**3GPP TSG-RAN WG1 Meeting #109-e R1-220xxxx**

**e-Meeting, May 9– May 20, 2022**

**Agenda Item: 9.7.1**

**Source: Moderator (Huawei)**

**Title: FL summary for performance evaluation for NR NW energy savings**

**Document for: Discussion and Decision**

# Introduction

Study Item (SI) for network energy savings for NR is approved in [1]. For the study of performance evaluation for this SI, the relevant objectives include below

|  |
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| 1. Definition of a base station energy consumption model [RAN1]
* Adapt the framework of the power consumption modelling and evaluation methodology of TR38.840 to the base station side, including relative energy consumption for DL and UL (considering factors like PA efficiency, number of TxRU, base station load, etc), sleep states and the associated transition times, and one or more reference parameters/configurations.
1. Definition of an evaluation methodology and KPIs [RAN1]
* The evaluation methodology should target for evaluating system-level network energy consumption and energy savings gains, as well as assessing/balancing impact to network and user performance (e.g. spectral efficiency, capacity, UPT, latency, handover performance, call drop rate, initial access performance, SLA assurance related KPIs), energy efficiency, and UE power consumption, complexity. The evaluation methodology should not focus on a single KPI, and should reuse existing KPIs whenever applicable; where existing KPIs are found to be insufficient new KPIs may be developed as needed.

Note: WGs will decide KPIs to evaluate and how.The study should prioritize idle/empty and low/medium load scenarios (the exact definition of such loads is left to the study), and different loads among carriers and neighbor cells are allowed. The following example scenarios (mapping between scenarios and network loads is left to the study) including single-carrier and multi-carrier deployments are used as the starting point for discussion on prioritized scenarios for the study. The following example scenarios are listed in no particular order.* Urban micro in FR1, including TDD massive MIMO (note: this scenario can also model small cells)
* FR2 beam-based scenarios (note: this scenario can also model small cells)
* Urban/Rural macro in FR1 with/without DSS (no impact to LTE expected in case of DSS)
* EN-DC/NR-DC macro with FDD PCell and TDD/Massive MIMO on higher FR1/FR2 frequency

Note 1: legacy UEs should 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.Note 2: the study of energy savings specifically for IAB is not part of the scope.The study should coordinate with RAN4 as needed. |

For that purpose, the following email discussion is assigned:

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| [109-e-R18-NW\_ES-02] Email discussion on performance evaluation by May 20 – Yi (Huawei)* Check points: May 12, May 18, May 20
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This document provides FL initial observations on relevant discussion points and questions/proposals, by summarizing the contributions submitted to agenda item 9.7.1 [2]-[22]. Relevant contributions [23]-[29] submitted to agenda item 9.7.3 are also taken into account.

Draft(s) can be found in [Inbox](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Inbox/drafts/9.7.1) and will be updated per companies further input. The FL proposals starting with ‘study’ or ‘FFS’ consider the initial round of view summary based on contributions, thus can be possibly revised by extended proposals to be agreed/proceeded within this meeting once they are more converged. There is no intention to postpone those bullets in future meetings. When making comments and uploading the input, please see the guidance in [R1-2203012](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203012.zip) with recommended naming convention and [R1-2203013](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203013.zip) concerning the deadline(s) for each check point respectively.

Companies are invited to make your input for FL questions tagged with FL1 (all proposals in this round) concerning the first check point May 12, as well as to enter contact information in Annex.

# Energy consumption model for BS

## Framework for modeling BS energy consumption

Almost all contributions that have relevant discussion on this aspect confirm that on high level, some reference configurations (which could be differently represented in contributions e.g. as nominal configurations), and multiple BS power states including sleep/non-sleep states with relative power values are needed. In addition to what has been considered in SID, majority among these companies also confirm that the use of scaling for non-sleep state is needed. It appears to be commonly acknowledged that this framework similar to UE power saving model can be agreeable as the BS power consumption model framework. Therefore, the following proposal can be considered and it is noted that this proposal does not intend to preclude any finer modifications/differentiation among e.g. FR1 and FR2, UL and DL, other potential improvement etc. Other details for each ‘component’ can be further discussed in following sub-sections.

**FL1 Proposal 2.1-1**

* **For evaluation purpose, the energy consumption modeling for a BS include at least the following:**
	+ **Reference configuration**
	+ **Multiple power state(s) including sleep/non-sleep mode(s) with relative power values/units, and associated transition times**
	+ **Scaling method to be applied for non-sleep mode.**

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| **Company** | **Y/N** | **Comments** |
| Xiaomi | Y |  |
| Spreadtrum | Y | There are different types of BS, e.g. macro cell, micro cell, small cell. How to model the different types of BS? Using different sets for modeling or absorbed into scaling methods (e.g. power level and antenna ports number)? |
| OPPO | Y |  |
| IDCC | Y |  |
| Vodafone | Y | Although we see the importance on showcasing absolute gains rather than just relative |
| Intel | Y, partially | We are generally fine, except the scaling part. We think it is commonly understood that scaling applies to active states only. However, we think BS energy consumption modeling and considerations can be different considering various architectures. We are ok with applicability with scaling method. However, scaling method only applied to non-sleep modes might not fully represent how power may need to scale when different components of BS, e.g. TRPs, are in sleep mode.Let’s consider reference configuration assumes 1 TRP. Now, if we would like to extend the model to a network with 5 TRPs, how the scaling applies, if some of the TRPs are in sleep, for example if 2 out of 5 TRPs are not actively transmitting/receiving and in micro-sleep. Then to calculate energy consumption of that network based on reference configuration, how to correctly capture the status of the TRPs and whether that can be a component in micro-sleep value that can be scaled by the number of TRPs that are not active. We don’t have a good formulation to capture this, so for our suggestion is to remove the “scaling method to be applied to non-sleep mode”. Once sleep/non-sleep modes can be further developed, we should be able to come back to the scaling methods.Although not critical, we prefer to use term “energy states” instead of “power states”. |
| NOKIA/NSB | Y, partially | We are generally fine with the main contents proposed.Besides, we want to address the below issues:* There can be multiple Reference configurations, i.e. depends on BS types if Micro BS is further considered.
* For a sleep mode, the transition time and transition energy that is associated with should be defined as well.

