**3GPP TSG RAN WG1 #110 R1-22NNNNN**

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

**Source: Moderator (Ericsson)**

**Agenda item: 9.5.3**

**Title: Feature Lead Summary#1 for Positioning for RedCap UEs**

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

# Introduction

This document presents a summary of the contributions submitted to AI 9.5.3 (“Positioning for RedCap UEs”). The WID for Rel18 expanded and improved NR positioning provides the following objectives to be treated in this agenda item:

|  |
| --- |
| *From RP-213561:*Justification:Release-17 has specified support for RedCap UEs with reduced bandwidth support and reduced complexity including reduced number of receive chains. Such UEs could support NR positioning functionality but there is a gap in that the core and performance requirements have not been specified for the positioning related measurements performed by RedCap UEs, and no evaluation was performed to see how the reduced capabilities of RedCap UEs might impact eventual position accuracy. This gap is to be investigated by the present SI.Objectives* Positioning support for RedCap UEs, considering the following:
	+ Evaluate positioning performance of existing positioning procedures and measurements with RedCap UEs[RAN1]
	+ Based on the evaluation, assess the necessity of enhancements and, if needed, identify enhancements to help address limitations associated with for RedCap UEs [RAN1, RAN2]
 |

Based on the received contributions, the following aspects are discussed in this summary

* Use cases and target performance requirements for positioning of Redcap UEs
* Methodology to capture evaluation results
* Enhancements for positioning of RedCap UEs

**Contact information**

**To facilitate remote discussions, companies are kindly requested to provide an email address for the delegate handling the discussions for AI 9.5.3**

|  |  |  |
| --- | --- | --- |
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# Aspect 1 - Use cases and target performance requirements for Positioning of Redcap UEs

## Issue 1.1 - Accuracy Requirements

### background

Many contribution discussed the use cases for Redcap Positioning and their associated accuracy requirements. The main target use cases mentioned are IIoT [1][2][3][5][6] and commercial [1][2][3] [5][6].

Several contributions propose to relax the accuracy enhancements from Rel17 IIoT requirements[1][3][10] [12][18]. [2] propose to follow the rel17 IIOT requirement, i.e. 0.2m vertical and 3m horizontal accuracy. [1][3][10] [12][18] proposes to relax further the horizontal accuracy to 1-2m. [5] mentions the use case of industrial wireless sensors for IIOT. In [6], it is proposed to have requirements that do not exceed those of Rel-17

 In [1] [2][18] commercial requirements are proposed with the same target as for rel17, with [1] proposing to relax the percentile from 90 to 80 percent of UEs. In [3][10] [11] the requirements are proposed to be relaxed to 3m for vertical accuracy. [5] mentions the use case of wearables for commercial use cases. Outdoor accuracy of 10m is proposed in [11].

[2] proposes to report which percentile of UEs can achieve the target accuracy requirements if the target percentile cannot be reached.

[14] proposes to involve RAN4 regarding the positioning requirements for 1Rx.

For convenience, rel17 requirements for commercial and IIOT is copied below:

|  |
| --- |
| Agreement:* In Rel-17 target positioning requirements for commercial use cases are defined as follows:
	+ Horizontal position accuracy (< 1 m) for 90% of UEs
	+ Vertical position accuracy (< 3 m) for 90% of UEs
	+ End-to-end latency for position estimation of UE (< 100 ms)
	+ Physical layer latency for position estimation of UE (< 10 ms)
* In Rel-17 target positioning requirements for IIoT use cases are defined as follows:
	+ Horizontal position accuracy (< 0.2 m) for 90% of UEs
	+ Vertical position accuracy (< 1 m) for 90% of UEs
	+ End-to-end latency for position estimation of UE (< 100ms, in the order of 10 ms is desired)
	+ Physical layer latency for position estimation of UE (<10ms)
* Note 1: Target positioning requirements may not necessarily be reached for all scenarios and deployments
* Note 2: For some scenarios the requirement for Horizontal position accuracy can be relaxed to < 0.5 m in IIoT use cases.
* Note 3: All positioning techniques may not achieve the target positioning requirements over all scenarios
 |

