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

**e-meeting, October 10th – 19th, 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”), with the discussion triggered by the Chair as follow:

[110bis-e-R18-Pos-07] Email discussion on positioning for RedCap UEs by October 19 – Florent (Ericsson)

* Check points: October 14, October 19

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

* Evaluations of Redcap positioning
	+ Includes baseline evaluations and evaluations of enhancements, taking into account impairements such phase error, frequency offset/doppler, etc.
* Topics to study for enhancements of positioning performance for 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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| --- | --- | --- |
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# Aspect 1 – Summary of evaluations

## Issue 1.1 Baseline performance for commercial use cases

### Background

Several sources provided results for baseline performance for commercial and/or IIOT use cases. The outcome of the baseline evaluation is as follow for RedCap UEs.

**20MHz bandwidth evaluations:**

*IIOT use cases*

For inF-SH scenario, for UL TDOA in [1][19] , RTT[18][19] and DL-TDOA in [4][5][6][7][9][12][14][19] it is observed that the requirements for IIOT use cases (<1m@90%) is **not met**.

For inF-SH scenario, in UL TDOA, RTT and DL TDOA [2] it is observed that the requirements for IIOT use cases (<1m@90%) is **met**.

* + - * Note: [2] uses the RAIM outlier rejection algorithm. Without RAIM, the requirement is not met.

For UMi scenario, in [1] (UL TDOA) it is observed that the requirements for IIOT use cases (<1m@90%) is **not met**.

* + - * Note that eMBB UEs do not meet the requirement either in that scenario

*Commercial use cases*

For inF-SH scenario, in [1] (only UL TDOA) [2][19] (all methods) [18] (RTT) and [4][6][7][9][14] (DL-TDOA) it is observed that the requirements for commercial use cases (<3m@90%) is  **met**.

* + - * Note that [6] employs the MUSIC algorithm to pass the requirements. Without the algorithm the requirement is not met.

 For inF-DH scenario, in [7] (DL-TDOA) and [18] (DL AOD) it is observed that the requirements for commercial use cases (<3m@90%) is  **not met**.

For UMi scenario, in [1] (UL TDOA) it is observed that the requirements for commercial use cases (<3m@90%) is **not met**.

For UMi scenario, in [14] (DL TDOA) it is observed that the requirements for commercial use cases (<3m@90%) is **not met**.

Most results assume 1Rx Branch in the receiver of the UE. The impact on the number of Rx branch is evaluated in [2], where it is observed that the number of Rx branch can improve the accuracy by about 30cm, for DL methods without outlier rejection.

**5MHz bandwidth evaluations:**

For inF-SH scenario, in [2] it is observed that the requirements for IIOT use cases (<1m@90%) is **not met**.

For inF-SH scenario, in [2] it is observed that the requirements for commercial use cases (<3m@90%) is  **met**.

For inF-SH scenario, in [3] it is observed that the requirements for commercial or IIOT use cases are **not**  **met**.

|  |  |
| --- | --- |
| Source | Proposal |
| [1] | ***Observation 1: In the 3GPP InF-SH Scenario, for both all UEs and convex UEs, the positioning accuracy (horizontal) for RedCap UE fails to meet the target requirements for IIoT use cases (<1m@90%).******Observation 2: In the 3GPP UMi Scenario, there is a huge performance gap between the RedCap positioning with 20MHz and the target requirements.*** |
| [2] | * ***For positioning performance of 20MHz in InF-SH without RAIM*** ***algorithm, the horizontal accuracy of following positioning methods can reach 2m for 90% UEs.***
* ***For DL-TDOA positioning, horizontal accuracy can achieve {1.69m, 90%}***
* ***For UL-TDOA positioning, horizontal accuracy can achieve {1.68m, 90%}***
* ***For Multi-RTT positioning method, horizontal accuracy can achieve {1.68m, 90%}***
* ***For positioning performance of 20MHz in InF-SH with RAIM algorithm, the horizontal accuracy of following positioning methods can reach 1m for 90% UEs.***
* ***For DL-TDOA positioning, horizontal accuracy can achieve {0.32m, 90%}.***
* ***For UL-TDOA positioning, horizontal accuracy can achieve {0.35m, 90%}***
* ***For Multi-RTT positioning method, horizontal accuracy can achieve {0.34m, 90%}***
* ***The target accuracy requirements can be satisfied with the existing algorithm (e.g. RAIM algorithm )for RedCap UEs for IIoT use cases.***
* ***For positioning performance of 5MHz in InF-SH without RAIM algorithm, the horizontal accuracy of following positioning methods can reach 5m for 90% UEs.***
* ***For DL-TDOA positioning, horizontal accuracy can achieve {4.96m, 90%}.***
* ***For UL-TDOA positioning, horizontal accuracy can achieve {4.97m, 90%}***
* ***For Multi-RTT positioning method, horizontal accuracy can achieve {4.96m, 90%}***
* ***For positioning performance of 5MHz in InF-SH with RAIM algorithm, the horizontal accuracy of following positioning methods can reach 2m for 90% UEs.***
* ***For DL-TDOA positioning, horizontal accuracy can achieve {1.25m, 90%}.***
* ***For UL-TDOA positioning, horizontal accuracy can achieve {1.27m, 90%}***
* ***For Multi-RTT positioning method, horizontal accuracy can achieve {1.26m, 90%}***
* ***For DL-TDOA and Multi-RTT positioning, 2 Rx branches can bring further performance improvement compared to 1 Rx branch***
* ***In InF-SH scenario, for DL-TDOA positioning with 20MHz bandwidth without RAIM algorithm, using 2 Rx branches can bring further accuracy improvement compared to using 1 Rx branch, from 1.69m to 1.32m.***
* ***In InF-SH scenario, for Multi-RTT positioning with 20MHz bandwidth without RAIM algorithm, using 2 Rx branches can bring further accuracy improvement compared to using 1 Rx branch and Multi-RTT, from 1.68m to 1.26m.***
 |
| [3] | **Observation 2**: Rel-17 solutions can’t achieve the RedCap UE positioning accuracy requirements. **Observation 3**: Enhancements for RedCap positioning are needed in Rel-18.  |
| [4] | ***Observation 1The positioning performance of RedCap UE with 20MHz is outperformed by that of NR UE with 100MHz.*** ***Proposal 5: Study mechanisms for the positioning RS of RedCap UEs to cover more bandwidth, e.g. frequency hopping for positioning RS.***  |
| [5] | **Observation 2: For RedCap UEs positioning, the horizontal positioning accuracy is 1.7 m with DL-TDOA in the IIOT InF-SH scenario, which does not meet the requirements of RedCap UEs (1m for 90% of UEs).** |
| [6] | **Observation 1*** As a baseline performance (i.e., without any air interface enhancements):
* For RedCap UEs with limited bandwidth, i.e., 20MHz in FR1, and reduced number of Rx branches, < 3 m horizontal positioning accuracy may not be achievable using conventional FAP algorithm.
* When MUSIC algorithm is employed, < 3m horizontal positioning accuracy can be achieved for 90% of UEs

**Proposal 3*** For DL positioning, study schemes wherein a gNB may transmit a wideband DL PRS sequence in the allocated resource over multiple symbols/slots, while a RedCap UE may perform frequency hopping in different time instances to receive different parts (in frequency) of the wideband DL PRS.
* Simplified frequency hopping mechanism with frequency retuning gaps that are much shorter than Rel-15 BWP switching times should be explored.
 |
| [9] | ***Observation 1:*** *For a Rel-17 RedCap UE in FR1 and InF-SH scenario, the positioning performance is insufficient because of limited bandwidth.* |
| [12] | **Observation 1: In FR1, for 20 MHz bandwidth, RedCap UE positioning with frequency hopping compared to without frequency hopping leads to ~ 1.22 m accuracy gain for 90%ile UEs.** **Observation 2: In FR1, for 5 MHz bandwidth, RedCap UE positioning with frequency hopping compared to without frequency hopping leads to ~ 1.6 m accuracy gain for 90%ile UEs.**  |
| [14] | ***Observation 1: for the evaluated cases and methods, the DL-TDOA performance cannot reach the target performance of RedCap UEs.*** |
| [19] | ***Observation 1 In UMi, the target horizontal positioning accuracy could be achieved via DL-TDOA, UL-TDOA or multi-RTT in FR1 if UE bandwidth is 100MHz.******Observation 2 In UMi, the target horizontal positioning accuracy could not be achieved via DL-TDOA, UL-TDOA or multi-RTT in FR1 if UE bandwidth is reduced to 20MHz or even 5MHz.******Observation 3 In UMa, the horizontal positioning accuracy of 3m @ 67% could be achieved roughly via DL-TDOA in FR1 if UE bandwidth is 100MHz, but could not if UE bandwidth is reduced to 20MHz or even 5MHz.******Observation 4 In IOO with FR1, the target horizontal positioning accuracy could be achieved via DL-TDOA, UL-TDOA, or multi-RTT if UE bandwidth is 100MHz, but could not if UE bandwidth is reduced to 20MHz or even 5MHz.******Observation 5 In InF-SH with FR1, the target horizontal positioning accuracy could be achieved via DL-TDOA, UL-TDOA, or multi-RTT if UE bandwidth is 100MHz, and roughly achieved via multi-RTT is UE bandwidth is 20MHz.******Proposal 1 To meet the requirements, enhancements to improve the horizontal positioning accuracy for RedCap UEs are necessary.*** |

