# 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>.

[4] 3GPP R1-2205551: "FL summary#4 for performance evaluation for NR NW energy savings".

[5] 3GPP R1-2208216: "FL summary#3 for EVM for NR NW energy savings".

[6] 3GPP R1-2208312: "FL summary for Post-110-R18- NW\_ES2".

[7] 3GPP R1-2210592: "FL summary#4 for R18 NW\_ES".

# 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

BS Base Station

CC Component Carrier

EIRP Effective Isotropic Radiated Power

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:

* 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, 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 dBm\* |
| 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 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. Note: The BS power model defined in this study is a simplified model for the purposes of evaluations, considering single-RAT NR BSs only. This does not mean a BS cannot benefit from the identified techniques when serving multi-RAT. Transition among power states, transition time, are implementation specific, and different BS types may support a different number of power states with different characteristics, i.e., power consumption values and required transition time.

During the transition time period, relative power of sleep mode *i* is assumed to be consumed. For RAN1 evaluation purpose, the values of relative power *P* for BS Category 1 and BS Category 2 for respective set of reference configurations are provided in Table 5.1-3.

Additional transition energy *E* and total transition time *T* also include energy and time for both ramping down and ramping up. The values of total transition time for BS power state transition are given in Table 5.1-4, which are the same across different sets of reference configurations for a given BS Category. The values of additional transition energy for reference configuration Set 1, Set 2 and Set 3, with unit in (relative power)\*(duration in ms), are provided in Table 5.1-5.

For background and discussion related to the power models as well as the corresponding values for relative power, transition time and additional transition energy, see [4][5][6][7] and references therein.

Table 5.1-2: Power states of BS power consumption model

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Power state** | **Characteristic** | Relative Power *P* | Additional transition energy2 *E* | **Total transition time*****T*** |
| 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. | | | | |

Table 5.1-3: Relative power values P for reference configuration Set 1, Set 2 and Set 3

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Power state** | **BS Category 1** | | | **BS Category 2** | | |
| **Set 1** | **Set 2** | **Set 3** | **Set 1** | **Set 2** | **Set 3** |
| Deep sleep | 1 | | | 1 | | |
| Light sleep | 25 | | | 2.1 | | |
| Micro sleep | 55 | 50 | 38 | 5.5 | 5 | 3 |
| Active DL | 280 | 200 | 152 | 32 | 26 | 17.6 |
| Active UL | 110 | 90 | 80 | 6.5 | 5.8 | 4.2 |

Table 5.1-4: Total transition time *T* for reference configuration Set 1, Set 2 and Set 3

|  |  |  |
| --- | --- | --- |
| **Power state** | **BS Category 1** | **BS Category 2** |
| Deep sleep | 50 ms | 10 s |
| Light sleep | 6 ms | 640 ms |

Table 5.1-5: Additional transition energy *E* for reference configuration Set 1, Set 2 and Set 3

|  |  |  |
| --- | --- | --- |
| **Power state** | **BS Category 1** | **BS Category 2** |
| Deep sleep | 1000 | 17000 |
| Light sleep | 90 | 1088 |

For scaling method, 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 active DL transmission, the BS power consumption is provided by

where

* is a static part of power for BS in active, which is not scaled based on reference configurations.
  + - Baseline:
    - Optional:
* is a dynamic part of power for BS in active, which is scaled based on reference configuration.
  + - Baseline: , where ,, is the fraction of active TRxRUs, the ratio between the RF bandwidth and the maximum system BW, and the ratio of PSD per TxRU between the DL transmission and reference configuration, respectively.
      * + is the power part related to PA.
        + For simplicity
      * A = baseline: 0.4; optional: [0.1, 0.7];
      * For , in evaluation, company to report the assumption from below:

If one value of is used for evaluation, for any ;

If two values of are used for evaluation, if ; otherwise,

For active UL transmission, the BS power consumption for is provided by

where

* + is a static part of power for BS in active, which is not scaled based on reference configurations.
  + is a dynamic part of power for BS in active, which is scaled based on reference configuration, and is the percentage of active TRxRUs.
  + Baseline:
    - when no scaling is applied (i.e. scaling factor is 1).