Table 1 Table of proposals regarding target accuracy

|  |  |
| --- | --- |
| Source | Proposal |
| [1] | ***Proposal 1: Consider the following target requirements for RedCap positioning:**** + *IIoT: Horizontal position accuracy < 1 m, vertical position accuracy < 3 m for 90% of UEs*
	+ *Commercial: Horizontal position accuracy (< 1 m), vertical position accuracy (< 3 m) for 80% of UEs*
 |
| [2] | ***Proposal 1:*** *Study the RedCap UE positioning performance in commercial use case and IIoT use case.* ***Proposal 3:*** *For evaluation for RedCap UE positioning in commercial use cases and IIoT use cases, pursue the target positioning requirements defined in Rel-16/17.* |
| [3] | ***Proposal 1**** ***Support looser positioning accuracy requirement for RedCap UEs than normal UEs.***
* ***Commercial use cases: horizontal position accuracy of 3 m, vertical position accuracy of 3 m for 90% UEs***
* ***IIoT use cases: horizontal position accuracy of 1~2 m, vertical position accuracy of 3 m, for 90% UEs.***
 |
| [5] | 1. ***Regarding the positioning support for RedCap UEs, support the following two categories of use cases:***
	* ***Commercial use cases mainly for wearables***
	* ***IIoT use cases mainly for industrial wireless sensors***
 |
| [6] | **Proposal 1: The positioning accuracy requirement for Rel-18 RedCap UEs should be no higher than that for Rel-17 commercial and IIoT use cases, e.g., 1~3 meter (90% of UEs).** |
| [8] | **Proposal 1**: RAN1 to discuss the performance targets for RedCap UEs.  |
| [9] | ***Proposal 1: RAN1 needs to study at least the scenarios of interest, vertical and horizontal positioning accuracy and availability requirements for the RedCap devices considering indoor and outdoor deployments***  |
| [10] | **Proposal 1*** **The following positioning accuracy requirements can be considered for RedCap UEs:**
* **IIOT: Horizontal position accuracy (< 1 m), vertical position accuracy (< 1 m) for 90% of UEs**
* **Commercial: Horizontal position accuracy (< [3] m), vertical position accuracy (< 3m) for 90% of UEs**
 |
| [11] | ***Proposal 1: using positioning accuracy requirement for commercial use cases defined in R16 as :***- Horizontal positioning error < 3m for 90% of UEs in indoor deployment scenarios- Horizontal positioning error < 10m for 90% of UEs in outdoor deployments scenarios  |
| [12] | **Proposal 1: The requirements of the RedCap UE positioning is defined as:*** + - **Horizontal position accuracy (< 1 m) for 90% of UEs**
		- **Vertical position accuracy (< 3 m) for 90% of UEs**
 |
| [18] | **Proposal 1:** * **Horizontal positioning accuracy for IIoT use case may need to be relaxed from Rel-17 IIoT requirement (i.e., 0.2m) due to hardware restrictions, and it should be set to 1 m for RedCap UEs.**

**Proposal 2:** * **Horizontal positioning accuracy for commercial use case may need to be set as high as possible, e.g., in the 1 – 3 m range for RedCap UEs. The feasibility of the target positioning accuracy is discussed based on the evaluation results at RAN1#110 meeting.**
 |
| [20] | ***Proposal 1 Reuse the positioning requirements of wearables, industrial wireless sensors with the battery life limitation of a few years, and augmented reality in smart factories in TS 22.261 and TS 22.104 (i.e. the summary in Table 3) for RedCap positioning.******• For wearables, the horizontal positioning accuracy is 1m – 10m, and the horizontal positioning accuracy in indoor is 2m – 3 m, depending on use cases.******• For industrial wireless sensors, the horizontal positioning accuracy is 30 cm – 10 m, and the horizontal positioning accuracy in indoor is 2m – 3m, depending on use cases.*** |

### First round of discussion

Since several companies propose to relax IIOT and/or commercial target requirements, we propose to start the discussion with a relaxed set of requirements compared to release 17. From the received evaluations for indoor factory (InF SH/DH), it can be observed that that without any enhancements, the relaxed requirement is not met but would be within reach, with the average accuracy in the received contribution around 2-3 meters. For outdoor cases, the received evaluations were fewer and show the performance are quite far from the proposed target. Therefore, we propose to continue the discussion on whether to have a separate requirement for outdoor, as done in Rel16.

Proposal 1.1-1

* The target accuracy requirements for RedCap UEs in In Rel-18 for commercial **indoor** use cases are defined as follows:
	+ Horizontal position accuracy (< 3 m) for 90% of UEs
	+ Vertical position accuracy (< 3 m) for 90% of UEs
	+ FFS outdoor accuracy.
* The target accuracy requirements for RedCap UEs in In Rel-18 for for IIoT **indoor** use cases are defined as follows:
	+ Horizontal position accuracy (<1 m) for 90% of UEs
	+ Vertical position accuracy (< 3 m) for 90% of UEs

 Companies are encouraged to provide their view on proposal 1.1-1 in the table below:

**Proposal 1.1-1:**

|  |  |
| --- | --- |
| Company | comment |
| CATT | We are fine with the target accuracy requirements for commercial indoor use cases.And we prefer not to have a separate requirement for indoor/outdoor for IIoT use cases, since the IIoT use cases should be indoor use cases as we evaluated in Rel-17, it includes InF-SH and InF-DH scenarios, both of them are indoor use cases. Then our preferred proposal as follows,Updated Proposal 1.1-1* The target accuracy requirements for RedCap UEs in In Rel-18 for commercial **indoor** use cases are defined as follows:
	+ Horizontal position accuracy (< 3 m) for 90% of UEs
	+ Vertical position accuracy (< 3 m) for 90% of UEs
* The target accuracy requirements for RedCap UEs in In Rel-18 for for IIoT**~~indoor~~**use cases are defined as follows:
	+ Horizontal position accuracy (<1 m) for 90% of UEs
	+ Vertical position accuracy (< 3 m) for 90% of UEs
 |
| vivo | The same view as CATTFor commercial use cases, a unified accuracy requirement is preferred as what we did for commercial use cases in Rel-17. For IIoT use cases, the ‘indoor’ after IIoT can be removed. |
| ZTE | We are general fine with the proposal. Rel-17 commercial and IIOT scenairos should be reused. Furthermore, we more prefer not to specify the exact value of requirements for RedCap UE as this is not mandatory based on the SID. Perhaps, we can just say *For evaluation for RedCap UE positioning in commercial use cases and IIoT use cases, pursue comparable target positioning requirements as defined in Rel-17* |
| Qualcomm | 1st bullet: we still have preference to keep outdoor in there. 2nd bullet: similar view to CATT (Ok with the 1m accuracy target) |
| Samsung  | Before we make decision on supporting whether separate with indoor or outdoor, how do we count the scenarios with many O2I channels, such as UMi? Does it mean indoor or outdoor? |
| Huawei, HiSilicon | OK |
| NTT DOCOMO | OK with CATT’s updated proposal. |
| OPPO | Fine with CATT’s update on the proposal. |
| Apple | For the commercial case, we prefer to have a single target. We are fine with the relaxation.  |

