES management can deactivate the Distributed ES function.

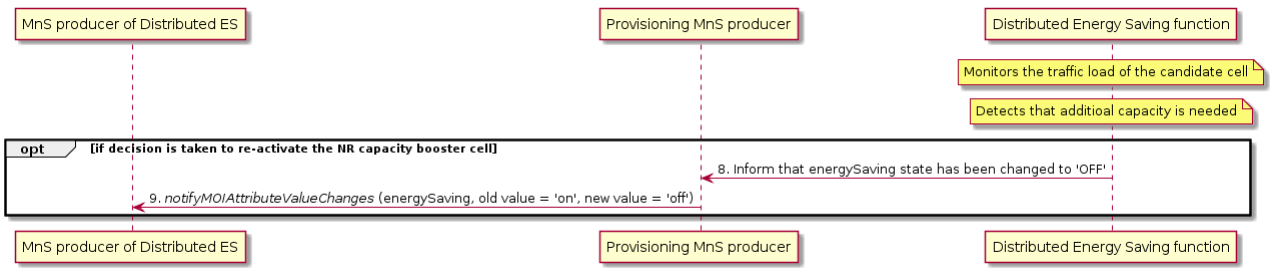

Figure 6.2.3.2.2-1: Distributed energy saving deactivation

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.

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): 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

History

Document history		
V16.1.0	August 2020	Publication