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| Technical Report |
| 3rd Generation Partnership Project;Technical Specification Group Radio Access Network;Study on network energy savings for NR(Release 18) |
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# Foreword

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

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

Version x.y.z

where:

x the first digit:

1 presented to TSG for information;

2 presented to TSG for approval;

3 or greater indicates TSG approved document under change control.

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

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

In the present document, 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" are not 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 captures the findings from the study item of "Study on network energy savings for NR" [2].

The study includes how to model network energy consumption especially for a base station, and evaluations of network energy saving gains as well as impact to network and user performance, by reusing existing KPI whenever applicable or new KPIs as needed. The study is also to identify techniques on gNB and UE side that can improve the network energy savings in various domains, potentially with UE feedback/assistance information and information exchange over network interfaces.

The study prioritizes idle/empty and low/medium load scenarios, allow different loads among carriers and neighbor cells, allows legacy UEs to be able to continue accessing a network implementing Rel-18 network energy savings techniques, with the possible exception of techniques developed specifically for greenfield deployments. The study does not include aspects related to IAB.

# 2 References

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

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

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

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

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

[2] 3GPP RP-220297: "Revised SI: Study on network energy savings for NR".

[3] GSMA, 5G energy efficiencies: Green is the new black, https://data.gsmaintelligence.com/api-web/v2/research-file-download?id=54165956&file=241120-5G-energy.pdf.

# 3 Definitions of terms, symbols and abbreviations

## 3.1 Terms

For the purposes of the present document, the terms given in 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 TR 21.905 [1].

**example:** text used to clarify abstract rules by applying them literally.

## 3.2 Symbols

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

<symbol> <Explanation>

## 3.3 Abbreviations

For the purposes of the present document, the abbreviations given in 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 TR 21.905 [1]

AAU Active Antenna Unit

OPEX Operating Expenses

UPT User Perceived Throughput

XR Extended Reality

# 4 Introduction

Network energy saving is of great importance for environmental sustainability, to reduce environmental impact (greenhouse gas emissions), and for operational cost savings. As 5G is becoming pervasive across industries and geographical areas, handling more advanced services and applications requiring very high data rates (e.g. XR), networks are being denser, use more antennas, larger bandwidths and more frequency bands. The environmental impact of 5G needs to stay under control, and novel solutions to improve network energy savings need to be developed.

Energy consumption has become a key part of the operators' OPEX. According to the report from GSMA [3], the energy cost on mobile networks accounts for ~23% of the total operator cost. Most of the energy consumption comes from the radio access network and in particular from the AAU, with data centres and fibre transport accounting for a smaller share. The power consumption of a radio access can be split into two parts: the dynamic part which is only consumed when data transmission/reception is ongoing, and the static part which is consumed all the time to maintain the necessary operation of the radio access devices, even when the data transmission/reception is not on-going.

Therefore, there is a need to study and develop a network energy consumption model especially for the base station (a UE power consumption model was already defined in TR38.840), KPIs, an evaluation methodology and to identify and study network energy savings techniques in targeted deployment scenarios. The study investigates how to achieve more efficient operation dynamically and/or semi-statically and finer granularity adaptation of transmissions and/or receptions in one or more of network energy saving techniques in time, frequency, spatial, and power domains, with potential support/feedback from UE, potential UE assistance information, and information exchange/coordination over network interfaces.

The study not only evaluates the potential network energy consumption gains, but also assesses and balances the impact on network and user performance, e.g. by looking at KPIs such as spectral efficiency, capacity, UPT, latency, UE power consumption, complexity, handover performance, call drop rate, initial access performance, SLA assurance related KPIs, etc. The techniques studied could avoid having a large impact to such KPIs.

# 5 Modeling and evaluation methodology

*Editor's note: for any FFS on details of any bullet, will be updated once more agreements are made.*

## 5.1 Energy consumption model for BS

For evaluation purpose, the energy consumption modeling for a BS for evaluation includes at least:

* Reference configuration
* Multiple power state(s) including sleep or non-sleep modes with relative power, and associated transition time/energy
* Scaling method to be applied.

For reference configuration, at least the following is considered for single CC case.

Table 5.1-1 Reference configuration for BS power consumption model

|  |  |  |  |
| --- | --- | --- | --- |
|  | Set 1 FR1 | Set 2 FR1 | Set 3 FR2 |
| Duplex | TDD | FDD | TDD |
| System BW | 100 MHz | 20 MHz | 100 MHz |
| SCS | 30 kHz | 15 kHz | 120 kHz |
| Number of TRP | 1 | 1 | 1 |
| Total number of DL TX RUs | 64 | 32 | 2 |
| Total DL power level | 55 dBm | 49 dBm | 33\* |
| Total number of UL Rx RUs | 64 | 32 | 2 |

Note: EIRP limit is 63 dBm for the reference configuration. The EIRP value is scaled with the number of TxRUs.

For power states, for at least non-sleep mode and TDD, the BS power consumption for DL and UL are separately modelled, allowing DL-only transmission or UL-only reception. The relative power value in power consumption model tables for UL reception and/or DL transmission is provided based on the reference configurations. For simultaneous DL and UL transmission for FDD, the power for UL reception is neglected in this study.

The power states of power consumption model are provided as Table 5.1-2. The entries are provided in Table 5.1-3 – 5.1-5 per reference configuration.