## Issue 1.2 - Latency Requirements

### background

in [9] it is proposed to study the end to end latency requirements for redcap devices. [2] proposes to deprioritize the issue in order to focus on accuracy.

Table 2 Table of proposals regarding latency

|  |  |
| --- | --- |
| Source | Proposal |
| [2] | ***Proposal 2:*** *For Rel-18 RedCap UE positioning, focus on position accuracy and de-prioritize the evaluation of latency.* |
| [9] | ***Proposal 2: Study the end-to-end latency requirements for the RedCap devices*** |

### First round of discussion

During RAN1#109e, the latency requirements were discussed during the requirement discussion. The comments received were split 2-3 in support and against including latency requirements. However, since there are few contributions on the issue, in a first step we should see what is the overall view on whether we should discuss further the latency requirements for positioning with RedCap UEs. If the consensus is not to define a requirement for latency, we should capture a conclusion to close the issue.

Question 1.2-1

Should latency requirements be defined and latency be evaluated in this agenda item?

 Companies are encouraged to provide their answer on question 1.2- in the table below:

**Proposal 1.1-1:**

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | comment |
| CATT | No | We prefer to put the latency requirements as the low priority and focus on the accuracy requirements. |
| vivo | No |  |
| ZTE | No | The workload is too high |
| Qualcomm | No |  |
| Samsung | No  | Low priority |
| Huawei, HiSilicon | No |  |
| NTT DOCOMO  | No | Low priority |
| OPPO | No | Low priority |
| Apple | No |  |

# Aspect 2 – Evaluations of positioning for Redcap UEs

## Issue 2.1 results format

### background

To align the results from the evaluations, we propose to re-use the methodology from rel17 and capture the results for UEs in the so called convex hull of the horizontal deployment, and optionally the results for all UEs. The results are proposed to be captured for the 50th, 67th, 80th and 90th percentile. Although no proposal for this issue was made in the contributions, it seems this needs to be agreed to move forward.

### First round of discussion

**Proposal 2.1-1: CDF values for evaluations of Redcap Positioning scenarios are derived based on:**

* **(Required): The UEs inside the convex hull of the horizontal BS deployment area.**
* **(Optional): All the UEs**
* **The reported CDF points used as performance metrics in the evaluation include at least the 50%, 67%, 80%, 90% percentiles.**

Companies are encouraged to provide their view on proposal 2.1-1 in the table below:

**Proposal 2.1-1:**

|  |  |
| --- | --- |
| Company | comment |
| CATT | Support |
| vivo | OK |
| ZTE | OK |
| Qualcomm | OK |
| Samsung  | support |
| Huawei, HiSilicon | OK |
| NTT DOCOMO | Support |
| OPPO | Okay |
| Apple | OK |

## Issue 2.2 Template for evaluation scenarios and parameters

### background

The parameters for each evaluated case should be documented when reporting the evaluation results. In table 3-2-1, a template for evaluation scenarios and parameter is proposed, based on the release 17 table and agreements in RAN1#109e, to which we propose to add the UE Rx branch and antenna configuration, as well as an entry for the evaluated enhancements.

|  |  |
| --- | --- |
| Parameter | Case XYZ (channel model, FRx) |
| Channel model (baseline, otherwise state any modifications) |  |
| Carrier frequency |  |
| Subcarrier spacing |  |
| Reference Signal Transmission Bandwidth |  |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) |  |
| Reference signal(type of sequence, number of ports, …) |  |
| Number of sites |  |
| Number of symbols used per occasion |  |
| number of occasions used per positioning estimate |  |
| Power-boosting level |  |
| Uplink power control (applied/not applied) |  |
| interference modelling (ideal muting, or other) |  |
| Description of Measurement Algorithm (e.g. super resolution, interference cancellation, ….) |  |
| Description of positioning technique / applied positioning algorithm (e.g. Least square, Taylor series, etc) |  |
| Network synchronization assumptions |  |
| UE/gNB RX and TX timing error |  |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) |  |
| Precoding assumptions (codebook, nrof antenna elements used, etc) |  |
| UE antenna configuration |  |
| Number of UE branches |  |
| Evaluated enhancements |  |
| Additional notes, if any |  |

### first round of discussion

it is proposed to discuss how to further update the table for scenarios and parameters.