Note,

* For multi-carrier, the total power consumption of BS is calculated as is the sum of the power consumption of each CC; for intra-band multi-carrier with contiguous CCs, the power consumption of each additional CC is scaled by [0.7].
* For multi-TRP, the total power consumption of BS is assumed as is the sum of the power consumption of each TRP. Company to report whether is shared among TRPs (if shared, is accounted once).
* Company to additionally report the assumption for antenna adaptation delay, e.g. immediate adaptation, or with a transition time of [1-3] ms, etc.
* In time domain, the power consumption in a slot is the sum of the power consumption associated with symbols in the slot. The symbol may correspond to uplink symbol, downlink symbol, or symbol without uplink and downlink. Company to report how the summation is performed along with evaluation results.

Other values for the above scaling formula, and other scaling approaches can be optionally reported, including

* At least = 1 is supported.
* , with being the ratio of RF BW to the maximum system BW.

## 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. All calculation of energy consumption is to use the same time unit. Companies are to indicate which time unit is used.

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.

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 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. Other KPIs can be optionally reported, conditioned with clear definition/descriptions provided. Note for potential new channel/signals, e.g. WUS from UE, the assumption for detection reliability at BS side is to be reported (performance and complexity impact would subject to results and further discussion).

For initial evaluations, there is always a non-sleep mode assumed between adjacent sleep modes.

System level evaluation assumptions are provided in Annex A and B.

Companies are to report the assumption details for the reception of a low-power UL channel/signal, if used, including power states, additional transition energy, and transition times, receiver details (e.g. architecture and receiver sensitivity), and other impact/change on the power consumption model.

# 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 time domain

### 6.1.1 Technique A-1 Adapting transmission/reception of common channels/signals

#### 6.1.1.1 Description of technique

*Editor's note:* *potential need of UE assistance is also to be described here.*

#### 6.1.1.2 Analysis of performance and impacts

*Editor's note: potential impact on UE side is also to be included here.*

*Editor's note:*

<*start*>

*For companies to consider when providing evaluation results:*

* *Use the following table with adding Category, as a draft template for collection of simulation results*
* *The template can be further adjusted with input when captured into TR.*
* *Other formats are not precluded.*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| *Company* | *NW energy saving scheme* | *ES Gain* | *ES gain for each configuration* | *UPT*  *~~(Optional: Energy Efficiency)~~* | *Other impact* | *Evaluation methodology/baseline assumption* | *Note* |
|  |  | *Editor Note: includes a range for different configurations, if possible.* | *Editor Note: include gain for each configuration, if possible. For example, per Load, configurations of common signals etc.* | *Editor Note: may include average UPT, target UPT (95%/50%/5%) and UPT loss/gain per ES techniques.*  *May also include scheduling latency, user plane latency etc.*  *~~Optionally, results with EE can be included with clear definition reported.~~* | *Editor Note: may include coverage, UE power consumption, EE with definition, etc.* | *Editor Note: may include selected parameters/baselines etc, if there are multiple.* | *Editor Note: other important setting that needs to be reported, e.g. the selected options/approaches as mentioned in* [*R1-2208654*](file:///C:\Users\youns\OneDrive\Documents\3GPP\RAN1%20tdocs\TSGR1_110b-e\Docs\R1-2208654.zip)*.* |

<*end*>

#### 6.1.1.3 Specification impacts

*Editor's note: potential need of UE assistance that may have RAN2 impact is also to be provided here, preferably using a separate paragraph for RAN2 easy reference.*

6.1.2 SCell without SSB in inter-band CA

6.1.2.x Higher layer procedures

The SCell without SSB in intra-band CA is considered as baseline, i.e., for a serving cell without transmission of SS/PBCH blocks, a UE acquires time and frequency synchronization with the serving cell based on receptions of SS/PBCH blocks on the SpCell or the SCell, of the cell group.

More detailed discussion on higher layer procedures for RAN2 may be needed in WI phase according to the other WGs input.

Feasibility of this solution is in RAN1 scope.

6.1.2.z Impacts on network interfaces

*Editor's note: will be updated once more agreements are made.*

6.1.3 NES Cell without SIB/SSB

6.1.3.x Higher layer procedures

The concept of non-anchor NES cell without SIB is only applicable in multi-carrier scenario, where the UE is in coverage of an anchor cell and one or multiple non-anchor NES cell(s).

Anchor cell is a cell where a UE is capable of receiving SSB, system information and paging.

