3GPP TSG-RAN WG1 #113 R1-23NNNN

Incheon, Korea, May 22nd – 26th, 2023

Agenda Item: 9.5.5

Source: Ericsson

Title: Feature Lead summary #1 for Positioning for RedCap UEs

Document for: Discussion, Decision

# Introduction

This document summarises the proposals received as part of Agenda Item 9.5.5 for RAN1#113 for the Rel-18 work item on expanded and improved NR positioning [1]. The objectives relevant for this agenda item are as follow:

|  |
| --- |
| * Specify support of positioning for UEs with Reduced Capabilities (RedCap UEs)
	+ Specify support of Frequency Hopping (FH) beyond maximum RedCap UE bandwidth for reception of DL PRS and transmission of UL SRS for positioning [RAN1, RAN2].
		- NOTE: The complexity of the corresponding capabilities for RedCap UEs should be addressed for the introduction of appropriate capabilities for RedCap UEs.
	+ Specify RRM requirements for positioning including RRM measurements and procedures for RedCap UEs for both with and without frequency hopping [RAN4].
 |

# General issues

## Switching Time and LS from RAN4

### Background

Multiple contribution highlight the need for allocating time for retuning prior to and after the UE performs frequency hopping[6][15][21][22], and confirming the RAN4 LS for retuning time between hops [18][19]. This was also a question from RAN4 in their LS[25]. Therefore, we should capture an agreement on the issue and use it to respond to RAN4.

In [2], additional values for retuning time are proposed:

- 210us, 500us for FR1

- 210us for FR2

From the FL perspective, we have now received a list of candidate values. RAN4 is already discussing further values during their may meeting. Therefore, to avoid the turnaround time incurring by sending an LS and waiting for a reply, it is preferable to discuss these new values directly in the RAN4 WG without having RAN1 sending an LS on the issue.

Company views are summarized in the table below:

|  |  |
| --- | --- |
| **Company** | **Proposal** |
| [2] | *Proposal 7** *For RedCap positioning frequency hopping switching time, the following values should be additional supported.*
* *210us, 500us for FR1*
* *210us for FR2*
* *Send an LS to RAN4 to confirm above values*
 |
| [6] | Proposal 8* Additional switch time for SRS transmission between the initial/active BWP to first hop and switch time between last hop to the initial/active BWP is relevant for positioning SRS with frequency hopping and can be discussed in RAN4.
 |
| [15] | Proposal 2: Send a reply LS to RAN4 with the following response: * Yes, the additional switch time for SRS transmission between the initial/active BWP to first hop and switch time between last hop to the initial/active BWP is relevant.
	+ In this case, numerology, bandwidth, Tx/Rx antennas between the initial/active BWP and the SRS hop(s) can be different

Proposal 7: For an SRS resource used for Positioning frequency hopping:* It is associated with a CC and includes a configuration of a numerology and bandwidth.
* Introduce a transmission/switching/retune gap before the first hop of such an SRS resource and after the last hop, so that the UE can tune from the active BWP and back to the active BWP.
	+ Up to RAN4 the details
 |
| [18] | *Proposal 4: a time gap configuration should be considered between hops, FFS the candidate value and applicable condition.**Proposal 5: FFS how to compensate the impacts on phase offset and/or amplitude change, from the time varying channel property.**Proposal 6: From RAN1 perspective, the potential other UL signal transmission/DL reception might require additional time for UE to handle, especially with different SCS or TA;* |
| [19] | Proposal 1* The switching time between hops should be {70us, 140us} for FR1 and {35us, 70us, 140us} for FR2 from RAN1 perspective.
	+ Final decision of the gap values may be up to RAN4.
 |
| [21] | 1. The RAN1 discussion of UE capability indication for the supported minimal RF retuning time can start after receiving further confirmation from RAN4.
2. RF retuning time should also be considered prior and after transmission of the PRS with Rx hopping.
 |
| [22] | Proposal 2-1: The additional switch time between BWP and the first hop, and between last hop and the return to BWP may be needed. It could reuse the agreed value and it is same as that between hops, and there is no need to be further discussed in RAN4Proposal 2-2: The SRS transmission duration may consider the switch time between BWP and the first hop, and between last hop and the return to BWP |

### Further considerations on the switching time [medium]

#### Round 1

The following proposal was advanced in [2]. From the FL perspective, it is preferred to leave it to RAN4. Therefore, we start with the following question:

**Question 2.1-1: should additional values for the switching time for RedCap positioning frequency hopping switching time, the following be discussed within RAN1?**

Companies are encouraged to comment on the question in the table below:

**Question 2.1-1:**

|  |  |
| --- | --- |
| **Company** | **Comment** |
|  |  |

### Response to RAN4 LS [separate discussion]

The response to RAN4 LS will be discussed in a separate document, as decided by the following:

|  |
| --- |
| **Rel-18 Positioning**R1-2304316 LS reply on switching time for DL PRS or UL SRS frequency hopping for RedCap UEs RAN4, EricssonRAN4 response to RAN1 LS in R1-2302127. In addition, RAN4 is requesting RAN1 input on whether additional switch time may be needed for SRS transmission between the initial/active BWP. Discussion on response LS to be handled in agenda item 9.5. To be moderated by Florent (Ericsson). |

## Subcarrier Spacing [low]

In [8], it is proposed to consider the use of small SCS for UEs with low speed:

|  |  |
| --- | --- |
| **Company** | **Proposal** |
| [8] | Proposal 15: Consider using small SCS to increase the positioning performance for RedCap UEs with low speed at least. |

From the FL perspective, this is an implementation issue and should not be impacting the specification. Therefore, it is proposed not to pursue the proposal further.

Companies are encouraged to comment on the proposal in the table below:

|  |  |
| --- | --- |
| **Company** | **Comment** |
|  |  |

## RACH [low]

In [18], it is proposed to study the impact of RACH on the PRS Rx hopping:

|  |  |
| --- | --- |
| **Company** | **Proposal** |
| [18] | Proposal 2: RAN1 to study the impact of RACH related signal to the PRS Rx reception FH. |

Since only 1 company has raised the issue above, let’s first collect some comments on the proposals to see the level of support. Not that the issue was also brought up during RAN1#112b-e but did not receive any comment.

Comments can be entered in the table below:

|  |  |
| --- | --- |
| **Company** | **comment** |
|  |  |

## Positioning methods [low]

In [11][20] it is proposed to consider time and angle-based methods for positioning of redcap UEs. In [7], it is proposed to support carrier phase based positioning for a single hop.

|  |  |
| --- | --- |
| **Company** | **Proposal** |
| [11] | Proposal 4: Support both DL/UL timing and angle based positioning methods for hopping based positioning methods |
| [20] | Proposal 1: Prioritize timing-based positioning techniques such as TDoA, RTT for Redcap positioning.  |
| [7] | ***Proposal 9:*** *Only single hop CP measurement is reported.** *FFS the first hop*
 |

This topic was also brought up in the RAN1#112b-e and RAN1#112 meeting. From the FL perspective, the WID does not specify a particular method to be supported. From the FL perspective, the support of CPP for redcap UE based on a single hop is not different from the support for CPP from non-RedCap UEs. the UE will report which band / DL PRS bandwidth it supports for CPP and perform the measurement accordingly. For the other methods mentioned in [11] and [20], the discussion so far does not restrict any existing method to be used. Therefore, it is proposed not to pursue the discussion on supported method further.

Companies are encouraged to comment on the proposal in the table below:

|  |  |
| --- | --- |
| Company | Comment |
|  |  |

# Measurement reporting

## Background

During RAN1#112b-e, we reached the following agreements:

|  |
| --- |
| **Agreement**For DL Rx hopping or UL Tx hopping, support the UE or gNB to report the following:* A single measurement based on receiving multiple hops of the DL PRS or UL SRS for positioning
* One [or more] measurements where each measurement is associated with one received hop
* FFS: indication of how many received hops / which received hops where used in the measurement report.
* Note: no new measurement definition is introduced in RAN1
* FFS: conditions when the above measurements are reported, and whether the above measurements can be reported together
 |

Within the contributions, the proposals discuss further the following issues (note: all proposal apply to both TRP and UE measurements, unless stated otherwise)

* Measurement per hops:
	+ Report only a single hop is proposed in [1][6][10][16] due to overhead concern
	+ Per-hop measurement is reported separately from the measurement based on multiple hops[2][7][9][11][14][18][21][22]
		- In [7], the proposal is to report either the wideband measurement or the single hop measurement. In [9][11][22], the single hop measurement is a fallback measurement reported when the wideband measurement fails.
		- In [14][15], the per hop measurement can be requested explicitely
	+ Support of per-hop indication [2][5][7][9][11][12][13][14][18][21]
		- Note:[2] suggest that the hop index is up to UE choice
	+ For DL measuements, the measurement bandwidth per hop is reported as a UE capability [13][21]
* Wideband measurement:
	+ Support of indicating which hop were used in the wideband measurement [7]
		- In [15] indication of which hop were used in not supported, but instead the use of the quality metric is suggest to convey that a more accurate measurement is being reported.
		- In [22] it is proposed to include the measurement bandwidth obtained from stitching multiple hops in the measurement report
	+ Restriction to use only contiguous hops in the wideband measurement [12]
* Connection to Measurement Gap: if a gap is too short, the UE reports on the hops within the gap[8]