**Proposal 2.2-1: the following table is endorsed to capture the evaluation scenarios and parameters in the evaluation results section of the TR:**

Table 3.2-1 evaluation scenarios and parameters template

|  |  |
| --- | --- |
| Parameter | Case XYZ (channel model, FRx) |
| Channel model (baseline, otherwise state any modifications) |  |
| Carrier frequency |  |
| Subcarrier spacing |  |
| Reference Signal Transmission Bandwidth |  |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) |  |
| Reference signal(type of sequence, number of ports, …) |  |
| Number of sites |  |
| Number of symbols used per occasion |  |
| number of occasions used per positioning estimate |  |
| Power-boosting level |  |
| Uplink power control (applied/not applied) |  |
| interference modelling (ideal muting, or other) |  |
| Description of Measurement Algorithm (e.g. super resolution, interference cancellation, ….) |  |
| Description of positioning technique / applied positioning algorithm (e.g. Least square, Taylor series, etc) |  |
| Network synchronization assumptions |  |
| UE/gNB RX and TX timing error |  |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) |  |
| Precoding assumptions (codebook, nrof antenna elements used, etc) |  |
| UE antenna configuration |  |
| Number of UE branches |  |
| Evaluated enhancements |  |
| Additional notes, if any |  |

Companies are encouraged to provide their view on possible revision of the table in the table below:

**Proposal 2.2-1:**

|  |  |
| --- | --- |
| Company | comment |
| CATT | Support in principle. We propose to add the following parameters in the table:* PRS Bandwidth
* gNB antenna configuration
* UE noise figure
* UE antenna height
* gNB antenna height
 |
| vivo | Maybe modifying “Evaluated enhancements” as “Description of enhancement solutions, if any” could be clearer since baseline simulation may not be enhanced and should be evaluated first based on the following SID* Evaluate positioning performance of existing positioning procedures and measurements with RedCap UEs
 |
| ZTE | OK |
| Qualcomm | OK |
| Samsung  | Ok, also fine with CATT and vivo’s suggestion. |
| Huawei, HiSilicon | OK |
| OPPO | Okay |

## Issue 2.3 – template section for collection of results

### background

In order to efficiently collect results and capture them in the TR, a common template and procedure for reporting results should be agreed. It is proposed to leverage on the experience from previous releases to speed up the process. In release 17, a template section for reporting was designed to collect the accuracy evaluations. Results from AI 9.3 should be captured in TR 38.859 in annex B.6.

A template for submitting results is provided in appendix of this summary. Note that the table for parameters in section B.6.X.1 is a placeholder and the final table should reflect the finalized table if agreed in proposal 2.2-1.

### First round of discussion

**Question 2-3-1: companies are requested to provide feedback regarding the draft structure of the TR section B.6 for providing results, provided in appendix.**

Question 2-3-1:

|  |  |
| --- | --- |
| Company | comment |
| CATT | We are fine with the template in B.6.X.2 for collecting the accuracy evaluations. |
| Qualcomm | OK |
| Huawei, HiSilicon | OK |
| Apple | OK with template |

## Issue 2.4 Parameters for RMa

### background

During RAN1#109e, the RMa scenario was agreed as case 3 (optional outdoor). However, the details were left FFS. In [18] and [20] parameters are proposed.

Table 2 Table of proposals regarding RMa Parameters

|  |  |
| --- | --- |
| Source | Proposal |
| [18] | **Proposal 4:** * **TR 38.901, TR 38.802, and/or TR 38.830 seem to be suitable as a starting point for RMa parameters.** Example parameters are described as follows.
* Table 1: Rural macro (RMa) scenario parameters

|  |  |
| --- | --- |
|  | FR1 Specific Values  |
| Layout  | Hexagonal grid, 3 sectors per site, 7 or 19 macro sites, ISD = 1730m or 5000m – Note 1Wrap-around is applied. Note 2 |
| Total gNB TX power, dBm | 49dBm |
| gNB antenna configuration | Agreement(M, N, P, Mg, Ng) = (4, 2, 2, 1, 1), (dH, dV) = (0.5, 0.8)λ – Note 4Applicable for 700MHz carrier frequency. |
| gNB antenna radiation pattern | Directional, 8dBi – Note 1, Table 6.1.1-5 |
| Channel model | RMa scenario – Note 3  |
| Penetration loss | For outdoor UEs: 0dBFor indoor UEs: 20dB+0.5d2D-in – Note 3 |
| Number of floors, (floor height) | TBD |
| Antenna Height:  | 35m |
| UE Height  | 1.5m  |
| UE dropping procedure | 50% indoor and 50% outdoor uniformly distributed over the horizontal area (separate statistic) |
| Min. gNB-UE distance (2D), m | 35m |
| UE mobility (for modeling Doppler effects) | For indoor UEs: 3km/h For outdoor UEs: 120km/h |
| Note 1: According to 3GPP TR 38.802Note 2: In case if interference considerations are not properly taken into account for 7 sites companies are encouraged to provide results for 19 sites.Note 3: According to 3GPP TR 38.901Note 4: According to 3GPP TR 37.830 |

 |
| [20] | ***Proposal 3 Use the simulation assumptions listed in Table 8 for performance evaluation in RMa.***