A non-anchor NES cell without SIB is a cell where the UE cannot receive SIB.

A non-anchor NES cell without SSB and SIB is a cell where a UE receives neither SSB nor SIB.

Depending on a design, the access may occur only via anchor cell or also directly in the non-anchor NES cell. If access directly to a non-anchor NES cell is supported, the SIB transmitted by anchor cell may also include the necessary information to access the non-anchor NES cell.

How and whether the timing, synchronization and QCL relationship of the non-anchor NES cell without SSB and SIB can be determined via another cell is decided within WI.

UE camps on an anchor cell, not on a non-anchor NES cell without SIB (or without SSB and SIB).

Paging on a non-anchor NES cell without SIB or a non-anchor NES cell without SSB and SIB is not supported.

Feasibility of this solution is in RAN1 scope.

6.1.3.z Impacts on network interfaces

*Editor's note: will be updated once more agreements are made.*

### 6.1.2 Technique A-2 XX

#### 6.1.2.1 Description of technique

#### 6.1.2.2 Analysis of performance and impacts

#### 6.1.2.3 Specification impacts

### 6.1.z Impacts on network interfaces

### 6.1.aa Cell DTX/DRX

#### 6.1.aa.1 Description of technique

#### 6.1.aa.2 Analysis of performance and impacts

#### 6.1.aa.3 Specification impacts

#### 6.1.aa.4 Higher layer procedures

Cell DTX/DRX is applied to at least UEs in RRC\_CONNECTED state. A periodic Cell DTX/DRX (i.e., active and non-active periods) can be configured by gNB via UE-specific RRC signalling per serving cell. Below examples on Cell DTX/DRX behaviour during non-active periods are assumed to be possible options, and the UE behaviour/impact will be studied:

* Example 1: gNB is expected to turn off all transmission and reception for data traffic and reference signal during Cell DTX/DRX non-active periods.
* Example 2: gNB is expected to turn off its transmission/reception only for data traffic during Cell DTX/DRX non-active periods (i.e., gNB will still transmit/receive reference signals)
* Example 3: gNB is expected to turn off its dynamic data transmission/reception during Cell DTX/DRX non-active periods (i.e., gNB is expected to still perform transmission/reception in periodic resources, including SPS, CG-PUSCH, SR, RACH, and SRS).
* Example 4: gNB is expected to only transmit reference signals (e.g., CSI-RS for measurement).

The study will focus on UE behavior when at any point in time the cell activates a single DTX/DRX configuration. It is up to NW whether legacy UEs can access cells with Cell DTX/DRX.

The Cell DTX/DRX mode can be activated/de-activated via dynamic L1/L2 signalling and UE-specific RRC signaling.  Both UE specific and common L1/L2 signalling can be considered for activating/deactivating the Cell DTX/DRX mode.

Cell DTX and Cell DRX modes can be configured and operated separately (e.g., one RRC configuration set for DL and another for UL). Cell DTX/DRX can also be configured and operated together. At least the following parameters can be configured per Cell DTX/DRX configuration: periodicity, start slot/offset, on duration. Details related to UE behaviour can be discussed during WI phase. Whether to support multiple Cell DTX/DRX configurations can be discussed later in the WI phase.

It is beneficial to align UE DRX with Cell DTX and DRX alignment among multiple UEs. The alignment mechanism will be studied.

From RAN2 perspective, Cell DTX/DRX is feasible.

6.1.aa.5 Impacts on network interfaces

*Editor's note: will be updated once more agreements are made.*

The cell DTX/DRX information is considered necessary to be exchanged and coordinated between neighbour gNBs. The gNB can use the received cell DTX/DTX information to determine its own cell DTX/DRX configuration for network energy saving purpose.