### First round of discussion

Based on the captured evaluations, it seems possible to draw some general observation for the TR on the baseline performance of RedCap UEs without any enhancements. The following proposals aim at discussing the baselines for the commercial and IIOT use cases

Proposal 1.1.1-1 capture the following observations in the TR, regarding the baseline performance for positioning of Redcap UEs for indoor scenarios:

* + Based on the results provided by a majority of sources, for InF-SH, the positioning requirement for IIOT use cases is not achieved by Rel.17 solutions using 5MHz or 20MHz of bandwidth.
		- Sources in R1-2208457, R1-2210179 show that UL TDOA cannot meet the requirement
		- Sources in R1-2209994, R1-2210179 show that multi-RTT cannot meet the requirement
		- Sources in R1-2208803, R1-2208985, R1-2209061, R1-2209108, R1-2209153, R1-2209217, R1-2209491, R1-2209740, R1-2210179 show that DL-TDOA cannot meet the requirement
		- Source in R1-2208652 shows that the requirement can be met using 20MHz of bandwidth.
		- Source in R1-2208652 shows that the requirement cannot be met using 5MHz of bandwidth.
	+ Based on the results provided by a majority of sources, for InF-SH, the positioning requirement for commercial use cases is achieved by Rel.17 solutions using 20MHz of bandwidth.
		- Source in R1-2208457, R1-2208652, R1-2210179 show that UL TDOA can meet the requirement
		- Sources in R1-2209994, R1-2208652, R1-2210179 show that multi-RTT can meet the requirement
		- Sources in R1-2208803, R1-2208652, R1-2209061, R1-2209108, R1-2209217, R1-2209740, R1-2210179 show that DL-TDOA can meet the requirement
		- Source in R1-2208652 shows that the requirement can be met using 5MHz of bandwidth.
		- Source in R1-2209740 shows that the requirement cannot be met using 5MHz of bandwidth.
	+ Based on the results provided by the following sources, for InF-DH, the positioning requirement for commercial use cases is not achieved by Rel.17 solutions using 20MHz of bandwidth.
		- Sources in R1-2209108 and R1-2209994 show that the requirements for commercial use cases cannot be met for InF-DH.
	+ Note: Editorial modifications and addition of references for the sources may be added by the rapporteur when capturing the agreement in the TR.

Proposal 1.1.2-1 capture the following observations in the TR, regarding the baseline performance for positioning of Redcap UEs for outdoor scenarios

* + Based on the results provided by R1-2208457, for Umi, the positioning requirement for IIOT use cases is not achieved by Rel.17 solutions using 20MHz of bandwidth and UL-TDOA.
	+ Based on the results provided by R1-2208457, for Umi, the positioning requirement for commercial use cases is not achieved by Rel.17 solutions using 20MHz of bandwidth and UL-TDOA.
	+ Based on the results provided by R1-2209740, for Umi, the positioning requirement for commercial use cases is not achieved by Rel.17 solutions using 20MHz of bandwidth and DL-TDOA.
	+ Note: Editorial modifications and addition of references for the sources may be added by the rapporteur when capturing the agreement in the TR.

 Companies are encouraged to provide their view on proposal 1.1.-1 and 1.1.2-1 in the table below:

**Proposal 1.1.1-1 and 1.1.2-1:**

|  |  |
| --- | --- |
| Company | comment |
| Nokia/NSB | In our understanding the requirements for IIoT are the only requirements that apply for InF-SH. Therefore, we don’t support the entire second main bullet in Proposal 1.1.1-1 and suggest to remove it. In addition, InF-DH was an optional evaluation scenario so we feel that should be captured in the 3rd main bullet somehow.  |
| Intel | We somehow share similar view as Nokia that InF-SH scenario is mainly targeting for IIoT use case. We are also fine to remove the second main bullet in Proposal 1.1.1-1.  |
| Samsung  | Support above two proposals. Just question to FL, how to deal with the evaluation results with evaluation using other positioning method like CPP? |
| Qualcomm  | A few comments:* With regards to InF-DH, QC’s paper is included (R1-2209994), but we didn’t have InF-DH results.
* We also had FR2 results which are not captured. Suggest to add a bullet on InF-SH and FR2 with 100 MHz BW.
* We had UMI results for RTT FR1 in our paper and we would like to add them:
	+ Based on the results provided by R1-2209994, for Umi, the positioning requirement for IIOT use cases is not achieved by Rel.17 solutions using 20MHz or 5 MHz of bandwidth and multi-RTT.
	+ Based on the results provided by R1-2209994, for Umi, the positioning requirement for commercial use cases is not achieved by Rel.17 solutions using 20MHz or 5 MHz of bandwidth and multi-RTT.
* Same view that InF-SH is supposed to be for IIoT

Overall, this proposal makes sense to be discussed as a potential working assumption so that there is room for updates for next meeting |
| Huawei, HiSilicon | Similar comments on the evaluation results under InF-SH/DH scenarios compared against commercial requirement, where the scenarios are targeting IIoT use cases. |
| CATT | For proposal 1.1.1-1, we share the same view with Nokia and Intel. The InF-SH and InF-DH scenarios are IIoT use cases, they had better to be removed from the requirements of commercial use cases.For proposal 1.1.1-2, Umi scenario is one kind of commercial use cases, they had better to be remove from the requirements of IIoT use cases. |
| ZTE | Comment 1:We share the similar view with Nokia, Intel and Qualcomm. According to TS 38.857, InF-SH and InF-DH are defined for evaluating positioning performance in IIoT use case. The second main bullet of Proposal 1.1.1-1 should be removed.Comment 2:We also have FR2 results in InF-SH scenario which are not captured. Agree with Qualcomm’s comments and support to add a bullet on InF-SH and FR2 with 100 MHz BW.* + Based on the results provided by a majority of sources, for InF-SH, the positioning requirement for IIOT use cases can be achieved by Rel.17 solutions using 100MHz of bandwidth in FR2.
		- Sources in R1-2209217 show that DL-TDOA can meet the requirement
 |
| vivo | Similar view as previous companies. It is better to remove the descriptions of commercial requirement for IIoT evaluation observation, and IIoT requirement for commercial evaluation observation. |
| Lenovo | Share most companies’ view that InF-SH should be decoupled from the commercial use cases as it a IIoT specific scenario |

## Issue 1.2 Impact of phase error on frequency hopping performance

### Background

Most companies evaluated enhancements of Redcap UEs by support of a frequency hopping scheme, either at the transmitter and/or at the receiver. Both UL SRS hopping and DL PRS hopping were evaluated. The impact of doppler and phase offset error on the frequency hopping scheme was evaluated by several sources. In [1] phase offset with or without compensation was evaluated for UL TDOA, using SRS hopping.

The following was observed by sources regarding the impact of phase error

For 20MHz bandwidth per hop:

* + - * As a baseline evaluation, [2][7][19] observed that for DL TDOA, both requirements can be met when there is no phase error and 5 hops are used to produce 100MHz of stiched bandwidth.
			* [7] also evaluated 3x20MHz hopping which also passed the requirements.
			* Note that this does not include outlier rejection
			* [12] evaluated 2-hop frequency hopping that met the commercial requirements
			* [18] evaluated 4x20MHz hopping, which also passed the requirement if no phase error present.
			* For UL TDOA, in the InF-SH scenario [1] observed that none of the requirements can be met without compensating the effect of phase offset
			* For UL TDOA, in the InF-SH scenario, [1] observed that both requirements can be met if phase offset is compensated by overlapped frequency hopping
			* [1] modelled phase offset with a 0.1 time drift
			* Note :This observation is valid If the time between hop is short (1 slot or under). The impact of the gap length is discussed separately.