|  |  |
| --- | --- |
| Parameters | Values |
| Layout | Hexagonal grid, 19 or 7 macro sites, 3 sectors per site, ISD = 1732m or 5000m, Note 1Wrap-around is applied, Note 2 |
| Carrier frequency | 700MHz |
| Bandwidth | 10MHz for DL and 10MHz for UL – Note 1 |
| Subcarrier spacing | 15kHz SCS |
| gNB noise figure | 5 dB |
| gNB antenna configuration | See Table A.2.1-4 in TR 38.802 |
| gNB antenna element gain + connector loss | See Table A.2.1-4 in TR 38.802 |
| Total gNB TX power | 49 dBm |
| UE max. Tx power | 23 dBm – Note 1 |
| UE noise figure | 9 dB – Note 1 |
| UE antenna configuration | The number of antenna: Rx={1,2}, Tx=1(Mg, Ng, M, N, P)={(1,1,1,1,1), (1,1,1,1,2)} and dH = 0.5λ |
| UE antenna radiation pattern  | Omni, 0dBi |
| Channel model | ITU Rural with LOS and NLOS |
| Number of floor | All UEs are on the ground |
| UE distribution | 50% outdoor in cars (120km/h) and 50% indoor (3km/h), uniformly distributed over the horizontal area (separate statistic) |
| UE height | 1.5 m |
| Min. gNB-UE distance (2D) | 35 m |
| gNB antenna height | 35 m |
| PHY/link level abstraction | Explicit simulation of all links, individual parameters estimation is applied. Companies to provide description of applied algorithms for estimation of signal location parameters. |
| Network synchronization | The network synchronization error, per UE dropping, is defined as a truncated Gaussian distribution of (T1 ns) rms values between an eNB and a timing reference source which is assumed to have perfect timing, subject to a largest timing difference of T2 ns, where T2 = 2\*T1– That is, the range of timing errors is [-T2, T2]– T1: 0ns (perfectly synchronized), 50ns |
| Note 1: According to 3GPP TR 38.802Note 2: In case if interference considerations are not properly taken into account for 7 sites companies are encouraged to provide results for 19 sites.Note 3: According to 3GPP TR 38.901 |

 |

### First round of discussion

Since only two companies made proposals, we would like to see if either of the assumptions can be captured as is, or if further modifications are necessary.

**Question 2.4-1: which of the two proposed parameters table for RMa should be used:**

 **Option 1: table 1 from [18]**

**Option 2: table 8 from [20]**

Companies are encouraged to provide their view on question 2.4-1 in the table below, including changes needed to the table:

**question 2.4-1:**

|  |  |
| --- | --- |
| Company | comment |
| CATT | Option 2. |
| ZTE | We more prefer to let companies report their evaluation details for RMa. In addition, we don’t prefer Option 2, why ITU channel model is suggested for NR? |
| Qualcomm | Let each company decide |
| NTT DOCOMO | TR 38.901, TR 38.802, and/or TR 38.830 can be reused, but more evaluations from companies are welcome.For Option 1, we made a typo: ISD = ~~1730m~~1732m or 5000m. |

# Aspect 3 – Enhancements for positioning of RedCap UEs

## Summary of proposed enhancements

All contributions discussing enhancements deal with solutions to overcome the limited bandwidth of the RedCap UE’s RF front end by some kind of frequency hopping for PRS and some of the contributions ([1] [12][14][16][17][18][19]) also proposed to use SRS hopping. The following enhancements were discussed:

* PRS Frequency hopping with partial overlapping was discussed in [1][2] [3][8][14][16][19]
* SRS frequency hopping was discussed in [1] [12][14][16][17][18][19]
* [3] proposes to involve RAN4 regarding the feasibility of frequency hopping
* [7][14] propose to study the re-use of exisiting PRS/SRS configurations used by non-RedCap UEs.
	+ Configurations parameter to be studied include intra/inter slot repetition of the PRS
* [7] discuss the issue of per-hop muting.
* The impact of DL BWP switching is mentioned in [8][11]
* Specific PRS configurations with FH hopping (new PRS pattern) is mentioned in [14]

 [3][16] discuss DRX enhancements for power efficiency

Additionally [3] discusses PRS/SRS collisions in half duplex, CA/DC considerations, initial BWP enhancements. Impact of RedCap specific features on positioning is mentioned in [8]. Group based SRS transmission is discussed in [8]

Carrier Phase positioning (CPP) is discussed in Rel18 for non-redcap UEs and in [10][12] it is propose to consider extending CPP to RedCap UEs.

Phase-Difference AoD is discussed in [14].

The reuse of existing communication signals (SSB, TRS, SRS-MIMO) for positioning measurements is discussed in [14].

Group based positioning is discussed by [16]

Table 4 Table of proposals regarding enhancements

|  |  |
| --- | --- |
| Source | Proposal |
| [1] | ***Proposal 3: Support overlapped SRS frequency hopping transmission for RedCap positioning.******Proposal 4: Support overlapped PRS frequency hopping reception for RedCap positioning.***  |
| [2] | ***Proposal 4:*** *Consider at least RS frequency hopping for positioning for RedCap UEs.****Proposal 5:*** *To eliminate phase difference between hops, some methods should be researched, e.g. support partial overlapping in frequency domain between two adjacent hops*. |
| [3] | ***Proposal 3**** ***For power saving, positioning impacted by CDRX should be considered for RedCap positioning, including:***
* ***PRS measurement behaviour inside/outside drx-onDurationTimer or DRX active time.***
* ***LMF awareness of DRX configurations and DRX state change(e.g., short-long DRX cycle transition due to drx-ShortCycleTimer, etc.).***
* ***Related signaling and procedure***

