**3GPP TSG RAN WG1 #110 R1-2206921**

**Toulouse, France, August 22nd – 26th, 2022**

**Agenda item: 9.5.2.3**

**Source: Moderator (CMCC)**

**Title: Summary for low power high accuracy positioning**

**Document for:** **Discussion and Decision**

**Introduction**

In the latest approved/revised Rel-18 SID on study on expanded and improved NR positioning [1], an objective to evaluate and study the low power high accuracy requirement provided by SA1 was justified as follows.

|  |
| --- |
| * + Study the requirements on LPHAP as developed by SA1 and evaluate whether existing RAN functionality can support these power consumption and positioning requirements. Based on the evaluation, and, if found beneficial, study potential enhancements to help address any limitations [RAN2, RAN1]
		- Study is limited to a single representative use case (use case 6 as defined TS 22.104). The choice of selected use case can be reviewed at the start of the study.
		- Study is limited to enhancements to RRC\_INACTIVE and/or RRC\_IDLE state
 |

This contribution provides a summary of the submitted contributions, issues for offline/online discussions and outcomes in RAN1#110 meeting.

**Remaining issues of evaluation methodology**

***Background:*** This agenda item aims to evaluate whether current RAN functionalities can meet the LPHAP requirement on battery life, and also potential enhancements to maximize the battery life. To better align the power consumption results for different evaluation cases from different companies and properly identify the performance gap and make conclusions, the evaluation methodology and power consumption models should be defined.

In RAN1#109-e meeting, a set of agreements on evaluation assumptions for baseline evaluation cases were achieved [2], as captured in Appendix A. However, there are still some remaining issues left for further study.

## 2.1 Battery life evaluation

***Background:*** In TR 38.840, the UE power consumption models, including power states and relative power consumption values for the reference configuration, and the power scaling schemes, are captured in Clause 8.1. With the power consumption models, the power saving gain can be evaluated in terms of relative power units. However, the target requirement of LPHAP is to achieve a battery life of 6~12 months, which cannot be directly evaluated based on relative power units. In RAN1#109-e meeting, companies shared the common understanding that a model to convert the relative power unit to the battery life should be defined, the following two examples were agreed for further study:

* + Alt. 1: battery life is used as the metric to identify the gap
		- Example:

$$T2= \frac{P1\*T1}{X}\* \frac{C2}{C1}\* \frac{1}{P2}$$

$$Gap\_{BatLife}= T2\_{req}-T2$$

* + Alt. 2: relative power unit is adopted as the metric to identify the gap
		- Example:

$$P2\_{req}= \frac{P1\*T1}{X}\* \frac{C2}{C1}\* \frac{1}{T2\_{req}}$$

$$Gap\_{PowUnit}= P2\_{req}-P2$$

in which

* C1 is the battery capacity of the reference device;
* T1 is the battery life of the reference device;
* P1 is the relative power unit obtained based on the reference traffic type;
* X is the percentage of the power consumed by the reference traffic type;
* C2 is the battery capacity of the LPHAP device;
* P2 is the evaluated relative power unit of the LPHAP device;
* P2\_req is the target relative power unit of the LPHAP device;
* T2\_req is the target battery life of the LPHAP device

In addition, the parameter values in the conversion models need to be determined as well, and following examples were provided in RAN1#109-e meeting:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **C1** | **T1** | **X** | **reference traffic type** | **C2** | **T2req** |
| [4500] mAh | [10] hours | [20] % | [FTP (model 3)] | [800] mAh | [12] months |

2.1.1 Summary of inputs

***Conversion model of battery life***

From reviewing contributions in this meeting, 9 companies (HW/Hisilicon, ZTE, Spreadtrum, vivo, Nokia/NSB, Intel, Samsung, CMCC, Qualcomm) discuss the conversion model and/or adopt the model to provide evaluation results of battery life:

* Support Alt. 1: 8 companies (HW/Hisilicon, ZTE, Spreadtrum, Nokia/NSB, Intel, Samsung, CMCC, Qualcomm)
	+ 3 companies (HW/Hisilicon, Samsung, CMCC) explicitly propose to adopt Alt. 1, i.e., using the battery life as the metric to identify the performance gap. The main reason is that as the target requirement developed by LPHAP use case 6 is a battery life of 6~12 months, using battery life as the metric to identify the performance gap is more straightforward.
	+ 5 companies (ZTE, Spreadtrum, Nokia/NSB, Intel, Qualcomm) adopt Alt. 1 in their evaluations to provide performance gaps.
* Support Alt. 2: 2 companies (vivo, Spreadtrum)
	+ 1 company (vivo) slightly prefer to adopt Alt. 2, i.e., using the relative power unit as the metric to identify the performance gap. As the result of the power consumption evaluation is generally the relative power unit, which understands the gap between the LPHAP evaluation result and the target more intuitively.
	+ 1 company (Spreadtrum) adopts Alt. 2 in the evaluations to provide performance gaps.
* Adopt Alt. 2 to evaluate target power unit: 4 companies (HW/Hisilicon, ZTE, vivo, CMCC)
	+ In [3/HW, Hisilicon], [4/ZTE] and [14/CMCC], Alt. 2 is additionally adopted to evaluate the target power unit to meet T2req, in order to explain the necessity of defining a new sleep type.

***Parameter values in the conversion model***

From reviewing contributions in this meeting, 9 companies (HW/Hisilicon, ZTE, Spreadtrum, vivo, Nokia/NSB, Intel, Xiaomi, CMCC, Qualcomm) discuss the parameter values of the conversion model and/or consider initial values in the evaluation of battery life.

Specifically, 5 companies (HW/Hisilicon, ZTE, vivo, CMCC, Qualcomm) provide recommendations on parameter values in the conversion model, including C1/C2, T1, X, reference traffic type, and T2req. In addition, 3 companies (Spreadtrum, Nokia/NSB, Intel) adopt the example values in the agreements of RAN1#109-e meeting to provide evaluation results of battery life. The recommendations / views are summarized as below:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Source** | **C1 (mAh)** | **T1 (hour)** | **X** | **reference traffic type** | **C2 (mAh)** | **T2req (month)** |
| **HW/Hisilicon** | 4500 | [8~12] under the reference C-DRX configuration of* 160ms DRX cycle
* 10ms on duration
* 100ms inactivity timer
 | 20% | FTP (model 3) | 800 | 12 |
| **ZTE** | [4500] | [10] | [20%] | [FTP (model 3)] | 4500 | 6 |
| **Spreadtrum** | [4500] | [10] | [20%] | [FTP (model 3)] | [800] | [12] |
| **vivo** | 4500 | 10 | 20% | FTP (model 3) | 4500] | 6 |
| **Nokia/NSB** | [4500] | [10] | [20%] | [FTP (model 3)] | [800] | [12] |
| **Intel** | [4500] | [10] | [20%] | [FTP (model 3)] | [800] | [12] |
| **CMCC** | [4500] | [8] | 20% | FTP (model 3) | [4500] | 6, 12 |
| **Qualcomm** | 4500 (reference device 1) | 12 | 20% | FTP (model 3) | 800 (low battery capacity) | 6, 12 |
| 3000 (medium battery capacity) |
| 5500(reference device 2) | 24 | 10% |
| 8400 (high battery capacity) |

Furthermore, 5 companies (ZTE, vivo, Intel, CMCC, Qualcomm) explicitly provide their views on the relative power unit of the reference device, P1, in order to further calibrate the evaluation results of the battery life and then the performance gaps among companies:

* In [4/ZTE], [11/Intel] and [14/CMCC], it is stated that without calibration of P1, the evaluation results of battery life among companies cannot be aligned. In [11/Intel], it is proposed to further discuss the evaluation assumptions for power consumption evaluations of reference device in order to align P1 among companies;
* In [4/ZTE], [6/vivo], [14/CMCC], and [16/Qualcomm], recommended values of P1 are provided based on evaluations/references in R16 power saving agenda items.

Meanwhile, 4 other companies (HW/Hisilicon, Nokia/NSB, Spreadtrum, Intel) provide their own evaluations on P1. The recommendations / views are summarized as below:

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **HW/Hisilicon** | **ZTE** | **Spreadtrum** | **vivo** | **Nokia/NSB** | **Intel** | **CMCC** | **Qualcomm** |
| **P1** | 37(74000 [PU/s]) | 73.65 or 52 | 37.73 | 73.65 | 13.08(26163 [REU/s]) | 37.7048 | 52.33 | 50 (same for reference device 1/2) |

2.1.2 Initial proposal

***FL comments on conversion model:*** It is observed that majority companies prefer to adopt Alt. 1 as the conversion model of battery life. Therefore, the following proposal is formulated:

**[High] Proposal 2.1-1 (I)**

* In the LPHAP evaluation, adopt the following model to convert the relative power unit to the battery life:
* Alt. 1: battery life is used as the metric to identify the gap

$$T2= \frac{P1\*T1}{X}\* \frac{C2}{C1}\* \frac{1}{P2}$$

$$Gap\_{BatLife}= T2\_{req}-T2$$

|  |  |
| --- | --- |
| **Company** | **Comments** |
| vivo | OK |
| ZTE | OK |
| Qualcomm | OK |
| CATT | OK |

***FL comments on parameter values:*** Regarding the parameter values in the conversion model, apparently, companies share common views that the values should be determined in order to evaluate battery life and identify the performance gap; however, companies’ views on particular parameters are different. From FL’s perspective, Qualcomm’s proposal to consider multiple types of reference and LPHAP devices is a reasonable way forward. For the candidate values of the reference device, as it is related to OEM and tier, Qualcomm provides two types of reference device with different values of C1, T1 and X. For the battery capacity of the LPHAP device, C2, three categories of industrial device type with low, medium and high battery capacity are considered in Qualcomm’s paper. As analysed by HW/Hisilicon’s contribution, a typical LPHAP device in the industry is a cost-friendly sensor-like UE with little communication requirement, not a regular eMBB-type UE. From this perspective, a LPHAP device with battery capacity larger than a regular mobile phone seems not reasonable and may not have stringent requirements on battery life (may easily get charged).

In addition, regarding the relative power unit of the reference device, P1, it seems reasonable to define some calibration values for P1, which would be helpful to align evaluation results among companies and hence to make convincing conclusions on whether the target requirement can be met or not. However, I don’t think it is necessary to further discuss details on the evaluation assumptions for power consumption of the reference device. First, it belongs to the scope of UE power saving agenda items not to the scope of LPHAP evaluations. Second, even in the study of UE power saving, seems that no such calibration is achieved and companies come up with their own numbers. From the inputs, it is observed that the slot-average power unit, P1, is within the range of 37~74 PUs, in which we could simply determine a value.