For DL TDOA, in the InF-SH scenario [1] [9] observed that none of the requirements can be met without compensating the effect of phase offset

* + - * For DL TDOA, in the InF-SH scenario [2] observed that the requirements cannot be met without compensating the effect of timing error 5ns or greater or phase offsets error.
			* For DL TDOA, in the InF-SH scenario, [1] [9] observed that both requirements can be met if phase offset is compensated by overlapped frequency hopping
			* For DL TDOA, in the InF-SH scenario, [2] observed that both requirements can be met if phase offset is compensated by overlapped frequency hopping
			* [1] modelled phase offset with a 0.1 time drift
			* [2] modelled phase offset with a [-pi pi] uniformly distributed RV.
			* Note :This observation is valid If the time between hop is short (1 slot or under). The impact of the gap length is discussed separately.
* For DL TDOA, in the Inf-SH scenario [18] observed that the requirements can be met in FR2 with or without compensation of the phase error, but that performance are higher with phase compensation, and with comparably lesser bandwidth.
	+ It is additionally observed that Tx power boosting can improve performance when Tx hopping is used
		- * For UL TDOA, in the UMi scenario [1] observed that none of the requirements can be met without compensating the effect of phase offset.
			* For UL TDOA, in the UMi scenario [1] observed that none of the requirements can be met even with compensating the effect of phase offset.
			*
			* For DL TDOA, in the UMi scenario [1][18, FR1] observed that none of the requirements can be met without compensating the effect of phase offset.
	+ For DL TDOA, in the UMi scenario [18] observed that the requirements can be met in FR2 with or without compensation of the phase error, but that performance are higher with phase compensation, and with comparably lesser bandwidth.
		- * For DL TDOA, in the UMi scenario [1] observed that none of the requirements can be met even with compensating the effect of phase offset.

|  |  |
| --- | --- |
| Source | Proposal |
| [1] | ***Observation 3: In the 3GPP InF-SH Scenario, the overlapped frequency hopping transmission/reception solution can effectively address the random phase offset issue and improve the positioning accuracy of RedCap UEs to meet the target requirements for IIoT use cases (<1m@90%).******Observation 5: In the 3GPP UMi Scenario, the positioning accuracy can be largely improved (~4m@90%) for RedCap UE with the overlapped frequency hopping reception.*** |
| [2] | ***Observation 5**** ***Under ideal conditions (e.g., without phase error modeling, low UE speed, no Rx/Tx timing error, 1-slot time gap), the accuracy performance of frequency hopping is improved compared to performance of the limited bandwidth of 20MHz.***
* ***The accuracy of 5 hops is improved from 1.69m to 0.376m, compared with the accuracy of 20MHz bandwidth***

***Observation 10*** * ***Rx timing errors between different hops results in large performance degradation for coherent combining multi-hops of frequency hopping.***
* ***For the case of hopping without phase error modeling, when the Rx timing error is {0ns, 1ns, 5ns} respectively, the accuracy performance is {0.376, 0.626m, 1.528m}.***
* ***For the case with 1ns Rx timing errors between hops, the performance of frequency hopping is degraded, but it is better than the performance of 20MHz bandwidth only.***
* ***For the case with 5ns Rx timing error between hops, the performance of frequency hopping is worse than 20MHz bandwidth only.***

***Observation 11**** ***The performance of frequency hopping is largely impacted by phase errors between hops.***
* ***For the case of hopping without phase error modeling, the accuracy performance is {4.01m}***
* ***For the case of hopping with phase error compensation, the accuracy performance is {3.24m}.***
 |
| [3] | **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 phase alignment for Multi-RTT and determine if phase alignment is needed in both UL and DL.  |
| [7] | Observation 4: Bandwidth stitching operation in RedCap positioning can significantly improve the positioning accuracy. The accuracy is improved by 2 m and 1.5 m, with using 5 hops and 3 hops, respectively. Proposal 1: Support adopting bandwidth stitching operation in RedCap positioning to improve the positioning accuracy. |
| [9] | ***Observation 2:*** *For RedCap UE positioning in FR 1, InF-SH scenario** *The random phase between hops will damage the positioning performance if it was not adjusted.*
* *PRS frequency hopping can improve positioning performance if the random phase between hops can be adjusted.*

***Observation 4:*** *For the case with 5 RS hops in FR1, if the phase offset between hops were not adjusted, it will affect positioning accuracy of hopping for RedCap UE.** *If the random phase offset is set to 0.5\*2π or larger than 0.5\*2π (in STD), the positioning accuracy requirement can not be satisfied. Otherwise, the requirement can still be met.*

***Observation 5:*** *For the case with 5 RS hops in FR1, the time offset between hops will decrease positioning accuracy of hopping for RedCap UE.** *When the random timing offset is equal to or larger than 3ns (in STD), the positioning accuracy requirement can not be met. Otherwise, the requirement can still be met.*

***Observation 6:*** *For RedCap UE positioning in FR 2, InF-SH scenario, PRS frequency hopping can improve positioning performance if the random phase between hops can be adjusted.* |
| [11] | ***Proposal 6: The impact of the impairments such as doppler shifts, power imbalance and timing offsets on coherent Rx combining of different positioning sub-bands should be further studied.******Proposal 7: The timing offset arising from the different TRPs can already be mitigated using the already discussed Rel-17 aspects such as TEG compensation/PRUs.*** |
| [12] | **Observation 1: In FR1, for 20 MHz bandwidth, RedCap UE positioning with frequency hopping compared to without frequency hopping leads to ~ 1.22 m accuracy gain for 90%ile UEs.** **Observation 2: In FR1, for 5 MHz bandwidth, RedCap UE positioning with frequency hopping compared to without frequency hopping leads to ~ 1.6 m accuracy gain for 90%ile UEs.**  |
| [18] | ***Observation 3: Enabling receiver’s PRS hopping would allow sharing the legacy PRS across eMBB and Redcap devices.*** ***Proposal 2: For the purpose of enhancing the performance of NR Positioning for Redcap devices, enhancements for enabling receive DL-PRS frequency hopping for both FR1 and FR2 should be introduced considering DL-PRS hopping with overlapping tones and intra-slot DL-PRS fast switching.*** ***Observation 4: The phase discontinuity introduced due to PRS frequency hopping results a in performance degradation which could be mitigated by using frequency hopping with overlapping tones.*** ***Observation 5: Enabling transmitter’s PRS hopping could improve the Tx power, and further improve the positioning accuracy.******Proposal 3: For the purpose of enhancing the performance of NR Positioning for Redcap devices, enhancements for enabling Transmit DL-PRS / SRS frequency hopping for both FR1 and FR2 should be introduced considering DL-PRS / SRS Tx hopping with overlapping tones and intra-slot DL-PRS / SRS fast switching.***  |
|  | **Proposal 1:** Consider bandwidth hopping of DL PRS when the degradation of positioning accuracy due to the reduced bandwidth of RedCap UEs cannot be tolerated.**Proposal 2:** Consider bandwidth hopping of UL SRS when the degradation of positioning accuracy due to the reduced bandwidth of RedCap UEs cannot be tolerated. |

### First round of discussion

Results from contributions agree that frequency hopping is a suitable candidate for redcap positioning at least for indoor cases, when the phase error occurring between hops is compensated using partially overlapped bandwidth between hops. For the outdoor cases, at least 1 source think the requirements cannot be met even if the phase difference is compensated.

Proposal 1.2.1-1 capture the following observations in the TR, regarding the performance for positioning of Redcap UEs using Rx frequency hopping in indoor scenarios

* + In FR1, Based on the results provided by the following sources sources, for InF SH the positioning requirement for IIOT use cases and commercial use cases can be achieved using Rx frequency hopping with partial overlap for the purpose of phase offset compensation, and if the phase offset is compensated.
		- Sources in R1-2208457 show that UL TDOA can meet the requirements
		- Sources in R1-2208457, R1-2209217, R1-2208652, show that DL TDOA can meet the requirements
	+ In FR2, R1-2209994 observed that the requirements can be met even if the phase is not compensated.
	+ Note: the observation regarding the size of the gap between hops is subject to a separate agreement

Proposal 1.2.2-1 capture the following observations in the TR, regarding the performance for positioning of Redcap UEs using Rx frequency hopping in outdoor scenarios

* + In FR1, Based on the results provided, for UMi the positioning requirement for IIOT and commercial use cases cannot be achieved if the phase offset between hops in Rx Frequency hopping is considered, even if Rx frequency hopping with partial overlap for the purpose of phase offset compensation is used , and if the phase offset is compensated.
		- Source in R1-2208457 show that UL TDOA cannot meet the requirements even when the phase is compensated
		- Source in R1-2208457 show that DL TDOA cannot meet the requirements even when the phase is compensated
	+ Note: the observation regarding the size of the gap between hops is subject to a separate agreement

Companies are encouraged to provide their view on proposal 1.3-1 in the table below:

**Proposal 1.2.1-1 and 1.2.2.1:**

|  |  |
| --- | --- |
| Company | comment |
| Nokia/NSB | We support proposal 1.2.1-1, not sure that proposal 1.2.2-1 brings much value.  |
| Intel | We are fine with the proposal. Some editorial changes: “In FR1, Based on the results provided by the following sources ~~sources~~” |
| Samsung | In addition to above, we think the size of “partial overlap” between two hops should be captured, and how to compensate the offset should be captured to be clearly understand the simulation results.  |
| Qualcomm | We think it is early to capture specific observations on the enhancements. Only limited sources evaluated in this meeting.Also, if the enhancement improves performance over the baseline it should also be captured. For example, with regards to UMI: QC also had results for UMI and related to 1.2.2-1, and even though, in the current results that QC submitted, the requirement were not met, the performance was improved significantly across all the percentile points. Finally, it also depends on the number of hops that are being tried, on the gap, etc. It is difficult to just distill all this information in this observation.  |
| Huawei, HiSilicon | In general OK. |
| CATT | For proposal 1.2.1-1, The InF-SH scenario is one kind of IIoT use cases, so the requirements of commercial use cases had better to be removed from the InF-SH sub-bullet.For proposal 1.2.2-1, Umi scenario is one kind of commercial use cases, so the requirements of IIoT use cases had better to be removed from the Umi sub-bullet. |
| ZTE | Comment 1:We have evaluation results (Case 14 to Case 19) for FR1 in InF-SH scenario for assessing phase offset impact which are not captured in Proposal 1.2.1-1. According to our results, when the random phase offset is set to 0.5\*2π or larger than 0.5\*2π (in STD of standard normal distribution), the positioning accuracy cannot satisfy the agreed requirements if the phase offset between hops were not adjusted. Otherwise, when the random phase offset is set to be smaller than 0.5\*2π (in STD of standard normal distribution), the positioning accuracy can satisfy the agreed requirements even if the phase offset between hops were not adjusted.Comment 2:Also, agree with CATT’s view on Proposal 1.2.1-1 and suggest to remove “and commercial use cases”. Comment 3:We also have FR2 results in InF-SH scenario which are not captured in Proposal 1.2.1-1. The bullet of FR2 observation and note should align with the first bullet.To sum up, we suggest to update proposal 1.2.1-1 as follows:Proposal 1.2.1-1 capture the following observations in the TR, regarding the performance for positioning of Redcap UEs using Rx frequency hopping in indoor scenarios* In FR1, Based on the results provided by the following sources sources,
	+ If the phase offset is compensated, for InF SH the positioning requirement for IIOT use cases ~~and commercial use cases~~ can be achieved using Rx frequency hopping with partial overlap for the purpose of phase offset compensation~~, and if the phase offset is compensated~~.
		- Sources in R1-2208457 show that UL TDOA can meet the requirements
		- Sources in R1-2208457, R1-2209217, R1-2208652, show that DL TDOA can meet the requirements
	+ If the phase offset is not compensated
		- Sources in R1-2209217 show that DL TDOA can meet the requirements if the random phase offset is set to be smaller than 0.5\*2π.
* In FR2, based on the results provided by the following sources sources,
	+ R1-2209994 observed that the requirements can be met even if the phase is not compensated.
	+ R1-2209217 observed that PRS frequency hopping can improve positioning performance if the random phase between hops can be adjusted in FR 2, InF-SH scenario.
* Note: the observation regarding the size of the gap between hops is subject to a separate agreement
 |
| vivo | It is too early to capture the observations on the enhancements, without enough sources evaluation and aligned assumptions for hopping. We think the multiple factors should be treated fairly. If issue 1.3 and issue 1.4 is postponed, the proposal also needs to be discussed in the next meeting with more evaluation.* **Agreement**
* **The potential benefits and performance gains of frequency hopping of the DL PRS and UL SRS can be investigated in release 18, 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

Details of frequency hopping (including Tx hopping and/or Rx hopping, BWP switching) for the study are FFSLastly, even for current proposal 1.2.2-1, our evaluation results are not correctly captured. In our contribution R1-2208652 [2], positioning requirement for IIoT can only be achieved without phase error modeling; while for the case with phase error modeling, the performance for the cases with/without phase error compensation cannot achieve the IIoT requirement. |
| InterDigital | As a part of proposal 1.2.1-1, we would like to ask the FL to capture our result. Our contribution(R1-2209491) show that for InF-SH scenario, commercial positioning requirements for RedCap UEs(20 MHz) can be satisfied with DL TDOA without overlapped frequency hopping and phase compensation.We also tend to agree with other companies that it may be too early to capture the observations. |

## Issue 1.3 Impact of rx switching time / gaps on frequency hopping performance

### background

the impact of switching time, or the time between hops in the frequency hopping scheme, was evaluated in [1][2][3] for UL and/or DL solutions. In [9] it is proposed to study further the switching gap values. Sources have compared different gap durations, based on the specification’s requierments for SRS switching and /or BWP switching using values ranging from 140us to up to 10 slots.

Note that phase offset compensation with overlapping of bandwidth between hops is assumed.

The following was observed by the sources regarding the impact of the gap duration on the accuracy:

* + - * For UL TDOA, in the InF-SH scenario, [1] observed that both requirements can be met if the gap between hops in the SRS frequency hopping is up to 2 slots
			* For DL TDOA, in the InF-SH scenario, [1] observed that both requirements can be met if the gap between hops in the PRS frequency hopping is up to 2 slots
			* For DL TDOA, in the InF-SH scenario, [2] observed that both requirements can be met if the gap between hops in the PRS frequency hopping is up to 4 slots
	+ [2] assumes no phase error remains
		- * For DL TDOA, in the InF-SH scenario, [2] observed commercial requirements can be met if the gap between hops in the PRS frequency hopping is up to 8 slots
	+ [2] assumes no phase error remains

|  |  |
| --- | --- |
| Source | Proposal |
| [1] | ***Observation 4: In the 3GPP InF-SH Scenario,*** * + ***When the time gap is less than 5ms, the positioning accuracy (horizontal) for overlapped frequency hopping transmission/reception can still meet the target requirements for IIoT use cases (<1m@90%).***
	+ ***The timing drift has little impact on the positioning accuracy with small time gap (e.g. <5ms) between hops.***
 |
| [2] | * ***Large time gap between adjacent hops results in accuracy performance degradation for coherent combining multi-hops of frequency hopping.***
* ***For the case of hopping without phase error modeling, when the time gap is {1 slot, 4 slots, 8 slots} respectively, the accuracy performance is {0.376m, 0.839m, 1.05m}.***
* ***Compared to the accuracy performance of 20MHz bandwidth of 1.32m, when the time gap is 4 slots or 8 slots, frequency hopping does not bring obvious performance gains.***
1. ***Observation 12***
* ***The performance of phase error compensation for frequency hopping is largely impacted by time gap between hops.***
* ***Under the condition of 1 symbol gap between hops, the performance improvement brought by phase compensation is more obvious than that of 1 slot gap between hops***
 |
| [3] | **Observation 4**: In frequency hopping it may be necessary for the UE to have some gap (e.g., 1 symbol) between the reception/transmission of different frequency hops.  |
| [9] | ***Proposal 3:*** *For RedCap UE positioning, further introduce switching gap between adjacent frequency hops. FFS the gap values.*  |
| [11] | ***Proposal 8: The time taken to perform RF tuning will have an impact on the number of positioning frequency hops which can be performed by the UE.***  |
| [17] | **Proposal 1:** * **RAN1 should study the detail procedures of frequency hopping. Examples are described below.**
	+ **Whether UE needs BWP switching or just RF retuning during the measurement gap for the PRS measurement.**
	+ **Whether we need a separate discussion or prioritization between DL PRS and SRS.**
 |

### First round of discussion

For this meeting, it is proposed to delay capturing observations for the gap used between bandwidth hops, to allow more companies to provide evaluations. If companies think an observation can be captured, please use the table below to comment.

|  |  |
| --- | --- |
| Company | comment |
| Qualcomm | OK to wait for next meeting. Maybe we could formulate a proposal on what companies are encouraged to evaluate. E.g. how much gap between the hops.  |
| Huawei, HiSilicon | OK in general. |
| ZTE | Agree with FL’s assessment. |
| vivo | If the observation is proposed to postpone, 2.2.2 also needs to be postponed. |

##  Issue 1.4 Impact of UE speed on frequency hopping performance

### background

In [2], the authors evaluated frequency hopping at different UE speed and observed that speed above 30kph would void the performance gain of frequency hopping. In[9], it is observed that a doppler of up to 1000Hz can be handled without effect on positioning accuracy.

|  |  |
| --- | --- |
| Source | Proposal |
| [2] | * ***For the operation without frequency hopping,*** ***the accuracy performance is less affected by changes in UE speed (from 3km/h to 30km/h and 60km/h).***
* ***Increasing the UE speed will result in large accuracy performance degradation for coherent combining multi-hops of frequency hopping.***
* ***For the case of hopping without phase error modeling, when the UE speed is {3km/h, 30km/h, 60km/h} respectively, the accuracy performance is {0.376m, 1.264m, 1.767m}.***
* ***For the UE speed of 30km/h, the performance of frequency hopping is close to the performance of 20MHz bandwidth only.***
* ***For the UE speed of 60km/h, the performance of frequency hopping is close to or even weaker than that of 20MHz bandwidth only.***
* ***The large impact of Doppler on coherent combining multi-hops of frequency hopping will lead to its performance worse than the performance without frequency hopping.***
* ***When the time gap between adjacent hops is larger than 4 slots, there is no performance gain compared to the performance of 20MHz bandwidth only***
* ***When the UE speed is larger than 30km/h, there is no performance gain compared to the performance of 20MHz bandwidth only***
 |
| [9] | ***Observation 3****: The Doppler shift has little effect on positioning accuracy of RS hopping for RedCap UE under InF-SH scenario in FR1.* |

### First round of discussion

There are only two contributions considering frequency hopping and doppler/UE speed. While [2] observe degradation in performance due to UE speed past 30km/h, [9] evaluated higher speed up to 300km/h without observing issues. Since the issue will have impact on the design of the time gap between hops, it is proposed to wait before capturing any observation on the issue and wait that companies provide more evaluation on the gap size between hops, considering also the doppler.