***Proposal 4**** ***The following aspects can be considered for RedCap positioning, including:***
* ***Separated initial BWP support for PRS measurement and SRS transmission.***
* ***Priority/collison rules for DL PRS processing and SRS transmission when Half-duplex FDD is supported.***
* ***The impact of UE not supporting CA/DC.***
 |
| [5] | ***Study mechanisms for the positioning RS of RedCap UEs to cover more bandwidth, e.g. frequency hopping for positioning RS.***  |
| [7] | ***Proposal 1: For NR REDCAP UEs, study the PRS frequency hopping scheme and consider the time and frequency allocation for each hopping subband.******Proposal 2: For NR REDCAP UEs, if frequency hopping is enable, study the muting mechanism for subbands.******Proposal 3: For NR RedCap UEs, study how to reuse the PRS configuration of normal UEs*** |
| [8] | **Proposal 2**: RAN1 to study the ability to receive/ wideband PRS/SRS signals with a narrow band receiver (e.g., over multiple 20 MHz chunks) and transmit wideband PRS/SRS signals on a narrow band transmitter (e.g., frequency hopping over multiple 20 MHz chunks). Identifying any specification impact should be part of the study.**Proposal 3**: RAN1 to discuss how to perform phase alignment between frequency chunks in PRS frequency hopping/stitching including the impacts of a poor channel on the overlapping RB/REs.**Proposal 4**: RAN1 to study PRS frequency hopping/stitching in PRS processing windows including but not limited to the impacts of DL BWP switching and PRS priority priority.**Proposal 5**: RAN1 to study more dynamic SRS transmissions for RedCap UEs. **Proposal 6**: RAN1 to investigate UL group based positioning schemes for RedCap UEs to save on SRS overhead. **Proposal 7**: RAN1 to study methods for reducing the impact of reduced capability features (e.g., RRM measurement relaxation) on the positioning measurement accuracy of RedCap UEs.  |
| [9] | ***Proposal 4: Evaluate and study the positioning performance of RedCap devices with longer PRS symbol lengths, e.g., 12 to support RedCap devices******Proposal 5: Analyse and study the complexity and capability to perform DL-PRS hopping including storing number of time domain PRS samples across different hops for coherent combining to achieve wideband PRS measurement for RedCap devices.***  |
| [10] | **Proposal 2*** **If enhancements are determined as necessary for RedCap UEs, study frequency hopping with bandwidth stitching technique for the UL-SRS and DL-PRS signal transmission to enhance the timing-based estimates of the DL-TDOA, UL-TDOA, and Multi-RTT positioning methods for the RedCap UEs.**

**Proposal 3*** **If enhancements are determined as necessary for RedCap UEs, study super resolution MUSIC-like methods for performance improvement of the DL-TDOA, UL-TDOA, and Multi-RTT positioning methods for RedCap UEs and the support of frequency hopping-based schemes to enable such algorithms.**

**Proposal 4*** **If enhancements are determined as necessary for RedCap UEs, study carrier phase measurements-based positioning techniques for positioning performance improvement for RedCap UEs.**
 |
| [11] | ***Proposal 2: for considering the FH-like adaption to reduced bandwidth, the impact of the TimeGap between different FH part in different BWP should be studied.***  |
| [12] | **Proposal 2: Further study enhancements of RedCap UE positioning:*** + - **SRS frequency hopping**
		- **Carrier phase positioning**
 |
| [13] | **Proposal 1: Study enhancements related to frequency hopping for DL-PRS to improve positioning accuracy for RedCap UEs** |
| [14] | ***Proposal 1: Send LS to RAN4 to ask them to include positioning requirements derived using simulation assumptions wherein 1 Rx is assumed at the UE.*** ***Proposal 2: Study inter & intra-slot repetition of a DL PRS resource for the purpose of enabling receive PRS hopping for both FR1 and FR2.******Proposal 3: Study inter & intra-slot repetition of a SRS resource for positioning for the purpose of enabling transmit SRS hopping for both FR1 and FR2.******Proposal 4: Study PRS/SRS overlapping configuration for the purpose of enabling phase estimation across PRS hops both FR1 and FR2.******Proposal 5: Study DL-PRS/ SRS resource configuration for the purpose of enabling transmitter PRS hopping.******Proposal 6: For the purpose of Redcap positioning enhancements, study supporting Phase-Difference AoD.*** ***Proposal 7: For the purpose of Redcap positioning enhancements, study supporting Positioning measurements (RSTD, UE Rx-Tx, RSRPP) derived on SSB, TRS.******Proposal 8: For the purpose of Redcap positioning enhancements, study supporting M-RTT using SRS-MIMO.*** |
| [15] | **Proposal 1:** Study bandwidth hopping of DL PRS when the degradation of positioning accuracy due to the reduced bandwidth of RedCap UEs cannot be tolerated.* Starting point is PRS hopping in LTE FeMTC