For each scaling of the non-sleep modes, the (de-)activation time to apply a scaling should be defined. |
| LG Electronics | Y,partially | In general, we are fine with Proposal 2.1-1.Considering the additional power consumed during state transition, we can add transition energy in the second sub-bullet, as follows.* **For evaluation purpose, the energy consumption modeling for a BS include at least the following:**
	+ **Reference configuration**
	+ **Multiple power state(s) including sleep/non-sleep mode(s) with relative power values/units, and associated transition times/energy**
	+ **Scaling method to be applied for non-sleep mode.**
 |
| China Telecom | Y | We are generally fine with the proposal 2.1-1.  |

Another general aspect is that there is converged preference that the time domain granularity of BS energy consumption model should be in a dynamic level, e.g. per slot basis [2][3][4][7][9][10][11] etc.. The following can be considered.

**FL1 Proposal 2.1-2**

* **The BS energy consumption model can be used to evaluate the power consumption of BS per slot.**

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| **Company** | **Y/N** | **Comments** |
| Xiaomi | Y |  |
| Spreadtrum | Y | The symbol level model should be studied. It can be absorbed into scaling methods in some companies’ contribution. Therefore, suggest adding a NOTE, e.g. the power consumption of BS for symbol(s) can be modeled in the scaling method. |
| OPPO | N | We think symbol-level evaluation is more reasonable. |
| IDCC | N | We think symbol-level evaluation is needed. However, this may be be achieved by scaling slot level power, for example using time and frequency occupancy. |
| Intel | Y | While we see that symbol level modeling can be made more accurate by considering different combination of signal/channels, we think for evaluation purposes, approximate model based on per slot assumption is sufficient and may not result in significantly different observation than symbol level model. It may be too cumbersome to assess transmission status on symbol by symbol level and evaluate in the SLS. Having said that we agree that based on per slot value, several important cases (e.g., 1 SSB transmission) can be identified for scaling. Alternatively, some quantization can be considered, such as if a transmission occupies half slot or less, a common scaling is applied and transmission occupying more than half slot are treated same way as per slot. |
| NOKIA/NSB | Y | Generally we are fine with the Proposal 2.1-2. But suggest to have below rewording:FL1 Proposal 2.1-2* The BS energy consumption model can be used to evaluate the powerenergy consumption of BS per slot.

NOTE: When we talk about something that is given for a certain time period it has to be energy not power |
| LG Electronics | Y | The power consumption of BS per slot can be considered as a baseline. |
| China Telecom | Y | We share the similar as Spreadtrum. We agree to evaluate the energy consumption in slot. However, since the techniques such as symbol-level ON/OFF can be adopted and the duration of the transmission may less than a slot. We suggest to take this into consideration by the scaling method.And we agree with Nokia/NSB that the **power consumption** should be replaced by the **energy consumption**, not only for this proposal, but for all the proposals. |

To further adapt the framework of UE power consumption modeling to BS side, views seem to be a bit split in terms of the considerations of UL and DL and of corresponding channels, unlike what has been done at UE side. For example, [2] focus on the DL part while also mention that power consumption of UL part can be considered relative to that of DL. A few others generally consider that UL and DL are separately modeled while [6][17][26] consider the DL and UL should be modeled together (possibly depending on duplex, e.g. TDD). It seems that in the case of separate modeling, what mostly differentiates in the model presented in companies input is to have separate relative power values in DL transmission and UL reception at BS, for non-sleep model. And modeling/evaluation for DL only or UL only should be possible in order to verify the scheme/gains for one direction only. A gNB is generally considered as sleep when data is communicating in neither DL nor UL. Thus, the following can be considered.

**FL1 Proposal 2.1-3**

* **For evaluation, the BS energy consumption for DL and UL can be separately modelled, allowing DL-only transmission or UL-only reception at least for non-sleep mode.**
* **Study whether/how to adopt channel/signal-specific modeling for some cases**

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| **Company** | **Y/N** | **Comments** |
| Xiaomi | Y(for the first bullet) | In fact we are not quite sure what is the meaning of second bullet. What is “channel/signal-specific” modeling? and what is the relation between “channel/signal-specific” modeling and separate DL/UL modeling？ |
| Spreadtrum | Y | As mentioned in some companies’ contribution, modeling of UL-only reception can be simplified due to tight time frame. |
| OPPO | Y | We suggest to study a simple modelling which is independent of specific channels/signals, e.g., a unified model for all the DL channels/signals. |
| IDCC | Y |  |
| Vodafone | Y |  |
| Intel | Y, partially | We agree that energy consumption states in DL and UL can be simplified and we may not need specific handling of different possible combinations of channels. Nonetheless, we think some categorization can still be useful, such as PDCCH + PDSCH channel are expected to be processed in a common block, whereas other channel/signal transmission comprising background activity, such as SSB, RS could be processed with less power. However, if majority agrees to go move forward with single DL active state, we can accept that for sake of progress. |
| NOKIA/NSB | Y | Generally we are fine. But we could like the clarification from @FL on: How to understand the 2nd-bullet bullet with “channel or signal specific modelling for some cases”, is it something targeting for slot type, such as SSB-only, PDCCH-only? Could you please elaborate a bit. Thanks! |
| LG Electronics | Y | For the simplicity, we can consider DL-only or UL-only per slot. In addition, for the sleep mode, we prefer to model BS energy consumption only for DL-only transmission, which means that the BS does not need a transition time/energy to wake up for UL reception. |

There are also contributions proposing to consider different BS types or BS categorizations in the modeling [3][4][5][18][20][22], e.g. macro BS, small cell or AAS gNB, possibly accounting for different scenarios and relative power value variations. This is one aspect that is different from the UE power saving model. Similarly, [3][18] also consider split of a BS, e.g. radio unit (RU) vs. baseband unit (BBU), or functional blocks. Since macro BS is widely adopted in previous study in IMT-2020 and also included as in above, the following can be considered.

