3GPP TSG RAN WG1 Meeting #105-e R1-2108217

**e-Meeting, Aug. 16th – 27th, 2021**

**Source: Moderator (ZTE)**

Title: FL summary #1 on SRS enhancements

Agenda Item: 8.1.3

Document for: Discussion and Decision

# Introduction

In RAN#86, the Rel-17 WID of further enhancements on MIMO for NR is approved [1]. In the approved WID, a particular point is about SRS enhancements in terms of flexibility, coverage and capacity, targeting both FR1 and FR2. The detailed scope of the SRS enhancement is given as follows.

*3. Enhancement on SRS, targeting both FR1 and FR2:*

* 1. *Identify and specify enhancements on aperiodic SRS triggering to facilitate more flexible triggering and/or DCI overhead/usage reduction*
	2. *Specify SRS switching for up to 8 antennas (e.g., xTyR, x = {1, 2, 4} and y = {6, 8})*
	3. *Evaluate and, if needed, specify the following mechanism(s) to enhance SRS capacity and/or coverage: SRS time bundling, increased SRS repetition, partial sounding across frequency*

Previous RAN1 agreements on these SRS enhancements are given in Section 6.1.

In this contribution, we summarize companies’ views on the above SRS enhancements submitted to RAN1#104b-e [2]-[25].

# Flexibility enhancements

## SRS triggering offset

### 2.1.1. Reference slot definition

Two options are given in RAN1#103e’s agreement on the definition of reference slot. The following table summarizes companies’ views on these two options.

Table 2-1

|  |
| --- |
| **Reference slot definition** |
|  | Number | Companies |
| Opt. 1 (Reference slot is the slot with the triggering DCI) | 5 | LGE, Huawei/HiSilicon, Futurewei, OPPO, Spreadtrum |
| Opt. 2 (Reference slot is the slot indicated by the legacy triggering offset) | 17 | Qualcomm, CMCC, MediaTek, Ericsson, Intel, Sharp, NTT DOCOMO, Xiaomi, Nokia/NSB, vivo, InterDigital, Samsung, CATT, NEC, Apple, Lenovo/MotM, ZTE |

Given the super-majority view, the following FL proposal is recommended.

***FL Proposal:*** *Support Opt. 2: Reference slot is the slot indicated by the legacy triggering offset.*

* *If DCI is transmitted in slot n, and k is the legacy triggering offset, reference slot is slot n+k.*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | These two options have been discussed in multiple meetings. As we commented several times, Option 2 has no benefit from the technical perspective. Considering that the deadline of R17 completion is approaching, we can compromise, for the sake of progress, to support both Option 1 and Option 2 by separate UE capabilities, e.g.,Capability 1: Support Option 2 with the legacy triggering offset configured Capability 2: Support Option 2 without the legacy triggering offset configuredIn this case, UE has the flexibility to support one or both of them  |
| Apple | We are fine. But we need clarification that when we use legacy triggering offset as the reference slot, is it based on the legacy rule (i.e., any slot), or the new rule (i.e., only the available slot) to determine the reference slot?*FL’s response:* Reference slot is determined by the legacy rule. Specifically, if DCI is transmitted in slot n, and k is the configured legacy triggering offset, reference slot is slot n+k. |
| NEC | Support the FL proposal. |
| Huawei, HiSilicon | Not support. There are many issues for Option-2: 1) Non-flexible: due to the legacy triggering offset is still kept in Option-2, the SRS transmission can only be later than the RRC configured triggering offset. 2) More overhead: if introduce negative values of t to overcome the issue of non-flexible, then more bits to define the negative values. 3) More complexity: due to more steps for UE to determine the slot for SRS transmission, not only with t, but also need consider the legacy triggering offset. |
| Futurewei | We think Apple raised a good question. For Option 2, the UE behavior for the legacy offset and new offset may be different in terms of how to count the slots, which leads to some complexity. That is, the UE has to follow two different ways to do the counting for an A-SRS. Option 1 is a better solution. |
| Lenovo/MotM | Support the LF proposal.  |
| InterDigital | Support FL proposal. Option 2 is a simpler enhancement, and it is the natural extension of the legacy system. Furthermore, Option 2 is more flexible, and has clear benefits over Option 1. If ever needed, Option 2 can be configured as Option 1 by simply configuring the legacy offset value to zero. |
| MediaTek | Support the FL proposal |
| Xiaomi | Support the FL proposal |
| ZTE | Although our first preference is Opt 1, we can accept the FL proposal for the sake of progress.  |
| QC | Support the FL proposal. |
| Samsung | Support FL’s proposal, we have similar view as IDC. As in Rel-15, the legacy offset can be absent (means zero) and has flexibility to use either or both option 1 and 2. |
| Spreadtrum | Support Opt.1, which is obviously a much simpler solution. |
| CATT | Support FL’s proposal. Option 2 is supported since option 1 is a special case of option 2 with *slotoffset* set to 0 or not configured. |
| Ericsson | Support FL Proposal |
| CMCC | Support the FL proposal. For the issue raised by Apple, according to the original description, the RRC configured offset should be the legacy offset counted as consecutive slots, which is also clarified by the FL.* *Opt. 1: Reference slot is the slot with the triggering DCI.*
* *Opt. 2: Reference slot is the slot indicated by the legacy triggering offset.*
 |
| Intel | Support FL proposal. Option 1 is a special case of Option 2. |

### 2.1.2. Collision handling

One FFS point from RAN1#104e’s agreement on available slot definition is “rules to handle the case of multiple SRS resource sets with overlapping symbols and/or triggered by a same DCI”. Companies’ detailed views are given in the table below.

Table 2-2

|  |
| --- |
| **Collision handling** |
| Views | Companies | Priority rules |
| Introduce dropping rule when collision happens among aperiodic SRS resource sets | Qualcomm, ZTE (for SRS in different CCs), Ericsson, Intel, vivo (including SRS in one or more CCs triggered by one or more DCIs), Futurewei (including SRS and other UL channels/signals) , Huawei/HiSilicon, Spreadtrum | Ericsson* Based on usage: AS > BM > CB

vivo* Including usage, order of triggering DCI, CC ID and set ID

Futurewei* A/N and AP UL triggered later than R17 flexible A-SRS > R17 flexible A-SRS > other UL
 |
| Do not introduce new dropping rule | OPPO | - |

Based on views provided by companies, the following proposal is given.