*Editor’s note: The details of cell DTX/DRX is finally up to RAN1 and RAN2.*

## 6.2 Techniques in frequency domain

### 6.2.1 Technique B-1 YY

#### 6.2.1.1 Description of technique

#### 6.2.1.2 Analysis of performance and impacts

#### 6.2.1.3 Specification impacts

### 6.2.2 Technique B-2 YYY

#### 6.2.2.1 Description of technique

#### 6.2.2.2 Analysis of performance and impacts

#### 6.2.2.3 Specification impacts

### 6.2.z Impacts on network interfaces

## 6.3 Techniques in spatial domain

### 6.3.1 Technique C-1 ZZ

#### 6.3.1.1 Description of technique

#### 6.3.1.2 Analysis of performance and impacts

#### 6.3.1.3 Specification impacts

### 6.3.2 Technique C-2 ZZZ

#### 6.3.2.1 Description of technique

#### 6.3.2.2 Analysis of performance and impacts

#### 6.3.2.3 Specification impacts

### 6.3.z Impacts on network interfaces

## 6.4 Techniques in power domain

### 6.4.1 Technique D-1 WW

#### 6.4.1.1 Description of technique

#### 6.4.1.2 Analysis of performance and impacts

#### 6.4.1.3 Specification impacts

### 6.4.2 Technique D-2 WWW

#### 6.4.2.1 Description of technique

#### 6.4.2.2 Analysis of performance and impacts

#### 6.4.2.3 Specification impacts

### 6.4.z Impacts on network interfaces

## 6.5 Other energy saving aspects and techniques

*Editor's note:* *placeholder.*

## 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.*

6.X.1 Cell selection/reselection

For backward compatibility, there is a need to allow NES cells to prevent legacy UEs from camping. NES cells should be able to configure whether to prevent legacy UEs, while allowing NES-capable UEs to camp on. Possible solutions may include but not limited to:

* Use *IntraFreqExcludedCellList*/*InterFreqExcludedCellList*
* Use the *cellBarred* or cell reservation fields in MIB/SIB

The definition of NES cell will be discussed in the WI phase.

The NW should be able to configure NES-capable UEs to prioritize/down-prioritize a specific NES cell or NES cells on a specific frequency. It is left to the WI phase whether the existing mechanism for cell (re)selection is sufficient according to the NES techniques specified.

From RAN2 perspective, legacy UEs and NES-capable UEs can be handled via cell selection/reselection techniques in the presence of NES cells.

### 6.X.2 Connected mode mobility

During the switching of NES modes, it is possible to handover the UEs faster by enhancing the CHO framework with:

1. Evaluation of conditional handover conditions depending on the NES mode of source/target cell,
2. How to indicate to UE the triggering of the CHO evaluation is up to the WI phase.

Whenever mobility from source cell is triggered, the NES mode of the target cell could also be considered, e.g., to avoid UEs selecting cells operating in NES mode if any other cell is available.

From RAN2 perspective, CHO enhancements are feasible.

Group HO (optimizing the Rel-15 HO procedure) and BWP adaptation with group signalling are not considered by RAN2.

# 7 Conclusions

Annex A: Evaluation scenarios, traffic models and loads

For FR1, at least urban macro is prioritized. Urban micro can be optionally considered. For FR2, urban micro is prioritized.

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.

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.

Table A-1

|  |  |
| --- | --- |
| 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 * 15 < 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. | |

It is up to company report the use of UE C-DRX.

* the baseline configuration (for alignment/calibration) for C-DRX, if reported, can be as below;
* Other inactivity timer values can be optionally reported.

Table A-2

|  |  |  |  |
| --- | --- | --- | --- |
| Traffic type | FTP | IM | VoIP |
| Model | FTP model 3 | FTP model 3 | As defined in R1-070674.  Assume max two packets bundled. |
| Packet size | 0.5 Mbytes | 0.1 Mbytes |
| Mean inter-arrival time | 200 ms | 2 sec |
| DRX Period | 160 ms | 320 ms | 40 ms |
| DRX Inactivity timer | 100 ms | 80 ms | 10 ms |
| On duration | FR1: 8 ms  FR2: 4 ms | FR1: 10 ms  FR2: 5 ms | FR1: 4 ms  FR2: 2 ms |

Annex B: Simulation assumptions

For FR1, the baseline SLS assumptions is provided as below. Other carrier frequencies can be optionally considered.