**Proposal 2:** Study bandwidth hopping of UL SRS when the degradation of positioning accuracy due to the reduced bandwidth of RedCap UEs cannot be tolerated. |
| [16] | ***Proposal 1:*** *RAN1 should investigate the following enhancements for RedCap UE positioning:* * *PRS and SRS bandwidth hopping with tone overlap*
* *Reduced accuracy requirement indication*
* *Group based positioning schemes*
* *Energy Aware Positioning*
 |
| [17] | ***Proposal 2: Discuss time/frequency domain enhancement (e.g., BWP hopping/switching and burst transmission of SRS for positioning) to compensate performance degradation of RedCap UE)*** |
| [18] | **Proposal 5:** * **RAN1 should study PRS/SRS frequency hopping if positioning accuracy enhancements for RedCap UEs are required according to the evaluation results.**
 |
| [19] | **Proposal 3-1**: Support DL-PRS transmission hopping**Proposal 3-2**: For DL-PRS transmission hopping, the partial overlapping in frequency domain between the BW before and after the hopping is preferred**Proposal 3-3**: The SRS transmission outside UL BWP may also be considered, especially for the positioning techniques of requiring DL and UL measurements |
| [20] | ***Proposal 2 Enhancement to improve the horizontal positioning accuracy of DL-TDOA positioning for RedCap is needed in the scenarios of at least InF-SH, IOO, UMa and UMi.******Proposal 4 PRS frequency hopping is one of the potential methods to improve the positioning accuracy of DL-TDOA positioning for RedCap UEs and the study of whether this method introduces additional error (e.g. phase rotation error) may be needed.*** |

## Issue 3-1 study of PRS and SRS Frequency hopping

### First round of discussion

Based on the proposed enhancements in received contributions, the following are proposed to be investigated in during the SI:

**Proposal 3.1-1a**

**Frequency Hopping of the DL PRS will be investigated in release 18. Enhancements considered in the investigation include but are not limited to**

* **PRS patterns for frequency hopping, including use of inter- or intra-slot repetitions**
* **Methods for UE receptions in partial PRS bandwidth, including partial overlapping**
* **Impact of RF retuning during frequency hopping**
* **Muting aspects**
* **Other aspects not precluded**

**Proposal 3.1-1b**

**Frequency Hopping of the UL SRS will be investigated in release 18.**

* **FFS details of aspects to be investigated**

Companies are encouraged to provide their view on proposals 3.1-1a/b in the table below

**Proposals 3.1-1 a/b:**

|  |  |
| --- | --- |
| Company | comment |
| CATT | We prefer the following version based on Proposal 3.1-1b,**Updated Proposal 3.1-1b****Frequency Hopping of the UL SRS will be investigated in release 18, if the target performance requirements for Positioning of Redcap UEs cannot be satisfied with existing positioning procedures and measurements.** * **~~FFS details of aspects to be investigated~~**
 |
| vivo | In general, we have some concerns about frequency hopping.From the evaluation in our contribution [3], it is observed that frequency hopping performance is largely affected by Doppler, Rx/Tx timing errors between hops. In addition, other impairments such as phase error, and power imbalance between hops should also be considered. Currently, it is not clear how these errors affect the performance of frequency hopping in real scenarios and how to eliminate these errors or ensure that these errors are within a certain range and to get guarantee the gain compared to previous methods. Moreover, frequency hopping may also require RedCap UE to have higher capabilities, which may exceed the ‘reduced capability’ of UE. For example, for DL frequency hopping, the RedCap UE is required to have higher baseband processing to aggregate the measurement results of multiple hops. Therefore, we think the following proposal should be supported first at this stage. And RAN 4 may be involved in the evaluation.**Proposal 3.1-1****The potential benefits and performance of frequency Hopping of the DL PRS and UL SRS can be investigated in release 18, if necessary, which may take into account at least the following:*** **The impact of Doppler, phase offset, timing offset, power imbalance among hops**
* **RedCap UE capability and complexity considerations**
* **Impact of RF retuning during frequency hopping**
 |
| ZTE | Support this proposal.  |
| Qualcomm | We support the proposal. We don’t think that we should send this to RAN4.  |
| Samsung | We share the concern with vivo, the non-ideal of the FH condition/operation and the contraints of the redcap UE could lead not much gain or no actual benefits for this FH-like manner. Besides, we did not prefer to directly called it FH, as it may not be exactly like the FH we have adopted in NR. So suggested change on top of Vivo’s version.**Proposal 3.1-1****The potential benefits and performance of frequency Hopping – like manner of the DL PRS and UL SRS can be investigated in release 18, if necessary, which may take into account at least the following:*** **The impact of Doppler, phase offset, timing offset, power imbalance among hops**
* **RedCap UE capability and complexity considerations**
* **Impact of RF retuning during frequency hopping**
* **Others not precluded.**
 |
| NEC | Support this proposal. |
| Huawei, HiSilicon | OK |
| NTT DOCOMO | OK |
| OPPO | Support both Proposal 3.1-1a and Proposal 3.1-1b. At current stage, it seems not necessary to trigger RAN4 to discuss the feasibility of frequency hopping for RedCap UE.  |
| Apple | Fine with proposal. For Poroposal 3.1-1a, a discussion of configuration and associated signaling should be added.  |

## Issue 3-2 study of other enhancements

The remaining proposals are proposed in one or two contributions. Therefore, we would like to first check if there is enough support to study further the different topics.