Company views are shown in the table below:

|  |  |
| --- | --- |
| **Company** | **Proposal** |
| [1] | Proposal 1: For DL Rx hopping or UL Tx hopping, support the UE or gNB to report the following:* A single measurement based on receiving multiple hops of the DL PRS or UL SRS for positioning
* One ~~[or more]~~ measurements where each measurement is associated with one received hop
* FFS: indication of how many received hops / which received hops where used in the measurement report.
* Note: no new measurement definition is introduced in RAN1
* FFS: conditions when the above measurements are report~~, and whether the above measurements can be reported together~~
 |
| [2] | Proposal 2* For frequency hopping report, support the following
* For ‘a single measurement based on receiving multiple hops’ and ‘one [or more] measurements where each measurement is associated with one received hop’, they cannot be reported together.
* For ‘one [or more] measurements where each measurement is associated with one received hop’, support indication of hop index along with each measurement.
* Note: different hop indices are not associated with actual hop locations, but are only used to distinguish each other
* Note: the associated hop indices are up to UE implementation other than network configuration
 |
| [5] | Proposal 1: An indicator is needed to indicate how many received hops or which received hops were used in the measurement report. |
| [6] | Proposal 3* More than one measurement where each measurement is associated with one received hop is not supported for DL PRS or UL SRS for positioning with frequency hopping.
 |
| [7] |  Proposal 2: For DL Rx hopping, support UE to report either* A single measurement based on receiving multiple hops of the DL PRS for positioning
	+ The frequency range or hop indications of the multiple hops should be reported as well
* Or one measurement which is associated with one received hop
	+ The frequency range or hop indication of the hop should be reported as well

Proposal 7: For UL Tx hopping, support TRP to report either.* A single measurement based on received multiple hops of SRS.
	+ The corresponding hop indications should be reported as well
* One single measurement which is associated with one received hop.
	+ The hop indication should be reported as well
 |
| [8] |  Proposal 7: Whether all the frequency hops are included in a single measurement gap or multiple measurement gaps, is determined by the measurement gap configuration and the PRS processing capability of RedCap UE. |
| [9] |  Proposal 7: Support both options on measurement report when using DL Rx hopping or UL Tx hopping (i.e., Option 1 and Option 2). One single measurement for multiple hops is used when UE has capability to perform bandwidth stitching, while measurement per hop is used as a fallback operation when UE has no/partial bandwidth stitching capability. |
| [10] |  Proposal 1: For DL Rx hopping or UL Tx hopping, * Support to report one ~~[or more]~~ measurement that is associated with a single received hop.
* No need to indicate how many / which hops are used to acquire the measurement
 |
| [11] |  Proposal 5: Support per-hop measurement by modifying the agreement made in RAN1#121b-e as follows, “One ~~[~~or more~~]~~ measurements where each measurement is associated with one received hop” Proposal 6: If not all hops in a pattern are received, the UE or gNB reports one or more measurements where each measurement is associated with one received hop of DL PRS or UL SRS for positioningProposal 7: If all hops in a pattern are received, the UE or gNB reports coherently combined measurements (e.g., single measurement based on receiving multiple hops of DL PRS or UL SRS for positioning)Proposal 8 : The UE includes the identify of received hop(s) in the measurement report |
| [12] |  Proposal 11: Support the UE to indicate which received hop(s) are associated with a given measurement. Proposal 12: Restrict multi-hop measurements to the case where the hops are contiguous in the frequency domain. |
| [13] | Proposal 5: For RedCap positioning, the number of hops, measurement bandwidth per hop, and overlapping bandwidth are UE’s capabilities. Proposal 6: The hop index and the number of hops used to perform should be reported along with the measurement.   |
| [14] |  Proposal 7: A single measurement can be fed back in the case that some of the hops are not combined in the measurement. To assist in the measurement, an indication of which received hops were used in the measurement report can be sent.Proposal 8: For the measurement per hop, this can (a) be configured to be reported always with the single measurement, (b) be reported in a fall-back mode (e.g. if there is a failure in the single measurement), or (c) be reported by itself based on an explicit measurement request. To assist in the measurement, an indication of which received hops were measured and sent can be reported. |
| [15] | Proposal 5: For DL Rx hopping or UL Tx hopping:* Do not support an additional indication of how many received hops / which received hops where used in the measurement report.
	+ Note: A UE may, up to UE implementation, to use the quality metric and the ReportingGranularityfactor to inform the LMF that a more accurate measurement is being reported.
* Up to RAN4 to define any conditions on when the measurements are reported, what/if requirements are needed to be specified if there collisions or hops are being dropped.

Proposal 6: Support an LMF to include an explicit request in the Location Request Signaling for a device to perform and report measurements according to DL PRS Rx frequency hopping. |
| [16] | Proposal 7-1: For UL SRS-pos Tx hopping, reporting the multiple measurements per hop from gNB is not supported.Proposal 7-2: For DL PRS Rx hopping, reporting the multiple measurements per hop from UE is not supported. |
| [18] |  Proposal 3: support FH based measurement reporting and associated FH part index within one complete PRS. |
| [21] | 1. In the measurement reporting for DL PRS frequency hopping, one measurement result is associated with the accumulated bandwidth information if the accumulated bandwidth is not aligned with the full bandwidth of configured PRS transmission, and one accumulated bandwidth has up to one measurement result.
2. It is up to UE capability to report narrow-bandwidth-based measurement result.
3. In the measurement reporting for UL SRS frequency hopping, one measurement result is associated with the accumulated bandwidth information (i.e. the number of hops in frequency domain) if the accumulated bandwidth is not aligned with the full bandwidth of configured SRS transmission, and one accumulated bandwidth has up to one measurement result.
 |
| [22] | Proposal 3-1: The measurement reporting based on either one received hop or multiple hops could be considered. To report together is not preferredProposal 3-2: If UE doesn't support measurements by the stitched and larger bandwidth, it is up to UE implementation to determine a location of the measurement bandwidth with good RSRP to measure and report. It also means, the reporting could be based on a selected received hopProposal 3-3: A hop with good RSRP would be changed with time due to mobility. Then to report the measurement with which hop and the corresponding location is less meaningful and it is not preferredProposal 3-4: For the measurement reporting by using multiple consecutive hops, since the overlapping RB number is up to implementation, UE could report based on the measurement bandwidth after stitching, instead of reporting the number of consecutive hops |

## Report of a single hop for per-hop measurements [high]

### Round 1

For per-hop measurement, the majority of proposals in contributions want to focus on a single-hop being reported.

**Proposal 3.2-1: For DL and UL measurements associated with one received hop, a single measurement, associated with one hop, is reported.**

Companies are encouraged to comment on the proposal in the table below:

**Proposal 3.2-1:**

|  |  |
| --- | --- |
| **Company** | **Comment** |
|  |  |

## Report of single hop measurement separately from the wideband measurement [high]

### Round 1

Several contribution proposed to use per-hop measurements as fall back to the main measurement, but there are also proposal to have the per-hop measurement independent from the main measurement. For both cases, there are proposals to let the LMF deceide on whether a fall-back measurement is of interest, or to request a per-hop measurement.

**Proposal 3.3-1: DL and UL measurements associated with one received hop are reported separately from the measurement based on multiple hops.**

* **Measurements associated with one received hop can be reported as a fall back when a measurement based on multiple hops fails, or independently of a measurement based on multiple hops**
* **The LMF indicates whether the UE or TRP should report the single-hop measurement as fall back to the multiple hop measurement in the measurement request. If no indication is present, the UE or TRP reports measurement failure.**
* **FFS: The LMF can separately request a measurement based on one received hop**

Companies are encouraged to comment on the proposal in the table below:

**Proposal 3.3-1**:

|  |  |
| --- | --- |
| **Company** | **Comment** |
|  |  |

## Hop bandwidth capability for per-hop measurement [medium]

### Round 1

One contribution proposes to report the hop bandwidth as a UE capability.

**Proposal 3.4-1**: **For DL measurements, measurement bandwidth for per-hop reporting is a UE capability**

Companies are encouraged to comment on the proposal in the table below:

**Proposal 3.4-1**:

|  |  |
| --- | --- |
| **Company** | **Comment** |
|  |  |

## Hop indication in per-hop measurements [high]

### Round 1

Several contribution point to the need to indicate which hop is reported for per-hop measurement. However, how the hop is indicated is not clear yet. For example, in the DL the hopping pattern is up to the UE implementation. In the UL the hopping pattern will be defined, but it remains to be decided.

**Proposal 3.5-1: For DL and UL measurements associated with one received hop, the measurement report includes an indication of the hop that was used to perform the measurement**

* **FFS: how the hop is indicated**

Companies are encouraged to comment on the proposal in the table below:

**Proposal 3.5-1**:

|  |  |
| --- | --- |
| **Company** | **Comment** |
|  |  |

## Hop indication in multiple hop measurements [high]

### Round 1

Several companies showed interest for indicating which of the hops were used in forming the mesurement based on multiple hops. As alternative to indicating the hops used, it was also proposed to report the measurement bandwidth.