Table B-1: Baseline SLS assumptions for FR1 Set 1 and Set 2

|  |  |  |  |
| --- | --- | --- | --- |
|  | | **Parameters** | |
| **Set 2** | **Set 1** |
| **Basic parameters** | **Channel model** | 3D-Uma as in TR 38.901 (low-loss O2I penetration model) | 3D-Uma as in TR 38.901 (low-loss O2I penetration model) |
| **Percentage of high loss and low loss building type** | 100% low loss | 100% low loss |
| **Device deployment** | 80% indoor, 20% outdoor | 80% indoor, 20% outdoor |
| **Inter-site distance** | 500m | 500m |
| **Network Topology** | 7\*3 Sector | 7\*3 Sector |
| **Carrier Frequency** | 2.1GHz | 4.0GHz or 2.6GHz |
| **Multiple access** | OFDMA | OFDMA |
| **Duplexing** | FDD | TDD |
| **Numerology** | 15KHz,  14 OFDM symbol slot | 30kHz,  14 OFDM symbol slot |
| **Guard band ratio on simulation bandwidth** | FDD: 6.4% (104RB for 15kHz SCS and 20 MHz BW) | TDD: 2.08% (272 RB for 30kHz SCS and 100 MHz bandwidth) |
| **Simulation bandwidth** | Follow reference configuration, (equal split of 10 MHz for UL and DL) | Follow reference configuration |
| **Frame structure** | / | DDDSU (S slot is assumed as 10D:2G:2U) |
| **UT attachment** | Based on RSRP | Based on RSRP |
| **Wrapping around method** | Geographical distance based wrapping | Geographical distance based wrapping |
| **Traffic model** | Follow previous RAN1 agreements | Follow previous RAN1 agreements |
| **BS parameters** | **BS antenna height** | 25 m | 25 m |
| **BS noise figure** | 5 dB | 5 dB |
| **BS antenna element gain** | 8 dBi | 8 dBi |
| **Antenna configuration at TRxP** | For 32T: (M,N,P,Mg,Ng; Mp,Np) = (8,8,2,1,1;2,8) (dH, dV)=(0.5, 0.8)λ | For 64T:  (M, N, P, Mg, Ng, MP, NP,) = (8, 8, 2, 1, 1, 4, 8).  based on 38.802 |
| **UE parameters** | **UE power class** | 23dBm | 23dBm |
| **UE noise figure** | 9 dB | 9 dB |
| **UE antenna element gain** | 0 dBi | 0 dBi |
| **UE antenna height** | Outdoor UEs: 1.5 m; Indoor Uts: 1.5m or consider floor height | Outdoor UEs: 1.5 m; Indoor Uts: 1.5m or consider floor height |
| **Antenna configuration at UE** | For 4R: (M,N,P,Mg,Ng; Mp,Np)= (1,2,2,1,1; 1,2)  (dH, dV)=(0.5, N/A)λ | For 4R: (M,N,P,Mg,Ng; Mp,Np)= (1,2,2,1,1; 1,2)  (dH, dV)=(0.5, N/A)λ |
| **Transmission parameters** | **Modulation** | Up to 256 QAM | Up to 256 QAM |
| **Transmission scheme** | SU-MIMO | SU-MIMO |
| **SU dimension** | For 4Rx: Up to 4 layers | For 4Rx: Up to 4 layers |
| **DL CSI measurement** | Non-precoded CSI-RS based | Precoded CSI-RS based |
| **DL codebook** | Type I/II codebook | non-PMI transmission |
| **SRS transmission** | N/A | For UE 4 Tx ports: Non-precoded SRS |
| **CSI feedback** | Company to report the assumptions | Company to report the assumptions |
| **Interference measurement** | SU-CQI; CSI-IM for inter-cell interference measurement | SU-CQI; CSI-IM for inter-cell interference measurement |
| **Scheduling** | PF | PF |
| **Receiver** | MMSE-IRC | MMSE-IRC |
| **Channel estimation** | Non-ideal | Non-ideal |
| **HARQ scheme** | Ideal | Ideal |
| **Max HARQ retransmission** | 3 | 3 |
| **Target BLER** | 10% of first transmission | 10% of first transmission |
| **Power control parameters** | Open loop, P0=-80dBm, alpha=0.8 | Open loop, P0=-80dBm, alpha=0.8 |
| **Common RS** | **SSB period** | 20ms | 20ms |
| **SS blocks per SSB burst** | Up to 4 | Up to 8 |
| **SSB time resource** | 4 symbols for each SSB | 4 symbols for each SSB |
| **SSB frequency resource** | 20 RBs | 20 RBs |

For FR2, the baseline SLS assumptions is provided as below. Other carrier frequencies can be optionally considered.