Companies are encouraged to provide their view on whether more observation can be captured on the issue:

|  |  |
| --- | --- |
| Company | comment |
| Qualcomm | Agree. We suggest to formulate a proposal in the form of: “Companies are encouraged to evaluate frequency hopping with different mobility considerations”  |
| ZTE | Fine.Reply to Qualcomm: the following was agreed in the last RAN1 meeting which already encourages companies to investigate the potential benefits and performance gains of frequency hopping considering Doppler. Therefore, we do not think a new proposal is needed.**Agreement**The potential benefits and performance gains of frequency hopping of the DL PRS and UL SRS can be investigated in release 18, 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

Details of frequency hopping (including Tx hopping and/or Rx hopping, BWP switching) for the study are FFS |
| vivo | If the observation is proposed to postpone, 2.2.2 also needs to be postponed. |

# Aspect 2 – Topics to study for enhancements of positioning performance for redcap UEs

## Issue 2.1 Carrier phase positioning for Redcap positioning

### background

in [5] the performance of carrier phase positioning for Redcap UEs was evaluated and it is proposed to adopt the solution to deliver the positioning requirements for redcap UEs. In[6][10] it is proposed to study carrier phase positioning for redcap UEs.

|  |  |
| --- | --- |
| Source | Proposal |
| [5] | **Observation 1: NR carrier phase positioning (CPP) is one of the promising enhancement methods for RedCap UEs positioning.****Observation 3: For RedCap UEs positioning, the horizontal positioning accuracy is 0.02 m with NR carrier phase positioning in the IIOT InF-SH scenario, which is far better than the requirements of RedCap UE (1m for 90% of UEs).****Proposal 1: NR carrier phase positioning should be adopted for Rel-18 RedCap UE positioning.** |
| [6] | **Proposal 5*** Study carrier phase measurements-based positioning techniques for positioning performance improvement for RedCap UEs, focusing on bandwidth requirements for accurate positioning using carrier phase-based methods.
 |
| [10] | **Proposal 2: Further study enhancements of RedCap UE positioning by using carrier phase positioning.** |
| [14] | ***Observation 2: DL-TDOA + CPP could reach the target in some cases.*** |

### First round of discussion

From the FL perspective, support of carrier phase positioning is in general not precluded by the release 18 study for any UEs. Therefore, if the carrier phase measurements are specified and a redcap UE support the requirements associated with it, it will support it and nothing RedCap specific needs to be added for this measurement in particular. It is therefore proposed not to further discuss the CPP issue in the Redcap agenda. Companies may provide results compatible with redcap in the CPP agenda, using e.g. reduced bandwidth for evaluations.

**Proposal 2.1.1-1: do not discuss carrier phase positioning specifically for redcap UEs.**

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

**Proposal 2.1.1-1:**

|  |  |
| --- | --- |
| Company | comment |
| Intel | We do not support the proposal. While there may not be a need to specify anything particularly for RedCap UEs (they can just support CPP related optional feature(s)), whether CPP can be applicable and provide benefits for RedCap UEs can be useful information for the TR in the context of the study of high accuracy positioning methods for RedCap UEs. |
| Samsung  | We generally agree that we don’t need to specifically optimize the CPP design for redcap, but the corresponding simulation results targeting for Redcap UE should be captured in here. |
| Qualcomm | Support. Limit the discussion within the corresponding subagenda |
| Huawei, HiSilicon | Support. |
| CATT | We do not support the proposal.We prefer to further discuss CPP with narrow bandwidth in RedCap UE agenda.In our view, if CPP with 20MHz bandwidth can fulfill the requirements of RedCap UE positioning, it will provide another solution out of frequency hopping to solve the accuracy issue of RedCap UE positioning, so CPP is a valuable solution for RedCap UE and it should be captured into the TR as a solution for RedCap UE positioning. We should evaluate the CPP solution with the simulation assumptions agreed in RedCap UE agenda, hence, we prefer to further discuss and evaluate the CPP in RedCap UE agenda.In addition, according to our simulation, CPP can achieve cm-level positioning accuracy with 20MHz bandwidth for RedCap UE, as shown in the following figure, |
| CMCC | We share similar views as Samsung and CATT, as CPP can be seen as a particular solution to cope with the reduced bandwidth, and it is reasonable to provide results under this AI.  |
| MTK | We support this proposal of “don't discuss” |
| ZTE | Share the similar view with Samsung. We are fine with the proposal because carrier phase positioning is being discussed and studied in another agenda and we may deprioritize the corresponding study in AI 9.5.3.  |
| vivo | We are okay to pursue any potential method to satisfy redcap requirements if the majority think the requirement can not be satisfied. Based on the SID, we shouldn’t preclude any enhancement method.* + 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]
 |
| InterDigital | Support the FL’s proposal |
| Lenovo | Support  |
| Apple | Support |

## Issue 2.2 SRS for positioning of Redcap UEs

### Background

During RAN1#109e, it was agree to consider both PRS and SRS for positioning for RedCap Ues. In [1] it is mentioned that UE complexity may favor SRS compared to PRS due to the need for the UE to perform the phase compensation for DL PRS reception. In [3] it is proposed to discuss SRS configuration enhancements, including group-based SRS transmission, dynamic allocation of resources, virtual configuration to realise the bandwidth stitching. In [6] it is proposed to study BWP hopping for SRS for redcap positioning. [13] proposes to update the configuration of SRS to include bandwidth hopping.

|  |  |
| --- | --- |
| Source | Proposal |
| [1] |  ***Proposal 1: Study the overlapped SRS frequency hopping transmission for RedCap positioning considering UE complexity.*** |
| [3] | **Proposal 6**: RAN1 to study a virtual SRS configuration for SRS for positioning frequency hopping. **Proposal 7**: RAN1 to study more dynamic SRS transmissions for RedCap Ues.**Proposal 8**: RAN1 to investigate UL group based positioning schemes for RedCap Ues to save on SRS overhead.  |
| [6] | **Proposal 1*** Further study Tx or Rx frequency hopping with bandwidth stitching technique for DL PRS and UL SRS to enhance the timing-based estimates of the DL-TDOA, UL-TDOA, and Multi-RTT positioning methods for RedCap Ues.

**Proposal 2*** For UL positioning, study schemes wherein a RedCap UE may transmit UL SRS for positioning in different BWPs beyond maximum RedCap UE bandwidth based on simplified BWP hopping to constitute a wideband SRS transmission.
* Simplified BWP hopping mechanism with frequency retuning gaps that are much shorter than Rel-15 BWP switching times should be explored.
 |
| [13] | ***Proposal 1:******RAN1 should update the PRS/SRS configuration (including frequency mapping, repetition, measurement gaps and muting patterns) to accommodate PRS Bandwidth Hopping with Tone Overlap.******Proposal 2: RAN1 should update the existing sets of values for the UE DL PRS processing capability as the maximum # of DL PRS resources that UE can process in a slot assumes no BWP switching (DL) or RF retuning. This may need some feedback from RAN4.*** |

###  First round of discussion

Considering that SRS will configuration will need to be updated to support the bandwidth hopping, it is proposed to discuss further how to realise this configuration

**Proposal 2.2.1-1: study the configuration of the UL SRS for positioning to enable frequency hopping and bandwidth stitching**

Companies are encouraged to provide their view on proposal 2.2.1-1 in the table below:

**Proposal 2.2.1-1:**

|  |  |
| --- | --- |
| Company | comment |
| Nokia/NSB | Support.  |
| Intel | We are fine with the proposal.  |
| Samsung  | Ok to study. |
| Qualcomm | We are generally supportive, but we think that it should also include in the study configuration for enabling overlapped hopping.  |
| Huawei, HiSilicon | We are fine with the proposal. However, we think we may firstly agree that SRS frequency hopping solution is supported for RedCap UEs. Please kindly note that RAN1#110 only agreed that we can investigate PRS and SRS frequency hopping.* **Agreement**
* **The potential benefits and performance gains of frequency hopping of the DL PRS and UL SRS can be investigated in release 18, 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
	+ Details of frequency hopping (including Tx hopping and/or Rx hopping, BWP switching) for the study are FFS
 |
| CATT | OK |
| CMCC | We are generally fine with the proposal. We believe that other details remain open for FFS. |
| MTK | Okay for the study |
| NEC | We are fine with the proposal. |
| ZTE | Support |
| vivo | We should confirm the feasibility and applicability for frequency hopping first, then, if found necessary, study the details of configuration.In addition, before discussing the detailed configuration, the performance gain with The impact of Doppler, phase offset, timing offset, and power imbalance among hops should be identified. Otherwise, we can not agree on the proposal. |
| InterDigital | We support the proposal |
| Lenovo | Ok to further study  |
| Apple | Support |

## Issue 2.3 SRS Switching time

### Background

The time gap required for a UE to switch from one of the sub-bandwidth of the PRS to another while doing PRS frequency hopping / stitching have been discussed in several contributions. Large gaps have been associated with degraded performance in [1].