Therefore, the following proposals are formulated:

**[High] Proposal 2.1-2 (I)**

* In the LPHAP evaluation, adopt the following parameter values in the conversion model to evaluate the expected battery life:
	+ Consider 2 types of reference devices in the conversion model:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Reference device** | **C1 (mAh)** | **T1 (hour)** | **X** | **reference traffic type** |
| Type 1 | 4500 | 12 | 20% | FTP (model 3) |
| Type 2 | 5500 | 24 | 10% | FTP (model 3) |

* + Consider 2 types of LPHAP devices in the conversion model:

|  |  |  |
| --- | --- | --- |
| **LPHAP device** | **C2 (mAh)** | **T2req (month)** |
| Type A (low battery capacity) | 800 | 6 |
| Type B (high battery capacity) | 4500 | 12 |

* Note: It is up to each company to provide evaluation results based on parameter values of either one or multiple combinations of the device types.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| ZTE | Generally OK.For both Type A and Type B LPHAP device, we prefer the T2req is 6~12 month as the use case 6 defined.  |
| Qualcomm | Thanks for the great efforts. We have 3 comments below:1) With regards to the main statement, we think that RAN1 should acknowledge that the reference device characteristics and LPHAP device characteristics may depend on implementation, manufacturer, design, cost, and then suggest on evaluating a couple of cases. For example:* The reference device and LPHAP device characteristics, and therefore the parameter values of a model for determining expected battery life, depend on implementation factors, manufacturer, design options and cost options. For the purpose of the LPHAP evaluation, the following example parameter values are adopted to evaluate the expected battery life:

2) Furthermore, for both devices the requirement should be 6~12 months and we should not make the requirement to depend on the device type. 3) With regards to the battery lifetime of an IIOT tracker, with an easy online internet search (“8400mAh iot tracker”, one can find already asset trackers that have much higher battery capacities than the 4500 mAh). Therefore, we think we should try a larger capacity than 4500 mAh.  |
|  |  |

**[Medium] Proposal 2.1-3 (I)**

* In the LPHAP evaluation, adopt the relative power unit of the reference device P1 = 50 to further align the expected battery life among companies.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| vivo | OK |
| ZTE | OK |
| Qualcomm | OK assuming the generic sentence we are suggesting above is added. It should be clear that P1=50 (or any value we eventually converge to) is just an example value that we are picking in this subagenda for the purpose of LPHAP evaluation, and that this value may depend on implementation, design, cost.  |
| CATT | OK |

## 2.2 New sleep type

***Background:*** In TR 38.840, three UE sleep types are defined for power consumption evaluation as follows.

|  |  |  |
| --- | --- | --- |
| Power State | Characteristics | Relative Power  |
| Deep Sleep | Time interval for the sleep should be larger than the total transition time entering and leaving this state. Accurate timing may not be maintained. | 1 (Optional: 0.5) |
| Light Sleep | Time interval for the sleep should be larger than the total transition time entering and leaving this state.  | 20 |
| Micro sleep | Immediate transition is assumed for power saving study purpose from or to a non-sleep state | 45 |

The table below captures the additional transition energy and total transition time of the three sleep types.

|  |  |  |
| --- | --- | --- |
| Sleep type | Additional transition energy:(Relative power x ms)  | Total transition time  |
| Deep sleep  | 450  | 20 ms  |
| Light sleep  | 100  | 6 ms  |
| Micro sleep  | 0  | 0 ms\*  |
| \* Immediate transition is assumed for power saving study purpose from or to a non-sleep state |



In RAN1#109-e meeting, the above three sleep types were adopted in the baseline evaluation assumptions. Meanwhile, an open issue of whether/how an additional new ultra-deep sleep mode can be considered in the evaluation of potential solutions to maximize the battery life was left for FFS.

2.2.1 Summary of inputs

Based on the submitted contributions in this meeting, 5 companies (HW/Hisilicon, ZTE, vivo, Intel, CMCC) support to define a new sleep mode in the LPHAP evaluation as one of the enhancements, and 1 company (10/Lenovo) proposes to consider a new sleep type if the already supported sleep states do not satisfy the target power saving evaluation requirements. The rationale and necessity to introduce a new sleep type (known as “ultra-deep sleep” in some contributions) include:

* The evaluation results provided by companies hardly meet the stringent battery life requirement of 6~12 months developed by SA1 based on the three sleep types in TR 38.840, and it is observed that most of the power is consumed by the deep sleep mode;
* In [3/HW, Hisilicon], [4/ZTE], [6/vivo], and [14/CMCC], the maximum allowed power unit to achieve the target battery life is evaluated, which is less than 1 to meet T2req = 6 months and 0.5 to meet T2req = 12 months. Without introducing a new sleep type that consumes less power than the deep sleep mode, there is no way that we can achieve the target requirement;
* In [3/HW, Hisilicon] and [6/vivo], it is mentioned that the ultra-deep sleep mode is not new in 3GPP standardization, it is similar as the “Power Saving State (PSS)” in the study of CIoT, in which the UE turns off most of its power supplies and consumes much less power even than that in RRC\_IDLE states.

In addition, the relative power, additional transition energy and total transition time of the new sleep type are considered in [3/HW, Hisilicon], [6/vivo], [11/Intel] and [14/CMCC], as summarized below:

|  |  |  |  |
| --- | --- | --- | --- |
| **Source** | **Relative power unit** | **Additional transition energy** | **Total transition time** |
| HW/Hisilicon | 0.01 | 450 | 25 ms |
| vivo | Baseline | 0.015 | 2000 (50 per ms) | 400 ms |
| Optional | 0.05 | 2500 (50 per ms) | 50 ms |
| Intel | 0.01 | 1100 | 250 ms |
| CMCC | 0.01 | [5000] | [500] ms |

2.2.2 Initial proposal

***FL comments:*** According to the evaluation results and observations provided by companies, based on the agreed three sleep types, none of the existing R17 RRC\_INACTIVE state positioning meets the target battery life of 6~12 months. Even for the enhanced evaluation cases provided by some companies, as most of the power is consumed by deep sleep and the corresponding state transition, the results hardly meet the target requirement. In this sense, it seems necessary to define a new deep sleep type as one of the enhancements, which consumes less power unit than the deep sleep mode to meet the expected battery life; otherwise, the whole evaluation is meaningless.

On the other hand, regarding the relative power, additional transition energy and total transition time of the ultra-deep sleep type, it seems that companies have different understandings on the LPHAP device type and also characteristics of the ultra-deep sleep mode, and common understanding should be aligned before we further reach the consensus on particular values:

* Understanding 1 (as in [3/HW, Hisilicon]): The LPHAP device has little communication service and dedicates all its capability to serve positioning functionalities. In addition, a potential implementation of LPHAP device is to decouple the communication and positioning RF bandwidth, which is similar to UWB. In such a case, as UE only needs to reload limited information with respect to positioning, the additional transition energy and time is much less than a regular UE.
* Understanding 2 (as in [6/vivo]): Assumptions for NB-IoT in power saving mode is reused as a starting point, in which a UE consumes less power than that in RRC\_IDLE state, due to the reason that, e.g., UE shuts down most of its power supplies to maintain a very low current, and accurate time/frequency synchronization with the network is not guaranteed.

Therefore, the following proposal is formulated:

**[High] Proposal 2.2 (I)**

* In the LPHAP evaluation, an ultra-deep sleep type is additionally defined as one of the enhancements to maximize the battery life.
* For the ultra-deep sleep type, down-select from the following two options of the power consumption model:
	+ Option 1:
		- The relative power unit: 0.015
		- Additional transition energy: 2000 (50 per ms);
		- Total transition time: 400ms
	+ Option 2:
		- The relative power unit: 0.01
		- Additional transition energy: 450;
		- Total transition time: 25ms

|  |  |  |
| --- | --- | --- |
| **Company** | **Option** | **Comments** |
| vivo | Option 1 | We think option 1 can be agreed upon as the start point since the model has already been supported in NB-IOT for power consumption evaluation. For option 1, the additional transition energy should be ‘20000’ instead of ‘2000’.  |
| ZTE |  | We think the first bullet can be agreed in this meeting, and further details can be discussed in next meeting. In our view, both options can work as long as it leads to long battery life for LPHAP device. For the first bullet, we prefer to clarify that whether having spec impact is another discussion. So it is better to avoid the wording of ‘enhancement’ * In the LPHAP evaluation, an ultra-deep sleep type is additionally defined ~~as one of the enhancements~~ to maximize the battery life.
 |
| Qualcomm |  | We can accept the ultra-deep sleep that was agreed in NB-Iot (Option 1) with the following changes:1. We also agree with ZTE that this “ultra-deep sleep” is not an enhancement. It is just for evaluation and we prefer to remove also “to maximize the battery life”:
* In the LPHAP evaluation, an ultra-deep sleep type is additionally defined ~~as one of the enhancements to maximize the battery life~~.
1. We should write the transition energy as 50 per ms (as it was in the NB-IoT agreement)
 |

## 2.3 eDRX and paging

2.3.1 Summary of inputs

Based on the submitted contributions in this meeting, 4 companies (HW/Hisilicon, vivo, Intel, CMCC) provide views and/or evaluation results considering eDRX and/or no paging reception as one of the enhancements to maximize the battery life.

* In [6/vivo], [11/Intel], and [14/CMCC], evaluation assumptions on eDRX configuration or no paging reception are proposed.
* In [3/HW,Hisilicon], [6/vivo], [11/Intel] and [14/CMCC], evaluation results with eDRX cycle of longer than 10.24s to meet the positioning interval or no paging reception are provided to maximize the battery life.

2.3.2 Initial proposal

***FL comments:*** To maximize the battery life to meet the target requirement developed by SA1, and to further allow the UE to enter an ultra-deep sleep mode when sleeping, it seems necessary to consider eDRX configuration or no paging reception as one of the enhancements in the evaluations. Therefore, the following proposal is formulated:

**[Medium] Proposal 2.3 (I)**

* In the LPHAP evaluation, adopt the following assumptions on eDRX configuration and/or paging reception as one of the enhancements to maximize the battery life:
	+ The eDRX cycle to evaluate: 20.48s; 30.72s;
	+ For paging reception:
		- The length of paging time window (PTW) is 1.28s;
		- 1 paging cycle is included in a PTW;
		- 10% paging rate is considered in a PTW;
	+ No paging reception can be optionally evaluated to show potential power saving gain;
	+ 1 DL PRS and/or UL SRS for positioning occasion per 1 eDRX cycle, and within the PTW if configured;
		- Alignment of PRS measurement, SRS transmission and/or measurement reporting with paging monitoring in time domain is encouraged to show potential power saving gain.

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| --- | --- |
| **Company** | **Comments** |
| vivo | Support |
| ZTE | We are general fine with the proposal. However, we should clarify this is only for evaluation purpose. So the wording of ‘enhancement’ should be avoided.  |
| Qualcomm | We also think that it should be for “evaluation”.  |
| CATT | Support. Also fine to remove enhancement with the understanding the evaluation of a potential enhancement. |

## 2.4 Other considerations

2.4.1 Revisiting assumptions on paging

2.4.1.1 Summary of inputs

In [3/HW, Hisilicon], it is proposed to update the evaluation assumption on paging and revert the agreement in RAN1#109-e meeting:

* UE attempts to receive paging DCI in two consecutive slots associated with the SSB.
* One slot is treated as PDCCH-only.
* The other slot is treated as 90% PDCCH-only and 10% PDCCH+PDSCH.
* For the two slots associated with paging reception, the mean power unit per slot is 53.5.

2.4.1.2 Initial proposal

***FL comments:*** The updated assumption on paging shortens the duration from 2ms as agreed in RAN1 meeting to 1ms, and reduces the slot-averaged power unit of paging from 57 to 53.5, which seems trivial in the evaluation. FL suggests to treat this issue as low priority, and it can be up to each company to optionally provide evaluations with the following assumptions, if interested.

**[Low] Proposal 2.4-1 (I)**

* For paging reception, the following assumptions can be optionally considered:
	+ UE attempts to receive paging DCI in two consecutive slots associated with the SSB.
	+ One slot is treated as PDCCH-only.
	+ The other slot is treated as 90% PDCCH-only and 10% PDCCH+PDSCH.
	+ For the two slots associated with paging reception, the mean power unit per slot is 53.5.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| ZTE | Not necessary, this does not impact the final evaluation results  |
| Qualcomm | Low priority |
|  |  |

2.4.2 Cell-reselection of SRS configuration

2.4.2.1 Summary of inputs

In [4/ZTE], it is proposed to model the power consumption of SRS re-configuration in case of cell-reselection for R17 RRC\_INACTIVE state positioning, and suggests to consider a power unit of 6020 for the procedure.

2.4.2.2 Initial proposal

***FL comments:*** Indeed, the SRS for positioning configuration in RRC\_INACTIVE state is per serving cell, and in case of UE cell-reselection, the UE has to re-enter RRC\_CONNECTED state to update the SRS configurations. In my view, RAN1#109-e agreed that the UE is in low mobility of up to 3km/h, we can assume that the UE does not change serving cell during the evaluated power cycle. In addition, the agreement on power components for UL positioning in the last RAN1 meeting include a note saying that individual company may consider additional power components in the evaluation, it does not preclude individual company to evaluate additional power consumption for SRS reconfiguration in case of cell-reselection. For example, in [16/Qualcomm], corresponding power consumption is considered. From the perspective of simplifying the evaluation, FL suggests to treat this issue as low priority in this meeting.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Qualcomm | SDT for SRS configuration may not be due to cell-reselection, it may be because some parameters of the SRS need to change, because the RSRP dropped, or the TA expired. We think that it is important for companies to understand that the “SRS configuration SDT” is power consumption costly; For UL or DL+UL positioning, the power cost of SRS re-configuraton should be included in the study, so that we consider ways to improve/enhance them. |
|  |  |
|  |  |

2.4.3 Confirmation on values in bracket

2.4.3.1 Summary of inputs

In [4/ZTE], it is proposed to confirm all values in bracket in the previous agreements on the power consumption model common for the baseline evaluation of Rel-17 RRC\_INACTIVE state positioning.