**FL1 Proposal 2.1-4**

* **At least macro BS can be assumed for energy consumption model.**
* **Study whether/how to further adapt the energy consumption model considering different BS types/categorizations/components.**

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| **Company** | **Y/N** | **Comments** |
| Xiaomi | Y |  |
| Spreadtrum | Y | As commented for FL1 Proposal 2.1-1, we are open for modeling the different BS types. If the scaling method (e.g. power level and antenna ports number) cannot describe the difference among different BS types, we need to define several sets of modeling (e.g. macro BS, AAS gNB and small cell BS). |
| OPPO | Y |  |
| IDCC | Y |  |
| Vodafone | Y |  |
| Intel | N | We think at least two BS types should be considered, such as one macro and one small cell. Based on listed scenarios in SID, modeling of small cell BSs are important, such as for SLS evaluation of 2-layer HetNet like deployment where several small cell BSs may exist under a macro BS and it is expected that energy states of a small cell BS can be simpler. |
| NOKIA/NSB | Y | Agree to start with focusing on Macro BS.For FR2, it makes more sense to have Micro BS being considered and modeled (if needed). |
| LG Electronics | Y | The macro BS can be a baseline and the energy consumption for different BS types/categorizations/components can be scaled or derived from the energy consumption model for the macro BS. |

[3][20] mention that the BS energy consumption model may need to reflect the technology trend for potential improvements or being future proof.

**FL1 Proposal 2.1-5**

* **Study whether/how to further adapt the energy consumption model in consideration of technology trend in e.g. a few years.**

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| **Company** | **Y/N** | **Comments** |
| Xiaomi | Y |  |
| Spreadtrum | Y | As mentioned in SID, the green fields and non-backward compatibility can be considered. |
| OPPO |  | This can be discussed in a case-by-case manner. A general consideration of technology trend might be too vague and it might cause some aggressive/impractical assumptions. |
| IDCC | Y |  |
| Vodafone |  | Agree with OPPO’s view. We sort of see the opposite of the proposal, not to adapt on new trends but rather for current configurations that will stay for a while such as DSS. |
| Intel | Y | We think it is very important that develop model remains flexible enough so that different functional splits of future BS architectures can be accommodated into the developed model. One good example is defining multiple sleep modes, such as up to 4. This may allow modeling of architectures such as different groups of HW components can be operated in a distributed manner. |
| NOKIA/NSB | Y | To our view, it is an important issue need to be clarified for this study, on whether the BS power consumption should reflect today’s base stations or future BS technologies. And it is understood from the FL’s proposal that, the modelling consideration is on future BS technologies. |

[3] proposes to clarify that the study does not consider multi-RAT mode. There was a relevant discussion in RAN plenary on consideration for LTE, and the outcome is that ‘no impact to LTE expected in case of DSS’. This proposal can be further considered if clarification is deemed necessary.

## Reference configuration

Generally both FR1 and FR2 are considered. And there is good convergence on the inclusion of frequency, BW size, antenna configuration, SCS, number of component carriers (CC), and power level. There are also channel/signal specific configurations proposed. In view of proposed parameters, the following can be considered. Note currently it is proposed with square bracket even if it is proposed by an operator. Some parameters may be missing due to lack of proposals but can be further discussed/determined within this meeting. TDD structure is listed in [5][18]. This can be further discussed/determined along with other (missing) parameters.

**FL1 Proposal 2.2-1**

* **At least TDD should be included for evaluation of FR1 and FR2. FFS FR1 FDD.**
* **For FR1, at least the following should be considered for reference configuration**
	+ **DL**
		- **frequency range [2.6 GHz]**
		- **system BW [100 MHz]**
		- **SCS [30 kHz]**
		- **number of CC [1]**
		- **TX [64]**
		- **Power level [FFS]**
		- **[common signal/RS, SSB periodicity 20 ms x 2 per slot]**
		- **FFS other channel/signal, e.g. PDCCH/PDSCH**
	+ **UL**
		- **system BW [100 MHz]**
		- **SCS [30 kHz]**
		- **number of CC [1]**
		- **RX [1]**
* **For FR2, at least the following should be considered for reference configuration**
	+ **DL**
		- **frequency range [28 GHz]**
		- **system BW [400 MHz]**
		- **SCS [120 kHz]**
		- **number of CC [16]**
		- **TX chain [2]**
		- **Power level [FFS]**
		- **[common signal/RS, SSB periodicity 20 ms x 2 per slot]**
		- **FFS other channel/signal, e.g. PDSCH**
	+ **UL**
		- **system BW [400 MHz]**
		- **SCS [120 kHz]**
		- **number of CC [16]**