**Proposal 3.6-1: For DL and UL measurements associated with multiple received hop, the measurement report includes**

* **Option 1: an indication of the hops that was used to perform the measurement**
	+ **FFS: how the hop is indicated**
* **Option 2: the measurement bandwidth**
	+ **FFS: details of the measurement bandwidth**

Companies are encouraged to comment on the proposal in the table below:

**Proposal 3.6-1**:

|  |  |
| --- | --- |
| **Company** | **Comment** |
|  |  |

## Measurements with partially overlapping measurement gap [medium]

### Round 1

[8] proposed to consider the case where the measurement gap is too short to overlap with the whole DL PRS duration so that only a subset of the Rx hopping can be performed. From the FL perspective, this is an unlikely case, since the UE requests the measurement gaps. However, companies are encouraged to comment on the proposal:

**Proposal 3.7-1: For DL and UL measurements associated with multiple received hop, when a measurement gap overlap partially with the measured DL PRS, the UE reports the DL measurement based on the hops received within the measurement gaps.**

Companies are encouraged to comment on the proposal in the table below:

**Proposal 3.7-1**:

|  |  |
| --- | --- |
| **Company** | **Comment** |
|  |  |

# DL-PRS Frequency Hopping

## PPW support [high]

### Background

During RAN1#112b-e, support of PPW for DL PRS Rx hopping was discussed, but an agreement was not reached, so that the FFS on PPW was left unresolved.

Based on the received proposals support of PPW is as follow:

* Not supported: 10 Companies ([2][3][4][6][9][10][14][16][19][21])
* Supported: 5 Companies ([5][11][12][15][18])
	+ This includes different level of support, eg. Different types of PPW.

|  |  |
| --- | --- |
| **Company** | **Proposal** |
| [2] | Proposal 1* For PRS Rx frequency hopping, PPW-based method is not supported.
 |
| [3] | Proposal 2: Only measurement gap based measurement for DL PRS frequency hopping should be considered. |
| [4] | Proposal 1: Do not further consider PPW-based/ MG-less scheme for PRS Rx frequency hopping for the target UE. |
| [5] | Proposal 6: For RedCap UE positioning with DL Rx frequency hopping, support the use of PPW, e.g., one/multiple PPWs based BWP frequency retuning method.Proposal 7: For RedCap UEs positioning in HD-FDD, collision handling rules for DL PRS and other UL signals/channels within PPW should be defined by the one of the following two methods.* Method 1: Reuse collision handling rule for DL PRS and other DL signals/channels in PPW in Rel-17, with new definition of PPW types (Type 3/4).
* Method 2: Reuse the collision handling rule for other DL signals/channels and UL signals/channels for RedCap UE in HD-FDD.

Proposal 8: Support a RedCap UE to use an on-demand method to provide the recommended PPW-related configuration information to the network (serving gNB/LMF). |
| [6] | Proposal 2* For DL PRS with Rx frequency hopping for RedCap UEs, only MG-based measurement is supported.

Proposal 7* For HD-FDD RedCap UE, collision handling between DL PRS and UL channels/signals within a configured PPW needs to be addressed at least for the case where DL PRS is configured without Rx frequency hopping.
 |
| [9] | Proposal 8: Down-prioritize the frequency hopping operation within a PRS Processing Window (PPW) for RedCap UE. |
| [10] | Proposal 2: For RedCap UEs, the PPW-based DL PRS measurement with Rx frequency hopping should be treated as low priority. |
| [11] | Proposal 3: Support PRS processing window to receive PRS via Rx hopping |
| [12] | Proposal 3: RAN1 should support DL PRS frequency hopping outside MG for RedCap UE at least for the case of Type-1A PPW.Proposal 4: RAN1 should specify solutions to effectively support DL PRS frequency hopping within PPW configurations. |
| [14] | Proposal 2: Additional design details DL PRS Rx Hopping are as follows:• Time domain repetition may have to account for the hops across the bandwidth as a single repetition is over multiple hops. • The muting pattern may either mute a single hop or may mute a hop set. • The measurement gap may have to accommodate the duration of the hop set. This may be accommodated by a single large MG or multiple instances of a MG.• Gapless measurements based on the PRS Processing Window (PPW) should be lower priority. |
| [15] | Proposal 4: Support Rx frequency hopping for MG-less PRS processing only for PPW Type-1A using the following principle as a starting point: * A UE may perform Rx frequency hopping within a PPW instance under the condition that the required retune time before and after each hop is treated as part of the PRS duration in the specified PRS prioritization/collision rules.
	+ If the retune time before or after a low-priority PRS hop collides with a high-priority channel, then the UE does not perform the Rx frequency hopping.
* Note: No additional specification impact beyond UE capabilities is expected from RAN1 perspective.
 |
| [16] | Proposal 1: Deprioritize DL-PRS frequency hopping outside MG. |
| [18] | Proposal 1: PPW only with PRS as higher priority could to be used for PRS Rx FH. |
| [19] | Proposal 2* RAN1 may not need to support PPW with FH.
 |
| [21] | 1. PPW is not supported with DL PRS Rx hopping.
 |

### Round 1

RAN1#113 is the third meeting where PPW support is discussed. There is a majority of contribution that does not want to support PPW, or at least down-prioritize it. Regarding down-prioritization, RAN1 only has two meetings left, so down-prioritization now means it will not be supported in rel-18. Thus we should make a decision on PPW support during this meeting.

Based on the majority of contribution, it is proposed not to support PPW:

**Proposal 4.1-1: PPW is not supported with DL PRS Rx hopping in Rel-18.**

Companies are encouraged to comment on the proposal in the table below:

**Proposal 4.1-1:**

|  |  |
| --- | --- |
| **Company** | **Comment** |
|  |  |

## Measurement gap configuration [high]

### Background

The issue of a single or multiple measurement gap was discussed in previous meetings. In this meeting, the majority of companies propose to support a single measurement gap[3] [5] [9] [15], and two contributions [10][15] propose to leave it to RAN4. In [15] it is proposed to leave to RAN4 to decide the duration of the MG and of the number of hops (Rx retunings) covered by the MG.

|  |  |
| --- | --- |
| **Company** | **Proposal** |
| [3] |  Proposal 3: UE should only apply a single instance of a measurement gap to complete one PRS frequency hopping reception. |
| [5] | Proposal 5: For DL PRS Rx hopping using measurement gap(s), a single measurement gap should be configured to overlap with at least 1 DL PRS hopping sequence.* Send an LS to RAN4 to check if there is any issue to support the above enhancement.
 |
| [9] | Proposal 9: For RedCap UE positioning, only support the use of a single instance of MG for DL PRS with Rx frequency hopping. |
| [10] | Proposal 3: It is up to RAN4 to define RRM requirements for UE performing DL PRS Rx frequency hopping using a measurement gap.• A LS to RAN4 can be sent. |
| [15] | Proposal 3: The UE is expected to perform up to N Rx Retunings during a single MG instance in order to measure multiple frequency parts of a single PRS resource Up to RAN4 to decide the maximum number of Rx Retuninings within a single MG instance |
| [21] | Proposal: Gap duration for PRS Rx hopping can be handled by RAN4.  |

### Round 1

Based on the received proposal we can discuss the use of a single measurement gap. RAN4 should be informed of the agreement.

**Proposal 4.2-1: For DL PRS Rx hopping, support the use of a single instance of a measurement gap over all the hops for DL PRS with Rx frequency hopping.**

* **Send an LS to RAN4 including the agreement.**

Companies are encouraged to comment on the proposal in the table below:

**Proposal 4.2-1**

|  |  |
| --- | --- |
| **Company** | **comment** |
|  |  |

## Further details on Configuration of Rx hopping

### Background

 In [8][3], it is propose to further specify how repetitions are used to implement Rx hopping.

In other contributions it is propose to introduce parameters for the time between hops[7] , the overlap between hops [9][13]. In [14] it is propose to consider extending the existing parameters for repetitions in the time domain.

|  |  |
| --- | --- |
| **Company** | **Proposal** |
| [3] | Proposal 1: UE perform frequency hopping reception between different PRS transmission repetitions within one period of one PRS resource can be considered. |
| [7] | Proposal 1: With regards to Rx frequency hopping for positioning for RedCap UE:* UE reports a capability on the maximum number of supporting frequency hops to network, the candidates at least include {2, 3, 4, 5}
* UE reports a capability on the overlapping PRB(s) between adjacent hops or a capability on the maximum equivalent bandwidth after combing all hops

Proposal 10: The parameters are recommended for higher layer.* maximum number of supported frequency hops [1,2, ..., 5]
* overlapping PRB(s) between adjacent hops or a capability on the maximum equivalent bandwidth after combing all hops [0,1,2, 4]
* UE capability on support of on-demand PRS with Rx hopping [Yes/No]
 |
| [8] | Proposal 1: Repetition scheme for PRS can be considered to realize DL PRS frequency hopping in Rx.Proposal 2: Support an additional indication to indicate which repetitions will be received by UE as a frequency hopping pattern. |
| [9] | Proposal 1: Support frequency hopping with partial overlap with two adjacent frequency bands to compensate the performance loss due to the phase offset.Proposal 2: Introduce two higher layer parameters for configuration of hops, Tgap (the time gap between two hops) and F\_ovl (the overlap resources in frequency domain), to facilitate bandwidth stitching in the frequency hopping operation.Proposal 3: These parameters (T\_gap and F\_ovl) should be configured for each measurement occasion or semi-consistent for multiple occasions. |
| [13] | Proposal 2: For UE-assisted Redcap positioning, bandwidth overlap between the frequency hops should be supported. |
| [14] | Proposal 1: For DL PRS Rx Hopping, the UE hops within a DL PRS resource. The specification impact includes the following:* Frequency domain: no change
* Time domain: increase number of repetitions to enable mapping over BW. This may need an update to parameters like the L-PRS-ResourceRepetitionFactor, DL-PRS-ResourceTimeGap and the DL-PRS-Periodicity.