2.4.3.2 Initial proposal

***FL comments:*** Those values in bracket are either from the agreement of R17 power saving agenda item or optional in the evaluations. It seems that further confirmation is not necessary.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| ZTE | In our view, all agreements should be clear without something put in bracket.  |
|  |  |
|  |  |

2.4.4 Scaling of DL PRS power unit

2.4.4.1 Summary of inputs

In [4/ZTE], it is proposed to consider 1-symbol DL PRS as one of the potential enhancements, of which a scaling factor of 0.75 is proposed for the power consumption adaptation.

2.4.4.2 Initial proposal

***FL comments:*** This enhancement seems trivial from power saving gain perspective, and FL suggest to treat this issue as low priority in this meeting. It can be up to each individual company to evaluate if interested.

**[Low] Proposal 2.4-2 (I)**

* For support of 1-symbol PRS, power consumption of PRS measurement is scaled down to 0.75 time of Rel-17.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| ZTE | Support this proposal. 1-symbol PRS can not only introduce power saving gain but also increase the system capacity for PRS. It is good to optionally support this evaluation assumption. |
| Qualcomm |  |
|  |  |

2.4.5 Revisiting power model of SRS

2.4.5.1 Summary of inputs

In [9/Nokia, NSB], it is proposed to update the baseline power consumption model of SRS transmission to 700 which corresponds to 23 dBm.

2.4.5.2 Initial proposal

***FL comments:*** In TR 38.840, the power consumption model in FR1 for UL is defined as below, which is 700 for 23 dBm UE transmit power.

|  |  |  |
| --- | --- | --- |
| Power State | Characteristics | Relative Power  |
| UL | Long PUCCH or PUSCH.  | 250 (0 dBm)700 (23 dBm) |

In addition, the TR 38.840 also defines the power scaling factor for SRS transmission, which is 0.3\*UL in both FR1 and FR2, as follows.

|  |  |  |
| --- | --- | --- |
| Scaling for FR1 | Proposal | Comment |
| SRS | SRS power = 0.3 x uplink power | Applicable for FR1 and FR2. |

In fact, the baseline power consumption mode of SRS transmission agreed in RAN1#109-e meeting, i.e., 210, is corresponding to 23 dBm UE transmit power. During the discussion in the last RAN1 meeting, some companies mentioned that the scaling factor of 0.3 is based on the assumption that the SRS is a short SRS, and suggested to optionally consider a long SRS configuration (e.g., up to 12 symbols) whose relative power is equal to UL (700). From the evaluations on accuracy of UL positioning in Rel-17, many companies adopted the SRS configuration with 4 symbols, which can be considered as a short SRS, and the accuracy of sub-meter can be met. In this sense, FL suggests to keep the baseline power consumption model of SRS transmission agreed in RAN1#109-e meeting as it is.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| ZTE | The same view as FL |
|  |  |
|  |  |

2.4.6 Revisiting power model of DL PRS measurement

2.4.6.1 Summary of inputs

In [9/Nokia, NSB], it is proposed to update the number of TRPs in the power consumption model of DL PRS measurement to align with the R17 evaluation assumption with 18 TRPs in InF-SH/DH scenarios.

2.4.6.2 Initial proposal

***FL comments:*** It is correct that simulation assumptions in TR 38.901 consider 18 TRPs in an indoor factory; however, it is also observed that in the Rel-17 evaluations, some companies implemented TRP selection algorithm to only use less than 8 TRPs to obtain the location estimates, and the accuracy requirement of sub-meter can be achieved, please refer to [21]-[24]. On the other hand, even more than 8 TRPs are considered for positioning, the DL PRS from other TRPs can be treated as TDM (In such a case, more than 1 slot of DL PRS should be considered in the LPHAP evaluation, which can be totally up to individual company to evaluate). Basically, the agreed power consumption model for DL PRS measurement is based on an aligned configuration with that for RRM measurement; however, if we further update the number of TRPs of the DL PRS measurement where no such reference configuration can be found in TR 38.840, it would be difficult to define the power unit that are acceptable to all companies. From this perspective, FL suggests to keep the number of TRPs in the power consumption model of DL PRS measurement agreed in RAN1#109-e meeting as it is.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| ZTE | The same view as FL. |
|  |  |
|  |  |

**Observations on evaluation results**

## 3.1 Rel-17 baseline

3.1.1 Summary of inputs

From reviewing submitted contributions in this meeting, 12 (HW/Hisilicon, ZTE, Spreadtrum, vivo, Nokia/NSB, Intel, Xiaomi, Samsung, CMCC, Qualcomm, LGE, Ericsson) out of 18 companies provide power consumption evaluations for baseline Rel-17 RRC\_INACTIVE state positioning based on the relative power unit, in which 8 companies (HW/Hisilicon, ZTE, Spreadtrum, vivo, Nokia/NSB, Intel, CMCC, Qualcomm) further present results on battery life to identify the performance gap.

***Performance gap identification***

For performance gap identification, two target requirements are considered, which are 6 months and 12 months, and two alternatives of metric are adopted, including battery life and relative power unit. The results are summarized as follows (based on the 8 sources providing identified performance gap):

* Target battery life of 6 months can be met:
	+ Yes: 2
		- [4/ZTE]: Consider LPHAP device with 4500mAh battery capacity and the optional relative power unit of deep sleep type as 0.5;
		- [16/Qualcomm]: Consider reference device type 1 and LPHAP device with high battery capacity, or reference device type 2 and LPHAP device with medium battery capacity;
	+ No: 6
* Target battery life of 12 months can be met:
	+ Yes: 1
		- [4/Qualcomm]: Consider reference device type 2 and LPHAP device with high battery capacity;
	+ No: 7

***FL comments***: It is observed that from the results provided by majority of sources, a target battery life of 6~12 months cannot be achieved. In addition, the evaluated battery life is highly related to the parameter values of the reference device and LPHAP device in the conversion model, it is proposed to settle on the discussions in Section 2.1 before making a convincing conclusion.

***Performance analysis on power consumption***

Based on the results presented by the 12 sources, the following aspects are observed from the evaluation results of UE power consumption:

* Power consumption on deep sleep
	+ The evaluation results from 5 companies (HW/Hisilicon, ZTE, vivo, Intel, CMCC) observe that the power consumed by deep sleep state accounts for the highest proportion in the total power, which is the bottleneck of a UE to meet the expected battery life.
* Power consumption on power state transitions
	+ The evaluation results show that by reducing the occurrence of power state transitions, the power consumption degrades. To be specific,
		- 9 companies (HW/Hisilicon, ZTE, vivo, Intel, Samsung, CMCC, Qualcomm, LGE, Ericsson) provide evaluation results using I-DRX cycle of both 1.28s and 10.24s, it is observed that as UE needs to wake up every I-DRX cycle for paging reception, with the increase of I-DRX cycle, the power consumption on power state transitions for paging reception degrades.
		- 1 company (Qualcomm) observes that time-domain proximity of the PRS/SRS/Paging/Reporting-opportunity reduces the power consumption by ensuring the UE stays in sleep mode longer times and reducing the need of sleep mode switches.
* Power consumption on different positioning techniques
	+ The evaluation results on different positioning techniques, including UE-assisted DL positioning, UE-based DL positioning, UL positioning, UE-assisted DL+UL positioning, show that without measurement reporting, UE-based DL positioning consumes the least power if location is required at UE side, and UL positioning consumes the least power if location is required at LMF side.
	+ Furthermore, for UL positioning, the evaluation results in [4/ZTE] and [16/Qualcomm] show that SRS (re)configurations via SDT significantly increases the power consumption.

3.1.2 Initial proposal

From the inputs, the following initial observations can be made:

**[High] Proposal 3.1-1 (I)**

Capture the following in TR as an observation:

* Evaluations of baseline Rel-17 RRC\_INACTIVE state positioning show that the power consumption on deep sleep state accounts for the highest proportion in the total power.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| vivo | OK |
| ZTE | OK |
| CATT | OK |

**[High] Proposal 3.1-2 (I)**

Capture the following in TR as an observation:

* Evaluations of baseline Rel-17 RRC\_INACTIVE state positioning show that the power consumption on the power state transition for paging reception degrades with the increase of the DRX cycle.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| vivo | OK |
| ZTE | It seems that this observation is nothing related to positioning. It can even be observed from 38.840 models. It is better to clarify how it impacts for the positioning.We should note that in Rel-17, PRS reception in RRC\_INACTIVE is not tied with DRX cycle. Perhaps, we can say* Evaluations of baseline Rel-17 RRC\_INACTIVE state positioning show that ~~the power consumption on the~~ reducing the times of power state transition for paging, SSB and PRS reception can degrade the power consumption ~~with the increase of the DRX cycle~~.
 |
|  |  |

**[High] Proposal 3.1-3 (I)**

Capture the following in TR as an observation:

* Evaluations of baseline Rel-17 RRC\_INACTIVE state positioning show that the UE-based DL positioning consumes the least power if location is required at UE side, and UL positioning consumes the least power if location is required at LMF side.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| vivo | OK |
| ZTE | We prefer not to include this observation even though it is observed based on the agreed assumptions. That’s because the power consumption of location calculation is not considered in the agreed model for UE-based DL positioning. For UL, we didn’t consider SRS (re-)configuration, that’s why the power consumption is least. In short, it depends on the detailed models, but may not be aligned with the real situation.  |
| Qualcomm | We generally support this. To ZTE: we could add the following statement (or something similar): * At least based on the baseline evaluation assumption and scenario, evaluations of baseline Rel-17 RRC\_INACTIVE state positioning show that the UE-based DL positioning consumes the least power if location is required at UE side, and UL positioning consumes the least power if location is required at LMF side.
 |

**[High] Proposal 3.1-4 (I)**

Capture the following in TR as an observation:

* Evaluations of baseline Rel-17 RRC\_INACTIVE state UL positioning show that SRS (re)configuration procedure via SDT upon events of invalidity (e.g., cell re-selection) consumes large part of total power consumption.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| ZTE | Support |
| Qualcomm | Support with the following change: “UL or DL+UL” positioning, also we can add a generic statement as above: “At least based on the baseline evaluation assumption and scenario” |
|  |  |

## 3.2 Rel-18 enhancement

3.2.1 Summary of inputs

From reviewing submitted contributions in this meeting, 4 (HW/Hisilicon, vivo, Intel, CMCC) out of 18 companies provide power consumption evaluations for potential enhancements to maximize the battery life. To be specific,

* 3 companies (HW/Hisilicon, vivo, CMCC) provide evaluation results considering the new ultra-deep sleep mode;
* 3 companies (vivo, Intel, CMCC) provide evaluation results considering eDRX with cycle longer than 10.24s to meet the positioning interval of 15~30s;
* 2 companies (HW/Hisilicon, CMCC) provide evaluation results considering UE stops paging reception;

The results are summarized as follows:

* Target battery life of 6 months can be met:
	+ Yes: 3
	+ No: 0
* Target battery life of 12 months can be met:
	+ Yes: 2
	+ No: 0

3.2.2 Initial proposal

***FL comments***: It is observed that only 4 sources provide results for potential enhancements, the inputs are not sufficient to capture observations. In addition, as the evaluations on potential enhancements are dependent on the progress of evaluation assumptions on ultra-deep sleep mode and eDRX, etc., it is proposed to settle on the discussions in Section 2.1 before making a convincing conclusion.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| ZTE | The same assessment as FL. We should be careful to enhance DRX mechanism. For example, the good synchronization may not be held anymore if paging cycle is further increased. Then, the QCL/Beam/power control source of PRS/SRS will be vanished since UE may not receive SSB anymore. In such case, how does the existing PRS/SRS work should be discussed.  |
|  |  |
|  |  |

## 3.3 Template for collection of evaluation results

3.3.1 Initial proposal

To facilitate the evaluation and analysis work in the upcoming meetings, it is desired to develop a template for collection of evaluation results.