Note that the switching time for SRS was discussed by RAN4 and the following was sent to RAN1 in R1-2205709:

|  |
| --- |
| RAN4 discussed the candidate values for the UE capability on the switching time when transmitting SRS outside initial UL BWP or with difference SCS than the initial UL BWP (option 2 scenario), and agreed the following candidate values:* {100us, 140us, 200us, 300us, 500us}

RAN4 respectfully asks RAN1 and RAN2 to take the above information into account in the future work for SRS transmission in RRC\_INACTIVE. |

 In [1], it is proposed to study fast switching for SRS Tx transmission. In [6] it is proposed to send an LS to RAN4 to request to investigate the feasibility of much shorter switching time compared to BWP switching time from rel-15.

|  |  |
| --- | --- |
| Source | Proposal |
| [1] | ***Proposal 2: Study the fast switching of SRS Tx transmission (e.g., sub-ms level*** ***switching time) between adjacent hops for frequency hopping based positioning for RedCap UEs.*** |
| [6] | **Proposal 4*** Send an LS to RAN4 soliciting feedback on feasibility of simplified BWP and frequency hopping methods for UL SRS transmission or DL PRS reception using much shorter RF retuning gaps than Rel-15 BWP switching times, considering at least the following assumptions:
* BWP or frequency hopping may be limited to DL-PRS reception or UL-SRS transmissions only (i.e., no Rx/Tx of other channels/signals), and
* the hopping patterns may be known a priori based on higher layer configuration.
 |

###  First round of discussion

We should discuss first whether RAN1 thinks the answer from RAN4 is sufficient, or if indeed further feedback is required. Regarding the study of fast switching, few companies have made evaluation considering the time between hops for SRS or PRS in this meeting. Hopefully, more results will be available next meeting.

**Question 2.3.1-1: should RAN1 send a new LS to RAN4 regarding short retuning gap, considering the information already received?**

Companies are encouraged to provide their view on question 2.3.1.1 in the table below:

**Question 2.3.1.1:**

|  |  |
| --- | --- |
| Company | comment |
| Intel | We think it is necessary to send an LS to RAN4 given that RF retuning time or simplified BWP switching time has large impact on the positioning accuracy.  |
| Samsung  | It seems premature to send this new LS. We feel some more information indeed is needed from RAN4. However, it should not be triggered by asking “short retuning gap”, as it sounds like a optimization already. From our perspective, what we want know more from RAN4 LS is whether the switching time applied to Redcap UE or not? The reason is that the value is given in the case of normal UE in inactive state. It could be different for a UE to do RF retuning based on whether it’s capable of 100mhz or only 20mhz, e.g., switching 20mhz within the 100mhz, or switching from one 20mhz to another new 20mhz.  |
| Qualcomm | No, there is not really a need to send an LS to RAN4. There have been a few LS on SRS switching times, including a recent one, which could be used as a starting point for RAN1 evaluation. Eventually, if this goes to a WID, RAN4 will be involved on the final numbers of the RF retuning (DL or UL).  |
| Huawei, HiSilicon | We should wait and send LS to RAN4 until more progress on frequency hopping are made in RAN1. |
| CATT | Yes, we support to send an LS to RAN4 for clarification based on the previous RAN4 LS in R1-2205709, since the faster switching time for SRS transmission and shorter retuning gap are important for the performance of frequency hoppoing. |
| CMCC | I guess the whole switching time issue should be in the scope of RAN4, and at this stage, we don’t find the need to send a new LS to RAN4. |
| MTK | 1, the shorter retuning gap will influence RAN1 design? It seems not. We prefer RAN1 to continue our work. Sending LS to RAN4 at this moment is not hurry |
| ZTE | No, wait until there are progress on Issue 1.3.  |
| vivo | We should carefully reach conclusions for RF retuning gap for RedCap, since ‘fast RF retuning’ not only affect the design of frequency hopping for R18 RedCap positioning but also affect the design of R18 RedCap WI. Whether ‘fast RF retuning’ can be achieved should be consistent with R18 RedCap WI, instead of independent study and optimization in R18 positioning SI/WI. At least, as far as we know, ‘fast RF switching’ is not currently supported in RedCap WI. Therefore, we suggest that the study of frequency hopping retuning gap be limited to RF retuning gap already supported by R17/18 RedCap WI (e.g., 0.5ms for FR1) instead of ‘short RF retuning gap’.  |
| Apple | Ultimately, we will need to do so. Maybe wait for some additiona progress before sending it so that we have a good idea of the questions we need to ask |

## Issue 2.4 Power Saving

### Background

In [2] and [3] the issue of the impact of the UE’s power saving features and reduced capabilities on the positioning performance is discussed.

|  |  |
| --- | --- |
| Company | comment |
| [2] | * ***For power saving, positioning impacted by CDRX should be considered for RedCap positioning, including:***
* ***PRS measurement behavior 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.***
 |
| [3] | **Observation 5**: RedCap Ues may have positioning measurement performance degradation due to power saving/reduced capability features it is implementing.  |

###  First round of discussion

From the FL perspective, it seems the DRX discussion is not RedCap specific, and the LPHAP agenda may be more appropriate for this issue.

**Proposal 2.4.1-1: power saving feature can be discussed in the LPHAP agenda**

Companies are encouraged to provide their view on proposal 2.4.1-1 in the table below:

**Proposal 2.4.1-1:**

|  |  |
| --- | --- |
| Company | comment |
| Nokia/NSB | Okay.  |
| Intel | We are fine to discuss this under LPHAP AI.  |
| Samsung  | We feel this is not the top priority for redcap. |
| Qualcomm | We prefer to discuss it here. LPHAP discusses only RRC Inactive and Idle Positioning. If it included power consumption enhancements for RRC connected, we could move it there. CDRX is about Connected DRX, though so we think it cannot be discussed within the LPHAP agenda. **We are in principle supportive of the proposal/direction that vivo has above.**  |
| Huawei, HiSilicon | Agree. |
| CATT | Support |
| CMCC | In our views, LPHAP specifically aims at UEs in RRC\_INACTIVE and/or RRC\_IDLE states. Any enhancements regarding to power saving for Redcap UEs in INACTIVE and IDLE state can be discussed in LPHAP, but enhancements regarding C-DRX is out of the scope of LPHAP. The objective of RedCap UE positioning mainly focuses on positioning accuracy, not power efficiency. If the enhancement of C-DRX is found necessary for RedCap UE positioning, it can be discussed in this AI. |
| MTK | okay |
| ZTE | Deprioritize the discussion of power saving feature in RedCap AI, |
| vivo | We share the same understanding with QC, LPHAP discusses only RRC Inactive and Idle Positioning. If we want to discuss the power saving feature in RRC connected state in LPHAP may need to change the SIDBut if the majority suggests discussing the power saving feature in RRC connected state in LPHAP, we suggest making the proposal clear**power saving feature in RRC connected state can be discussed in the LPHAP agenda** |
| InterDigital | We support the proposal. |
| Lenovo | Supportive of studying RRC\_CONNECTED state enhancements related to C-DRX. |
| Apple | Support studying this in this Agenda item. In fact, we have a proposal as follows:* *Energy Aware Positioning: the positioning procedure may account for the DRX cycle so as to (a) ensure that the RS configurations match the DRX ON duration in the short and long DRX cycle (b) the RS measurements occur only during a DRX active time and/or (c) for a DRX inactive time, the RS configurations match the paging cycle*
 |

## Issue 2.5 1-Rx Antenna requirements

### Background

In [18] is it observed that single Rx antenna requirements are not present in RAN4 specifications and an LS may be needed.

|  |  |
| --- | --- |
| Company | comment |
| [18] | ***Observation 2: Performance requirements for the case of single Rx antennas have not been included in NR Rel-16/17 RAN4 specification.*** ***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.***  |

###  First round of discussion

Let’s discuss the potential LS to RAN4 for this issue.