Proposal 3: On the overlap between hops and number of hops, the hopping configuration needs to identify at least the following:* the number of hops,
* the bandwidth of each hop,
* the amount of overlap between hops.

These are dependent on the UE capability. |
| [20] | Proposal 3: Specify the timing gap resulting from the PRS reception of different frequency hops.  |
| [15] | Proposal 1: For DL-PRS Rx frequency hopping, support performing Rx hopping with overlapping tones and with non-overlapping tones.* Support a UE to report a per-band capability for the amount of overlap required for DL PRS frequency hopping
* Note: RAN1 assumes that no additional UE requirements shall be specified for the case of Rx hopping with non-overlapping tones; e.g., a UE is not responsible for keeping phase continuity across the hops in either case of overlapping or non-overlapping hops.
* Send an LS to RAN4 with the above agreement
 |

From the received proposals, it seems at least either the amount of overlap between hops and the hopping bandwidth, or alternatively, total accumulated bandwidth across hops, should be reported as a UE capability in order for the network to form the assistance data (for example, the overall bandwidth of the DL PRS depends on the total bandwidth across hops).

 Regarding the time gap between hops, it could be reported to secure that repetitions are not too close from each other so allow the UE to perform retuning.

Regarding identifying the repetition used for Rx hopping, it should be noted that all repetitions from the network perspective are identical. The UE can use the repetition to either perform Rx beam sweeping or accumulate more power, based on its implementation. Thus the benefit of identifying the repetition involved in the Rx hopping is unclear.

### Capability reporting for the bandwidth across all hops [high]

#### Round 1

**Proposal 4.3.2-1: To report the UE capability for the DL PRS bandwidth across all hops, the UE reports as a capability the hop bandwidth and the overlap between hops.**

Companies are encouraged to comment on the proposal in the table below:

|  |  |
| --- | --- |
| **Company** | **comment** |
|  |  |

### Capability reporting for the time gap between hops [high]

#### Round 1

**Proposal 4.3.3-1: for DL PRS Rx hopping, the time gap between Rx retunings is reported by the UE as a capability.**

Companies are encouraged to comment on the proposal in the table below:

|  |  |
| --- | --- |
| **Company** | **comment** |
|  |  |

### Identification of repetitions used for Rx hopping [low]

#### Round 1

**Proposal 4.3.4-1: for DL PRS Rx hopping, the network indicates which of the repetitions are used for Rx hopping**

Companies are encouraged to comment on the proposal in the table below:

**Proposal 4.3.4-1**

|  |  |
| --- | --- |
| **Company** | **comment** |
|  |  |

## Number of hops [high]

### Background

 In [7] [9] [20], it is proposed that the UE reports the maximum number of hops used in Rx hopping. Such capability could be used by the network to configure the number of DL PRS repetitions.

|  |  |
| --- | --- |
| **Company** | **Proposal** |
| [7] | Proposal 1: With regards to Rx frequency hopping for positioning for RedCap UE:* UE reports a capability on the maximum number of supporting frequency hops to network, the candidates at least include {2, 3, 4, 5}
* UE reports a capability on the overlapping PRB(s) between adjacent hops or a capability on the maximum equivalent bandwidth after combing all hops
 |
| [9] | Proposal 5: Support the UE capability parameter to reflect the supported frequency hopping operation for NR RedCap UE. (i.e, by considering the RedCap UE constraints / limitations). |
| [20] | Proposal 4: Specify the configuration and related capabilities associated to the number of Rx hops to combine and number of DL-PRS samples across different hops to be stored for coherent Rx combining to achieve wideband DL-PRS measurement for RedCap devices.  |

### Round 1

**Proposal 4.4-1: for DL PRS Rx hopping, the UE reports a capability on the maximum number of hops it supports.**

Companies are encouraged to comment on the proposal in the table below:

**Proposal 4.4-1**

|  |  |
| --- | --- |
| **Company** | **comment** |
|  |  |

## Further assistance data to support Rx hopping [medium]

### Background

In [7] it is propose to include the hopping parameter in the assistance data. In [8] it is proposed to make the bandwidth overlap configurable for Rx Hopping.

|  |  |
| --- | --- |
| **Company** | **Proposal** |
| [7] | Proposal 3: For PRS reception with hopping, one or more of the following parameters in assistance data or location request should be introduced to facilitate UE’s PRS measurement.* Number of hops
* Number of overlapped RB between hops
* Total bandwidth of all hops
 |
| [8] | Proposal 3: For frequency hopping of PRS or SRS, support configurable overlapped bandwidth between two adjacent hops to address the influence caused by phase offset between hops. |

### Round 1

We can start by checking the support to introduce Rx hopping parameters in assistance data for DL PRS Rx hopping

**Proposal 4.5-1: for DL PRS Rx hopping, the LMF sends the number of hops, overlap between hops and total bandwidth of all hops as part of the assistance data to the UE**

Companies are encouraged to comment on the proposal in the table below:

**Proposal 4.5-1**

|  |  |
| --- | --- |
| **Company** | **comment** |
|  |  |

## Intra-slot hopping [medium]

### Background

Since rel16, the repetition framework of the DL PRS only support inter-slot hopping. In [10][21], intra slot hopping is proposed. [10] proposes to support it by configuring DL PRS patterns with repetition exceeding comb size, while [21] proposes to introduce intra-slot hopping parameters:

|  |  |
| --- | --- |
| **Company** | **Proposal** |
| [10] | Proposal 4: Both intra-slot and inter-slot DL PRS Rx frequency hopping can be supported.* No RAN1 specification enhancement is required.
 |
| [21] | Proposal 2 Support intra-slot (symbol) level repetitions, with a new intra-slot repetition factor and intra-slot resource time gap using symbol resolution. Potential values for resource time gap for intra-slot hopping includes 2, 4, 8 symbols. Potential values for intra-slot repetition include 1, 2, 3, 4. |

### Round 1

Since the proposal in [10] does not have specification impact, we can start by checking the support to introduce intra-slot hopping based on [21]:

**Proposal 4.6-1: for DL PRS Rx hopping, intra-slot hopping is supported by a new intra-slot repetition factor and intra slot resource time gap**

* **FFS details on values for repetition factor and time gap.**

Companies are encouraged to comment on the proposal in the table below:

**Proposal 4.6-1**

|  |  |
| --- | --- |
| **Company** | **comment** |
|  |  |

## DL PRS Processing [medium]

### Background

 The DL processing capability is expressed since rel16 as the number of DL PRS resources N the UE is able to process in a time window T at a given maximum bandwidth B. in [9][14][20][22], it is proposed to discuss the capability of DL PRS processing in the context of RedCap UEs and DL Rx hopping

|  |  |
| --- | --- |
| **Company** | **Proposal** |
| [9] | Proposal 6: Support the RedCap UE’s processing time for Rx frequency hopping as part of the UE capability. |
| [14] | Proposal 6: A reply from the RAN4 LS is needed to update the existing sets of values for the UE DL PRS processing capability. |
| [20] | Proposal 5: Support Redcap PRS processing capabilities corresponding to different (N,T) values with reduced bandwidths e.g., 20MHz for FR1 and 100MHz for FR2 including a reduced Rx antenna/RF chain of a single antenna. |
| [22] | Proposal 4-1: The processing capability may depend on DL-PRS pattern, the RF switch time of UE and the processing strategy. As such, the processing capability could be determined and reported after the DL-PRS configuration is sent to the UEProposal 4-2: The measurement capability could be defined as the measurement bandwidth per resource per TRP, and the total number of resource number times the TRP number within a time window |

### Round 1

The proposals do not mention a specific new set of values for DL Processing capability. Thus we start by checking whether new capability should be defined at all, and we will discuss further details later:

**Proposal 4.7-1: for DL PRS Rx hopping, a new processing capability for processing of DL PRS with Rx hopping is defined.**

* **FFS: details of the new capability regarding number of resources, maximum bandwidth and time window.**

Companies are encouraged to comment on the proposal in the table below:

**Proposal 4.7-1**

|  |  |
| --- | --- |
| **Company** | **Comment** |
|  |  |

## PRS Tx hopping

In [6][9], it is proposed to re-consider the use of Tx hopping for the DL PRS:

|  |  |
| --- | --- |
| **Company** | **Proposal** |
| [6] |  Proposal 1* For DL PRS for RedCap UEs, frequency hopping pattern for the reception of DL PRS across different subbands is defined.
* gNB may choose between the option of transmitting a single common DL PRS that may be received by RedCap and non-RedCap UEs and the option of transmitting DL PRS for RedCap UEs separate from that for non-RedCap UEs.
 |
| [9] | Proposal 10: Support frequency hopping is configurable across multiple DL PRS resources or resource-sets. |

Since the issue was resolved during RAN1#112 with the following agreement, it is proposed not to consider the issue further.

|  |
| --- |
| **Agreement**For positioning for RedCap UEs with DL PRS Rx Hopping, the UE hops within a DL PRS resource* FFS: whether there is specification update needed for RAN1
* FFS: remaining details
 |

Companies may leave their comment in the table below:

|  |  |
| --- | --- |
| **Company** | **comment** |
|  |  |

## On-demand PRS [low]

### Background

In [7], it is proposed to include a UE capability for support of on-demand PRS with Rx hopping.

|  |  |
| --- | --- |
| **Company** | **Proposal** |
| [7] | Proposal 10: The parameters are recommended for higher layer.* maximum number of supported frequency hops [1,2, ..., 5]
* overlapping PRB(s) between adjacent hops or a capability on the maximum equivalent bandwidth after combing all hops [0,1,2, 4]
* UE capability on support of on-demand PRS with Rx hopping [Yes/No]
 |

### Round 1

We can start by discussing whether a new capability for on-demand PRS specifically for DL PRS with Rx hopping is needed.