**[High] Proposal 3.3 (I)**

* Adopt the following tables to collect evaluation results from each source:

Table 3.3-1: Evaluation cases and assumptions

|  |  |  |  |
| --- | --- | --- | --- |
| Evaluation assumption | [Case ID], [Frequency Band], [Positioning method], [Reference device type], [LPHAP device type] | [Case ID], [Frequency Band], [Positioning method], [Reference device type], [LPHAP device type] | [Case ID], [Frequency Band], [Positioning method], [Reference device type], [LPHAP device type] |
| DRX cycle |  |  |  |
| RS periodicity |  |  |  |
| M-sample |  |  |  |
| RRM measurement |  |  |  |
| BWP switching |  |  |  |
| Measurement reporting (e.g., RA/CG-SDT, reporting interval) |  |  |  |

* Note: Companies are recommended to provide the following information for each evaluation case:
* Case ID
* Positioning method: e.g., UE-assisted DL positioning, UL positioning, UE-assisted DL+UL positioning, etc.
* Frequency range: e.g., FR1
* Reference device type: e.g., Type 1, Type 2
* LPHAP device type: e.g., Type A, Type B

Table 3.3-2: UE power consumption result for each evaluation case

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Evaluation case | Power states | Relative power unit | Duration (in slots) | Instances | Sum Durations (in slots) | Relative power | Power ratio |
| **Case ID** | e.g., Deep/light/micros sleep, SSB, paging, PRS measurement, UL, SRS, etc |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
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|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
| **Total (every power cycle)** |  |  |  |
| **Slot-averaged power unit** |  |

Table 3: Summary for UE power consumption results

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Evaluation case description | Slot-averaged relative power unit (P2) | Power saving gain (over baseline) | Battery life (in month) | Target requirement are met – Yes/No; If no, provide gaps |
| 6 months | 12 months |
| **[Case ID], [Power saving scheme, if any]** |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |

* Note: Companies are recommended to provide the adopted power saving scheme (e.g., ultra-deep sleep, eDRX, etc) and power saving gain.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| vivo | OK |
| ZTE | Why we have to output relative power unit for P2? In proposal 2.1-1, battery life is used as the metric rather than relative power unit. Based on this table, it seems proposal 2.1-1 is not needed anymore. Probably, ‘Slot-averaged power unit’ in Table 3.3-2 can be replaced by ‘battery life(in month)’, then Table 3 will not be needed anymore.  |
|  |  |

**Potential enhancements**

***Background:*** As clarified by the objective, potential enhancements will be studied if found necessary based on evaluations. In RAN1#109-e meeting, due to the limited time, issues on potential enhancements were marked as low priority without further discussion. In this section, the potential enhancements on positioning in RRC\_INACTIVE and/or RRC\_IDLE states are summarized.

## 4.1 Clarification on study scope

4.1.1 Summary of inputs

As described in the SID [1], the study scope of the potential enhancements is limited to enhancements to RRC\_INACTIVE and/or RRC\_IDLE state. In [13/Samsung], it is mentioned that further clarifications on the study scope of whether positioning for RRC\_IDLE state is within the scope is required. As the clarification should be made by RAN2, it is proposed that RAN1 to wait for RAN2’s clarification on the scope.

4.1.2 Initial proposal

***FL comments:*** Similar situation was experienced in R17 of whether UL positioning for UEs in RRC\_INACTIVE state, and I understand that the final decision on whether positioning for UEs in RRC\_IDLE state is within the scope should be made by RAN2. My suggestion is that at least RAN1 should focus on studying potential enhancements on RRC\_INACTIVE state, and wait for RAN2’s clarification on RRC\_IDLE state. Therefore, the following proposal is formulated:

**[High] Conclusion 4.1 (I)**

* RAN1 waits for RAN2’s decision on whether positioning for UEs in RRC\_IDLE state is within the study scope.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| vivo | Support |
| ZTE | OK |
| Qualcomm  | We don’t interpret the SID description the same way. For us, enhancements on both RRC Idle AND RRC inactive are in scope. The “OR” didn’t mean that one or the other is not considered in scope. We think that both are in scope for “study”. |
| CATT | Share the similar view as Qualcomm. |

## 4.2 DL Positioning in RRC\_IDLE state

4.2.1 Summary of inputs

From reviewing the contributions in this meeting, 6 companies (vivo, CATT, CMCC, InterDigital, Sharp, Qualcomm) provide views on the study of DL positioning in RRC\_IDLE state.

* 3 companies (vivo, CMCC, Qualcomm) propose that at least DL PRS measurement in RRC\_IDLE state should be supported.
* 3 companies (CATT, InterDigital, Sharp) propose to study DL positioning in RRC\_IDLE state, in which [8/CATT] mentions that support of measurements/location estimates reporting in RRC\_IDLE state should be considered.

4.2.2 Initial proposal

***FL comments:*** In Rel-17 SI, the following agreements were achieved in RAN1#103-e meeting:

|  |
| --- |
| Agreement:Capture the following in the TR:From a physical layer perspective, it is feasible for a UE to perform DL positioning measurement in RRC\_IDLE state.* Note: This does not imply that measurements have to be reported in RRC\_IDLE state.

Conclusion:It is up to RAN2 to decide whether to support the enhancements of NR positioning reporting of DL positioning measurements and/or positioning estimates for RRC\_IDLE UEs. |

As commented in Section 3.1, whether RRC\_IDLE state is within the scope is up to RAN2, at this stage, any issues on the study to support DL positioning in RRC\_IDLE state and/or DL measurements / location estimates reporting in RRC\_IDLE state should be postponed until RAN2’s decision. From RAN1 perspective, we can safely discuss the DL PRS measurement in RRC\_IDLE state, as it is total in charge of RAN1.

Therefore, the following proposal is formulated:

**[Medium] Proposal 4.2 (I)**

* From RAN1’s perspective, it is feasible for a UE to perform DL positioning measurements in RRC\_IDLE state.
	+ Note: RAN1 does not imply that reporting of DL measurements and/or location estimates is in RRC\_IDLE state. Whether/how to support such feature is up to RAN2.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| vivo | Support |
| ZTE | OK |
| Qualcomm | We think a stronger statement is needed; We have already said that it is feasible from RAN1 perspective. We think that we need to say that “From Ran1 perspective, it should be supported” |
| CATT | OK. Qualcomm's suggestion is also fine to us. |

## 4.3 UE mobility support for UL/DL+UL positioning

***Background:*** In Rel-17 positioning, UL SRS for positioning transmissions in RRC\_INACTIVE state was specified. The UE keeps using the SRS configuration obtained via RRCRelease unless validity criteria fails (e.g., upon cell re-selection, TA invalidation, etc.).

4.3.1 Summary of inputs

Based on the submitted contributions in this meeting, 8 companies (HW/Hisilicon, ZTE, vivo, CATT, Nokia/NSB, Xiaomi, CMCC, Qualcomm) discuss the enhancements on SRS for positioning configuration/activation/request to support UE mobility in RRC\_INACTIVE state, such that the UE does not need to frequently enter RRC\_CONNECTED state to update the SRS (re)configurations and hence the power consumption is reduced.

* In [3/HW/Hisilicon], [4/ZTE], [6/vivo], [8/CATT], [12/Xiaomi], [14/CMCC], and [16/Qualcomm], enhancements on SRS (pre)configurations applicable to multiple cells (a positioning area) are proposed.
* Furthermore, [6/vivo], [8/CATT], [12/Xiaomi] and [16/Qualcomm] discuss activation/request enhancements of SRS configuration, e.g., allows the NW to configure/activate and/or the UE to request SRS configuration by paging or RACH procedure, etc.
* A solution to enable SRS beam sweeping is proposed in [6/vivo] to address the validation failure of spatial relation info.

4.3.2 Initial proposal

***FL comments:*** The frequent power state transition to enter RRC\_CONNECTED mode to update SRS configurations in RRC\_INACTIVE state and the corresponding power consumption is harmful to meet the expected battery life. From the input, companies are interested in support of UE mobility for UL/DL+UL positioning. Therefore, the following proposal is formulated:

**[High] Proposal 4.3 (I)**

* For UL and DL+UL positioning for UEs in RRC\_INACTIVE state, study at least the following enhancements on UE mobility support of SRS for positioning transmission:
	+ The (pre-)configuration of SRS for positioning that is applicable to an area across multiple cells;
	+ SRS for positioning configuration/activation/request procedure(s), e.g., NW configuration/activation of SRS via paging, UE request to obtain/update SRS via RACH-based procedure;
		- FFS: Events of invalidity of SRS configuration to trigger the UE request procedure.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| vivo | Support |
| ZTE | Support. Besides, other solutions may also be considered.  |
| Qualcomm | We generally support it, and we are OK to be more general at this meeting; for example: * For UL and DL+UL positioning for UEs in RRC\_INACTIVE state, study at least the following enhancements on ~~UE mobility support of~~ SRS for positioning ~~transmission~~:
	+ (pre-)configuration of SRS for positioning ~~that is applicable to an area across multiple cells,~~ enhancements related to SRS for positioning configuration/activation/request procedure(s), e.g., NW configuration/activation of SRS via paging, UE request to obtain/update SRS via RACH-based procedure;
		- FFS: Events of invalidity of SRS configuration to trigger the UE request procedure.
 |
| CATT | Support. Qualcomm's suggestion is also fine to us. |

## 4.4 Enhancements on DRX

4.4.1 Summary of inputs

From reviewing the submitted contributions in this meeting, 7 companies (HW/Hisilicon, vivo, CATT, Lenovo, Intel, Xiaomi, CMCC) provide their views on DRX related considerations/enhancements.

* In [3/HW,Hisilicon], [6/vivo], [11/Intel], and [14/CMCC], it is proposed to consider the eDRX mechanism enabling a cycle of longer than 10.24s in RRC\_INACTIVE state to help reduce the power consumption. Corresponding UE behaviors and coordination among positioning nodes (e.g., to allow the LMF to recommend appropriate SRS configuration to the gNB according to the eDRX configuration) are suggested for further study in [6/vivo].
* In RAN1#109-e meeting, the evaluation assumption on DRX was agreed with a note saying that potential solutions considering no I-DRX cycle nor paging to maximize the battery life are not precluded. In this meeting, 3 companies (HW/Hisilicon, CATT, CMCC) consider reduced/no paging reception to further acquire power saving gain, especially when mobile terminated services are barely required.
* Moreover, 6 companies (ZTE, vivo, Lenovo, Xiaomi, CMCC, LGE) discuss I-DRX related enhancements, in which 4 companies (ZTE, vivo, CMCC, LGE) propose to align the PRS measurement and/or SRS transmission with paging monitoring, e.g., by defining a time window. Furthermore, [6/vivo] and [10/Lenovo] propose to allow the LMF to be aware of the DRX configuration of a positioning UE for the adaptation of the PRS/SRS configuration. In [12/Xiaomi], it is proposed to study the UE behavior for SRS transmission or PRS measurement in non-wake up paging occasions.