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| **Company** | **Y/N** | **Comments** |
| Xiaomi | Y(generally) | Detailed values can be changed based on further discussion |
| Spreadtrum | Partial Y | The reference configuration is used as the reference of BS energy consumption. The reference should be single CC. For CA case, the energy consumption of multi CC can be multiples of that of single CC. |
| OPPO |  | Detailed parameters/values can be further discussed. |
| IDCC | Y | Final values can be decided based on further discussion. |
| Intel | Y, partially | We have following suggestion for revision* Carrier frequency : ~~2.6 GHz~~ 4GHz
* Add for both FR1 and FR2, Number of TRP: 1
* BS Power level in FR1 and 2 can follow the assumption in TR 38.802

FR2: Number of CC: ~~16~~ 1 |
| NOKIA/NSB | Y, partially | For FR2, we have the following proposal regarding system BW and number of CC* For FR2, at least the following should be considered for reference configuration
	+ DL
		- frequency range [28 GHz]
		- system BW [~~400~~100 MHz]
		- SCS [120 kHz]
		- number of CC [~~16~~1]
		- TX chain [2]
		- Power level [FFS]
		- [common signal/RS, SSB periodicity 20 ms x 2 per slot]
		- FFS other channel/signal, e.g. PDSCH
	+ UL
		- system BW [~~400~~100MHz]
		- SCS [120 kHz]
		- number of CC [~~16~~1]
 |
| LG Electronics | Y,partially | We are fine except for the number of CCs for FR2. We prefer 1 CC evaluation as the baseline for both FR1 and FR2, and companies can extend evaluation assumption to CA case if needed. |
| China Telecom | Y, partially | We are generally fine with the proposal.However, for the frequency range for FR1, we think the 4GHz may be more representative and common. We suggest to modify the reference configuration as follow:• Carrier frequency : 4GHz [2.6GHz]The details for other parameters can be further discussed. |

## Power states and transition time

Relative power value should be clearly defined. A few companies mentioned that similar to UE power saving model, the deepest sleep mode consumes the least power and is considered as the basic power unit.

**FL1 Proposal 2.3-1**

* **In the evaluation, the power consumption value is normalized relatively to the deepest sleep mode to be defined for BS energy consumption model.**

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| **Company** | **Y/N** | **Comments** |
| Xiaomi |  | Does that mean the power for deepest sleep mode is ‘1’, and other state is ‘n’(n>=1)? Is that really suitable for the real case? In fact we are not sure, and hope to get clarified. |
| Spreadtrum | Y | For simplicity |
| OPPO |  | It is reasonable to normalize the power consumption value to a mode, we can further discuss whether it is the deepest sleep mode.The goal is to control the dynamic range among different power consumption modes. |
| IDCC | Y | It is reasonable to use normalization. But the reference state can be decided after agreeing on the states. For example, deep sleep may be used as reference with power level [1] but hibernating state may have power smaller than [1]. |
| Vodafone | Y | We agree to have the evaluation done relatively but it is also important to convey the absolute gains obtained from the different techniques |
| Intel | Y | We could just agree that deepest sleep mode is assigned relative value 1, and power values for other states are obtained relative to that.  |
| NOKIA/NSB | Y | @FL: try to further check our understanding, so the “deepest sleep mode” here you refer to is the BS Standby state as in our Tdoc, or so-called Hibernate state in Ericsson’s presentation/Tdoc, is it correct understanding? |
| LG Electronics | Y | Agree with Proposal 2.3-1 but it is first necessary to discuss how many BS power saving modes will be defined considering the SSB periodicity and the transition time. Since gNB should transit to active mode periodically in order to transmit the periodic signal such as SSB, some sleep modes may not be able to be reached depending on the periodicity of SSB if transition time corresponding to the sleep mode is longer than SSB periodicity. Therefore, among multiple sleep modes, it is needed to determine whether to allow a sleep mode for which transition time can be longer than periodicity of SSB/SIB1.  |
| China Telecom | Y | We are fine with the proposal 2.3-1. But we think the details should be clarified after further defining the sleeping states. |

Views on different power states are quite diverse. For consideration of sleep mode, there are more sleep modes preferred in general. Particularly, 4 modes are considered in [3][6][16][18][20]. 3 modes are considered in [4][5][7][10][11][14][15][17][21] while two modes are considered in [2][8][18]. Depending on BS split/types, there may also be multiple preference from companies. More discussion is needed.

**FL1 Proposal 2.3-2**

* **Study how to define sleep modes and determine the characteristics for each mode from one or multiple of the below**
	1. **Relative power level range or power saving range**
	2. **Transition time range**
	3. **BS breakdown/components that can be turned off**
	4. **Other approaches are not precluded**
* **Study the assumption of order for BS entering/resume from a sleep mode to another mode (sleep or non-sleep), i.e. state machine which may have impact on the additional transition energy.**