**Proposal 4.9-1: a new UE capability on support of on-demand PRS with Rx hopping is introduced.**

* **FFS: details of the capability**

## PRS Muting enhancements [low]

### Background

In [8], enhancements for the DL PRS muting framework to account for the use of Rx hopping are proposed to be studied:

|  |  |
| --- | --- |
| Company | Proposal |
| [8] |  Proposal 8: For NR RedCap UEs, study the muting mechanism for frequency hopping sub-bands. |

### Round 1

The issue was brought up during RAN1#112b-e, but no feedback except from the proponent was received. Muting was not discussed during the SI phase, and no recommendation to extend the muting framework was captured. Therefore, we propose to restart the discussion again for this meeting with checking the support for the proposal above.

Comments can be entered in the table below:

|  |  |
| --- | --- |
| **Company** | **comment** |
|  |  |

# UL SRS Tx Hopping

## SRS Tx Hopping Pattern [high]

### Background

In RAN1#112b-e, we agreed to support the SRS tx hopping within one resource. In this meeting, many companies submitted proposals as to how to configure frequency hopping for the SRS.

We can see 3 different solution types presented in the contributions:

*Solution 1:*

Some companies focus on a so-called “staircase pattern”, which has hops overlapping consecutively as in figure X. this is proposed by [1][3][6][7]

* In[3] the stair case pattern is controlled by a repetition factor wich controls the number of hops-.
* In [6], the stair case pattern is controlled by
	+ In time: the starting symbol of the first hop, number of symbols per hop and switching period between hops.
	+ In frequency: the starting frequency allocation for the first hop, overlap and hop bandwidth for each hop.

*Solution 2:*

Other companies instead propose to instead reuse the SRS mimo frequency hopping equation, with some adaptations[2][15], using the existing parameters for frequency hopping, and introduce a parameter to control the amount of overlap.

* In [2], an update to the SRS bandwidth configuration table, is proposed, with additional rows taylors for Tx hopping.
* Additionally, intra-slot FH is proposed to be supported with a new symbol-level time gap between hops in [2][15].
* The number of hop is proposed to be computed based on configured total number of symbols across all hops, repetition factor and the retuning time capability of the UE in [15], noting that there is already a configured number of symbols and repetition factor in RRC.

*Solution 3:*

Finally, contributions in [4][5][14][16][21] propose to have a configurable hopping pattern using a combination

* Starting symbol for the first hop and Time domain offset between hops
	+ In [16], one option is to use slot based hopping and each hop starts in the same symbol position but in a different slot
* Starting frequency allocation and Frequency domain offset between time-consecutive hops
	+
* Number of hops

In [1], it is clarified that the hopping pattern should fit within the channel bandwidth, excluding the channel edges’ guard bands.

In [12], it is proposed to ensure that the overlap covers both the upper and the lower part of the hop in frequency domain. While a gap between allocation of different UEs in different part of the spectrum of the same symbol is introduced, in order to make sure that as many UE can be multiplexed without interfering with each other. From the FL perspective this could be seen as an optimization of the parameters to configure the staircase pattern, that could be achieved by implementation using solution 3.

|  |  |
| --- | --- |
| **Company** | **Proposal** |
| [1] |  Proposal 3: For UL SRS Tx hopping, support the following: * the staircase hopping pattern (as a starting point); and
* FFS the staggered hopping pattern

Proposal 4: For UL SRS frequency hopping with partial overlapping, support* excluding the guard bands on either side of the channel edge from the overlapping bandwidth determination
* the overlapping bandwidth is a configurable parameter
 |
| [2] | Proposal 3 * For SRS for positioning frequency hopping within one SRS resource, support to reuse the framework of MIMO SRS frequency hopping as a starting point.

Proposal 4* For frequency domain design of SRS for positioning frequency hopping, support the following.
* Reuse following parameters and mechanism for MIMO SRS frequency hopping
* freqDomainShift: $n\_{shift}$
* freqHopping:$C\_{SRS}$, $B\_{SRS} $and $b\_{hop}$
* freqDomainPosition: $n\_{RRC}$
* Frequency hopping enable mechanism: ‘$b\_{hop}<B\_{SRS}$’, e.g., $b\_{hop}=0, B\_{SRS}=1$
* Introduce ‘virtual UL BWP’ for hopping, similar to ‘SRS only BWP’ in RRC\_INACTIVE state
* Slightly update rows of Table ‘SRS bandwidth configuration’ in TS38.211, considering number of hops, hop bandwidth, frequency hopping total bandwidth, overlapping bandwidth, e.g.,

Table 6.4.1.4.3-1: SRS bandwidth configuration.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  |
| … | … | … | … | … | … | … | … | … |
| 63 | 272 | 1 | 16 | 17 | 8 | 2 | 4 | 2 |
| … | … | … | … | … | … | … | … | … |
| 64 | A1 | 1 | B1 | C1 | / | / | / | / |
| 65 | A2 | 1 | B2 | C2 | / | / | / | / |
| … | … | … | … | … | … | … | … | … |

* Slightly update frequency hopping offset function in TS38.211 to subtract the effect of overlapping bandwidth, e.g.,

$$n\_{offset}^{FH}=\sum\_{b=0}^{B\_{SRS}}(m\_{SRS,b}-overlap\\_BW)N\_{sc}^{RB}n\_{b}$$Proposal 5* For intra-slot time domain design of SRS for positioning frequency hopping, support the following:
* Reuse following parameters and mechanism for MIMO SRS frequency hopping
* The quantity of OFDM symbol number within a slot for an SRS resource: $l'\in \left\{0,1,…,N\_{symb}^{SRS}-1\right\}$
* Table of the $k\_{offset}^{l^{'}}$ (the table of relative RE offset)
* Repetition factor R
* Introduce symbol-level ‘time gap’ within an SRS resource
* Update the existing concept of$ N\_{symb}^{SRS}$ for ‘concecutive OFDM symbols’, considering symbol-level ‘time gap’
* Update symbol position within a slot for an SRS resource:$ l^{'}+l\_{0}$, considering symbol-level ‘time gap’
* For inter-slot time domain design of SRS for positioning frequency hopping, support the following:
* Introduce inter-slot repetition within an SRS resource
* Update the function of the quantity $n\_{SRS} $considering inter-slot repetition within an SRS resource
 |
| [3] |  Proposal 4: For SRS frequency hopping within one SRS resource, introducing the SRS repetition mechanism, UE achieve SRS frequency hopping between different SRS repetitions with one SRS resource. Proposal 6: Diagonal frequency hopping pattern should be supported and the overlapping hops are adjacent in the time domain.Proposal 9: For positioning for RedCap UEs, the number of hops for DL PRS Rx frequency hopping is a UE capability. |
| [4] |  Proposal 5: For the enhancement of pos-SRS configuration to achieve overlapped or non-overlapped Tx frequency hopping within one SRS resource, support introducing the following parameters:* Time domain offsets between adjacent hops
* Frequency domain offsets between (time-domain) adjacent hops
* Number of hops for the pos-SRS resource
* Note: The overlapping hops should be adjacent in the time domain for a single SRS hopping pattern.
 |
| [5] |  Proposal 2: Both the diagonal hopping pattern of SRS-Pos and the hopping pattern of SRS-MIMO can be supported.Proposal 3: UL Tx frequency hopping pattern information should include the following SRS-Pos resource configuration information in time domain and frequency domain.* In time domain:
	+ the start time of the frequency hopping pattern
	+ the end time of the frequency hopping pattern
	+ time gap between two consecutive hops (in unit of slot or OFDM symbol)
* In frequency domain:
	+ partial overlapping size(granularity: PRB or RE)
	+ starting PRB index per frequency hopping
	+ the number of frequency hopping N,N subject to UE capability
 |
| [6] |  Proposal 5* For SRS for positioning with frequency hopping for RedCap UEs,
* At least a staircase-like frequency hopping pattern is supported.
* In the time domain, the starting symbol of the first hop, number of symbols for SRS transmission and switching period between adjacent hops can be configured.
* In the frequency domain, the starting PRB of the first hop, number of overlapping PRBs, size of subband for each hop can be configured.
 |
| [7] |  Proposal 5: To improve positioning performance of SRS with hopping, overlapped PRBs are supported for two adjacent hops. * The hopping order in time is { nhop, nhop+1, …, nhop+N-1}mod N, where nhop is the start hop index and N is the number of hops

Proposal 6: For RedCap UE with positioning SRS, the number of overlapping PRBs in adjacent hops is based on the bandwidth of each hop* Larger bandwidth of each hop corresponds to more overlapped PRBs, the candidates of PRBs can be {1, 2, 4}
 |
| [12] |  Proposal 9: Support configuration of UL FH patterns which take advantage of both the top and bottom PRBs in the overall 100 MHz as shown in Figure 3. |
| [13] |  Proposal 1: The effects of the time and phase offset and the UE speed should be considered while designing the hopping patterns for the RedCap UEObservation 2: The effects of the phase offset between the frequency hops should be mitigated to get the gains of the frequency hopping operation.Proposal 2: For UE-assisted Redcap positioning, bandwidth overlap between the frequency hops should be supported.Proposal 3: The exact pattern of frequency hops should not be restricted.  |
| [14] |  Proposal 4: For the UL SRS Tx hopping pattern, overlapping hops do not have to be adjacent in the time domain as long as they occur within a duration of the channel not changing. |
| [15] |  Proposal 8: Downselect between the following alternatives for the SRS frequency hopping pattern:* Alt. 1: Use the current hopping formula of SRS as a starting point and update it such that there can be frequency domain overlap over 2 hops that are adjacent in frequency.
	+ Example of the update in the frequency-domain starting position $k\_{0}^{(p\_{i})}$ :

$$k\_{0}^{(p\_{i})}=\overbar{k}\_{0}^{(p\_{i})}+\sum\_{b=0}^{B\_{SRS}}(K\_{TC}M\_{sc,b}^{SRS}n\_{b} -M\_{overlap}⋅n\_{b}⋅\prod\_{b^{'}=b+1}^{B\_{SRS}}N\_{b^{'}})$$* Alt.2 2: Use a staircase-like hopping formula with a parameter that controls the amount of overlap of frequency domain adjacent hops.