**Proposal 2.5.1-1: : Send LS to RAN4 to ask them to include positioning requirements derived using simulation assumptions wherein 1 Rx is assumed at the UE**

Companies are encouraged to provide their view on proposal 2.5.1-1 in the table below:

**Proposal 2.5.1-1:**

|  |  |
| --- | --- |
| Company | comment |
| Nokia/NSB | Too early for LS on this issue.  |
| Intel | We may need more discussions on the requirement for 1 Rx antenna.  |
| Qualcomm | This LS will be to guide RAN4 work and not really to solicit feedback. We don’t see a problem sending it during the study item, and we are supportive of it. RAN4 will consider it during the RAN4-specific goals for the WID. |
| Huawei, HiSilicon | No need to our understanding. RAN4 can be aware of their work even without this LS, and in addition, the positioning requirement in RAN4 is more of the WI phase effort. Informing them in the SI does not make much sense. |
| CATT | We prefer to study more on this issue before sending the LS to RAN4. |
| MTK | Similar view as the above companies that it is not needed at this moment |
| ZTE | Not needed. |
| Lenovo | Could wait for a more conclusive outcome from RAN1 side. |

##  Issue 2.6 PRS configuration for Redcap UEs

### Background

In [8], the authors mentions that the existing muting mechanism may need to be updated in order to support the frequency hopping pattern of the PRS. In [8], it is proposed to discuss the PRS configuration reuse. In [11] the authors propose to evaluate longer PRS patterns. [13] proposes to update the configuration of PRS to include bandwidth hopping.

|  |  |
| --- | --- |
| Company | comment |
| [8] | **Proposal 2: For NR RedCap Ues, if frequency hopping is enable, study the muting mechanism for frequency hopping sub-bands.****Proposal 3: For NR RedCap Ues, study how to reuse the PRS configuration scheme of normal Ues.** |
| [11] | ***Proposal 2: RAN1 to study further processing capability enhancements based on the RedCap positioning performance evaluation with reduced bandwidths e.g., 20MHz for FR1 and 100MHz for FR2 including a reduced Rx antenna/RF chain of a single antenna.*** ***Proposal 3: Evaluate and study the positioning performance of RedCap devices with longer PRS symbol lengths, e.g., 12 to support RedCap devices.******Proposal 4: Analyse and study the complexity and capability to perform DL-PRS hopping including storing the number of time domain PRS samples across different hops for coherent Rx combining to achieve wideband PRS measurement for RedCap devices.*** ***Proposal 5: RAN1 to study the hierarchical relationship of a positioning sub-band with respect to a frequency layer, TRPs and DL-PRS resource set.***  |
| [13] | ***Proposal 1:******RAN1 should update the PRS/SRS configuration (including frequency mapping, repetition, measurement gaps and muting patterns) to accommodate PRS Bandwidth Hopping with Tone Overlap.******Proposal 2: RAN1 should update the existing sets of values for the UE DL PRS processing capability as the maximum # of DL PRS resources that UE can process in a slot assumes no BWP switching (DL) or RF retuning. This may need some feedback from RAN4.*** |
|  |  |

###  First round of discussion

Similar to the discussion on SRS configuration, the PRS may have to be updated if TX hopping is considered.

**Proposal 2.6.1-1: study the configuration of the DL PRS for positioning to enable TX frequency hopping and bandwidth stitching, including but not limited to impact on muting configuration, processing capability, hopping bandwidth configuration in the positioning frequency layer.**

Companies are encouraged to provide their view on proposal 2.6.1-1 in the table below:

**Proposal 2.6.1-1:**

|  |  |
| --- | --- |
| Company | comment |
| Nokia/NSB | We are not sure that muting configuration has been discussed enough to warrant being included here so prefer to remove it from the proposal. We should focus on the baseline operation first.  |
| Intel | Our understanding is that we may also need to study Rx frequency hopping and impact of time gap between hops. It is also not clear to us the processing capability in the context of DL PRS frequency hopping. So we suggest the following update:study the configuration of the DL PRS for positioning to enable TX or Rx frequency hopping and bandwidth stitching, including but not limited to impact on muting configuration, ~~processing capability~~, time gap between frequency hopping, hopping bandwidth configuration in the positioning frequency layer |
| Samsung  | Ok to study. |
| Qualcomm | Similar view with Intel. We think that this proposal could treat also Rx DL-PRS frequency hopping. There may be impact on processing capabilities, measurement period, hopping bandwidth, etc. We think both Tx and Rx DL-PRS frequency hopping should be studied together. **Study the configuration of the DL PRS for positioning to enable TX or Rx frequency hopping and bandwidth stitching, including but not limited to impact on muting configuration, processing capability, hopping bandwidth configuration in the positioning frequency layer,** time gap between frequency hopping, **measurement period.** |
| Huawei, HiSilicon | Similar reply with that for Proposal 2.2.1-1. We think we may firstly agree that DL PRS frequency hopping solution is supported for RedCap UEs. |
| CATT | In our view, we should focus on the hopping bandwidth configuration, and leave the muting configuration and processing capability as low priority. |
| CMCC | We think that the feasibility of DL PRS frequency hopping reception for RedCap UE should be first studied, as it is more complex in implementation for UEs with reduced capability.  |
| MTK | Both TX and RX hopping should be studied. For the muting, low priority |
| NEC | We support this proposal. |
| ZTE | Generally fine. We may also include the study of frequency hopping range (e.g. frequency hopping within one resource, frequency hopping within one resource set, frequency hopping between different CCs/BWPs/PFLs/resource sets). |
| InterDigital | We support the proposal. |
| Lenovo | Supportive of FL’s Proposal |
| Apple | Support  |

## Issue 2.7 AoA / AOD enhancements for Redcap UEs

### Background

In [16] AoA for positioning of RedCap Ues is proposed, while [18] that requirements may be met with phase-difference based AoD:

|  |  |
| --- | --- |
| Company | comment |
|  [16] | **Observation 1: AoA-based positioning imposes little requirements on the bandwidth.****Observation 2: AoA-based positioning requires additional hardware at Rx end, antenna array specifically.****Observation 3: The UL AoA-based positioning accuracy can be enhanced by link selection.****Observation 4: UL AoA-based positioning potentially allows reaching decimeter accuracy for RedCap (low BW) users in InF scenario.****Proposal 1: Further study on the accuracy of AoA-based positioning taking into account various hardware/algorithm configurations and the performance impairment factors.** |
| [18] | ***Observation 6: Phase-Difference-based AoD is a positioning method that demonstrates performance gains in scenarios with small number of Tx beams at the transmitter side (e.g. FDD scenarios)**** ***A performance of 1m at 80% in the InF-SH scenario, with 20 MHz, is achievable with Phase-Difference DL-AoD, whereas the legacy RSRPP-based DL-AoD, with 2 or 4 Tx beams achieve 5 and 2.2 m respectively***

***Proposal 6: For the purpose of Redcap positioning enhancements, study further Phase-Difference AoD.***  |

###  First round of discussion

Considering only 1 company for each of AoA and phase difference AoD have proposal for these methods, it is proposed to discussed whether these should be studied.

**Question 2.7.1-1: should phase Difference AoD be studied for the purpose of redcap positioning enhancements?**

**Question 2.7.2-1: should UL AoA be studied for the purpose of redcap positioning enhancements?**

Companies are encouraged to provide their view on these questions in the table below:

**Questions 2.7.1-1 and 2.7.2-1**

|  |  |
| --- | --- |
| Company | comment |
| Nokia/NSB | Q1: We think phase difference for AoD should be handled under 9.5.2.2 and not discussed in the RedCap AI.Q2: We don’t understand what we would need to study about UL-AoA. It is already specified in Rel-16/17. Companies can bring results as part of evaluations but otherwise we see no need to study it. The proposal in [16] has no specification impact in our opinion.  |
| Intel | We think these can be deprioritized for RedCap positioning.  |
| Samsung | We think there should be no limitation on what positioning method could be applied to redcap. This SI should capture the evaluation of evaluation results based on positioning method from companies. |
| Qualcomm | Q1: We think that results (or any observations based on the results) could still be captured in the Redcap positioning if they are using redcap-positioning-specific simulation assumptions. Now, from enhancement perspective, we are open to focus the discussion on the 9.5.2.2 subagendaQ2: Not sure what UL-AoA enhancements can be considered or are proposed. |
| Huawei, HiSilicon | Similar to the discussion in carrier phase positioning, we prefer to have it lower priority, and use of phase measurement reporting from the UE can be up to LMF implementation.OK to capture the evaluation results of phase difference AoD for RedCap in the RedCap section of the TR. |
| CATT | Q1: Yes, we support to further study the phase difference AoD.Q2: Yes, UL-AoA can be studied for RedCap UE positioning. |
| CMCC | We are open for study |
| MTK | For the two questions, we tend Not to study |
| ZTE | Further study or enhancement of phase difference for AoD and UL-AoA should be deprioritized. Companies may provide corresponding results if any. |
| Vivo | Q1: If the performance gain can be identified by companies, it can be discussed. But in my understanding, with lower bandwidth, the performance of AoD may also be difficult to satisfy the requirement.Q2: in my understanding, AoA is an existing method that can be captured in the baseline |
| Lenovo | Both cases may be deprioritized for the study |

## Issue 2.8 Processing window for PRS with frequency hopping/stitching

### Background

Two contributions propose to consider priority/collision rules for PRS for redcap Ues.

|  |  |
| --- | --- |
| Company | comment |
| [2] | * ***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.***
 |
| [3] | **Proposal 5**: 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. |

###  First round of discussion

From the FL perspective, the rel17 framework for priority may be applied to a redcap UE supporting it, at list for the case of Rx Frequency hopping. Since only two companies bring up the issue, let’s discuss whether it should be included in the study.