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| **Company** | **Y/N,****Preferred option** | **Comments** |
| Xiaomi | Y(generally) | for the second bullet, “**order for BS entering/resume from a sleep mode to another mode**”, our view is that ,to simplify power modeling, sleep mode can only turn into non-sleep mode. Currently we see no needs to discuss the power consumption/transition from one sleep mode to another sleep mode. |
| Spreadtrum | Y, prefer a) and b) | c) can be discussed, but we are not sure companies can have the consensus. In UE power model, the sleep modes defined in an abstract way, e.g. time of sleep, relationship b/w sleep energy and transition energy.For state machine, we are not sure how complicated it should be. In UE power model, we only assume the transition b/w sleep mode and non-sleep mode. The prerequisite is UE will perform a definite sleep mode after a non-sleep behavior. UE simply follows the semi-static tasks and the limited NW- triggered states. BS may face more dynamic situation? |
| OPPO | Y |  |
| IDCC | Y |  |
| Vodafone | Y |  |
| Intel | Y | We think 4 sleep modes are needed to flexibly consider different functional splits at BS and how different groups of HW components can be turned on/off, some of which may need longer activation/deactivation time. We think modeling considers all of a), b), and c) and these considerations are inter-related. For example, 1 first group of components may consume more power and/or longer activation time than a second group or vice versa.Additionally, we should further discuss the 2nd bullet if possible.We think there is value in discussing how the BS enter/exit sleep modes (SM). For example, whether deeper SM can be entered directly (e.g entered from active mode only) or need to be entered from a previous SM state.This is related to the question discussed during GTW for Ericsson sleep mode state transition diagram.Lastly, we should add a 3rd bullet.Study energy consumption during transition time to and from a sleep mode |
| NOKIA/NSB | Y, prefer a+b | The sleep modes can be defined based on a and b (from the list above) plus the transition energy, similarly to their definition for the UE power model.  |
| LG Electronics | Y, At least a) b) | For the state transition model, it is necessary to discuss whether to transition step by step or direct when switching between active mode and each sleep mode. For example, assuming that there are four sleep modes, BS may transition from sleep mode 1 to the deepest sleep mode 4 via sleep modes 2 and 3. Alternatively, in another state transition model, the BS may directly transit any of the sleep modes from active mode. |
| China Telecom | Y at least a) + b) | For the sleep modes, at least a) and b) should be defined. As for c), we think it can be discussed and related to the specific value of a) and b), but the details may not be needed for the study at this stage, a general definition of c) is enough.For the state transition model, whether the transition of state can happen between the two SM directly should be studied. |

For non-sleep mode, which could possibly be split into DL and UL (if agreed), for each direction, there could be different approaches for determining the power value/unit. It is FL understanding that [21] may be proposing a different approach from those in [3]. Further, [3] proposes not to consider specially the case of simultaneous UL and DL.

**FL1 Proposal 2.3-3**

* **For evaluation purpose, the power consumption for DL/UL (if agreed) in active mode is determined based on one of the following**
1. **Explicit power consumption values per slot-type (FFS definitions)**
2. **A single power consumption value linearly scaled by the number of occupied symbols over 14**
3. **Interpolation between a base power state and a peak power state (FFS definitions)**
* **FFS dependency on other conditions e.g. scenario, RB utilization**
* **FFS whether there is need to adapt the model for simultaneous UL and DL in active mode for this SI.**

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| **Company** | **Y/N,****Preferred option** | **Comments** |
| Xiaomi | Y(generally) | For the last bullet, our thinking is we can first identify which components are shared by DL and UL, and which component are operating separately for DL /UL. and by such classification, we can model for simultaneous UL and DL in active mode. And this FFS is also related to **FL1 Proposal 2.1-3** |
| Spreadtrum | Y, prefer c), also fine for a) | For b), we are not sure the energy consumption is only scaled with symbols number. Maybe, it is also scaled with bandwidth (or loading). Moreover, b) can be included in c) as a factor of interpolation.For a), we think per-slot-type PHY channel(s) may not be practical, since gNB should perform multi-tasks, e.g. broadcast, unicast for multiple UEs. |
| OPPO | Y | A base power value can be defined and it reflects power consumption for full bandwidth occupancy in a symbol. Scaling approach can be applied on top of it. |
| IDCC | Y |  |
| Intel | Y (a, b) | We think (b) should be further generalized.For example, a set of quantized (scaled) values based on number of occupied symbols, e.g. 1 ~ 7 occupied symbols apply a specific scaling, 8 ~ 14 occupied symbols doesn’t apply any scaling, etc.Linear scaling should still be covered by this generalization. |
| NOKIA/NSB | Y, prefer b) |  |
| LG Electronics | Y, prefer a) | At least the power consumption value for each DL signals/channels in active mode should be defined per slot-type.Alternatively, we can accept (b) if RB utilization is considered as well as symbol-level utilization. |
| China Telecom | Y, prefer b) |   |

## Scaling

The scaling approach is proposed to be reused by majority companies with same or different scaling factors. Among various aspects, the BWP size, number of CC in CA, antenna configurations and power spectrum density (PSD) gain most support. Again, if DL- and UL-only is agreed, scaling can be separately applied to e.g. DL BWP and UL BWP. The exact values need further discussion. In general, the following seems agreeable.

**FL1 Proposal 2.4-1**

* **For evaluation, the scaling in a BS energy consumption model can be applied based on the following,**
	+ **antenna port**
	+ **BWP in one CC and number of CC in CA**
	+ **PA related aspects.**
	+ **FFS other domain scaling**

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| **Company** | **Y/N** | **Comments** |
| **Xiaomi** |  | Other factors should be considered,such as, TRX chain , RB utilization |
| Spreadtrum | Y | For BWP in one CC, we are not sure. It is common understanding that PA is dominant for energy consumption of transmission. If PSD is not largely variant, the bandwidth in one CC may cause different total power output. If PSD can be largely variant, maybe gNB can keep the constant total power output. |
| OPPO |  | For simplicity, we can assume the PSD is constant, then bandwidth scaling can be applied. Here we suggest to replace “BWP” with “used PRB”. |
| IDCC | Y |  |
| Intel | Y, partially | Further discuss how to take PA scaling into account, whether to absorb into BW scaling or consider separately |
| NOKIA/NSB | Y, partially | Regarding “PA related aspects”, we prefer to rewording with “PSD” or transmit power scaling |
| LG Electronics | Y but need clarification for antenna port | Similar to UE power consumption scaling for adaptation, the linear scaling formula can be applied to BS power consumption for CC/BW, the transmission power, or occupied symbols.However, regarding antenna port, it is necessary to clarify if gNB typically implements PA per each of antenna ports. If this is the case, we can adopt linear scaling model also for antenna port, similar to UE power consumption model. Otherwise, we may consider the formula other than linear scaling formula especially for antenna port. |
| China Telecom | Y | What “the PA related aspects” includes need further discussed. Besides, the scaling in time domain should also be considered if the power defined for power state is based on the slot level. |

# Methodology

## KPI

For evaluation methodology and KPI, the baseline may need to be clarified [5][13][17]. Due to lack of input and common view, companies are invited to share your answer for the question.