Proposal 10: Support intra-slot SRS hopping and inter-slot hopping in X consecutive available slots for periodic, semi-persistent, aperiodic SRS for positioning.* Support at least $N\_{interslot}=\{2\}$ slots
	+ FFS: Additional $N\_{interslot}$ values
* Introduce a new RRC parameter on the number of inter-slot repetitions
* FFS: Definition of “available” slot for SRS frequency hopping

Proposal 11: The nominal number of hops in a slot ($N\_{h})$ is computed as follows: $ N\_{h}= \left⌊\frac{N\_{s}+N\_{RF}}{N\_{RF}+R}\right⌋$, where* $N\_{RF} $: UE capability for the number of symbols gap needed between hops
* $N\_{s}$ : Configured total number of symbols of an SRS resource (nrofSymbols) in a slot.
	+ Note: This configuration already exists in RRC.
* $R$: Number of OFDM symbols within each hop, configured through the parameter repetitionFactor .
	+ Note: This configuration already exists in RRC.
 |
| [16] | * The number of symbols of SRS-pos resource is used to determine the number of symbols of each hop

Proposal 3: For the intra-slot + inter-slot SRS-pos Tx hopping mechanism:* Select one of the methods for resource mapping scheme for preventing the hop from crossing over the slot boundary
	+ Alt 1: By limiting the start position according to the symbol length of each hop and switching gap between consecutive hops.
	+ Alt 2: By repeating the time-domain hopping pattern of the first slot in other slots

Proposal 4: SRS for positioning frequency hopping configured with frequency hopping configuration ID which is pre-defined via RRC should be supported.  |
| [21] |  Proposal 6 Introduce a new frequency domain offset to support multiplexing of SRS frequency hopping and its value range can be from 0 to [14].Proposal 7 Introduce a new repetition number to indicate the number of SRS frequency hopping where each hop has one symbol in one SRS frequency hopping, or to indicate the number of symbols in one SRS hop, if partially overlapped SRS frequency hopping is configured. |
| [22] |  Proposal 5-1: The SRS hopping pattern could be up to NW configuration except that, the duration between end of a hop and the beginning of next hop should be longer than RF switch time reported by a UE |

### Round 1

Before going into a detailed solution, we should start by identifying which of the 3 solution we should implement,

* A Staircase pattern
* Re-use the mimo FH equation with an update to account for overlap and retuning time
* A comfigurable pattern, not limited to the staircase pattern.

The details on how granular the configuration is (e.g. the starting symbol for each hop, inter-slot or intra slot hopping, etc) can be discussed afterward. The ambition is that we should continue discussing the details during this meeting, i.e. not downselect later.

**Proposal 5.1-2: For the SRS Tx hopping pattern configuration support (select one)**

* **A Staircase pattern, where each hop follows the preceeding hop with an overlap in frequency**
* **Re-use the mimo FH equation with an update to account for overlap and retuning time**
* **A comfigurable pattern, not limited to the staircase pattern, where each hop overlap with another hop in the pattern, but the overlapping hops do not need to be adjacent in time.**

Companies are encouraged to comment on the proposal in the table below:

**Proposal 5.1-2:**

|  |  |
| --- | --- |
| **Company** | **Comment** |
|  |  |

## Collision rules [high]

### Background

Collision was discussed last meeting and two option were agreed for further discussion:

|  |
| --- |
| **Agreement**For RedCap UEs positioning transmitting the UL SRS with frequency hopping, regarding the collisions between other UL and DL signals/channels and the UL SRS with frequency hopping, study whether to support one or both of the following options, according to UE capabilities:* Option 1: UL time window where the UE is not expected to receive/transmit other signals/channels and is only expected to transmit FH SRS for positioning.
	+ FFS details of an UL time window
	+ Note: it implies that UE drops the transmission of other signals/channels and transmits SRS for positioning
* Option 2: additional collision rules between the UL SRS with frequency hopping and other UL and DL signals/channels
	+ FFS: details on the collision rules
 |

In this meeting, the contributions show that companies have interest for both of the options:

* Option 1: UL time window [5][6][8][12][14][16][18][19][22]
	+ Not supported by [11]
* Option 2: Additional collision rules: [2][3][4][7][8][10][11][15][16][22]

Regarding the UL time window, [5][8] proposes to specify a periodic time window, similar to DL measurement gap. [8] discuss whether the

Regarding the additional dropping rules, the following is proposed:

* [2][8] propose to discuss whether to drop all the SRS hops, only the affected hop, or the affected symbols
* [4] proposes to add a condition for dropping the SRS to come back to the active BWP. If the turnaround time to and from the active BWP is larger than the time between hops, the UE does not return to the active BWP
* [7] proposes to treat the SRS with low priority when outside of the active BWP, similar to SRS in RRC inactive in release 17.
* [10],[15] [21] propose to re-use formulation from SRS carrier switching to drop the SRS with Tx hopping if the UE receives notification of UL dynamic scheduling with enough advance. [15] proposes to drop only the colliding hop.

|  |  |
| --- | --- |
| **Company** | **Proposal** |
| [2] | Proposal 9* For SRS for positioning frequency hopping collides with other DL/UL reception/transmission, Option 2 is supported with the following aspects.
* The dropping rules should include the following based on different scenarios and UE capabilities
* Alt 1: UE drops all the SRS hops
* Alt 2: UE drops affected hops
* Alt 3: UE drops affected symbols
* The other DL/UL reception/transmission should include other UL signals/channels, DL signals/channels in TDD, DL signals/channels for half-duplex UE (HD-UE) in FDD