***FL Proposal:*** *Introduce dropping rule when collision happens among multiple aperiodic SRS resource sets in a same CC or different CCs.*

* *FFS the priority rule considering usage, order of triggering DCI, CC ID and set ID, whether the SRS is the Rel-17 flexible SRS, etc.*
* *FFS collision handling among Rel-17 flexible SRS and other UL channels/signals*
* *FFS whether to restrict this rule is only applicable to SRS resource sets triggered by a same DCI or different DCI*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | We don’t think this is a problem. It is up to gNB implementation.  |
| Apple | We do not prefer collision handling. If we want to discuss it, we prefer to limit the case when colliding SRS resource sets are triggered by the same DCI *FL’s response:* Thanks for the clarification. Your position is updated in the table. An FFS point is added in the proposal on the applicable case. |
| NEC | Fine with the FL proposal. |
| LGE | Generally fine, but can we “study” whether to support dropping rule, rather than “introduce”? Because there is no details yet on the dropping rule to be supported in our perspective.And, we have similar view with Apple’s comment. |
| Huawei, HiSilicon | We are fine for it. |
| Futurewei | Support the FL proposal. We think collision handling is quite necessary, especially insufficient triggering flexibility has been introduced and the SRS capacity is limited. If companies wish to minimize collision handling spec impact, then we think more DCI indication flexibility (such as frequency domain resource indication) should be introduced to reduce potential collisions. |
| Lenovo/MotM | We prefer to leave it to NW implementation but ok to discuss. |
| MediaTek | Same view as Apple, LGE and Lenovo. We’d like know if this can be handled in NW in a transparent way. If not possible, then we can discuss the scope of dropping rule (e.g., by the same DCI or whether includes other channels)  |
| Xiaomi | Agree with LGE to “study” first |
| ZTE | We support the FL proposal. We think both same DCI and different DCI should be considered. Specifically, for the UEs which cannot support to transmit SRS simultaneously in different CCs, it is hard for gNB scheduler to avoid collision as all the intra-band CCs should have same slot format, and available slot rule will potentially cause more collision. For collided SRS in different CCs, without collision handling rule, gNB cannot transmit SRS in neither CCs, which will cause large restriction and complexity for gNB scheduler design. |
| QC | We support collision rule for same CC and same DCI. Also, open to discuss the other case for multiple CCs. |
| Samsung | Share same view as Lenovo |
| Spreadtrum | Support FL proposal. |
| CATT | Collision handling for SRS resource sets triggered by the same DCI is not needed since the collision can be avoided by gNB’s implementation. We are open to discuss whether collision handling is needed for cross CA to reduce the scheduling complexity of gNB’s scheduling. |
| Ericsson | Support the FL proposal and aim for detailed solution agreements next meeting. |
| CMCC | Do not see this issue at least for the same CC scenario. For the collision among SRS resources aperiodic triggered, it is solved through the configuration of the RRC offsets. And it could be solved in the same way at least for the same CC.  |
| Intel | Support to have collision handling rule for aperiodic SRS across different CC. Similar view as CATT regarding SRS triggered by the same DCI. |

### 2.1.3 Determination on the value of t

**DCI indication mechanism**

A WA was achieved in RAN1#104bis-e on DCI indication of t as given in Section 6.1. A number of companies propose to confirm this WA. Further, some companies discuss whether another mechanism is introduced for non-scheduling DCI when this new field is not configured. Companies’ views are summarized in the following table

Table 2-3

|  |
| --- |
| **On WA of DCI indication mechanism of t** |
| Number | Companies |
| Confirm the WA | ZTE, CATT, Huawei/HiSilicon, OPPO, vivo, Lenovo/MotM, Xiaomi, MediaTek, Nokia/NSB, InterDigital, Futurewei, LGE, Apple, NEC, Qualcomm, Spreadtrum, Samsung, Ericsson |
| **Whether another mechanism is introduced** |
| Number | Companies |
| Repurpose unused filed(s) to indicate t when the new field is not configured, for DCI format 0\_1/0\_2 without CSI request and without data | ZTE, MediaTek, Ericsson, NTT DOCOMO, Samsung, CATT |
| Do not introduce another mechanism to indicate t | Qualcomm |

At least it is common understanding to confirm the WA. Whether the other scheme is introduced can be further discussed in 2.2.

***FL Proposal:*** *Confirm the following WA.*

*For DCI indication of “t” in Rel-17 SRS triggering offset enhancement*

* *For both DCI that schedules a PDSCH/PUSCH and DCI 0\_1/0\_2 without data and without CSI request*
	+ *t is indicated by adding a new configurable DCI field (up to 2 bits)*
		- *Applies only when there are multiple candidate values of t configured*
	+ *No further enhancement to indicate “t” for DCI 0\_1/0\_2 without data and without CSI request at least when the new DCI field is configured*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | Support to confirm the WA |
| Apple | Support |
| NEC | Support to confirm the WA. |
| LGE | We are also fine with confirming WA. And, unified solution for “t” indication for all cases is slightly preferred. |
| Huawei, HiSilicon | Support |
| Futurewei | Support. Also fine with other mechanisms. |
| Lenovo/MotM | Support |
| InterDigital | Support |
| MediaTek | Support |
| Xiaomi | Support  |
| ZTE | Support |
| QC | We are fine with FL proposal given the super-majority support to confirm the working assumption as is. The discussion for ‘t’ indication for non-scheduling DCI when this DCI field is not configured can be continued at 2.2.  |
| Samsung | Support |
| Spreadtrum | Support |
| CATT | Support |
| Ericsson | Support |
| CMCC | Support to confirm the WS. One issue need clarification, when the 2bits could be configured in the DCI fields, in which use case the fields will not be configured for DCI 0\_1/0\_2 without data and without CSI request?  |
| Intel | Fine with FL proposal. |

**Whether to support MAC CE update**

Some companies discuss whether MAC CE is used to update the list of t for DCI indication. Companies’ views are summarized as follows.

Table 2-4

|  |
| --- |
| **Whether to support MAC CE as an inter-mediate step** |
| Alternatives | Number | Companies |
| Support using MAC CE to update the candidate values of t | 6 | Qualcomm, NTT DOCOMO, Xiaomi, Lenovo/MotM, Samsung, MediaTek |
| Deprioritize or do NOT support | 10 | CMCC, vivo, OPPO, LGE, Apple, NEC, Huawei/HiSilicon, Futurewei, Spreadtrum, CATT, Ericsson |

Since we have agreed to have up to 2 bits in DCI and 4 values configured in RRC in the list of t, the need of using MAC CE is unclear. Hence FL has the following proposal.

***FL Proposal:*** *Do not support MAC CE for t value update in Rel-17.*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | Support FL proposal |
| Apple | We are fine with FL proposal  |
| NEC | Fine with the FL proposal. |
| LGE | Prefer to deprioritize. |
| Huawei, HiSilicon | Support FL proposal |
| Futurewei | Support FL proposal. |
| InterDigital | We would be OK for further discussion. |
| Spreadtrum | Support FL proposal |
| CATT | Support FL proposal |
| Ericsson | Support FL proposal |
| CMCC | Support FL proposal. |
| Intel | Support FL proposal. |

## Flexible DCI format

**Re-purpose**

Based on the agreement of using DCI 0\_1/0\_2 to trigger SRS without data and without CSI request, companies propose the following schemes to repurpose unused fields in these DCI fields to indicate SRS parameters dynamically.