**FL1 Proposal 3.1-1**

* **Companies view are invited to clarify the baseline for evaluation for this SI**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Spreadtrum | For simplicity, the energy consumption without energy savings can be considered as baseline |
| OPPO | The energy consumption without energy savings can be considered as baseline. |
| IDCC | Energy consumption without energy savings can be considered as baseline. |
| Intel | Baseline may assume without modeling of any sleep modes |
| NOKIA/NSB | The baseline(s) for evaluation can be defined based on the reference configuration, the number of UEs per cell/network, and traffic model. For the calibration, we can assume 1 single stationary UE per cell, and a single load level. The load can be bursty (FTP3) or constant (% of PRB utilization). |
| LG Electronics | Energy efficiency should be included as one of KPIs in evaluation methodology for network energy savings, considering LSs from SA working group.  |
| China Telecom | The baseline for evaluation should be defined as the state without any sleep modes or energy saving techniques. |

The SID has already listed multiple potential KPIs for consideration. In addition to the most natural KPI of energy/power saving gain, energy efficiency (EE) in unit of bit per Joule is drawing more interest. As this is a new KPI for PHY study, some discussion is needed. Companies are invited to share your consideration for the definition of EE.

**FL1 Proposal 3.1-2**

* **Companies view are invited to clarify the definition of energy efficiency for evaluation.**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Xiaomi | For empty to low traffic, energy efficiency can be expressed by consumed energy per time unit. For medium to high traffic, energy efficiency can be expressed by consumed energy per time unit or consumed energy per bit. |
| Spreadtrum | EE is usually defined as capacity over energy consumption or coverage area over energy consumption, as mentioned in TR 21.866. For simplicity, it can be regarded an energy consumption for a given scenario (with fixed capacity and/or coverage area). Or, the capacity (equal to UPT in some cases) and coverage area should be stated in the evaluation results. |
| OPPO | We agree with the FL summary, i.e., energy efficiency (EE) is defined in unit of bit per Joule. |
| Intel | We think similar to UE power saving study, we could use mean energy consumption per slot as KPI to compute energy consumption and compare different techniques and baseline |
| NOKIA/NSB | Please find our propose in the following:We propose multi-dimensional NW EE KPIs that jointly consider the energy consumption of the network and system/UE performance. In our Tdoc, we list UPT-aware, cell throughput-aware,data volume aware, EE KPIs. On the contrary, if the evaluation was based on comparing a set of independent KPIs, (say X % network energy saving gain, Y % UPT gain, and Z % latency gain), it would be challenging to derive any conclusion.In accordance with the proposed BS power consumption model, the network power consumption is expressed as a relative power consumption to the most power-efficient sleep state and is unitless. Therefore, the energy consumption in the NW EE metrics should be unitless (i.e. not be expressed as Joule) |
| LG Electronics | The definition of EE from TR 38.913 Clause 7.19 is as follows:$$EE\_{global}=\sum\_{scenario K}^{}b\_{K}EE\_{scenario K}$$* where$b\_{K}$ refers to the weights of every deployment scenario where the network energy efficiency is evaluated and,
* $EE\_{Scenario}=\sum\_{load level 1}^{}a\_{1}\frac{V1}{EC\_{1}}$
	+ where **V1**= Refers to the traffic per second served by a base station (in bits/s),
	+ $EC\_{1}$ = Refers to the power consumed by a base station to serve V1 (in Watt = Joule/s), and
	+ $a\_{1}$ = Refers to the weight for each traffic load level.

According to the above equation captured from TR 38.913, the absolute power value is required to calculate EE. However, according to the objective of SID or the UE power saving model in TR 38.840, the relative power can be used to define gNB power consumption model. Therefore, the definition of EE may need to be modified so that it can also be calculated based on a relative power value. A simple solution could be to replace the absolute power in EE formula with the relative power (i.e., new EE = ratio of throughput to reference power consumed by gNB). Given the relationship between absolute power and relative power, the original EE value calculated by the absolute power can be derived from the new EE value calculated by the relative power. Therefore, the EE value calculated by relative power can also be considered as a valuable KPI for evaluation methodology. |
| China Telecom | We share the similar view as Nokia/NSB. The traditional definition of EE is in unit of bit/Joule. While the KPIs in multiple dimensions can be considered for the NES, we proposed a more general expression of EE = the concerned KPI/energy consumption, the concerned KPI can be UPT/throughput/latency/coverage. With this method, the performance can be better valued and associated with the specific scenarios and techniques. Besides, as Nokia pointed, if we want to jointly considered several KPIs at the same time, then using the gain in percentage instead of the absolute value would be better, and the EE can be unitless. |

For study of the impact on system performance, UPT can be considered as adopted in UE power saving study and proposed by majority contributions. It may also be combined for joint consideration with EE. Other KPIs for system impact evaluation may vary depending on techniques and scenarios, and companies view are split.

For UE side impact evaluation, it seems the below can be considered.