**Question 3.2-1 Please provide your opibon on whether the following topics could be studied further during the SI**

1. **DRX enhancements for power efficiency**
2. **PRS/ SRS collisions in half duplex**
3. **Redcap UE CA/DC consideration**
4. **Initial BWP enhancements**
5. **Group based SRS transmission**
6. **Carrier phase positioning for RedCap UEs**
7. **Phase Difference AOD for RedCap UEs**
8. **Use of SSB, TRS, SRS-MIMO for positioning of RedCap UEs**
9. **Group based positioning schemes**

Companies are encouraged to provide their view the different enhancements in the table below

**Question 3.2-1**

|  |  |
| --- | --- |
| Company | comment |
| CATT | We support to study carrier phase positioning for RedCap UEs. |
| ZTE | We suggest to deprioritize all of above study. For Carrier phase positioning, the feature being agreed in another agenda can be naturally reused for RedCap UEs.  |
| Qualcomm | We primarily support the following three:* H: SSB, TRS, SRS-MIMO for positioning
* G: Phase difference AoD
* A: DRX enhancements
 |
| Samsung | We feel like any of these directions/solution could provide some gain in a given selected cases for the evaluation. But it doesn’t necessily mean all of them should be studied or purely based on companies interest. It may need to bulid up some criteria for selecting this, e.g., the agreed KPI eventually, the gain, the cost etc. so we suggest to postpone on this question.  |
| NEC | Share the same view as ZTE |
| Huawei, HiSilicon | We support the use of MIMO-SRS for RTT positioning and INACTIVE state positioning. |
| NTT DOCOMO | For carrier phase positioning, we have a similar view with ZTE. Discussions on AI 9.5.2.2 can be reused. |
| Apple | A and I. We think that carrier phase positioning should not be discussed simultaneously under two sub-agenda items. |

Conclusions

References

1. R1-2205872, Discussion on RedCap positioning, Huawei, HiSilicon
2. R1-2205905, Discussion on Positioning for RedCap UE, ZTE
3. R1-2206050, Discussion on positioning for RedCap UEs, vivo
4. R1-2206126, Discussion on positioning for RedCap UEs, Sony
5. R1-2206276, Discussion on Positioning for RedCap Ues, OPPO
6. R1-2206426, Discussion on positioning for RedCap UEs, CATT
7. R1-2206473, Discussion on positioning support for RedCap UEs, NEC
8. R1-2206493, Views on Positioning for RedCap UEs, Nokia, Nokia Shanghai Bell
9. R1-2206502, Positioning for RedCap devices, Lenovo
10. R1-2206592, Positioning for RedCap UEs, Intel Corporation
11. R1-2206835, Discussion on Positioning for RedCap UEs, Samsung
12. R1-2206922, Discussion on RedCap positioning, CMCC
13. R1-2207092, Discussions on positioning for RedCap UEs, InterDigital, Inc.
14. R1-2207242, Positioning for Reduced Capabilities UEs, Qualcomm Incorporated
15. R1-2207287, Views on positioning for RedCap Ues, Sharp
16. R1-2207342, Discussions on Positioning for RedCap Ues, Apple
17. R1-2207362, Discussion on positioning support for RedCap Ues, LG Electronics
18. R1-2207415, Discussion on positioning for RedCap UEs, NTT DOCOMO, INC.
19. R1-2207482, The potential solutions for RedCap UEs for positioning, MediaTek Inc.
20. R1-2207624, Considerations for RedCap Positioning, Ericsson

Appendix: template for the capture of RedCap UE positioning performance evaluation.

Annex B.6: Evaluation Results for Positioning for RedCap UEs

#### B.6.X Results from source [X]

##### B.6.X.1 Description of evaluation scenarios

[brief descriptions of the evaluated scenarios]

Evaluation assumptions for system level analysis are provided in Table B.6.X.1-1 [multiple tables are OK]

Table B.6.X.1-1: NR RedCap positioning - evaluation scenarios and parameters

|  |  |
| --- | --- |
| Parameter | Case XYZ (channel model, FRx) |
| Channel model (baseline, otherwise state any modifications) |  |
| Carrier frequency |  |
| Subcarrier spacing |  |
| Reference Signal Transmission Bandwidth |  |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) |  |
| Reference signal(type of sequence, number of ports, …) |  |
| Number of sites |  |
| Number of symbols used per occasion |  |
| number of occasions used per positioning estimate |  |
| Power-boosting level |  |
| Uplink power control (applied/not applied) |  |
| interference modelling (ideal muting, or other) |  |
| Description of Measurement Algorithm (e.g. super resolution, interference cancellation, ….) |  |
| Description of positioning technique / applied positioning algorithm (e.g. Least square, Taylor series, etc) |  |
| Network synchronization assumptions |  |
| UE/gNB RX and TX timing error |  |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) |  |
| Precoding assumptions (codebook, nrof antenna elements used, etc) |  |
| Evaluated enhancements |  |
| Additional notes, if any |  |

##### B.6.X.2 Positioning accuracy evaluation results

[brief description of the content, without observations]

Table B.6.X.2-1 provides summary of …

Table B.6.X.2-1: Rel.16 NR positioning (baseline) - horizontal location error results from [4]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Cases |  | 50% | 67% | 80% | 90% |
| Case #,channel model, FRx, positioning method  | (Optional) All UEs |  |  |  |  |
| Convex UEs |  |  |  |  |

Figures B.6.X.2-1 provides the results of ….



Figure B.6.X.2-1: results from [X]