Table 2-5

|  |
| --- |
| **Repurpose unused fields in DCI format 0\_1/0\_2 without data and without CSI** |
| Categories | Detailed alternatives | Companies |
| CAT-A (Time-domain parameters) * 10 supporting companies: ZTE, MediaTek, Ericsson, NTT DOCOMO, Xiaomi, Samsung, CATT, vivo, LGE, Futurewei
 | A-1: Indication of available slot position, i.e., the t values  | ZTE, MediaTek, Ericsson, NTT DOCOMO, Xiaomi, Samsung, CATT |
| A-2: Indication of slot offset  | vivo |
| A-3: Indication of SRS symbol-level offset  | LGE, Futurewei |
| A-4: Indication of time-domain behavior for SRS transmission over multiple OFDM symbols, e.g., repetition, hopping, and/or splitting  | Futurewei |
| CAT B (Frequency-domain parameters)* 7 supporting companies: Qualcomm, Futurewei, Xiaomi, Ericsson, LG, Intel, CMCC
* 1 company has concern
 | B-1: Indication of a group of CCs for SRS transmission | Qualcomm, Xiaomi |
| B-2: Indication of frequency domain resource in a BWP for SRS transmission | Ericsson, CMCC, LGE, Xiaomi, Futurewei |
| B-3: Indication of whether DL/UL BWP is applied for SRS transmission | Intel |
| Do not support this category | vivo |
| CAT C (Power control parameters)* 5 supporting companies: Qualcomm (for each CC), Futurewei, Intel, Xiaomi, Huawei/HiSilicon
* 2 companies have concern
 | C-1: Re-purpose ‘TPC command for PUSCH’ as ‘TPC command for SRS’ | Qualcomm (for each CC), Intel, Xiaomi, Futurewei |
| C-2: Indication of open loop power control parameter e.g., p0. | Huawei/HiSilicon |
| Do not support this category | CMCC, vivo |
| CAT D (Spatial-domain parameters, i.e., indication of SRS port and beamforming)* 1 supporting company: Futurewei
* 1 company has concern
 | Re-purpose CSI-RS/TPMI indication to indicate SRS spatial-domain parameters | Futurewei |
| Do not support this category | CMCC |
| CAT E (Extend the number of DCI codepoints for aperiodic SRS trigger states)* 4 supporting companies: Futurewei, Intel, Xiaomi, NTT DOCOMO
 | Extend the number of DCI codepoints for aperiodic SRS trigger states | Intel, NTT DOCOMO, Xiaomi, Futurewei |
| New functionalities | Re-purpose to indicate set usage | Spreadtrum |
| No or deprioritize | - | Apple, OPPO, Lenovo/MotM, InterDigital, NEC |

It seems it is hard converge on this issue. Since we have discussed this issue for long time costing a lot of meeting resources, the following is recommended by FL.

***FL Proposal:*** *Further discuss the issue of repurposing DCI field(s) for SRS parameter indication until RAN1#106bis-e. If no consensus can be achieved, conclude this issue as following.*

* *No repurpose of DCI field(s) is supported for SRS parameter indication in Rel-17.*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | We failed to see any strong motivation to repurpose some of the existing DCI fields |
| Apple | We prefer not to repurpose unused DCI fields  |
| NEC | Fine with the proposal, while we prefer no repurposing the unused fields. |
| LGE | We are fine with no repurpose of DCI field(s), for the sake of progress. |
| Futurewei | The unused DCI fields can be used to indicate other parameters for the SRS transmission. A key objective of this WI is “*enhancements on aperiodic SRS triggering to facilitate more flexible triggering*”, and repurposing unused DCI fields for A-SRS triggering parameters is a great way to achieve this objective. Thus we think the repurposing should be further pursued.If companies wish to reduce the DCI redesign effort, we could simply change the unused DCI fields from “for the scheduled PUSCH transmission” to “for the triggered SRS transmission” whenever applicable. |
| Lenovo/MotM | We failed to see motivation to repurpose the existing DCI fields. |
| InterDigital | Same view as OPPO |
| QC | As highlighted in our tdoc and commented in previous meetings, we see benefits for repurposing bitfields for at least CAT-B and CAT-C.  |
| CATT | Fine with the proposal. |
| Ericsson | Support FL proposal |
| CMCC | Support FL’s proposal. |
| Intel | Support CAT B, C, E.In addition, we have the following questions for clarification.Q1: Even without repurposing DCI fields, how to determine the SRS transmit power (including SRS is configured with same power control adjustment state as PUSCH and SRS is configured with separate power control adjustment state) if SRS is triggered by DCI 0\_1/0\_2 without data?Q2: When SRS is triggered by DCI 0\_1/0\_2 without data, for the field of BWP indicator, is it still used as BWP switching command or not? What’s the UE behavior on handling this field? |

**Group-common DCI**

Another remaining issue is whether to enhance group-common DCI in addition. Companies’ views are summarized as follows.

Table 2-6

|  |
| --- |
| **Whether group-common DCI enhancement is supported additionally** |
| Alternatives | Number | Companies |
| Yes | 5 | Qualcomm, Xiaomi, vivo, Samsung, Futurewei |
| No or deprioritize | 5 | Apple, LGE, Huawei/HiSilicon, Lenovo/MotM, CATT |

***FL Proposal:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | We need to see what the detailed solution is and what values offered by this enhancement are |
| Apple  | We think it is lower priority, at least. If it is referring to DCI 2\_3, based on our previous investigation, the specification itself needs some further clarification.  |
| LGE | Prefer to deprioritize. |
| Huawei, HiSilicon | We do not think the group common DCI need to be enhanced for AP-SRS triggering, since AP-SRS is triggering one slot with randomized, which is not an use case for group common DCI. |
| Futurewei | This is for DCI 2\_3. We provided some design considerations in our tdoc, but we are open for other enhancements. Also what Intel proposed in Sec. 2.6 can also be an example. We are willing to answer questions if any.  |
| InterDigital | Same view as OPPO |
| CATT | Fine to deprioritize. |
| Ericsson | TBD is a fair conclusion based on the status |
| CMCC | Do not see the motivation to enhance the group-common DCI. |
| Intel | We think at least the indication of available slot via DCI could be applied for DCI 2\_3. |

## Usage/overhead reduction

One remaining issue is whether to support specification enhancement on using SRS resources configured in SRS resource set with usage = “antennaSwitching” for codebook based UL transmission. Table 2-7 summarizes companies’ views.

Table 2-7

|  |
| --- |
| **Whether to support specification enhancement on using SRS resources configured in SRS resource set with usage = “antennaSwitching” for codebook based UL transmission** |
|  | Number | Companies |
| Action 1: Add a UE capability to ensure same virtualization if SRS resource(s) for antenna switching also belong to a set for codebook | 3 | Apple, NTT DOCOMO, Ericsson |
| Action 2: Add a RRC parameter to turn on/off the UE behavior in Action 1 | 4 | Apple, NTT DOCOMO, vivo, Ericsson |
| Action 3: Clarify same virtualization is used if SRS resource(s) for antenna switching also belong to a set for codebook | 3 | Ericsson, CATT, InterDigital |
| None of the above actions is needed | 3 | Huawei/HiSilicon, Samsung, Lenovo/MotM |