**FL1 Proposal 3.1-3**

* **For network performance impact evaluation, at least UPT should be considered,**
	+ **FFS in combination with other KPIs e.g. UTP-aware EE, UPT/latency, UPT-UE power etc.**
* **For UE performance impact balance, UE power consumption/access delay/latency can be considered,**
	+ **FFS in combination with energy consumption of BS.**
* **Note, this does not preclude to consider other KPIs when found appropriate for certain techniques/scenarios**

|  |  |  |
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| **Company** | **Y/N** | **Comments** |
| Xiaomi | Y(generally fine) | For the first bullet, when the traffic load is from empty to low, for network performance impact evaluation, our thinking is packet latency seems a more suitable KPI than UPT. |
| Spreadtrum | Y | UPT should be considered in a certain form, e.g. combined form or individual form. The additional UE power consumption should be stated in the evaluation results. |
| OPPO | Y |  |
| IDCC | Y |  |
| Intel | Y | Agree |
| NOKIA/NSB | Y,partially | Network performance can be evaluated with cell throughput aware and data volume aware EE. FFS in combination with other KPIs.UE performance can be evaluated with UPT-aware EE. FFS in combination with other KPIs (e.g. UE power consumption). |
| LG Electronics | Y | In our understanding, if above performance metrics are to be reported, performance loss or gain needs to be compared with the reference configuration. Would it be the correct understanding? |
| China Telecom | Y |  |

## Evaluation scenario

Among the listed example scenarios in SID, i.e.

* Urban micro in FR1, including TDD massive MIMO (note: this scenario can also model small cells)
* FR2 beam-based scenarios (note: this scenario can also model small cells)
* Urban/Rural macro in FR1 with/without DSS (no impact to LTE expected in case of DSS)
* EN-DC/NR-DC macro with FDD PCell and TDD/Massive MIMO on higher FR1/FR2 frequency

The first and third scenario gain most of support in the initial round of contrition view summary. If we go with this approach for down-selection, FR2 will be completely deprioritized which may be less preferable since it is expected to establish more insight of the saving potential especially for scenario with large energy consumption. Therefore, companies are invited to further consider your priority for evaluation scenarios. Note it is not necessary to be limited by the exact bullet from the above scenarios – as they are examples in no order, other combinations from/than those can also be considered.

**FL1 Proposal 3.2-1**

* **Companies are invited to further consider priority for evaluation scenarios for BS energy saving study.**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Spreadtrum | Urban scenarios should be prioritized. |
| OPPO | Urban scenarios should be prioritized. |
| IDCC | Urban scenarios should be prioritized. |
| Vodafone | Urban scenarios should be prioritized, making sure that DSS scenarios are covered within the evaluation. |
| Intel | Urban scenario with Massive MIMO, 2-layer Hetnet |
| NOKIA/NSB | We have the following proposal in our Tdoc for prioritization of the evaluation scenarios:RAN1 to prioritize evaluations in the following scenarios: * Urban macro in FR1 without DSS and with CA, with/without massive MIMO,
* Rural macro in FR1 without DSS and with CA, and
* Urban micro in FR1 and FR2

RAN1 to focus on NR-only scenarios and consider with lower priority evaluations in the following scenarios: * EN-DC/NR-DC macro with FDD PCell and TDD/Massive MIMO on higher FR1/FR2 frequency, and
* Scenarios "With DSS"
 |
| LG Electronics | We prefer to prioritize NR-only scenarios with massive MIMO in FR1 and FR2, while EN-DC and DSS scenarios can be considered as low priorities. |
| China Telecom | The Urban scenarios should be prioritized. And the SSB-less with inter-band CA should also be considered. |

## Traffic model

One of the objective of SID is highlighted as below:

*The study should prioritize idle/empty and low/medium load scenarios (the exact definition of such loads is left to the study), and different loads among carriers and neighbor cells are allowed.*

Several contributions contribute to this. In general, there is an aligned understanding that the load at least refers to the PRB utilization while there is proposal that it also concerns other factors e.g. number of UEs per cell. [3] propose to agree on a definition used in other standard, i.e. the load levels defined by ETSI in ES 202 706-1, which may be reasonably reused. To allow unbalanced load, [6][18] propose to adopt non-uniform UE distributions.

**FL1 Proposal 3.3-1**

* **The load for evaluation for BS energy saving study refers to the network load levels defined by ETSI in ES 202 706-1, where ‘idle/empty’ refers to ‘unloaded’ cell, ‘low load’ refers to ‘low load’ utilizing 30% PRB and ‘medium load’ refers to ‘medium load’ utilizing 50% PRB.**
* **Non-uniform UE distribution can be considered. Other approaches that are used for achieving different loads among carrier/cells should be clearly stated.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| Spreadtrum | Y | Idle/empty load can be referred to 5~10% load to address the common signal/channel, e.g. SSB/SIB/… |
| IDCC | Y |  |
| Intel |  | Resource utilization (RU) corresponding to a specific load should consider a range of RU values. During evaluations, it is quite difficult to simulated a fixed RU in all cells, let alone in a single cell due to dynamics of the scheduling and traffic burstiness.Suggest changing low load to be 5% ~ 25% RU, medium load to be 25% ~ 50%.Also, we would like to clarify that “unloaded” cell still may need to send SSB, and SIBx and can results in some RU measured in the evaluations, and it does not necessarily correspond to 0% RU. |
| NOKIA/NSB | Y |  |
| LG Electronics |  | We prefer to define the level of traffic load based on resource utilization, e.g., 20% and 40% RU correspond to low and medium load, respectively.Regarding non-uniform UE distribution, does it mean non-uniform load across gNBs for a given frequency, or across carriers? |

The proposed traffic models based on contributions for the study include:

1. FTP3: 0.5MB, 200ms
2. FTP3 IM: 0.1MB, 2s
3. VOIP
4. XR: 30/45Mbps
5. C-DRX: 40/160/320ms cycle, on-duration 4/8/10

Similar to UE power saving study, multiple models can be considered.