4.4.2 Initial proposal

***FL comments***: Based on the evaluations and analysis provided by companies, enhancements on DRX and/or paging are critical to maximize the battery life to meet the target requirement developed by SA1. Therefore, the following proposal is formulated:

**[High] Proposal 4.4 (I)**

* For the purpose of reducing power consumption for LPHAP, study at least the following enhancements with respect to DRX and/or paging reception in RRC\_INACTIVE state:
	+ eDRX cycle of larger than 10.24s in RRC\_INACTIVE state
	+ UE suspends monitoring the paging occasions in RRC\_INACTIVE state
		- FFS applicable conditions, e.g., device type, deferred MT-LR, etc.
	+ Alignment of DRX configuration and paging occasions with PRS measurement and/or SRS transmission
		- FFS details on how to achieve the alignment, e.g., by defining time window to restrict UE behavior on PRS measurement and/or SRS transmission, coordination among positioning nodes (LMF, gNB) for the adaptation of PRS and/or SRS configurations, etc.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| vivo | Support |
| ZTE | OK. Technically, we think the study should be more careful. For example, how could UE get synchronization without paging reception and how TDOA work in such case.  |
| Qualcomm | We are generally supportive to study these aspects |
| CATT | OK |

## 4.5 Enhancements on PRS/SRS configuration and PHY layer procedure

4.5.1 Summary of inputs

Based on the submitted contributions in this meeting, 5 companies (ZTE, Nokia/NSB, Qualcomm, LGE, NTT DOCOMO) provide their considerations on PRS and/or SRS configuration and physical layer procedure:

* In [4/ZTE], support of more compact and flexible PRS resource pattern is proposed to save power;
* In [4/ZTE], the alignment of PRS and SSB configurations in the time domain is studied to avoid unnecessary power state transitions, to achieve which the LMF should be aware of the identity of a LPHAP device.
* In [9/Nokia, NSB] and [18/LGE], it suggests to consider the impact of BWP switching on power consumption when SRS outside of initial UL BWP is configured in RRC\_INACTIVE state.
* In [9/Nokia, NSB], it is proposed to study how to reduce UE positioning activities (e.g., PRS reception in DL positioning, or SRS-pos transmission in UL positioning) on demand.
* In [16/Qualcomm], it is proposed to study PRS/SRS configuration restrictions and corresponding new UE capabilities for enabling reduced power consumption for RTT positioning, e.g., same centre frequency of PRS and SRS is requested to avoid extra retuning, to configure PRS and SRS close in time, to have PRS and SRS on different bands.
* In [18/LGE] and [19/DCM], enhancements on priority of PRS and/or SRS is discussed in terms of positioning accuracy and latency. In addition, [18/LGE] considers the enhancement on OPLC of SRS to achieve power saving gain and accuracy requirement.

4.5.2 Initial proposal

***FL comments:*** Multiple companies are interested in enhancements regarding PRS and/or SRS configurations and related PHY layer procedures. As the solutions are quite diverse, the following high-level proposal is formulated based on the inputs:

**[Medium] Proposal 4.5 (I)**

* For the purpose of reducing power consumption for LPHAP, study enhancements with respect to PRS and/or SRS configurations and corresponding physical layer procedures and UE capabilities:
	+ The study can include PRS and/or SRS resource pattern, PRS and/or SRS configuration restrictions in time and frequency domain, priority of PRS and/or SRS, OPLC of SRS, etc.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| ZTE | Can we add examples for the sub-bullet? * + The study can include PRS and/or SRS resource pattern (e.g. 1-symbol PRS, comb size > 12), PRS and/or SRS configuration restrictions in time and frequency domain, priority of PRS and/or SRS, OPLC of SRS, etc.
 |
| Qualcomm | We are generally supportive to study these aspects |
|  |  |

## 4.6 TRS-based synchronization

4.6.1 Summary of inputs

From reviewing the submitted contributions in this meeting, results of using TRS to serve time/frequency synchronization for UL positioning are evaluated in [3/HW, Hisilicon]. In the evaluation, the TRS for synchronization is configured adjacent to SRS occasions. It shows that the power consumption is further reduced. Based on the evaluations, it is proposed to further study the configuration of TRS for synchronization before the SRS transmission for LPHAP in RRC\_INACTIVE state.

4.6.2 Initial proposal

***FL comments:*** The enhancement on TRS-based synchronization in RRC\_INACTIVE seems trivial when compared to other enhancements and only 1 company provide views on it. In this sense, FL suggests to treat it as low priority for now, interested companies can further provide evaluations and discussion on this issue in next meetings.

**[Low] Proposal 4.6 (I)**

* For the purpose of reducing power consumption, study the configuration of TRS for synchronization in adjacent to the SRS for positioning transmission in RRC\_INACTIVE state.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| ZTE | We prefer not to include everything in the study. The workload is too high. For this one, we think it impacts too much. SSB is needed from our side since it is the QCL source of TRS/PRS/SRS.  |
| Qualcomm | Low priority |
|  |  |

## 4.7 Ultra-deep sleep

4.7.1 Summary of inputs

From reviewing the contributions in this meeting, [3/HW, Hisilicon] proposes to support ultra-deep sleep mode in LPHAP and to study the specification impact.

4.7.2 Initial proposal

***FL comments:*** From FL’s perspective, in this meeting, we should first try to reach consensus on defining ultra-deep sleep mode in the evaluations. If agreed, the specification impact of ultra-deep sleep can be further discussed.

**[Low] Proposal 4.7 (I)**

* Ultra-deep sleep should be considered to achieve the battery life target for LPHAP.
	+ RAN1 should further study the impact to support ultra-deep sleep.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| ZTE | We prefer not to include it in the enhancement for now. Ultra-deep sleep was discussed for Rel-17 power saving, but it has no spec impact. So does here in our view.  |
| Qualcomm | We don’t think this is an enhancement with spec impact.  |
|  |  |

## 4.8 Decoupling of communication and positioning BW

4.8.1 Summary of inputs

From reviewing the contributions in this meeting, in [3/HW, Hisilicon], it is proposed to study the decoupling of bandwidth of communication and positioning for LPHAP, such that a LPHAP UE is able to satisfy high accuracy positioning services, meanwhile, the communication functionality is limited to reduce power consumption and cost.

4.8.2 Initial proposal

***FL comments***: To my understanding, from potential enhancements perspective, the specification impact seems trivial and too early for this stage to consider. Nevertheless, such LPHAP device type with decoupled communication and positioning BW would be a promising implementation in the industry, and it is also related to several issues in the evaluations, e.g., parameter values of the LPHAP device in the battery life evaluation model, transition energy and time of the ultra-deep sleep mode, enhancements on eDRX and paging reception, etc. From this perspective, FL suggests companies to keep this in mind when discussing evaluation assumptions and potential enhancements.

 **[Low] Proposal 4.8 (I)**

* RAN1 should further study the decoupling of bandwidth of communication and positioning for LPHAP.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| ZTE | We prefer not to include it in the enhancement until we are clear what else new should be studied. It is noted that PRS/SRS bandwidth is already decoupled with other signals in Rel-17.  |
| Qualcomm | We don’t think it should be added as an enhancement |
|  |  |

## 4.9 Enhancements on assistance data and/or measurement reporting

4.9.1 Summary of inputs

From reviewing the contributions in this meeting, enhancements on assistance data delivery and/or measurement reporting to save power are discussed by 2 companies (Nokia/NSB, OPPO):

* In [3/Nokia, NSB], it is proposed to study optimization on the measurement reporting and assistance data delivery, e.g., skip some measurement reports, partial updates or reports of PRS assistance data or measurements of UEs in RRC\_INACTIVE mode.
* In [9/OPPO], it is proposed to study whether to introduce more candidate values for the reporting interval for the UE power saving.

4.9.2 Initial proposal

***FL comments:*** The enhancements on AD and/or measurement reporting seems trivial when compared to other enhancements. In this sense, FL suggests to treat it as low priority for now, interested companies can further provide evaluations and discussion on this issue in next meetings.

**[Low] Proposal 4.9 (I)**

* For purpose of reducing power consumption for LPHAP, study enhancements on assistance data delivery and/or measurement reporting for UEs in RRC\_INACTIVE state:
	+ The study can include partial update of assistance data and/or measurements, introducing more candidate values for reporting interval.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| ZTE | We prefer not to include it in the enhancement until the gain is clear. In our view, partial update of assistance data/ measurement results does not reduce the transition times then no power saving gain.  |
|  |  |
|  |  |

## 4.10 Enhancements on network-initiated DL message transmission

***Background:*** In Rel-17 positioning, RAN2 agreed that the NW can send DL LCS, LPP message and RRC message to the UE if the UE initiates data transmission using UL SDT beforehand. Otherwise, if the UE did not initiate UL SDT, the NW shall rely on the legacy operation, i.e., transit the UE to RRC\_CONNECTED mode.

4.10.1 Summary of inputs

From reviewing the contributions in this meeting, 2 companies (ZTE, InterDigital) propose to study and support of network-initiated DL LCS/LPP message transmission via MT-SDT in RRC\_INACTIVE states.

4.10.2 Initial proposal

***FL comments:*** As the support of MT-SDT for UEs in RRC\_INACTIVE state is to be studied in RAN2 in Rel-18 SDT agenda item, RAN1 should wait for the progress of RAN2.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| ZTE | It is better to make it as a conclusion in RAN1 to avoid repeat discussion.  |
| Qualcomm | This is up to RAN2, do not treat it in RAN1.  |
|  |  |

## 4.11 PRACH-based UL positioning

4.11.1 Summary of inputs

From reviewing the submitted contributions in this meeting, 2 companies (InterDigital, Sharp) propose to study whether/how PRACH can be used for UL positioning in RRC\_IDLE state.

4.11.2 Initial proposal

***FL comments:*** As commented in Section 3.1, my suggestion is to wait for RAN2’s clarification on the study for UEs in RRC\_IDLE state.

|  |  |
| --- | --- |
| **Company** | **Comments** |
|  |  |
|  |  |
|  |  |

**Collection of proposals for online GTW**

TBD

**Summary of contributions**

6.1 Remaining issues of evaluation methodology

|  |  |
| --- | --- |
| **Source** | **Proposals** |
| Huawei, HiSilicon [3] | ***Proposal 1: Adopt Alt.1 to use the battery life as the metric to identify the gap.**** ***Alt.2 can be considered to evaluate the maximum allowed power unit for any “ultra-deep sleep” to meet the battery life target.***
* ***Adopt the following table as the starting point for evaluating the battery life of LPHAP.***

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **C1** | **T1** | **X** | **reference traffic type** | **C2** | **T2req** |
| 4500 mAh | [8~12] hours under the reference C-DRX configuration of* 160ms DRX cycle
* 10ms on duration
* 100ms inactivity timer
 | 20 % | FTP (model 3) | 800 mAh | 12 months |

***Observation 1: Both CIoT and UWB considered a very deep sleep mode with current in the order of uA, which is much lower than the assumption of the current in the deep sleep in TR 38.840.******Proposal 2: Define a new ultra-deep sleep type for the evaluation of LPHAP.**** ***The power unit of ultra-deep sleep can take 0.01 power unit as the starting point.***
* ***The transition energy is 450 power unit.***
* ***The transition time is 25ms.***

***Proposal 3: For paging reception, update the previous assumption that**** ***UE attempts to receive paging DCI in two consecutive slots associated with the SSB.***
* ***One slot is treated as PDCCH-only.***
* ***The other slot is treated as 90% PDCCH-only and 10% PDCCH+PDSCH.***
* ***Note: This reverts the previous agreement of paging receive duration of 2ms.***

***Proposal 4: For the two slots associated with paging reception, the mean power unit per slot is 53.5.*** |
| ZTE [4] | ***Proposal 1:*** *Confirm all values in bracket in the previous agreements for LPHAP evaluation assumption as follows*

|  |  |
| --- | --- |
| (Optional) PRACH | 210 |
| (Optional) BWP switching | 50 |
| (Optional) Intra-frequency RRM measurement (Pintra) | 60 (synchronous case, N=8, measurement only; Pintra, meas-only)80 (combined search and measurement; Pintra, search+meas) |
| (Optional) Inter-frequency RRM measurement (Pinter) | 60 (measurement only per freq. layer; Pinter, meas-only)150 (neighbor cell search power per freq. layer; Pinter, search-only)Micro sleep power assumed for switch in/out a freq. layer |
| * + - * RRCRelsease after the CG-SDT can be optionally included with **1** ms duration;
 |
| (Optional) BWP switching with 1 ms duration |
|

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| C1 | T1 | X | C2 | T2req |
| 4500 mAh | 10 hours | 20 % | 4500 mAh | **6-**12 months |

 |

***Proposal 2:*** *P1 for the relative power unit obtained based on the reference traffic type should be aligned among companies for fair comparison.* ***Proposal 3:*** *Extra power consumption should be optionally modelled for cell reselection which leads to SRS reconfiguration or initial access for positioning service* * *The relative power is around 6020*