***FL proposal:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | Before we can agree any new action, we need to see the detailed solution and benefits, e.g., configuration, UE behavior, and so on |
| Apple | We support to discuss since some questionable configuration was observed in the field.  |
| Huawei, HiSilicon | SRS resource sharing can be used from Rel-15. There was agreement before that the use case for SRS is decided by UE in Rel-15. So, not necessary to discuss again. |
| Futurewei | We do not think spec impact is necessary, but we are open to further discuss technical issues such as virtualization to promote better understanding across companies (especially across UE vendors and NW vendors). |
| Lenovo/MotM | We still believe this feature can be implemented by Rel-15. |
| InterDigital | Further discussion needed, in our view some clarification in spec may be needed to ensure use of a same virtualization in case of SRS resource sharing. |
| ZTE | We believe Rel-15 can implement this resource sharing through proper IODT. We are okay to use action 3 as a conclusion. If UE vendors want to introduce capability signaling for Rel-17 UEs, we should make sure that this does not impact Rel-15 behavior, i.e., this feature can be implemented by Rel-15 after IODT. |
| CATT | We prefer to clarify UE’s antenna virtualization behavior of SRS resources for usage sharing. |
| Ericsson | We’re fine also with Action 1,2 as long as the UE behaviour is clarified. Benefits should be well known by now, based on previous discussions. To Lenovo, Huawei, what does “can be implemented” mean? There is no doubt that it can be implemented or even configured, but the question is can performance be ensured if behaviour is undefined? Will a NW vendor really implement and configure a feature where UE behaviour is undefined? |
| Intel | Same view as OPPO. |

## Flexible antenna switching

Multiple companies discuss the issue of indicating the number of antennas to support more flexible antenna switching in dynamic signaling. Their views are summarized in the following table.

Table 2-8

|  |
| --- |
| **Update Tx/Rx antennas for SRS antenna switch in dynamic signaling** |
|  | Number | Companies | Further details |
| Support indicating the number of Tx/Rx antennas for SRS antenna switching via MAC CE or DCI | 7 | Qualcomm (MAC CE), Ericsson (MAC CE), Intel, Xiaomi, Huawei/HiSilicon (MAC CE), ZTE, Lenovo/MotM | **UE reporting**Apple, Xiaomi* Support UE reporting of the preferred antenna switching configuration/Rx/Tx antenna numbers

**Applicable cases**Case 1: aperiodic SRS* Ericsson

Case 2: periodic or semi-persistent SRS* Huawei/HiSilicon
 |

The following proposal is given based on companies’ input to RAN1#106e.

***FL proposal:*** *Support indicating the number of Tx/Rx antennas for SRS antenna switching via MAC CE.*

* *Applicable to at least one of the following two cases*
	+ *Case 1: aperiodic SRS*
	+ *Case 2: periodic or semi-persistent SRS*
* *FFS UE reporting of the preferred antenna switching configuration*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | The benefits of MAC CE over RRC is still not clear. Would some proponents like to explain what the benefit is?Moreover, it has large impact on UE hardware implementation. In R15/16, the xTyR configuration for periodic, semi-persistent and aperiodic cases are the same. Thus, UE can keep the RF circuit and switching modules in the same state before each transmission. If this new proposal is used, MAC CE may indicate x’Ty’R for aperiodic, but the existing periodic SRS is for xTyR. When some transmission of them are closed to each other, UE need to change the state of RF circuit (e.g. turn on, turn off)/switching modules in a short time |
| Apple | We do not see the need to discuss this first. Firstly, the critical issue now in the specification is that NW does not know when UE changes its antenna configuration, for example, for power saving etc. Secondly, even if the antenna configuration is changed, it is normally on a longer time scale. RRC is enough, there is no meaningful benefit of using MAC-CE |
| Huawei, HiSilicon | We can support UE report the number of Rx antennas for SRS.Then, for the main bullet, remove “Tx”, since dynamic switching the number of Tx may be some problems on dynamic switching on the RF chains, which need to be discussed in RAN4. |
| Futurewei | The issues/questions we raised before and in the tdoc have not been addressed/answered. For example, “It seems that the discussions are trying to cover both the UE Tx antenna switching and UE Rx antenna switching, and often times the discussion are mixed together, though Tx antenna switching and Rx antenna switching are considerably different.” Please refer to our tdoc for the detailed analysis and questions. More discussions are needed to align the basic understanding of this topic. |
| InterDigital | We are OK to discuss it with a lower priority. |
| Xiaomi | Our preference is to allow the gNB to configure multiple SRS antenna switching configurations for the same BWP, and trigger dynamically by DCI SRS request codepoints. We are open to other design considerations, and also we think this mechanism is feasible better based on UE’s reporting assistance. In our view, the reporting of UE preferred Tx or Rx antennas can also be considered aiming for antenna switching configuration change too.  |
| ZTE | We support the FL proposal. |
| QC | There are benefits for UE reporting the #Rx antennas and NW adaptation of SRS resources by MAC-CE. From UE perspectives, For example, 1T8R configuration, the UE may prefer to limit sounding only to 4Rx (ie. 1T4R) based on either quality of the channel or for some power savings adaptation. And from NW perspective, it provides a faster method to adapt antenna switching other than RRC reconfiguration. Also, we agree with HW that Rx adaption is much feasible than Tx antenna adaptation.  |
| CATT | We are ok to support dynamic changing the number of SRS resources/SRS resource sets for DL CSI acquisition via MAC-CE or DCI. Applying the enhancement for aperiodic SRS or semi-persistent SRS is preferred. Besides, indicating which antennas are to be used for SRS transmission is more preferred than only indicating the number of Tx/Rx antennas. |
| Ericsson | Support FL proposal. We are also fine with DCI based solution, as long as faster switching than RRC based is supported. Also, we agree that this is about switching of the number of RX. The benefits are better management of available SRS resources in the cell, when SRS load is excessive (sudden peak in traffic load). The network can temporarily down-grade some UEs to transmit on fewer SRS resources (fewer RX) at the cost of some loss in channel acquisition and DL MU-MIMO performance. But it is better to have somewhat degraded channel knowledge temporarily, than to have no channel knowledge at all due to SRS congestion.  |
| Intel | We support to have flexible antenna switching for aperiodic SRS via DCI. |

## Implicit determination of SRS parameters from data channel

Some companies propose to associate aperiodic SRS parameters (e.g., bandwidth) with scheduled data channel (e.g., PUSCH/PDSCH). The following summarizes companies’ views on this issue.

Table 2-9

|  |
| --- |
| **Implicit determination of SRS parameters from data channel** |
|  | Number | Companies |
| Inherit SRS parameters from data channel transmission parameters by associating them with co-scheduled PUSCH or PDSCH | 2 | LGE, Futurewei |