**Question 2.8.1-1: for positioning support for RedCap Ues, should the study consider the issue of PRS priority/PPW?**

Companies are encouraged to provide their view on question 2.8.1-1 in the table below:

**Question 2.8.1-1:**

|  |  |
| --- | --- |
| Company | comment |
| Nokia/NSB | Yes, how PRS frequency hopping might work with PPW should naturally be included in the work but we are okay to leave it to WI as well.  |
| Intel | We think these can be deprioritized for RedCap positioning. |
| Samsung  | PPW as specified in Rel17, if supported by the redcap UE, then naturally the rules by using PPW should be applied. We fail to see the intention of the proposals/question? Does proponent intend to have some further optimization on PPW specifically to Redcap? |
| Qualcomm | Yes, but this can be part of a generic study item on changes needed for Rx DL-PRS frequency hopping.  |
| Huawei, HiSilicon | We need to firstly agree that DL PRS frequency hopping solution is supported for RedCap Ues. The issue of PRS priority/PPW may be discussed in future meetings. |
| CATT | Yes, the PRS priority/PPW can be studied to support the RedCap UE positioning.  |
| CMCC | Similar comments to issue 2.6, after we have consensus on the feasibility of DL PRS frequency hopping reception for RedCap UE, then the related enhancements can be further considered. |
| MTK | This could be discussed in WI |
| ZTE | Deprioritize, RAN1 should focus on the support and evaluation of frequency hopping for RedCap UE positioning first. |
| Vivo | The above issues may be discussed after the conclusion of frequency hopping is made. |
| InterDigital | We support to study the proposed aspect. |
| Lenovo | This can await further study until the specific benefits for RedCap Ues are clear.  |

## Issue 2.9 Latency

### Background

|  |  |
| --- | --- |
| Company | comment |
| [11] | ***Proposal 1: Study the end-to-end positioning latency requirements for RedCap devices*** |
|  |  |

###  First round of discussion

In previous meeting, we discussed the requirements for latency and downprioritized the issue. Unless there is any objections, it would be preferable not to reopen this discussion. Please comment below if the issue of latency should be re-opened.

|  |  |
| --- | --- |
| Company | comment |
| Huawei, HiSilicon | The issue of latency should not be discussed again. |
| ZTE | The issue of latency should not be re-opened. |
| Lenovo | Ok with the down-prioritization of this issue. |
| Apple | Low priority |

## Issue 2.10 Other reference signals for Redcap for Positioning

### Background

[17] [18] proposes to study other reference signals already available for communication, for Redcap Positioning:

|  |  |
| --- | --- |
| Company | comment |
|  [17] | **Proposal 2:** * **RAN1 can study positioning methods based on SSB, TRS, or SRS for MIMO after the clarification of benefits.**
 |
| [18] | ***Proposal 4: For the purpose of Redcap positioning enhancements, supporting Positioning measurements (RSTD, UE Rx-Tx, RSRPP) derived on SSB, TRS should be introduced.*** ***Proposal 5: For the purpose of Redcap positioning enhancements, supporting M-RTT / UL-TDOA / UL-AoA using SRS-MIMO should be introduced.***  |

### First round of discussion

In previous meeting, we started the discussion regarding the use of other reference signals than DL-PRS and UL SRS for positioning for the study. Given that few companies considered the issue, we can either decide not to include these signals in the scope of the study, or alternatively leave it to companies to provide the reference signal description in their evaluation assumptions.

**Question 2.10.1-1: for positioning support for RedCap UEs, should the study consider other reference signals than DL-PRS or UL SRS for positioning?**

Companies are encouraged to provide their view on question 2.10.1-1 in the table below:

**Question 2.10.1-1:**

|  |  |
| --- | --- |
| Company | comment |
| Nokia/NSB | Don’t support. In Rel-16 we introduced PRS/SRS for positioning as we deemed it necessary to meet the requirements. As it is even more challenging for RedCap UEs to meet the requirement we don’t understand the motivation.  |
| Intel  | No. only DL-PRS and UL SRS should be considered. |
| Samsung  | Not motivated so far and it should be deprioritized. |
| Qualcomm | Accuracy is not the only KPI that should be considered. We think Redcap UEs will benefit from lower complexity solutions that would be globally available even if their performance is worse than the optimized PRS/SRS-positioning-based solutions.Adding other reference signals is not for the purpose of improved accuracy positioning. It is for those scenarios that we could be OK with worse accuracy performance, e.g. some IoT scenarios, with low additional complexity at the devices and with global support (e.g. using only mandatory features, e.g. TRS-based measurements, SRS-MIMO-based measurements).  |
| Huawei, HiSilicon | We see the value as always to use MIMO SRS for UE Rx – Tx time difference measurement. The difference between MIMO SRS and positioning SRS in terms of accuracy is very small for a 1Tx UE. |
| CATT | We prefer to reuse existing PRS/SRS for RedCap UE positioning as much as possible and study possible enhancements.  |
| ZTE | Low priority. Measurement(s) on other signal will bring a lot of work to justify. |
| InterDigital | We are ok to discuss this issue once the framework for frequency hopping is solidified. |
| Lenovo | May be deprioritized, can focus on the current PRS/SRS-pos design |

## Issue 2.11 Other issues

### Background

In [3] and [13] it is proposed to discuss methods to take into account the reduced capabilities of the UEs. In. [3] studing the impact of RRM measurement relaxation is proposed. In  [13] it is proposed to investigate allowing signalling of the required accuracy or the need for positioning update.

|  |  |
| --- | --- |
| Company | comment |
|  [3] | **Proposal 10**: 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.  |
| [13] | ***Proposal 3: RAN1 should investigate additionally investigate the following enhancements for RedCap UE positioning:*** * ***Reduced accuracy requirement indication: the RedCap UE may indicate that it may not require high accuracy positioning or it is stationary and does not require any position update***
* ***Group based positioning schemes: RedCap UEs that are co-located (or in close proximity) to other UEs (e.g. with better positioning capability), may form a group to estimate the UE positions.***
* ***Energy Aware Positioning: the positioning procedure may account for the DRX cycle so as to (a) ensure that the RS configurations match the DRX ON duration in the short and long DRX cycle (b) the RS measurements occur only during a DRX active time and/or (c) for a DRX inactive time, the RS configurations match the paging cycle***
 |

### First round of discussion

Regarding the proposal for signalling the reduced accuracy for a redcap UE, it seems the issue is a better fit for a discussion in the higher layer. Therefore it is the FL’s recommendation to leave it to RAN2/RAN3. Regarding RRM measurement relaxation, it is unclear what RAN1 should study. Companies are encouraged to comment below to clarify the issue:

|  |  |
| --- | --- |
| Company | comment |
| Nokia/NSB | For our proposal on RRM measurement relaxation we think that UE positioning performance could be impacted by RRM measurement relaxation (e.g., out of date QCL information). So we suggest RAN1 should consider it as it is one feature a RedCap UE may be performing.  |
| Apple | On the issue of signalling the reduced accuracy we do think there could be a RAN1 effect e.g. switching PRS/SRS configuration  |

Conclusions

References

1. R1-2208457, Discussion on RedCap positioning, Huawei, HiSilicon
2. R1-2208652, Discussion on positioning for RedCap UEs, vivo
3. R1-2208738, Views on Positioning for RedCap UEs, Nokia, Nokia Shanghai Bell
4. R1-2208803, Discussion on Positioning for RedCap Ues, OPPO
5. R1-2208985, Discussion on positioning for RedCap UEs, CATT
6. R1-2209061, Enhancements for positioning for RedCap UEs, Intel Corporation
7. R1-2209108, Considerations on positioning for RedCap UEs, Sony
8. R1-2209153, Discussion on positioning support for RedCap UEs, NEC
9. R1-2209217, Discussion on Positioning for RedCap UE, ZTE
10. R1-2209346, Discussion on RedCap positioning, CMCC
11. R1-2209397, Positioning for RedCap devices, Lenovo
12. R1-2209491, Discussions on positioning for RedCap UEs, InterDigital, Inc.
13. R1-2209590, Discussions on Positioning for RedCap Ues, Apple
14. R1-2209740, Discussion on Positioning for RedCap UEs, Samsung
15. R1-2209787, Views on positioning for RedCap UEs, Sharp
16. R1-2209807, Discussion on positioning support for RedCap Ues, LG Electronics
17. R1-2209911, Discussion on positioning for RedCap UEs, NTT DOCOMO, INC.
18. R1-2209994, Positioning for Reduced Capability UEs, Qualcomm Incorporated
19. R1-2210179, Positioning for RedCap Ues, Ericsson