**FL1 Proposal 3.3-2**

* **FTP3, FTP3 IM and VOIP can be considered in the evaluation.**
* **FFS other traffic models that can be optionally considered.**

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| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| Spreadtrum | Y |  |
| OPPO | Y |  |
| IDCC | Y |  |
| Intel | Y | We suggest including XR traffic model, at least as an option. Periodic XR traffic may offer energy saving opportunity at the BS. |
| NOKIA/NSB | Y, partially | We prefer to prioritize the FTP3 with 0.5MS, 200ms for the evaluation of this study |
| LG Electronics | Y | Similar to UE power saving, FTP model 3 and VoIP can be considered for the performance evaluation. |
| China Telecom | Y |  |

## Simulation assumption

SLS is explicitly mentioned in the SID thus should be considered. Additionally, [7][14] propose numerical methods for e.g. handover drop rate analysis and [10] propose LLS for e.g. power saving signal detection. The following can be considered.

**FL1 Proposal 3.4-1**

* **At least SLS should be considered in the evaluation. Other method, including numerical analysis and LLS for KPI(s) other than UPT can also be considered.**

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| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| Spreadtrum | Y |  |
| OPPO |  | The high priority can be given for baseline simulations, which is based on system level simulations. |
| IDCC | Y |  |
| Intel | Y | Agree with proposal |
| NOKIA/NSB | Y | We think SLS is sufficient for this study |
| LG Electronics | Y | We agree that SLS should be the baseline for performance evaluation. |
| China Telecom | Y |  |

For other assumption parameters, the following are proposed in contributions: IMT-2020, 38.802, 38.840 and 38.830. It may be good to look into the overall SLS parameters first to check if some of them can be referred to.

The simulation assumptions proposed by companies for this meeting may be provided later.

# Other issues/discussion points/missing proposals

If there is any other important issue/discussion point/missing proposal that you consider should be discussed, please share your proposal below.

|  |  |  |
| --- | --- | --- |
| **Company** | **Domain (optional, for potential categorization)** | **Issue content/comments/questions** |
| OPPO |  | In this meeting, we should at least nail down the details of section 2.2 to section 2.4. |
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# Simulation results

It seems there is no strong need to treat the initial simulation results submitted for the first meeting for this SI. Therefore, there is no particular proposal set along that.

# References

|  |  |  |  |
| --- | --- | --- | --- |
|  | RP-[220297](https://www.3gpp.org/ftp/TSG_RAN/TSG_RAN/TSGR_95e/Docs/RP-220297.zip) | Revised SI: Study on network energy savings for NR | Huawei |
|  | [R1-2203172](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203172.zip) | Discussion on performance evaluation for network energy saving | Huawei, HiSilicon |
|  | [R1-2203224](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203224.zip) | NW energy savings performance evaluation | Nokia, Nokia Shanghai Bell |
|  | [R1-2203341](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203341.zip) | Discussion on performance evaluation of network energy savings | Spreadtrum Communications |
|  | [R1-2203481](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203481.zip) | Evaluation Methodology and Power Model for Network Energy Saving | CATT |
|  | [R1-2203575](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203575.zip) | Discussions on NW energy savings performance evaluation | vivo |
|  | [R1-2203603](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203603.zip) | Discussion on NW energy saving performance evaluation | ZTE, Sanechips |
|  | [R1-2203662](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203662.zip) | Discussion on network energy saving performance evaluation methods | China Telecom |
|  | [R1-2203830](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203830.zip) | Discussions on performance evaluation of network energy saving | xiaomi |
|  | [R1-2203919](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203919.zip) | NW energy savings performance evaluation | Samsung |
|  | [R1-2204073](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204073.zip) | On network energy savings evaluation methodology and power model | Panasonic |
|  | [R1-2204100](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204100.zip) | Base station energy consumption model, evaluation methodology, and KPIs for network energy saving | FUTUREWEI |
|  | [R1-2204256](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204256.zip) | On NW energy savings performance evaluation | Apple |
|  | [R1-2204318](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204318.zip) | Discussion on network energy saving performance evaluation | CMCC |
|  | [R1-2204391](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204391.zip) | Discussion on NW energy savings performance evaluation | NTT DOCOMO, INC. |
|  | [R1-2204628](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204628.zip) | Discussion on performance evaluation for network energy savings | LG Electronics |
|  | [R1-2204686](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204686.zip) | NW energy savings performance evaluation | MediaTek Inc. |
|  | [R1-2204811](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204811.zip) | Discussion on Network Energy Saving Evaluations | Intel Corporation |
|  | [R1-2204831](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204831.zip) | Performance evaluation for network energy saving | InterDigital, Inc. |
|  | [R1-2204881](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204881.zip) | Modeling and evaluation methodology for network energy saving | Ericsson |
|  | [R1-2205045](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2205045.zip) | NW energy savings performance evaluation | Qualcomm Incorporated |
|  | [R1-2205083](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2205083.zip) | Initial views on NW energy savings performance evaluation | Fujitsu Limited |
|  | [R1-2203226](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203226.zip) | Others | Nokia, Nokia Shanghai Bell |
|  | [R1-2203605](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2203605.zip) | Consideration about NW energy saving | ZTE, Sanechips |
|  | [R1-2204320](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204320.zip) | Discussion on network energy saving scheme in deployment | CMCC |
|  | [R1-2204883](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204883.zip) | Other aspects related to network energy saving | Ericsson |
|  | [R1-2204918](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2204918.zip) | Disucssion on information assistance for network energy saving | Huawei, HiSilicon |
|  | [R1-2205160](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_109-e/Docs/R1-2205160.zip) | Evaluation results of network energy saving | CATT |
|  | [R1-2205175](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Inbox/R1-2205175.zip) | Initial evaluation results for network energy saving scheme | vivo |

# Annex

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| **Company** | **Contact** | **Email address** |
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