***FL proposal:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | The benefit is not clear |
| Apple | No need to discuss at this stage. To deploy a feature and to implement a feature, the principle is that things need to be explicitly configured as much as possible.  |
| LGE | Support. The benefit is below.Only RRC based SRS bandwidth configuration is supported at this stage, which has less flexibility. This can also be a potential enhancement point for aperiodic SRS. Dynamic indication of SRS band may require additional DCI bits. If we’d like to avoid this issue, it is considerable to align SRS band with PUSCH and/or PDSCH band. This approach has a clear benefit to reuse former sounded/scheduled bandwidth with good channel quality and to avoid multi-UE SRS collision based on the multi-UE PUSCH/PDSCH multiplexing. |
| Futurewei | @OPPO: The performance benefit has been shown in our tdoc, which provides significant UPT gains (8% ~ 46% gain for mean UPT, and 44% to more than 2x gains for 5%ile UPT).@Apple: Here some of the SRS transmission parameters are the same as the co-scheduled PDSCH/PUSCH, so there won’t be any ambiguity/confusion in implementation. Maybe the term “implicit determination” can be improved to, e.g., “reusing”.@FL: Maybe we could change to something like “Reusing data channel transmission parameters as SRS parameters”, “Inheriting SRS parameters from data channel transmission parameters”, and remove “implicitly”?@all: One of the key ideas here is that if the A-SRS has the same transmission parameters as a PDSCH/PUSCH, such as the same PRBs, then the gNB can learn the CSI (including interference information) from the A-SRS on the PRBs and improve the PDSCH/PUSCH spectrum efficiency. And since they share the same PRBs (FDRA), the same FDRA field can be used for both transmissions without additional overhead increase. The flexibility inherited from data scheduling also leads to significant collision avoidance capability.*FL’s response:* The table has been revised per your request. |

## Others

The following issues are discussed by one company.

|  |  |
| --- | --- |
| Extend the mechanism to indicate t for available slot to SRS triggered by group common DCI 2\_3 | Intel |
| Support single scheduling DCI to trigger simultaneous A-SRS transmission across multiple component carriers | Qualcomm |
| Updating the association between AP SRS resource sets and aperiodic SRS triggering states | Lenovo/MotM |
| Allow the gNB to configure multiple SRS antenna switching configurations for the same BWP and trigger dynamically by DCI SRS request codepoints. | Xiaomi |

Companies’ further views on the above issues are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Futurewei | Support Intel’s proposal |
| Xiaomi | We think the QC’s proposal to trigger SRS across multiple CCs is beneficial |
| Ericsson | Support Intel’s proposal |
| Intel | Support to discuss the application of available slot indication via group DCI 2\_3. The purpose of introducing available slot is to remove the restriction on PDCCH triggering SRS. If the available slot operation is not applied for DCI 2\_3, the restriction on PDCCH is still there. |

# Antenna switching up to 8Rx

## Aperiodic SRS configurations for >4Rx

RAN1 agreed the general framework including N\_max to support configuring >4Rx SRS configurations, while the supported values for N is FFS. The following tables summarize companies’ views. Note that 4T6R is not included as the decision is pending.

Note that one related issue of determining N values is whether to support configuring multiple SRS resource sets for antenna switching in one slot. It decides whether to support N=N\_max is sufficient by configuring multiple resource sets in one slot.

**N values**

Table 3-1

|  |
| --- |
| **Supported N values** |
| Alternatives | Companies |
| Alt 1: All the non-zero integer values N<= N\_max are supported  | ZTE, Ericsson, Xiaomi, Nokia/NSB, OPPO |
| Alt 2: Support N=N\_max only | vivo, Spreadtrum |
| Alt 3: Support specific values for N<=Nmax | Qualcomm, Huawei/HiSilicon, CATT: all N<=Nmax except N=1 for 1T8RCMCC: * 1T6R: N=1, 2, 3
* 1T8R: N=2, 3, 4
* 2T6R: N=1, 2
* 2T8R: N=1, 2
* 4T8R: N=1

Intel, Lenovo/MotM |
| **Whether multiple SRS resource sets can be configured in one slot** |
| Views | Companies |
| Multiple SRS resource sets for antenna switching can be configured in one slot | vivo |
| UE does not expect multiple SRS resource sets for antenna switching are configured in one slot | Qualcomm |

Given companies’ input, FL believes to support N<=Nmax except N=1 for 1T8R is a good compromise among companies. Hence the following proposal is recommended.

***FL Proposal:*** *For aperiodic xTyR antenna switching SRS, where xTyR is from {1T6R, 1T8R, 2T6R, 2T8R, 4T8R}, support all the non-zero integer values N<=N\_max except N=1 for 1T8R*

* *For each xTyR configuration, UE does not expect multiple SRS resource sets are configured in one slot*
* *FFS considerations on channel variation in time domain if the number of spanned slots is large*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | Support FL proposal |
| Apple | We are fine |
| NEC | Fine with the FL proposal. |
| LGE | Slightly prefer Alt 3, but alt 1 is also fine. Regarding the sub-bullet, it should be carefully investigated since whole transmission of specific xTyR configuration can be located in 4 different slots which can spread more than 4 slots up to specific TDD UL-DL configuration with less UL slot. In this case, channel estimation performance can be degraded because of channel variation and phase discontinuity.*FL’s response:* In general, it can be solved by gNB implementation. If the performance is degraded because of channel variation, gNB can choose to configure a small N value. What we discuss here is anyway the values which can be supported. Despite the above, one FFS point is added to reflect your concern. |
| Huawei, HiSilicon | OK for the proposal |
| Lenovo/MotM | Prefer Alt 3, but fine with FL proposal. |
| InterDigital | FFS not needed. |
| Xiaomi | Fine with the FL proposal |
| ZTE | We support the FL proposal. |
| QC | Support FL proposal.We believe the next detail of discussion is the mapping of SRS resources across the N SRS resource set whether specific or all possible mapping is specified Also, would be discussed in this meeting or next meeting. |
| Samsung | Support FL’s proposal without FFS bullet |
| Spreadtrum | Prefer Alt 2, but OK for FL proposal |
| CATT | Support the proposal |
| Ericsson | Support FL proposal |
| Intel | Do not support.The subcarrier spacing and UE capability on which OFDM symbols can be used for SRS should be considered. The UE can support all the OFDM symbols can be used for SRS or only the last 6 OFDM symbols can be used for SRS. And different subcarrier spacing requires different guard period symbols. According to current spec, SCS of 15KHz, 30KHz, and 60KHz requires one symbol guard period, SCS of 120KHz requires two symbols guard period.For example, for 120KHz SCS, 2 symbols are required for guard period. In such case, up to 5 SRS resources can be contained in one slot if the UE supports all the symbols can be used as SRS. For 1T6R, obviously at least two SRS resource set is needed.In addition, we think in multi-TRP case, more aperiodic SRS resource sets are needed to reduce the signaling overhead for SRS reconfiguration. If the same number of SRS resource sets are configured for multi-TRP case, gNB needs to update the SRS spatial relation and power control parameters before triggering the SRS toward one TRP. We suggest adding some text in main bullet to clarify this proposal is for single TRP case.Below is the suggested modification:***FL Proposal:*** *For aperiodic xTyR antenna switching SRS in single TRP, where xTyR is from {1T6R, 1T8R, 2T6R, 2T8R, 4T8R}, ~~support all the non-zero integer values N<=N\_max except N=1 for 1T8R~~ support the following configuration of N:***UE supports all the symbols in one slot can be used for SRS:***1T8R (N\_Max=4)** N=2, 3, 4 for SCS=15KHz, 30KHz, 60KHz, 120KHz

*1T6R (N\_Max=4)** N=1, 2, 3, 4 for SCS=15KHz, 30KHz, 60KHz
* N=2, 3, 4 for SCS=120KHz