  |
| [3] |  Proposal 7: When one or more SRS frequency hops collide with other UL and DL signals/channels in once SRS transmission, additional collision rules between the UL SRS with frequency hopping and other UL and DL signals/channels need to be defined. |
| [4] |  Proposal 6: Consider introducing the following collision rule between SRS and other UL&DL signals/channels.• To ensure the transmission of two adjacent SRS hops not collide with other signals/channels in the active UL BWP, if the sum of the retuning time to the active UL BWP after the first hop, and the retuning time from the active UL BWP prior to the second hop is larger than the configured time domain offsets, UE is not required to switch to the active UL BWP; otherwise UE is required to switch to the active UL BWP. |
| [5] |  Proposal 4: Support the following parameters for UL time window indication from gNB to UE (Option 1),• UL time window ID(Indicates the pre-configured ID for UL time window configuration)• starting slot/symbol• Periodicity• Duration(indicates the length of DL-PRS processing window) |
| [6] |  Proposal 6• For collision handling of positioning SRS with frequency hopping, at least Option 1 (UL time window where the UE is not expected to receive/transmit other signals/channels and is only expected to transmit FH SRS for positioning) is supported. |
| [7] |  Proposal 8: For RedCap UEs positioning transmitting the UL SRS with frequency hopping, regarding the collisions between other UL and DL signals/channels and the UL SRS with frequency hopping, * If the SRS hop is within the initial BWP, the existing dropping rule for RRC\_CONNECTED state is reused.
* If the SRS hop is outside the initial BWP, Rel-17 defined rule for SRS outside initial BWP in RRC\_INACTIVE state is reused, i.e. SRS has low priority.
 |
| [8] |  Proposal 10: Definition of DL measurement gap can be taken as a start point for UL time window definition, which includes period, offset and length at least.Proposal 11: Support same period configuration for DL measurement gap and UL time window for positioning, and the period can be the indicated one or two times of the indicated one when both DL measurement gap and UL time window are configured or activated.Proposal 12: Two level offsets can be considered to decrease the overhead of UL time window, where one offset is a legacy one in terms of subframe, and another one is in unit of slot with length in unit of slots simultaneously.Proposal 13: Several dropping alternatives can be considered when dropping positioning SRS with frequency hopping is needed, which are:Alt-1: Drop the collided symbols within the collided hops, the rest symbols within the collided hop and the rest hops are still transmitted.Alt-2: Drop the collided hop, the rest hops are still transmitted.Alt-3: Drop the collided hop and the rest hops after the collided hop. |
| [10] |  Proposal 8: For RedCap UEs positioning transmitting the UL SRS with frequency hopping, support to define additional collision rules between the UL SRS with frequency hopping and other UL and DL signals/channels:* If SRS resources for Tx frequency hopping collides with a Type 1 configured grant of UL/DL channels/signals, UE drops SRS resources for Tx frequency hopping;
* If a DCI scheduling a dynamic grant or Type 2 configured grant of UL/DL channels/signals arrives before T ahead of the first symbol of SRS resources for Tx frequency hopping, and collides with SRS resources for Tx frequency hopping, UE drops SRS resources for Tx frequency hopping; otherwise, UE drops the schedule UL/DL channels/signals;
	+ - T is a preparation time for transmission of SRS resources for Tx frequency hopping and switching time.
 |
| [11] |  Proposal 9: Do not support Option 1 “UL time window where the UE is not expected to receive/transmit other signals/channels and is only expected to transmit FH SRS for positioning”Proposal 10: Support Option 2 “Additional collision rules between the UL SRS with frequency hopping and other UL and DL signals/channels”Proposal 11: Adopt collision rules between higher-priority UL channel/signal transmission and gap between SRS for positioning hops |
| [12] |  Proposal 8: Support Option 1: an UL time window where the UE is not expected to receive/transmit other signals/channels and is only expecting to transmit FH SRS for positioning.  |
| [14] |  Proposal 9: RAN1 should support the UL time window concept for UL SS with frequency hopping to account for possible collisions between other UL and DL signals/channels and the UL SRS with frequency hopping. Proposal 10: An UL Hopping SRS instance collides with DL/UL signal/channel if any portion of the other DL/UL signal/channel overlaps with the time interval starting X symbols before the transmission and ending Y symbols after the transmission. Note that X and Y may be different for UL and DL signals and channels. Proposal 11: It is also necessary to discuss if the window spans a single hop or spans the entire hop sequence. This could be chosen based on a UE capability. The UL time window can be configured based on higher level signaling. Observation: If the UL time window spans the entire hop sequence and no additional collision rules are defined then, at least for SRS measurement, there is no need to discuss the per-hop or single measurement issue. Proposal 12: The use of any additional collision rules should be based on a UE capability. |
| [15] |  Proposal 13: For the purpose of SRS frequency hopping, support additional collision rules between the UL SRS with frequency hopping and other UL and DL signals/channels where the rules defined in the SRS carrier switching framework are used as starting point (Section 6.2.1.3 of 38.214). * An SRS hop is dropped whenever one or more symbols of the hop, including any interruption due to uplink RF retuning time collides with a higher priority channel
 |
| [16] |  Proposal 6: For collision handling rule, support both following options: * Opt. 1) UL time domain window where UE is expected to transmit only SRS for positioning
* Opt. 2) Hop level dropping with priority rule between SRS for positioning and other UL transmission
 |
| [18] |  Proposal 7: the option 1 with a configured UL time window to prioritize SRS transmission is supported.  |
| [19] |  Proposal 3* RAN1 should support UL time window where the UE is not expected to receive/transmit other signals/channels and is only expected to transmit FH SRS for positioning.
 |
| [21] | 1. For RedCap UEs positioning transmitting the UL SRS with frequency hopping, a UL time window is supported.
	* The uplink time window starts Nstart symbols ahead of the first SRS symbol in the first hop and ends Nend symbols after the last SRS symbol in the last hop.
	* When the UE is scheduled with a dynamic PUSCH within the UL time window so that the UE receives a DCI scheduling PUSCH N2 symbols ahead of the UL time window or is scheduled to transmit a PUSCH/PUCCH transmission carrying HARQ-ACK/positive SR/RI/CRI/SSBRI, or aperiodic CSI within the window, the UE drops the SRS for positioning with Tx hopping transmission.
	* Otherwise, the UE drops the transmission of other signals/channels and transmits only the SRS for positioning.
 |
| [22] |  Proposal 5-2: Support both options for collision issue during SRS hopping. Proposal 5-3: The collision rule may consider the dropping of SRS hopping in a per slot basis, if the time window is across slots |

### Round 1

Since there is clearly interest for both options, let’s see first if supporting both of the two studied option is agreeable, or if downselection is necessary:

**Proposal 5.2-1: For RedCap UEs positioning transmitting the UL SRS with frequency hopping, regarding the collisions between other UL and DL signals/channels and the UL SRS with frequency hopping, support both of the following options, according to UE capabilities:**

* **Option 1: UL time window where the UE is not expected to receive/transmit other signals/channels and is only expected to transmit FH SRS for positioning.**
	+ **FFS details of an UL time window**
	+ **Note: it implies that UE drops the transmission of other signals/channels and transmits SRS for positioning**
* **Option 2: additional collision rules between the UL SRS with frequency hopping and other UL and DL signals/channels**
	+ **FFS: details on the collision rules**

Comments can be entered in the table below:

**Proposal 5.2-1**

|  |  |
| --- | --- |
| **Company** | **comment** |
|  |  |

## Configuration outside the active BWP [medium]

### Background

In [4][10][15], it is propose to configure the SRS with Tx hopping outside of the active BWP, using either a virtual BWP, or a SRS configuration separate from the active UL BWP and associated with a CC.

|  |  |
| --- | --- |
| **Company** | **Proposal** |
| [4] | Proposal 3: Support SRS transmission outside the active UL BWP to support SRS Tx hopping based positioning of RedCap UEs in RRC\_CONNECTED state. |
| [10] | Proposal 5: For RedCap UEs, consider the following enhancement on BWP configuration to support SRS for positioning frequency hopping:* Define a virtual UL BWP which is outside of RedCap UE active BWP limitation and covers all SRS for positioning hops;
 |
| [15] | Proposal 7: For an SRS resource used for Positioning frequency hopping:* It is associated with a CC and includes a configuration of a numerology and bandwidth.
* Introduce a transmission/switching/retune gap before the first hop of such an SRS resource and after the last hop, so that the UE can tune from the active BWP and back to the active BWP.
	+ Up to RAN4 the details
 |

### Round 1

There is consensus in the proposals that the configuration for SRS tx hopping should be outside of the active UL BWP. We can check whether further details can be included in the agreement:

**Proposal 5.3-1: The SRS for positioning resources with Tx Hopping are configured in a configuration separate from the UL active BWP configuration.**

* **The configuration consists of**
	+ **Option1: a virtual BWP containing the SRS configuration.**
	+ **Option 2: a SRS resource configuration with an associated CC, numerology, and bandwidth.**

Comments can be entered in the table below:

**Proposal 5.3-1**

|  |  |
| --- | --- |
| **Company** | **comment** |
|  |  |

## Configuration of the Bandwidth overlap between hops [high]

### Background

In [4], it is proposed to extend the support of DL and UL measurements with FH to the RRC\_INACTIVE mode:

|  |  |
| --- | --- |
| **Company** | **Proposal** |
| [1] | values) to cover 100 MHz (FR1) and 400 MHz (FR2) bandwidth. Proposal 2: For Tx frequency hopping configured within one positioning SRS resource, support the following configurable parameters as a baseline: * Hop switching time which can be any of this set of values: {70 µs, 140 µs} for FR1 and {35 µs, 70 µs, 140 µs} for FR2
* Hopping bandwidth which can be any of this set of values: for instance, {5 MHz, 10 MHz, 15 MHz, 20 MHz} for FR1 and {50 MHz, 100 MHz} for FR2
* Short Zadoff-Chu sequence with length up to the hopping bandwidth or long Zadoff-Chu sequence with length up to the total (or wide) frequency-hopping bandwidth
 |
| [2] | Proposal 8* For the sizes of overlapping bandwidth for different hops, the balance between phase error compensation performance and bandwidth span of frequency hopping should be considered.
* A size smaller than 8 PRBs can be considered
 |
| [3] | Proposal 8: The number of overlapping frequency resources in adjacent hops required for the UE to perform phase offset compensation the overlap between hop for DL PRS Rx frequency hopping is a UE capability. |
| [8] | Proposal 3: For frequency hopping of PRS or SRS, support configurable overlapped bandwidth between two adjacent hops to address the influence caused by phase offset between hops.Proposal 6: For frequency hopping of PRS or SRS, support size of overlapped bandwidth between two adjacent hops is decided by channel quality. |
| [10] | Proposal 6: To support RS frequency hopping, the partial overlapping in the frequency domain should be considered to mitigate the phase discontinuity between different hops.Proposal 7: To support RS frequency hopping, at least consider the following additional parameters on top of that supported for Rel-15 SRS resources:* Number of overlapped PRB or PRB offset between two adjacent hops
* The switching time gap between two adjacent hops
 |
| [11] | Proposal 1: The amount of overlapped bandwidth is associated with gap between two consecutive frequency hops for UL frequency hopping and Rx frequency hopping |
| [12] | Proposal 7: For the SRS frequency hopping, the SRS configuration independent with the existing UL BWP supports at least with the following configuration parameters * Starting RB index and the number of RBs of the SRS resource,
* Starting slot, the number of slots and/or the number of symbols
* Periodicity and offset
* SRS sequence ID
* Number of frequency hops,
* Gap time between frequency hops,
* Number of RBs overlapped between frequency hops
 |
| [16] | Proposal 2-1: Adopt following new parameters are included in SRS-pos frequency hopping configuration* Number of hops
* Overlap size which can be set to zero

 Proposal 2-2: Following parameters in legacy SRS-pos resource configuration can be reused to SRS-pos frequency hopping configuration* Bandwidth of SRS-pos resource is used to determine the bandwidth of each hop
* Starting position of SRS-pos resource in time/frequency domain is used to determine the Starting position in time/frequency domain for the first hop
* The number of symbols of SRS-pos resource is used to determine the number of symbols of each hop
 |
| 13 | **Proposal 4**: For RedCap positioning, the overlap of bandwidth between the adjacent hops is X PRB. The possible values of X are 1,2,4,8 PRB. |
| [15] | Proposal 9: Support in the specification multiple overlap options between 2 frequency-adjacent hops with a minimum value of 1 PRB and a minimum granularity of 1 PRB.  |
| [14] | Proposal 3: On the overlap between hops and number of hops, the hopping configuration needs to identify at least the following:* the number of hops,
* the bandwidth of each hop,
* the amount of overlap between hops.