***Proposal 4:*** *Support a new type of deep sleep mode with less than 0.5 power unit to pursue 0.5~1 year battery life.****Proposal 6:*** *For support of 1-symbol PRS, power consumption of PRS measurement is scaled down to 0.75 time of Rel-17.* |
| vivo [6] | ***Proposal 1:**** ***Regarding the alternatives of conversion between the relative power unit and the battery life to identify the performance gap, support Alt.2.***
	+ ***Alt. 2: relative power unit is adopted as the metric to identify the gap***
		- ***Example:***

$$P2\_{req}= \frac{P1\*T1}{X}\* \frac{C2}{C1}\* \frac{1}{T2\_{req}}$$$$Gap\_{PowUnit}= P2\_{req}-P2$$***Proposal 2:**** ***For LPHAP device, the power consumption requirement should be converted to slot-average relative power unit.***
* ***Consider [0.85] as target slot-average relative power unit (***$P2\_{req}$***) .***

***Proposal 4:*** * ***‘Ultra-deep sleep mode’ can be agreed to evaluate the power consumption for LPHAP in RRC inactive and RRC idle state to meet the power consumption requirements of LPHAP.***
* ***The already agreed assumptions for NB-IoT power consumption evaluation can be adopted as a start point for LPHAP power evaluation, e.g.,***
* ***Relative power: 0.015;***
* ***Transition power unit: 50 per ms;***
* ***Total transition time: 400ms***

***Proposal 5:**** ***Adopt the power evaluation assumption of eDRX configurations in Table 9*** ***to maximize the battery life for LPHAP power consumption evaluation.***
 |
| OPPO [7] | ***Proposal 1: For the study/evaluation of LPHAP, additional target positioning requirements is suggested as**** ***End-to-end latency for position estimation of UE (< 1 s).***

***Proposal 2: If RAN1 evaluation is needed for LPHAP, support to reuse the evaluation assumptions of FR1 InF-DH scenario captured in TR 38.857******Proposal 3: For evaluating the power consumption of LPHAP, suggest to take the power consumption model of [5] as the starting point and further consider the following power states**** ***For positioning methods based on DL PRS***
	+ ***Deep sleep***
	+ ***PRS reception and processing***
	+ ***UL transmission for positioning reporting***
* ***For positioning methods based on UL SRS resources for positioning***
	+ ***Deep sleep***
	+ ***SRS*** ***transmission***
* ***For positioning methods based on both DL PRS and UL SRS resources for positioning***
	+ ***Deep sleep***
	+ ***PRS reception and processing***
	+ ***UL transmission for positioning reporting***
	+ ***SRS*** ***transmission***
		- ***Note: SRS transmission and UL transmission for positioning reporting may be merged into one state***
 |
| Nokia, NSB [9] | **Observation 1:** RAN1 agreed that baseline of SRS transmission power is 0 dBm, but Rel-16/17 NR positioning study item assumed 23 dBm for the maximum power of SRS transmission.**Observation 2:** For InF-SH/DH scenario, the UE could measure far more than 4 TRPs as the number of TRPs in InF is 18. 4 TRPs may be the minimum number of TRPs for DL-TDOA and may not be a baseline assumption of Rel-16/17 NR positioning. **Proposal 1**: RAN1 to update LPHAP baseline assumptions such that SRS transmission power is 700 which corresponds to 23 dBm. **Proposal 2**: RAN1 to update the number of TRPs for DL PRS measurement such that it corresponds more closely to the Rel-17 assumption. |
| Lenovo [10] | ***Proposal 1: In terms of the LPHAP power evaluation and potential solutions, only consider new potential sleep states if the already supported sleep states do not satisfy the target power saving evaluation requirements.*** |
| Intel [11] | **Proposal 1: Detail simulation assumptions for power consumption evaluations of reference device needs to be discussed further and aligned across companies.****Proposal 2: Consider support of extended DRX cycle in excess of 15s to align with positioning interval.****Proposal 3: Consider new ultra-deep sleep state with relative power value of 0.01 with the following transition energy and transition durations as a starting point:*** **Transition energy: 1100**
* **Transition time: 250ms.**
 |
| Xiaomi [12] | ***Proposal 1: The parameters in the model of the battery life and relative power unit should be decided first.*** |
| Samsung [13] | **Proposal 2: RAN1 shall adopt battery life as the final metric to evaluate power consumption.*** **Further study how to convert power unit into battery life.**
 |
| CMCC [14] | **Observation 1: With the assumption that the reference device and LPHAP device have the same energy utilization efficiency, the conversion between the relative power unit and the battery life can be derived by proportion.****Observation 2: By aligning the evaluation methodology of the LPHAP evaluation, it is only able to align the evaluation results of the relative power unit, P2; however, without the calibration of the relative power unit of the reference device, P1, the outcome for identifying the performance gap may not be by aligned.****Proposal 1: In the LPHAP evaluation, adopt the following conversion model between the relative power unit and the battery life to identify the performance gap:*** **Alt. 1: battery life is used as the metric to identify the gap**

$$T2= \frac{P1\*T1}{X}\* \frac{C2}{C1}\* \frac{1}{P2}$$$$Gap\_{BatLife}= T2\_{req}-T2$$**Proposal 2: In the LPHAP evaluation, study the following parameter values of the conversion model as starting point:**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **C1** | **T1** | **P1** | **X** | **reference traffic type** | **C2** | **T2req** |
| [4500] mAh | [8] hours | [52.33](refer to [4] in the Appendix) | 20 % | FTP (model 3) | [4500] mAh | 6, 12 months |

**Observation 3: To meet the requirement of 6~12 months battery life, the target slot-averaged relative power unit should be less than 0.5, which is even less than the relative power state of deep sleep mode.****Observation 4: Considering a UE only interested in low power and high accuracy location service, it is only required to wake up every tens of seconds (15~30s as the requirement defined by LPHAP use case 6) for positioning purpose, and is able to turn off most of its power components to save power.****Proposal 3: For the LPHAP evaluation, consider a new ultra-deep sleep type as one of the enhancements, and with the following parameters:**

|  |  |  |
| --- | --- | --- |
| **Relative power unit** | **Additional transition energy** | **Total transition time** |
| 0.01 | [5000] | [500]ms |

**Proposal 4: Consider the following power state transition model in the LPHAP evaluation of potential enhancements, if eDRX is considered:*** **The periodicity of DL PRS / UL SRS for positioning is 20.48s;**
* **DL PRS is processed in 24ms light sleep before measurement reporting for UE-assisted DL positioning;**
* **CG-SDT is used for measurement reporting for UE-assisted DL positioning**
* **eDRX cycle is 20.48s (i.e., 1 RS occasion per eDRX cycle);**
* **eDRX pattern is aligned with the RS occasion or the measurement reporting procedure**

**Proposal 5: Consider the following power state transition model in the LPHAP evaluation of potential enhancements, if no paging monitoring considered:*** **The periodicity of DL PRS / UL SRS for positioning is 20.48s;**
* **DL PRS is processed in 24ms light sleep before measurement reporting for UE-assisted DL positioning;**
* **CG-SDT is used for measurement reporting for UE-assisted DL positioning**
 |
| Qualcomm [16] | ***Observation: Evaluate the expected battery lifetime using different reference devices, wherein**** ***C1 ~ {4500, 5500} mAH***
* ***X ~ {10,20}%***
* ***P1 = 50***
* ***T1 ~ {0.5, 1} day***

|  |  |  |
| --- | --- | --- |
| **Reference Device Parameters** | **Ref Dev 1** | **Ref Dev 2** |
| C1 | 4500 | 5500 |
| X | 20% | 10% |
| P1 | 50 | 50 |
| T1 | 0.5 day | 1 day |

***Observation: Evaluate the expected battery lifetime using multiple C2 values (e.g. C2 = {800, 3000, 8400} mAh).***

|  |  |  |  |
| --- | --- | --- | --- |
| **IIoT Device Parameters** | **IIoT 1 (Large battery)** | **IIoT 2 (medium battery)** | **IIoT 3 (small batter)** |
| C2 | 8400 | 3000 | 800 |

 |

6.2 Evaluation results and observations

|  |  |
| --- | --- |
| **Source** | **Proposals** |
| Huawei, HiSilicon [3] | ***Observation 2: Rel-17 baseline UL and DL positioning in RRC\_INACTIVE state can achieve 200 – 300 hours battery life, which cannot meet the LPHAP requirements.******Observation 3: The power consumption of deep sleep is the bottleneck for further extending the battery life for LPHAP.******Observation 4:**** ***With ultra-deep sleep***
	+ ***UL positioning can meet the requirement of 6 months***
* ***By further removing paging reception***
	+ ***UL and DL positioning can meet the requirement of 6 months***
* ***By further replacing SSB-based synchronization with TRS-based synchronization***
	+ ***UL positioning can meet the requirement of one year***
 |
| ZTE [4] | ***Observation 1:*** *For most of the cases based on the existing procedures, the evaluation results show that the requirement of battery life for LPHAP device cannot be satisfied.****Observation 2:*** *The power consumed by deep sleep state accounts for the highest proportion in the evaluation.****Observation 3:*** *Based on the UE consumption model in TR 38.840, when the power unit consumed by deep sleep state is reduced to 0.5(optional), the battery life can be extended to 6 months in some cases.* |
| Spreadtrum Communications [5] | ***Observation 1: The gap between the evaluated battery life of the LPHAP device with UL positioning and the target battery life is 11.58 months, which is very large.******Observation 2: The gap between the evaluated relative power unit of the LPHAP device*** ***with UL positioning and the target relative power unit is 2122 (units/s)******, which is very large.******Observation 3: The gap between the evaluated battery life of the LPHAP device with UE- assisted DL positioning and the target battery life is 11.58 months, which is very large.******Observation 4: The gap between the evaluated relative power unit of the LPHAP device*** ***with UE-assisted DL positioning and the target relative power unit is 2120 (units/s), which is very large.******Observation 5: The gap between the evaluated battery life of the LPHAP device with UE-based DL positioning and the target battery life is 11.57 months, which is very large.******Observation 6: The gap between the evaluated relative power unit of the LPHAP device*** ***with UE-based DL positioning and the target relative power unit is 2077 (units/s), which is very large.*** |
| vivo [6] | ***Observation 1:**** ***When I-DRX cycle is 1.28s, the power consumption results for baseline cases are as follows***
* ***1.8715 for baseline case of PRS measurement only (high SINR)***
* ***2.5230 for baseline case of PRS measurement and report (high SINR, CG-SDT)***
* ***1.8035 for baseline case of SRS transmission (high SINR)***
* ***When I-DRX cycle is 10.24s, the power consumption results for baseline cases are as follows***
* ***1.1089 for baseline case of PRS measurement only (high SINR)***
* ***1.1904 for baseline case of PRS measurement and report (high SINR, CG-SDT)***
* ***1.1004 for baseline case of SRS transmission (high SINR)***

***Observation 2:**** ***With the increase of IDRX cycle (from 1.28s to 10.24s), the power consumption gain is significantly improved.***

***Observation 3:**** ***Regardless of I-DRX cycle is selected as 1.28s or 10.24s, the power consumption in inactive state for all the cases cannot meet the requirement***.
* ***e.g., even for the lowest power consumption in the case of SRS transmission under high SINR and with 10.24s IDRX cycle, the power consumption is 0.2504 power units higher than the target.***

***Observation 4:**** ***Under large I-DRX cycle (e.g., 10.24s), the main factor that restricts the further reduction of power consumption to meet the power consumption requirement is the power consumption of ‘deep sleep’***.