*2T8R (N\_Max=4)** N=1, 2, 3, 4 for SCS=15KHz, 30KHz, 60KHz, 120KHz

*2T6R (N\_Max=3)** N=1, 2, 3 for SCS=15KHz, 30KHz, 60KHz, 120KHz

*4T8R (N\_Max=2)** N=1, 2 for SCS=15KHz, 30KHz, 60KHz, 120KHz

**UE supports only the last 6 symbols in one slot can be used for SRS:***1T8R (N\_Max=4)** N=3, 4 for SCS=15KHz, 30KHz, 60KHz
* N=4 for SCS=120KHz

*1T6R (N\_Max=4)** N=2, 3, 4 for SCS=15KHz, 30KHz, 60KHz
* N=3, 4 for SCS=120KHz

*2T8R (N\_Max=4)** N=2, 3, 4 for SCS=15KHz, 30KHz, 60KHz, 120KHz

*2T6R (N\_Max=3)** N=1, 2, 3 for SCS=15KHz, 30KHz, 60KHz
* N=2, 3 for SCS=120KHz

*4T8R (N\_Max=2)** N=1, 2 for SCS=15KHz, 30KHz, 60KHz, 120KHz
* *For each xTyR configuration, UE does not expect multiple SRS resource sets are configured in one slot*
* *FFS considerations on channel variation in time domain if the number of spanned slots is large*
 |

**Subject to UE capability on maximum number of SRS symbols in a slot or not**

An FFS point in previous agreement is whether different configurations are specified subject to the UE capability on maximum number of symbols that can be used for SRS in a slot. Companies’ views are summarized as below.

Table 3-2

|  |
| --- |
| **Whether different configurations are specified subject to the UE capability on maximum number of symbols that can be used for SRS in a slot** |
|  | Companies |
| Yes | Intel, Xiaomi |
| No | Nokia/NSB, OPPO, LGE |

***FL Proposal****: TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | NO |
| Apple | At least we need to address whether UE supports Rel-16 SRS in any symbol or Rel-15 SRS in only the last 6 symbols of a slot |
| LGE | Not needed. |
| ZTE | We think it is not needed to specify different configurations for different UE capabilities. What is sufficient is to clarify in the specification to restrict UE’s expectation on gNB’s configuration. |
| Intel | Different configuration should be specified considering UE capability whether it support SRS in any symbols or only in the last 6 symbols. Details can be found in our previous comment on SRS configuration. |

## Extension for aperiodic SRS with <=4Rx

One FFS point is whether to support more values of N for aperiodic SRS with <=4Rx. Companies’ views are summarized as follows.

Table 3-3

|  |
| --- |
| **Whether to support more N values for 1T4R, 2T4R, T=R and 1T2R cases** |
|  | Companies |
| Yes | Ericsson, Xiaomi, Nokia/NSB, Huawei/HiSilicon* Support N=4 for 1T4R and N=2 for 1T2R/2T4R

CATT* Support N=4 for 1T4R and N=2 for 1T2R/2T4R
* Support one resource set for 1T4R if all the symbols in a slot can be used for SRS

Intel, ZTE |
| No or deprioritize | Qualcomm, OPPO, Lenovo/MotM |

Given majority view expressed, the following FL proposal is recommended.

***FL Proposal:*** *For extension of antenna switching SRS configurations for <=4Rx, support N=4* *for 1T4R and N=2 for 1T2R/2T4R.*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | The current spec has supported these xTyR and additional configurations are not helpful.Moreover, it is not in the scope of R17 feMIMO WID |
| Huawei, HiSilicon | We support N=4 for 1T4R and N=2 for 1T2R/2T4R |
| Lenovo/MotM | Agree with OPPO that it is out of Rel-17 feMIMO scope |
| Xiaomi | Support the FL proposal |
| ZTE | We support the FL proposal. |
| QC | We prefer to discuss it later.  |
| CATT | Supporting N=4 for 1T4R and N=2 for 1T2R/2T4R are useful for the scenarios with scarce UL resource, and supporting N =1 for 1T4R allows gNB get DL CSI earlier than N= 2 for 1T4R for UEs support SRS starting at any symbol in the slot. In order to provide more scheduling flexibility and to allow more quick DL CSI acquisition, we propose to support N=1 and N=4 for 1T4R and N=2 for 1T2R/2T4R. |
| Ericsson | This is very important for some network vendors and the TDD patterns they are forced to use. It can alternatively be resolved by a TEI-17, but since we already discuss this topic in this WI and all the SRS experts are “here”, it’s better to solve it right now in this WI.  |
| Intel | Support to discuss this issue. |

## Configurations for periodic and semi-persistent SRS

Two alternatives have been proposed on the number resource sets supported for periodic and semi-persistent antenna switching SRS. Companies’ views are summarized as follows.

Table 3-4

|  |
| --- |
| **Number of resource sets for periodic or semi-persistent SRS** |
| Alternatives | Companies |
| Support maximum one SRS resource set for periodic SRS and maximum one SRS resource set for semi-persistent SRS | Qualcomm, vivo |
| Support up to two semi-persistent SRS resource sets in addition to a periodic SRS resource set | CMCC, Nokia/NSB, Huawei/HiSilicon, OPPO (UE optional for two SP sets), MediaTek, Xiaomi, ZTE, CATT, Ericsson |

FL would like to suggest the following, which seems to be a good mid-ground.

***FL Proposal:*** *For antenna switching SRS, support maximum one SRS resource set for periodic SRS and maximum X SRS resource sets for semi-persistent SRS.*

* *UE can report the value of X from {1, 2} as capability*
* *Note: If UE reports X=2, the two SP-SRS resource sets are not activated at the same time*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | We can support it if UE is allowed to report how many SP SRS resource sets it supports. |
| Apple | SP SRS itself is an UE optional feature. Not sure the spec impact, but as long as UE can report the corresponding capability, we are open  |
| LGE | Slightly prefer maximum one SRS resource set for periodic SRS and maximum one SRS resource set for semi-persistent SRS. |
| Huawei, HiSilicon | At first, the issue is from real deployment. Due to only one SP-SRS resource set can be configured per UE, so there is high probability of collision of SRS. Support two semi-persistent SRS resource sets can obviously reduce the SRS collision. The detailed analysis and evaluation can be found in our Tdoc.Second, since the feature is anyway an UE capability in Rel-17, no need a redundant UE capability for 1 or 2 resource sets on it. As said in the notation, only one SP-SRS resource can be activated in a time, no UE complexity introduced. So, we slightly prefer the original wording in last meeting:*For antenna switching SRS, Support up to two semi-persistent SRS resource sets in addition to a periodic SRS resource set** + *Note: the two SP-SRS resource sets are not activated at the same time.*