Table 5.1-2 Power states of BS power consumption model

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Power state** | **Characteristic** | Relative Power | Additional transition energy2 | **Total transition time** |
| Deep sleep1 | There is neither DL transmission nor UL reception. Time interval for the sleep should be larger than the total transition time entering and leaving this state.  | P1 | E1 | T1  |
| Light sleep | There is neither DL transmission nor UL reception. Time interval for the sleep should be larger than the total transition time entering and leaving this state. | P2 | E2 | T2  |
| Micro sleep | There is neither DL transmission nor UL reception.Immediate transition is assumed for network energy saving study purpose from or to a non-sleep state. | P3 | 0 | 0 |
| Active DL | There is only DL transmission. | P4 | N.A. |
| Active UL | There is only UL reception. | P5 |
| Note 1: Depending on implementations, there could be a state that the power is lower than deep sleep and requires larger total transition time, e.g. hibernating sleep or Quasi-off, which is not explicitly modeled in this study for evaluation purpose. Note 2: Unit in relative power times duration. |

*Editor note: the agreed P1=1 and P2>P1 in the above table is removed for now since it is likely naturally the case after values in tables are determined.*

Table 5.1-3 relative power values for reference configuration set 1

|  |  |  |
| --- | --- | --- |
| **Power state** | **Relative Power *P*** | **Total transition time *T*** |
| **Category 1** | **Category 2** | **Category 1** | **Category 2** |
| Deep sleep |  |  |  |  |
| Light sleep |  |  |  |  |
| Micro sleep |  |  |  |  |
| Active DL |  |  | N.A. |
| Active UL |  |  |

Table 5.1-4 relative power values for reference configuration set 2

Table 5.1-5 relative power values for reference configuration set 3

For scaling method, at least for non-sleep mode, the scaling can be based on one or more of the following:

* number of used physical antenna elements, or TX/RX RUs
* occupied BW/RBs for DL and/or UL in a slot/symbol in one CC
* number of CCs in CA
* number of TRPs
* PSD or transmit power
* number of DL and/or UL symbols occupied within a slot.

For evaluation, above does not necessarily imply that BS energy consumption model that takes into account all listed scaling factors are to be developed.

## 5.2 Evaluation methodology

*Editor's note: for any FFS on details of any bullet, will be updated once more agreements are made.*

For evaluation, the BS energy consumption model at least include the power consumption of BS on slot-level, and symbol-level power consumption to reflect different BW (or RB utilization) / time-occupancy / tx-rx direction of different symbols in a slot is considered. System simulation evaluations can be per slot regardless of detailed approach for calculating symbol-level power consumption.

The evaluation baseline includes at least NR R15 mandatory without capability features. Optional features from R15 onwards (e.g. CA, MIMO) as well as implementation-based energy saving techniques are to be explicitly reported and described if used in the evaluation baseline.

For evaluation purpose, network energy saving gain is computed based on the energy consumptions for a technique and the baseline over the same duration. Percentage of energy consumption reduction from the baseline is used to express BS energy saving gain. In addition to the BS energy saving gain, at least UPT/UE power consumption/access delay/latency is to be considered for performance impact evaluation.

In the evaluation,

* a load (L) of a cell is a percentage of resources used for UE specific PDSCH/PUSCH.
* The following load scenarios are considered.

|  |  |
| --- | --- |
| Load scenario | Characteristics |
| Idle/empty load | * Include cell-specific signals and channels, and
* L = 0
 |
| low load | * Include cell-specific signals and channels, and
* 0 < L≤15
 |
| Light load | * Include cell-specific signals and channels, and
* 0 < L≤30
 |
| Medium load | * Include cell-specific signals and channels, and
* 30< L≤50
 |
| For CA, the companies report whether the load is defined per CC or across all CCs. |

FTP3 (0.5MB as packet size, 200ms as mean inter-arrival time), FTP3 IM (0.1MB as packet size, 2s as mean inter-arrival time) and VOIP can be considered in the evaluation. It is up to company report which traffic model is used among the agreed three traffic models in their evaluations. Other models may be used as well, and parameter (e.g. packet size and arrival rate) adjustment can be optionally considered and reported.

SLS is considered as baseline evaluation method. Other method, including numerical analysis and LLS can also be considered. At least one of the methods is to be selected and used for evaluation of a specific technique (selection and criteria is up to proponent).

For FR1, at least urban macro is prioritized. Urban micro can be optionally considered. For FR2, urban micro is prioritized, with ISD=200 m is assumed.

# 6 Techniques to improve network energy savings

*Editor's note: simulation results to be captured under this section.*

*Editor's note: RAN2 and RAN3 related aspect to be provided by using separate sections like 6.X when applicable.*

## 6.1 Techniques in X domain

### 6.1.1 Technique 1 (e.g. Adapting transmission/reception of common channels/signals)

#### 6.1.1.z Impacts on network interfaces

## 6.2 Techniques in Y domain

## 6.x Higher layer aspects for network energy savings

*Editor's note: This section includes common aspects of higher layers deduced from the above candidate directions.*

# 7 Conclusions

Annex <A>:
Simulation assumptions

 Annex <X>:
Change history

|  |
| --- |
| **Change history** |
| **Date** | **Meeting** | **TDoc** | **CR** | **Rev** | **Cat** | **Subject/Comment** | **New version** |
| 2022-05 | RAN1#109-e | R1-2205307 |  |  |  | TR Skeleton | 0.0.1 |
| 2022-05 | RAN1#109-e | R1-2205694 |  |  |  | Endorsed TR Skeleton | 0.0.2 |
| 2022-08 | RAN1#110 | R1-220xxxx |  |  |  | TR update per agreements in RAN1#109-e and RAN1#110 | 0.1.0 |