***Proposal 3:**** ***Power saving mechanism should be studied for LPHAP to meet the power consumption requirement.***

***Observation 5:**** ***When eDRX is applied to LPHAP devices, the power consumption is largely reduced.***
* ***With 30.72s eDRX cycle and baseline/optional ultra deep sleep assumptions, the power consumption evaluation results can meet the requirement of [0.85].***
 |
| Nokia, NSB [9] | **Observation 3:** For DL-based positioning,the gap between the current battery life and the required battery life in LPHAP is quite large.**Observation 4:** For UL-based positioning,the gap between the current battery life and the required battery life in LPHAP is quite large.  |
| Intel [11] | **Observation 1: LPHAP device remains in deep sleep state for significant %-age of time at least when extended DRX cycle is considered, implying that consideration of a deeper sleep state with significantly lower power value could help improve battery lifetime further.**  |
| Xiaomi [12] | ***Observation 1: The minimum power consumption for UE-based DL positioning is about 1.88/1.84 with 1/8 I-DRX cycle (1280ms) when considering only SSB proc., PRS measurement and paging monitoring******Observation 2: The minimum power consumption for UE-assisted DL positioning is about 2.08/2.04 with 1/8 I-DRX cycle (1280ms) when considering only SSB proc., PRS measurement, paging monitoring and CG-SDT.******Observation 3: The minimum power consumption for UL positioning is about 1.92/1.85 with 1/8 I-DRX cycle (1280ms) when considering only SSB proc., SRS transmission and paging monitoring.*** |
| CMCC [14] | **Observation 5: For UE-assisted DL positioning, using CG-SDT for DL measurement reporting is more power efficient than using RA-SDT for DL measurement reporting.****Observation 6: As no measurement reporting is required, UL positioning and UE-based DL positioning are more power efficient than the UE-assisted DL positioning.****Observation 7: The existing Rel-17 RRC\_INACTIVE state positioning functionalities cannot meet the target requirement of 6~12 months battery life.****Observation 8: With the increase of the positioning interval and the DRX cycle, the ratio of the power consumed by deep sleep and the corresponding power state transition energy significantly increases, from 36.54%~78.91% to 92.28%~98.59%.****Observation 9: Considering longer positioning interval with ultra-deep sleep type, all evaluation cases can meet the target requirement of 6~12 months battery life.** |
| Qualcomm [16] | ***Observation 1: For UL-only, or DL+UL Positioning, RA-SDT may correspond to a procedure requiring between 4320 to 13190 power units depending on the delays involved in the overall signaling UE<->NG RAN<->LMF.*** ***Observation 2: If the location is needed at the UE, the smallest Power consumption is achieved for UE-based DL Positioning******Observation 3: If the location is needed at the network, the smallest Power consumption is achieved for UL-only Positioning******Observation 4: Positioning-related (re-)configuration(s) (e.g. SDT) increase significantly the power consumption, mainly due to increased latency and longer awake time for the devices.*** ***Observation 5: Time-domain proximity of the PRS/SRS/Paging/Reporting-Opportunity reduces the power consumption by ensuring the UE stays in sleep mode longer times and reducing the need of sleep mode switches.******Observation 6: Increasing I-DRX and/or SRS periodicities would reduce the power consumption while keeping the latency-related QoS within the required targets (e.g. 20.48, 30.72 SRS periodicities and/or I-DRX).******Observation 6: Reducing the latencies involved in the legacy SDT procedure may significantly reduce the power consumption.***  |
| LG Electronics [18] | ***Observation #1:*** * The shorter I-DRX cycle causes more power consumption at UE.

***Observation #2:*** * UE power consumption can be saved if the PRS resources are allocated with near the other DL channels.

***Proposal #1:*** * Enhancements for power saving in RRC inactive state should be studied.
 |
| Ericsson [20] | Observation 1: With 8 TRP measured per DRX, it is possible to completely sound the indoor factory deployment in 3 10.24s DRX cycles, and still be within the reporting periodicity budget of use case 6 (30 secs). Observation 2: Knowledge of the DRX pattern configured to the UE by the LMF is beneficial in order to optimize the assistance data. Observation 3: Further power saving is possible using N=3 with 10.24 DRX cycle, or N=30 with 1.28 DRX cycle.Observation 4: Short SRS is sufficient to provide UL coverage in InF cases |

6.3 Potential enhancements

|  |  |
| --- | --- |
| **Source** | **Proposals** |
| Huawei, HiSilicon [3] | ***Proposal 5: Ultra-deep sleep should be considered to achieve the battery life target for LPHAP.**** ***RAN1 should further study the impact to support ultra-deep sleep.***

***Proposal 6: RAN1 acknowledges the benefit of DRX enhancement (e.g. no paging reception) to reduce the power consumption for LPHAP.******Proposal 7: RAN1 should further study the decoupling of bandwidth of communication and positioning for LPHAP.******Proposal 8: RAN1 should further study the configuration of TRS for synchronization before the SRS transmission.******Proposal 9: RAN1 should further study the configuration of SRS that is applicable to an area consisting of multiple cells.*** |
| ZTE [4] | ***Proposal 5:*** *Support the following enhancement for PRS configuration** *Support 1-symble PRS/SRS*
* *Support the comb size {24, 48}*

***Proposal 7:*** *For power saving, PRS should configured close to SSBs** *LMF can request/recommend PRS’s time domain location*
* *LMF and TRP should be able to identify which UEs are LPHAP UEs*

***Proposal 8:*** *For DL/DL+UL positioning, further study the following enhancements for LPHAP:** *PRS reception is limited in a time period, like a PPW*

***Proposal 9:*** *Rel-18 should further enhance the UE mobility of UL positioning in RRC\_INACTIVE/RRC\_IDLE, in order to ensure the low power consumption, e.g. reduce SRS reconfiguration.****Proposal 10:*** *Support MT-LR for positioning via MT-SDT in RRC\_INACTIVE in Rel-18.* |
| vivo [6] | ***Proposal 6:**** ***In idle/inactive state, the solutions for LPHAP with eDRX mechanism should be studied to maximize the battery life, including***
* ***Potential UE behavior when eDRX is configured***
* ***Extending eDRX cycle beyond 10.24s in inactive state***
* ***eDRX/positioning related coordination between positioning nodes***

***Proposal 7:**** ***The following solutions related to inactive DRX can be considered for LPHAP, including***
* ***LMF requesting inactive DRX configurations (e.g. DRX cycle, etc.) from the cells including UE serving cell and neighboring cells that may be reselected can be considered for LPHAP***
* ***PRS measurement/SRS transmission in the vicinity of paging monitoring***

***Proposal 8:**** ***Mobility for SRS transmission in active state can be considered for LPHAP, including***
* ***Pre-configured SRS***
* ***UE initiated SRS configuration update request***
* ***SRS beam sweeping enabling***

***Proposal 9:**** ***Introduce longer candidate values for SRS periodicity, e.g., 15360, 20480, 30720ms.***

***Proposal 10:**** ***Support the following enhancements related to idle state positioning***
* ***DL-PRS measurement in idle state***
* ***Reporting of DL-PRS measurement and/or location estimate performed in idle state when the UE is in inactive/connected state.***
 |
| OPPO [7] | ***Proposal 4: Study whether or not to introduce more candidate values for the reporting interval for the UE power saving.*** |
| CATT [8] | **Proposal 1: For DL positioning, enhancement to support measurement reporting in RRC\_IDLE state could be considered for LPHAP in Rel-18.****Proposal 2: For UL positioning, the mechansim of SRS-Pos configuration for UE in RRC\_INACTIVE/RRC\_IDLE state should be enhanced especially for the case when UE moves out of the original gNB in Rel-18.****Proposal 3: The following SRS-Pos configuration method for UL positioning could be considered:*** **Introducing a new RACH procedure for UE to obtain the SRS-Pos configuration information.**

**Proposal 4: UE could stop monitoring the Paging Occasions (POs) during the deferred MT-LR period.**  |
| Nokia, NSB [9] | **Proposal 3**: RAN1 to study allowing UE to skip some measurement reports (e.g., when measurement results are similar).**Proposal 4:** For purpose of the power consumption reduction, RAN1 investigates the impact of the partial measurement reporting functionality and identifies the necessary physical layer procedure.**Proposal 5:** RAN1 to study partial updates of PRS AD for UEs in RRC\_INACTIVE mode to reduce overhead and power consumption.**Proposal 6**: RAN1 to study methods to reduce frequent configuration or update of UL SRS for positioning, e.g., by configuring common UL SRS for positioning within a positioning area.**Proposal 7**: RAN1 to study how to avoid frequent BWP switching to transmit SRS resource outside of UL BWP.**Proposal 8**: RAN1 to study how to reduce UE positioning activities (e.g., PRS reception in DL positioning, or SRS-pos transmission in UL positioning) on demand. |
| Lenovo [10] | ***Proposal 2: The serving gNB may provide/share the applicable UE’s DRX configuration with the LMF for adaptation the of the PRS measurement configuration. FFS they type of DRX configuration to be shared with the LMF, e.g., C-DRX, I-DRX. RAN3 coordination may be required.*** |
| Xiaomi [11] | ***Proposal 2: The positioning SRS con be configured per cell group for UE power consumption reduction.******Proposal 3: Study SRS configuration request by random access.******Proposal 4: Study SRS transmission or PRS measurement in PO indicated not necessary to wake up by DCI format 2\_7.*** |
| Samsung [13] | **Proposal 1: RAN1 shall wait for RAN2’s clarification on the scope of the study. Especially, one of the following options shall be clarified:*** **Option 1: The study investigates potential enhancement to positioning in RRC\_INATIVE state to support LPHAP.**
* **Option 2: The study investigates supporting of positioning in RRC\_IDLE state and potential enhancement to support LPHAP.**
* **Option 3: Option 1 + Option 2.**
 |
| CMCC [14] | **Proposal 6: From RAN1 perspective, support of DL measurement for UEs in RRC\_IDLE state.****Proposal 7: The following DRX related enhancements should be considered:*** **Introduction of the eDRX mode in LPHAP**
* **Reduce the number of PDCCH monitoring occasions in RRC\_INACTIVE/IDLE state for LPHAP**
* **Align the DRX pattern and the DL PRS / UL SRS occasions**

**Proposal 8: The following enhancement of SRS transmission in RRC\_INACTIVE state should be considered:*** **SRS resources are (pre-)configured within an area in RRC\_INACTIVE state.**
* **FFS: How to define this area.**
 |
| InterDigital [15] | **Proposal 1: Study achievable accuracy of IDLE mode positioning****Proposal 2: Study feasibility of IDLE mode positioning methods using SRS for positioning and/or PRACH** |
| Qualcomm [16] | ***Proposal 1: Support Positioning measurements in RRC Idle state.*** ***Proposal 2: Study at least the following enhancements in RRC Inactive Positioning for the purpose of reducing power consumption:**** ***Study ways of optimizing the SRS configuration/activation/request procedure(s) included in the UL/DL+UL RRC inactive positioning (e.g. SRS pre-configuration, RACH-based SRS request from the UE, paging-based SRS activation).***
* ***Study ways for SRS transmission continuation after cell change in RRC Inactive (e.g., continuity of the configured SRS across cell change).***
* ***Study PRS/SRS configuration restrictions & corresponding new UE capabilities for enabling reduced power consumption for RTT positioning.***
 |
| Sharp [17] | **Proposal:** For LPHAP, the DL positioning in RRC\_IDLE state should be studied.**Observation:** When studying PRACH-based UL positioning in RRC\_IDLE state, the difference of power consumption between the positioning in RRC\_INACTIVE state and the positioning in RRC\_IDLE should be the metric. |
| LG Electronics [18] | ***Observation #3:*** * For LPHAP, following issues should be considered from a time domain perspective:
	+ For higher accuracy, configuring the shorter periodicity and/or the larger repetition on PRS/SRS resources could be used, but it costs of UL/DL resources and UE power.
	+ The time domain window is not supported for inactive state UE in Rel-17.

***Observation #4:*** * For LPHAP, following issues should be considered from a frequency domain perspective
	+ When separated BWP for positioning SRS is configured for UE in RRC inactive state, power consumption due to the BWP switching should be considered.