But anyway, if the additional UE capability is a majority view, we are open on it. |
| MediaTek | We’re okay to the FL proposal with UE capability report, or original wording with at most one activated SP set at the same time is also fine. |
| Xiaomi | We are fine to support allowing the configuration of more than 1 SP-SRS resource sets, since the motivation is from real deployments, and we think the UE capability for the supported number of SP-SRS resource sets is a bit redundant based on the UE capability for SP-SRS, and more preferred with the FL’s original version. |
| ZTE | FL proposal is acceptable to us. |
| QC | Don’t support. Alt-1 is sufficient given enhanced PFS and comb-8 enhancement. Also, we think there is no need to complicate the specification with UE capability to support the proposed solution. |
| Spreadtrum | Fine with FL proposal. |
| CATT | Fine with the proposal. |
| Ericsson | Support the FL proposal in principle, although we would like to avoid unnecessary UE capabilities. It is a headache for NW operations to handle the set of different reported UE capabilities, and we believe whether UE support X=1 or X=2 is marginal in UE complexity. There will be a capability to whether this feature is supported anyway, and we don’t see the need to further divide into X=1 and X=2. We propose X=2 always if UE support the feature.  |
| CMCC | From the observation of 4G network and 5G fields, the SRS capacity is always not enough in some crowded cells. Configuration of longer period of SRS is one solution, but with the price of performance degradation. Current configuration of the SRS resource sets are shared or reused among many users in a cell. And the collisions for SP SRS would happen when the UE numbers increase. Setting two sets of SRS for one UE would reduce the collision from 1/N to around 1/N2 . That is the benefit we see from this case. As the enhancements of Rel-17 would be optional to all UEs, current wording indicates that a UE should announce supporting one optional capability within another optional capability. We would prefer the original wording in the agreements.* *Alt 2: Support up to two semi-persistent SRS resource sets in addition to a periodic SRS resource set*
	+ *Note: the two SP-SRS resource sets are not activated at the same time.*
 |
| Intel | Regarding the number of periodic or semi-persistent SRS resource sets with antenna switching:* For single TRP case, we support only one periodic or semi-persistent SRS resource sets.
* For multi-TRP case, we support up to two periodic or semi-persistent SRS resource sets.
 |

## Guard period

Some companies discuss possible enhancements on guard symbols for antenna switching SRS. The proposed alternatives and companies’ positions are summarized as follows.

Table 3-5

|  |
| --- |
| **Whether to enhance guard symbols for antenna switching** |
|  | Companies |
| Alt 0: Guard symbols are always-on, which is same as Rel-15 | OPPO, Apple, Qualcomm |
| Alt 1: Guard symbols are configurable subject to UE capability | Ericsson, vivo, Lenovo/MotM, InterDigital |
| Alt 2: Introduce guard symbols between two sets mapped to consecutive slots | Qualcomm, Huawei/HiSilicon, vivo, OPPO, Apple, Xiaomi, CATT |

***FL Proposal:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | Alt.0 and Alt.2 are not mutually exclusive. Alt.0 is talking about the SRS within a set, whereas Alt.2 is talking about the two sets in two slots.In summary, we support Alt 0 and Alt.2  |
| Apple | We support both Alt 0 and Alt 2 |
| InterDigital  | Support Alt.1. Use of guard symbols has direct impact on the spectrum efficiency of the system. Therefore, when possible, they should be avoided. |
| QC | Rel-15 was only limited to guard symbol(s) between SRS resources within one set. Because it wasn’t possible to have two SRS sets across consecutive slots as SRS was limited to last 6 symbols within the slot. Alt-2 addresses that and follows the same concept to introduce guard symbols between sets mapped to consecutive slots. So, both Alt-0 and Alt-2 are needed. |
| CATT | Support Alt 2. |
| Ericsson  | Support Alt.1 |
| Intel | Support Alt 0. Regarding Alt 2, it could be addressed via implementation. For example, the first symbol is not configured for SRS. |

## Whether 4T6R is supported

One remaining issue is whether 4T6R is supported. Companies’ views are summarized as follows.

Table 3-6

|  |
| --- |
| **Whether to support 4T6R SRS antenna switching** |
|  | Companies |
| Yes | Qualcomm, CMCC, Xiaomi, InterDigital, Lenovo/MotM, MediaTek |
| No | Ericsson, Huawei/HiSilicon |

Given the time we have spent for this discussion and the fact that we haven’t achieved consensus, FL proposes the following.

***FL Proposal:*** *Do not support 4T6R SRS antenna switching in Rel-17.*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | We would like to clarify that we are open to it. If it is not supported due to the lack of consensus, we can accept it.  |
| NEC | We prefer to support 4T6R, while we can accept the FL proposal if no consensus. |
| InterDigital | There is no reason not to support 4T6R configuration. |
| Xiaomi | We support the configuration of 4T6R, otherwise only 2T is supported for 6Rx configuration which is not sufficient. |
| QC | Unfortunately, we don’t support FL proposal. We see the need for such configuration, not only for completeness and future support, but not to limit UE implementation as spec doesn’t support it. |
| Ericsson | Support FL proposal |
| Intel | Open for discussion |

## Others

The following issues are discussed by one or two companies.

|  |  |
| --- | --- |
| Support UE capability reporting of power offset across antenna ports for SRS DL CSI acquisitions | Qualcomm, InterDigital |
| A 6Rx can report a capability of two, four or six layers of maximum number of DL MMO layers. And 8Rx UE can report a capability of two, four, six or eight layers of maximum number of DL MMO layer. | Qualcomm |
| Consider multi-panel UEs for antenna switching. | LGE, vivo |
| For antenna switching across multiple slots, restrict that the slots are contiguous or within a given period | LGE |
| Support antenna switching configuration for mTRP* Two periodic/semi-persistent SRS resource sets for antenna switching in multi-TRP
* The number of aperiodic SRS resource sets in single TRP is K, then number of aperiodic SRS resource sets for xTyR in multi-TRP should be 2\*K
 | Intel, vivo |

Companies’ further views on the above issues are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| QC | The impact of DL CSI because of power imbalance between antenna ports has been brough up by few companies (Qualcomm, InterDigital and Nokia). We believe RAN1 should study solutions to compensate this imbalance. |
| Intel | The SRS configuration for antenna switching in mTRP scenario should be discussed. In multi-TRP, the SRS transmission toward different TRP is expected to use different spatial relation and different power control parameter settings, e.g., pathloss reference signal.If only one periodic/semi-persistent SRS resource set is configured in multi-TRP case, before the UE transmits SRS toward one TRP, the network needs to reconfigure/update the SRS with corresponding spatial relation and power control parameters, which leads to a lot of singling overhead. The same issue exists for aperiodic SRS.Therefore, configuring more SRS resource sets in multi-TRP case is helpful to reduce the signaling overhead for SRS reconfiguration. |
|  |  |

# Coverage and capacity enhancements

## Increased repetition

**Additional values for N\_symbol and R**

We have agreed to support N\_symbol = 8, R = {1, 2, 4, 8} and N\_symbol = 12, R = {1, 2, [3], 4, 6, 12}. Some companies discuss whether some additional values can be supported. The following summarizes companies’ views.

Table 4-1

|  |
| --- |
| **Additional N\_symbol and R values** |
| Views | Companies |
| Support additional values for N\_symbol and R | * Qualcomm, Spreadtrum:
	+ Ns = 10, R
	+ Ns = 14, R
* vivo: N\_s = 14 with R = {1, 2, 7, 14}
* CMCC: Support additional 4 and 8 repetitions for N\_symbol = 10 and 14
* Ericsson, Huawei/HiSilicon, Futurewei: Support R=3 for N\_symbol = 12, i.e., remove the brackets
* LGE: Support more than 12 for N\_symbol
* Nokia/NSB: Support N\_symbol =10 and R={1,2,4,10} as well as N\_symbol =14 and R={1,2,7,14}
 |
| Do not support additional values | Intel, CATT, OPPO |

Given we have agreed a set of useful configurations, and companies’ views are divergent on the remaining values, FL recommends the following proposal.