These are dependent on the UE capability. Proposal 5 : To support SRS for positioning frequency hopping, the hopping configuration needs to identify at least the following:* the number of hops,
* the bandwidth of each hop,
* the amount of overlap between hops.
* The time between hops
* For the overlap configuration of SRS Tx hopping include the starting PRB for each hop

These are dependent on the UE capability. |
| [21] | Proposal 5 SRS for positioning Tx bandwidth hopping is supported for RedCap UEs, by extending the SRS configuration with at leasti. The total BW to be covered over all hopsii. The gap (in symbols) between two adjacent hopsiii. The overlap between two adjacent hops in frequency domain |

### Round 1

For the configuration of the SRS for positioning with Tx hopping, many parameters depends on how the Tx hopping pattern is built, either using an equation similar to the one for SRS Mimo FH, or a different configuration. For all solution, it seems at least necessary to introduce a parameter for the overlap between hops and based on the received proposal, the minimum overlap can be zero, i.e. no overlap:

**Proposal 5.4-1: SRS Tx Frequency hopping is configured with an overlap between hops.**

* **Support in the specification multiple overlap options between 2 frequency-adjacent hops with a minimum value of 0 PRB and a minimum granularity of 1 PRB.**
* **FFS: The maximum value of the overlap**

Companies are encouraged to comment on the proposal in the table below:

**Proposal 5.4-1:**

|  |  |
| --- | --- |
| Company | Comment |
|  |  |

## Support of SRS Tx hopping in RRC\_INACTIVE state [medium]

### Background

In [4], it is proposed to extend the support of DL and UL measurements with FH to the RRC\_INACTIVE mode:

|  |  |
| --- | --- |
| **Company** | **Proposal** |
| [4] | Proposal 4: Define a virtual BWP beyond maximum RedCap UE bandwidth to achieve SRS Tx frequency hopping for RedCap UEs in RRC\_INACTIVE or RRC\_CONNECTED state. |

### Round 1

**Proposal 5.5-1: SRS Tx Frequency hopping is supported for for both RRC\_CONNECTED and RRC\_INACTIVE state.**

Companies are encouraged to comment on the proposal in the table below:

**Proposal 5.5-1:**

|  |  |
| --- | --- |
| **Company** | **Comment** |
|  |  |

## Sequence design [medium]

### Background

 The transmitted sequence in a given SRS resource with FH is discussed in [1][12]. In [1] it is propose to have the sequence span a single hop, while in [12] it is instead proposed to a sequence spanning all hops (where each hop thus transmit part of the sequence) and let the UE request the network to configure a sequence satisfying a certain PAPR level

|  |  |
| --- | --- |
| **Company** | **Proposal** |
| [1] | Proposal 2: For Tx frequency hopping configured within one positioning SRS resource, support the following configurable parameters as a baseline: * Hop switching time which can be any of this set of values: {70 µs, 140 µs} for FR1 and {35 µs, 70 µs, 140 µs} for FR2
* Hopping bandwidth which can be any of this set of values: for instance, {5 MHz, 10 MHz, 15 MHz, 20 MHz} for FR1 and {50 MHz, 100 MHz} for FR2
* Short Zadoff-Chu sequence with length up to the hopping bandwidth or long Zadoff-Chu sequence with length up to the total (or wide) frequency-hopping bandwidth
 |
| [12] | Proposal 5: When UE is FH within an SRS resource it should transmit part of the SRS resource/sequence (i.e., 1 SRS frequency hop) during one hop.Proposal 6: RAN1 supports UE to request an SRS sequence that satisfies a certain level of PAPR performance. |

### Round 1

From the existing specification for the SRS for MIMO, frequency hopping is done across an SRS resource, such that each hop is a ZC sequence of size $M\_{sc,b}^{SRS}$ . Thus, it seems that if the same mapping used for SRS for MIMO is used for frequency hopping, a ZC sequence with the size of the hop will be used.

Further details may have to be discussed once the hopping patterns and how to generate them have been agreed. Regarding the proposal in [12] to have the UE request a certain level of PAPR, it is added as a possible FFS.

**Proposal 5.6-1: for UL SRS Tx hopping, a single ZC sequence is mapped to each of the hop**

* **FFS remaining details**
* **FFS: whether the UE can request an SRS sequence that satisfies a certain level of PAPR performance.**

Companies are encouraged to comment on the proposal in the table below:

**Proposal 5.6-1**

|  |  |
| --- | --- |
| **Company** | **comment** |
|  |  |

## MIMO SRS support for Tx Hopping [medium]

In [4] it is proposed to support the SRS for MIMO with frequency hopping to implement Tx hopping in UL.

|  |  |
| --- | --- |
| Company | Proposal |
| [4] | Proposal 7: Subject to UE capability, within a virtual BWP with bandwidth beyond maximum RedCap UE bandwidth to achieve SRS Tx frequency hopping, MIMO SRS can also be configured. |

Since there is only one company advancing this proposal, we should first collect views on the support of this proposal:

Companies are encouraged to comment on the proposal in the table below:

|  |  |
| --- | --- |
| Company | Comment |
|  |  |

## Pre-compensation of the Tx phase

In [12], it is proposed to support letting the UE perform pre-compensation prior to the transmission of the UL SRS.

|  |  |
| --- | --- |
| **Company** | **Proposal** |
| [12] | Proposal 2: RAN1 should support phase alignment for Multi-RTT and determine if phase alignment is needed for both UL at the gNB and DL at the UE. |

From the FL perspective, how pre-compensation is done is up to UE implementation. However, the UE could signal no need for overlap in the Tx hopping if it can maintain the phase by itself without the TRP requiring to perform phase compensation. Thus we propose instead to discuss the case of no overlap in the UL SRS configuration discussion.

Companies are encouraged to comment on the proposal in the table below:

|  |  |
| --- | --- |
| Company | Comment |
|  |  |

##  BWP Switching [low]

### Background

In [17], it is proposed to use BWP switching using an resource in each BWP:

|  |  |
| --- | --- |
| Company | Proposal |
| [17] | Proposal 1: For RedCap UEs positioning, support the SRS frequency hopping across multiple BWPs within one SRS resource.  |

In the previous meeting, the following agreement was reached:

|  |
| --- |
| **Agreement**For RedCap UEs, SRS for positioning Tx frequency hopping is configured within one SRS for positioning resource. |

Based on the previous agreement, the proposal seem to be contradicting the currently agreed design. Therefore, it will not be pursued. Companies are encouraged to comment below if further discussion is needed on the issue:

|  |  |
| --- | --- |
| Company | Comment |
|  |  |

## Support of Tx hopping with Aperiodic and Semi Persistent SRS [medium]

### Background

In [6][12][16] it is proposed to support aperiodic and semi persistent scheduling of the UL SRS with Tx hopping. Note that since the SRS configuration is outside of the active BWP transmission, the aperiodic SRS resource will have to be associated with a DCI sent in the active BWP.

|  |  |
| --- | --- |
| Company | Proposal |
| [6] | Proposal 4* Semi-persistent and aperiodic SRS transmission are supported for SRS for positioning with Tx frequency hopping for RedCap UEs.
 |
| [12] | Proposal 10: RAN1 should discuss the way to reduce the time gap and unnecessary signalling overhead of RedCap FH for positioning (e.g., support a single DCI triggering all the switching). |
| [16] | Proposal 5: Support frequency hopping of SRS-pos is activated/deactivated by MAC-CE. |

### Round 1

**Proposal 5.10-1: Semi-persistent and aperiodic SRS transmission are supported for SRS for positioning with Tx frequency hopping for RedCap UEs.**

**Proposal 5.10-1:**

|  |  |
| --- | --- |
| Company | Comment |
|  |  |

##  Power control of the UL SRS with Tx hopping [medium]

### Background

 In [21] power control for the SRS while hopping is discussed, and it is proposed to use the same pathloss estimate across the hopping procedure.

|  |  |
| --- | --- |
| **Company** | **Proposal** |
| [16] | Proposal 12 UE uses same pathloss estimation for SRS transmission during one SRS frequency hopping duration if uplink power control is configured. |

### Round 1

As only a single company has discussed the issue, we can start by collecting views.

**Proposal 5.11-1: UE uses same pathloss estimation for SRS transmission during one SRS frequency hopping duration if uplink power control is configured.**

Comments can be entered in the table below:

**Proposal 5.11-1:**

|  |  |
| --- | --- |
| **Company** | **Comment** |
|  |  |

# Conclusion

TBD

#  References

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