***Observation #5:*** * If the SRS for positioning always has lower priority than other UL channels, not only performance in terms of accuracy cannot be guaranteed, but also the latency can be increased because of the drop and/or delaying of SRS transmission due to lower priority.
 |
| NTT DOCOMO [19] | **Observation 1:** * **To achieve the requirements of Rel-18 LPHAP (i.e., use case 6 defined in TS 22.104), high reception priority of DL-PRS in RRC\_INACTIVE state may be needed.**
* **One possible solution is to reuse PPW for high priority reception of DL-PRS. In addition, RAN1 may need to discuss additional specification impacts.**

**Observation 2:** * **To achieve the requirements of Rel-18 LPHAP (i.e., use case 6 defined in TS 22.104), high transmission priority of SRS for positioning in RRC\_INACTIVE state may be needed.**
* **One possible solution is to introduce transmission priority indicator between SRS for positioning and other DL/UL signals.**
 |

**References**

1. RP-213588, Revised SID on Study on expanded and improved NR positioning, 3GPP TSG RAN Meeting #94e.
2. Chair’s Notes RAN1#109-e 9.5 EOM2.
3. R1-2205871 Evaluation and solutions for LPHAP Huawei, HiSilicon
4. R1-2205904 Discussion on low power high accuracy positioning ZTE
5. R1-2205996 Discussion on evaluation on LPHAP Spreadtrum Communications
6. R1-2206049 Discussion on Low Power High Accuracy Positioning vivo
7. R1-2206275 Discussion on Low Power High Accuracy Positioning OPPO
8. R1-2206408 Discussion on Low Power High Accuracy Positioning CATT
9. R1-2206492 Views on LPHAP Nokia, Nokia Shanghai Bell
10. R1-2206501 LPHAP considerations Lenovo
11. R1-2206591 Discussion on power saving evaluation and techniques for LPHAP Intel Corporation
12. R1-2206652 Discussion on Low Power High Accuracy Positioning Xiaomi
13. R1-2206834 Discussion on LPHAP Samsung
14. R1-2206920 Discussion on low power high accuracy positioning CMCC
15. R1-2207091 Discussions on Low Power High Accuracy Positioning (LPHAP) techniques InterDigital, Inc.
16. R1-2207241 Requirements, Evaluations, Potential Enhancements for Low Power High Accuracy Positioning Qualcomm Incorporated
17. R1-2207286 Views on low power high accuracy positioning Sharp
18. R1-2207361 Discussion on LPHAP in idle/inactive state LG Electronics
19. R1-2207414 Discussion on Low Power High Accuracy Positioning NTT DOCOMO, INC.
20. R1-2207623 Evaluations for Low Power High Accuracy Positioning Ericsson
21. TR 38.857 Study on NR Positioning Enhancements, v17.0.0
22. R1-2007665 Evaluation of NR positioning performance, vivo
23. R1-2009433 Evaluation results for Rel-16 positioning and Rel-17 enhancement Huawei, HiSilicon
24. R1-2007859 Discussion of evaluation of NR positioning performance CATT

**Appendix A: Agreements in RAN1#109-e meeting**

The agreements in RAN1#109-e meeting are recapped below [2].

**Agreement**

Confirm that use case 6 defined in TS 22.104 is the single representative use case for the study of LPHAP.

**Agreement**

At least the relative power unit is adopted as the performance metric to evaluate the power consumption of the Rel-17 RRC\_INACTIVE state positioning and potential enhancements.

**Agreement**

A reference device (e.g., a mobile phone) with reference traffic type, reference battery capability, and reference battery life is defined for the purpose of identification of the performance gap that achieved by the Rel-17 RRC\_INACTIVE state positioning baseline and the target battery life of LPHAP use case 6.

**Agreement**

* Adopt the following parameters as the common evaluation parameters for the LPHAP evaluation:
	+ Frequency range: FR1 (baseline); FR2 (optional)
	+ SCS: 30kHz for FR1 (baseline); 120kHz for FR2 (optional)
	+ BW of the DL PRS and UL SRS pos: 100MHz;
	+ Single-sample measurement per position fix (baseline); 4-sample measurement per position fix (optional)
	+ UE mobility: up to 3km/h
* Note: It is up to each company to provide detailed power model and evaluation results on power consumption in FR2.

**Agreement**

In the LPHAP evaluation, the power consumption of 5GC data traffic is not modelled. Only the power consumption of the traffic type related to LPHAP positioning (e.g., obtaining/updating SRS configurations, DL PRS measurement reporting, etc.) is considered.

* Note: This does not preclude the power consumption of paging monitoring in the baseline evaluation, but rather assumes that no power consumption of 5GC data traffic is considered during a power cycle.

**Agreement**

Adopt the following power consumption model common for the baseline evaluation of Rel-17 RRC\_INACTIVE state positioning.

|  |  |
| --- | --- |
| **Power State** | **Relative power** |
| PDCCH-only (PPDCCH) | 50Note |
| PDCCH + PDSCH (PPDCCH+PDSCH) | 120 |
| SSB proc. (PSSB) | 50 |
| UL | 250 (0 dBm)700 (23 dBm) |
| (Optional) PRACH | [210] |
| (Optional) BWP switching | [50] |
| (Optional) Intra-frequency RRM measurement (Pintra) | [60] (synchronous case, N=8, measurement only; Pintra, meas-only)[80] (combined search and measurement; Pintra, search+meas) |
| (Optional) Inter-frequency RRM measurement (Pinter) | [60] (measurement only per freq. layer; Pinter, meas-only)[150] (neighbor cell search power per freq. layer; Pinter, search-only)Micro sleep power assumed for switch in/out a freq. layer |
| Note: Power scaling to 20MHz reception bandwidth follows the rule in Section 8.1.3 of TR 38.840, i.e., max{reference power \* 0.4, 50}. |

**Agreement**

Adopt the following power consumption model for UL SRS for positioning transmission.

|  |  |
| --- | --- |
| **Power State** | **Relative power** |
| SRS | 210 (baseline);700 (optional) |

**Agreement**

* In Rel-18 low power and high accuracy positioning, adopt the following requirement:
	+ Horizontal positioning accuracy < 1 m for 90% of UEs
	+ Positioning interval / duty cycle of 15-30 s
	+ UE battery life of 6 months – 1 year
* Note: Setting an exact value each from the set of positioning interval / duty cycle and UE battery life in the evaluation and identification of performance gap will be discussed separately when necessary.

**Conclusion**

* At least when the positioning accuracy is evaluated without jointly evaluating the associated power consumption, the target horizontal positioning accuracy requirement on LPHAP of <1m can be achieved by Rel-16/17 positioning techniques with a positioning bandwidth of at least 100MHz.
* The main aspect of RAN1 evaluation is on power consumption.
* Note: This does not preclude the case that the positioning accuracy can be revisited, if found necessary at later stage.

**Agreement**

* Study further at least the following models and parameter values of conversion between the relative power unit and the battery life to identify the performance gap:
	+ Alt. 1: battery life is used as the metric to identify the gap
		- Example:

$$T2= \frac{P1\*T1}{X}\* \frac{C2}{C1}\* \frac{1}{P2}$$

$$Gap\_{BatLife}= T2\_{req}-T2$$

* + Alt. 2: relative power unit is adopted as the metric to identify the gap
		- Example:

$$P2\_{req}= \frac{P1\*T1}{X}\* \frac{C2}{C1}\* \frac{1}{T2\_{req}}$$

$$Gap\_{PowUnit}= P2\_{req}-P2$$

in which

* C1 is the battery capacity of the reference device;
* T1 is the battery life of the reference device;
* P1 is the relative power unit obtained based on the reference traffic type;
* X is the percentage of the power consumed by the reference traffic type;
* C2 is the battery capacity of the LPHAP device;
* P2 is the evaluated relative power unit of the LPHAP device;
* P2\_req is the target relative power unit of the LPHAP device;
* T2\_req is the target battery life of the LPHAP device
* Examples of these parameters are provided as follows:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **C1** | **T1** | **X** | **reference traffic type** | **C2** | **T2req** |
| [4500] mAh | [10] hours | [20] % | [FTP (model 3)] | [800] mAh | [12] months |

**Agreement**

Adopt the following periodicity of DL PRS / UL SRS for positioning in the baseline evaluation of Rel-17 RRC\_INACTIVE positioning:

* 1 DL PRS / UL SRS for positioning occasion per N I-DRX cycle(s);
	+ Candidate values of N to evaluate is 1 and 8 for I-DRX cycle of 1.28s;
		- Note: Individual company may consider either one or both in the evaluation.
	+ Candidate value of N to evaluate is 1 for I-DRX cycle of 10.24s.

**Agreement**

* The I-DRX configuration is included in the baseline evaluation of Rel-17 RRC\_INACTVIE positioning.
	+ Note: This does not preclude the case where no I-DRX cycle nor paging is considered in the evaluation of potential solutions to maximize the battery life.
* Adopt the following I-DRX cycle to evaluate:
	+ 1.28s (baseline); 10.24s (optional).

**Agreement**

* Adopt the power consumption model, additional transition energy and total transition time of the three sleep types (deep sleep, light sleep, and micro sleep) in TR38.840 as the evaluation baseline:
* FFS: whether/how an additional new ultra-deep sleep mode can be considered in the evaluation of potential solutions to maximize the battery life, including the determination of the relative power, additional transition energy and total transition time, if necessary.

**Agreement**

* Adopt the following reference configuration and assumption for DL PRS to define the power consumption model for DL PRS measurement:
	+ 1 Number of PFL;
	+ 8 DL PRS resources per slot are measured;
	+ DL PRS instance of smaller than or equal to 1 slot duration;
* Adopt the following table as the power consumption model for DL PRS measurement (derived from Table 22 in TR38.840):

|  |  |  |
| --- | --- | --- |
| N: Number of TRPs for DL PRS measurement | Synchronous case (baseline) | Asynchronous case (optional) |
| FR1 (baseline) | FR2 (optional) | FR1 | FR2 |
| N=4 (baseline) | 120 | 195 | 140 | 255 |
| N=8 (optional) | 150 | 225 | 170 | 285 |

**Agreement**

* For DL positioning, at least the following power components and parameter values are considered for the baseline evaluation of Rel-17 RRC\_INACTIVE positioning:
	+ For the UE-assisted DL positioning,
* SSB proc. with 2 ms duration and the periodicity of I-DRX cycle;
* Paging with 2 ms duration, the periodicity of I-DRX cycle, and group paging rate of 10%;
* DL PRS measurement with 0.5 ms duration;
* CG-SDT with 1ms duration and the periodicity of positioning interval;
	+ - * RRCRelsease after the CG-SDT can be optionally included with [1] ms duration;
* (Optional) BWP switching with [1] ms duration;
* (Optional) Intra-/inter-frequency RRM measurement in low SINR condition with [1] ms duration;
* (Optional) RA-SDT (e.g., including CORSET0 + SIB1, PRACH, RAR, Msg 3/4/5) in case of CG-SDT is unavailable;
	+ For the UE-based DL positioning,
		- SSB proc. with 2 ms duration and the periodicity of I-DRX cycle;
		- Paging with 2 ms duration, the periodicity of I-DRX cycle, and group paging rate of 10%;
		- DL PRS measurement with 0.5 ms duration;
		- (Optional) BWP switching with [1] ms duration;
		- (Optional) Intra-/inter-frequency RRM measurement in low SINR condition with [1] ms duration;
* Note: The power component and parameter values for UE-assisted DL positioning is also applicable to the DL part of UE-assisted DL+UL positioning method.
* Note: Individual company may consider additional power components and different parameter values in bracket in the evaluation.
* Note: Companies are encouraged to provide the assumption on the timeline between different power consumption events in the evaluation of potential enhancements to reduce the transition times between different power states and to extend the sleeping time as much as possible.

**Agreement**

* For UL positioning, at least the following power components and parameter values are considered for the baseline evaluation of Rel-17 RRC\_INACTIVE positioning:
	+ SSB proc. with 2 ms duration and the periodicity of I-DRX cycle;
	+ Paging with 2 ms duration, the periodicity of I-DRX cycle, and group paging rate of 10%;
	+ UL SRS for positioning transmission with 0.5 ms duration;
	+ (Optional) BWP switching with [1] ms duration;
	+ (Optional) Intra-/inter-frequency RRM measurement in low SINR condition with [1] ms duration;
* Note: The power component and parameter values for UL positioning is also applicable to the UL part of UE-assisted DL+UL positioning method.
* Note: Individual company may consider additional power components and different parameter values in bracket in the evaluation.
* Note: Companies are encouraged to provide the assumption on the timeline between different power consumption events in the evaluation of potential enhancements to reduce the transition times between different power states and to extend the sleeping time as much as possible.

**Appendix B: Contact information**

The contact information of delegates in charge of LPHAP AI is summarized in the following table for your information.

|  |  |  |
| --- | --- | --- |
| **Company** | **Name** | **Email** |
| CMCC | Jingwen Zhang | zhangjingwen@chinamobile.com |
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