Table B-2: Baseline SLS assumptions for FR2 Set 3

|  |  |  |  |
| --- | --- | --- | --- |
| **BS type** | Micro | **UE BWP** | 100 Mhz |
| **Network layout and inter-site distance** | 21 cells Wraparound (ISD=200m) | **UE height** | 1.5m |
| **Channel model** | UMi | **UE noise figure** | 13 dB |
| **Link direction** | Downlink | **UE antenna element gain** | 5 dBi |
| **Frequency range** | 30GHz | **UE receiver** | MMSE-IRC |
| **Duplex** | TDD | **UE deployment** | 20% Outdoor in cars: 30km/h,  80% Indoor in houses: 3km/h |
| **Frame structure** | DDDSU (S slot is assumed as 10D:2G:2U) | **Traffic model and C-DRx configuration** | follow previous RAN1 agreement |
| **Subcarrier spacing** | 120 kHz | **UE density/NW Load** | Follow previous RAN1 agreements |
| **Simulation bandwidth** | 100 MHz | **Maximum supported Modulation and coding scheme** | Up to 256QAM |
| **Number of carriers** | 1 CC | **Guard band ratio on simulation bandwidth** | 7.8% (64 RB for 120kHz SCS and 100 MHz bandwidth) |
| **Slot size** | 14 OFDM symbols | **Channel estimation** | Ideal |
| **BS antenna configuration** | 2 TxRU:  Baseline:  [(M, N, P, Mg, Ng; Mp, Np) = (4,4,2,1,1;1,1); (dH, dV) = (0.5λ, 0.5λ) (dg,H, dg,V) = (2.5λ, 2.5λ)  Optional:  (M, N, P, Mg, Ng)=(8:16:2:2:2)] | **HARQ scheme** | Ideal |
| **Total Tx power** | 33 dBm, EIRP limited to 63 dBm (as agreed in ref. conf. set 3) | **Max HARQ retransmission** | 3 |
| **BS height** | 10m | **Target BLER** | 10% of first transmission |
| **BS noise figure** | 7 dB | **Power control parameters** | Open loop, Alpha=1, P0=-106 dBm |
| **BS antenna element gain** | 8 dBi | **Scheduling algorithm** | PF |
| **UE antenna configuration** | 2T/4R, (M, N, P, Mg, Ng; Mp, Np) = (1,2,2,1,1;1,2),  (dH, dV) = (0.5λ, N/Aλ) | **Cell selection algorithm** | RSRP Slow Fading |
| **UE max transmit power** | 23 dBm | **SS blocks per SSB burst** | Up to 64 |

(M, N, P, Mg, Ng; Mp, Np)

- M: Number of vertical antenna elements within a panel, on one polarization

- N: Number of horizontal antenna elements within a panel, on one polarization

- P: Number of polarizations

- Mg: Number of panels in a column;

- Ng: Number of panels in a row;

- Mp: Number of vertical TXRUs within a panel, on one polarization

- Np: Number of horizontal TXRUs within a panel, on one polarization.

Other parameters can be optionally reported.

Company can also optionally report the actual total DL transmit power allocation for the baseline and the proposed technique, if different from the agreed reference configuration.

Additionally, for FR1, the following SLS assumptions can be optionally included:

* BS antenna configuration: 4T
* BS Total Tx power: derived based on the scaling in section 5.1
* SS blocks per SSB burst: reduced to 1
* Other assumptions are same as those corresponding to Set 2 reference configuration
* Additional transition energy is calculated taken into account the additional transition energy for Set 1/Set 2/Set 3 in section 5.1
* Company to report the details.

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 | R1-2208315 |  |  |  | TR update per agreements in RAN1#109-e and RAN1#110, and skeleton of TR 38.864 for NR network energy savings approved in RAN3 per R1-2207999. | 0.1.0 |
| 2022-10 | RAN1#110bis-e | R1-2209679 |  |  |  | TR update per agreements in post RAN1#110 email discussion and some editorials. | 0.2.0 |
| 2022-10 | RAN1#110bis-e | R1-2210792 |  |  |  | TR update per agreements during RAN1#110bis-e. | 0.3.0 |
| 2022-11 | RAN1#111 | R1-2212483 |  |  |  | TR update per agreements made in R2-2211067 in RAN2 #119bis-e and in R3-226001 in RAN3 #117bis-e. | 0.4.0 |