***FL Proposal:*** *For SRS increased repetitions in Rel-17, support the following configurations, and no other values are supported.*

* *(N\_symbol, R) = {(8, 1), (8, 2), (8, 4), (8, 8), (12, 1), (12, 2), (12, 4), (12, 6), (12, 12)}*
* *Note: N\_symbol SRS symbols are adjacent in a slot.*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | Support FL proposal |
| Apple | We are fine with FL proposal |
| NEC | Fine with the FL proposal. |
| LGE | We think (12, 3) can also be supported since R=3 is already supported in LTE. |
| Huawei, HiSilicon | Don’t support the proposal. Same view with LGE, R=3 for N\_symbol = 12 can achieve four times frequency hopping in one slot, so it also should be supported. |
| Futurewei | Agree with LGE |
| Lenovo/MotM | Fine with FL proposal. |
| Xiaomi | Fine with the FL proposal |
| ZTE | Support FL proposal. |
| QC | We think Ns=10,14 should be supported as well for specification and scheduling flexibility.  |
| Samsung | OK with FL proposal |
| Spreadtrum | Support FL proposal. |
| CATT | Support FL proposal. But, based on previous agreements on *N\_symbol* SRS symbols, it does not clarify whether the *N\_symbol* SRS symbols are adjacent or not in a slot. In our views, the *N\_symbol* SRS symbols should be adjacent in a slot. In order to avoid confusion, we suggest that a note is added to clarify as follows.*Note: N\_symbol SRS symbols are adjacent in a slot.* |
| Ericsson | Support FL proposal |
| Intel | Support FL proposal |

**Reduced BW for R>1**

One FFS point in previous agreement is whether to support reduced SRS BW for repetitions with R>1. Companies’ views on this are summarized as follows.

Table 4-2

|  |
| --- |
| **Whether to support reduced SRS BW for R>1** |
| Views | Companies |
| Yes | Futurewei |
| No | vivo, CATT, Ericsson |

***FL Proposal:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| LGE | RRC-based bandwidth configuration can work for R>1. |
| Futurewei | We think when SRS repetition is supported, the remaining UL resources may become very scarce. In order to multiplex more SRS, reducing the SRS BW could be helpful. In addition, this can further increase the SRS coverage. So we think this is highly motivated. |
| CATT | The capacity loss incurred due to larger SRS repetition can be compensated by gNB’s implementation, such as P*F* value is configured for R>1. |

## RB-level partial frequency sounding (RPFS)

This section summarizes companies’ views on remaining issues for RPFS.

### 4.2.1 PF values

Companies discuss details about additional values for PF. Companies’ views are summarized as follows.

Table 4-1

|  |
| --- |
| **Additional PF values** |
| Values | Companies |
| Support additional PF values | * vivo: Support {3, 8, 12}
* NTT DOCOMO: Support larger P\_F values
* Futurewei: 3, 8, 12, 16, and fractional numbers
 |
| Do not support additional PF values  | * Intel, Nokia/NSB, Huawei/HiSilicon, OPPO
* CMCC: Do not support non-integer P\_F values
 |

For P\_F values, given there is no consensus to support PF values other than {2, 4}, FL recommend the following.

***FL Proposal:*** *Do not support PF values other than {2, 4}.*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | Support FL proposal |
| Apple | We are fine with FL proposal  |
| NEC | Fine with the FL proposal. |
| LGE | Support the proposal. |
| Huawei, HiSilicon | We are open to support {3} |
| Futurewei | Allowing more PF values leads to higher flexibility, collision avoidance capability, capacity enhancements, and coverage enhancements. We think more values should be considered. |
| ZTE | Support FL proposal.  |
| QC | Support FL proposal.  |
| Samsung | Support FL proposal |
| Spreadtrum | Support FL proposal |
| CATT | Support FL proposal |
| Ericsson | Support FL proposal |
| Intel | Support FL proposal |

### 4.2.2 RB location

There is an FFS point in previous agreement about start RB location hopping for different SRS occasions, symbols or frequency hopping periods. Companies’ views are summarized as follows on this aspect.

Table 4-2

|  |
| --- |
| **Start RB location hopping** |
| Views | Companies |
| Support start RB location (Noffset) hopping in different SRS frequency hopping periods | Qualcomm, ZTE, Ericsson (Optional feature with RRC to enable), Huawei/HiSilicon, vivo, CATT, MediaTek, Nokia/NSB, OPPO, NEC, Lenovo/MotM, Xiaomi |
| Do not support start RB location hopping | CMCC, NTT DOCOMO, Spreadtrum |

Given the fact that most of the vendors are interested to support this, the following proposal is recommended taking the concern from the other side into account.

***FL proposal****: Support start RB location (Noffset) hopping in different SRS frequency hopping periods for RPFS and at least periodic/semi-persistent SRS, where is the start RB index of the RBs in the RBs.*

* *For a given SRS transmission occasion, , where is same for SRS occasions within a legacy FH period but changes across legacy FH periods, kF and PF are at least configured by RRC signaling (kF = {0, 1, …, PF-1}).*
	+ *Support at least one pattern for in time domain, FFS detailed pattern*
* *This start RB location hopping is enabled or disabled by RRC signaling.*
	+ *FFS whether MAC CE or DCI can be additionally used*
* *This start RB location hopping is UE optional.*
* *FFS whether start RB location hopping is also applicable on SRS occasion(s) within one FH period and/or on aperiodic SRS, if so, how*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | In general, we are ok with the proposal. One question for clarification. What does “one fixed pattern” mean in the sub-bullet? If a pattern is based on some parameter(s) (e.g., PF or symbol index), is it a “fixed pattern”? *FL’s response:* Thanks for the good question. For different PF values, it should be different patterns as the length for hopping is different. For different symbol indices, if they are different symbol indices in different FH periods, they are part of the pattern as pattern here means how  changes in time domain. For symbols within one FH period, remains unchanged. To address any possible misunderstanding, “fixed” is removed. |
| Apple | We may not fully understanding the N\_offset equation, especially why we need term which is the number PRBs used for SRS transmission. Maybe we missed something. *FL’s response:* We have agreed on the definition of N\_offset in last meeting, which is the start RB index of the contiguous RBs in the RBs with RBs as granularity. What we discuss here is how N\_offset hops/changes in different SRS locations. That’s why we need the term . More details including example figures can be found in companies’ contributions [2][3][4][10][14][17][18]. The FL proposal is clarified based on this. |
| NEC | Fine with the FL proposal. |
| Huawei, HiSilicon | Ok |
| Futurewei | A couple of comments:* With a very limited set of PF values, the benefit of introducing k\_hopping becomes limited.
* How is the kF value determined? Would it go from 0 to PF-1 in the order of the hop numbering?

*FL’s response:* * At least in my understanding, the benefit does not depend on detailed values of PF as elaborated in [2][3][4][10][14][17][18]. Perhaps proponents can further reply.
* kF is determined at least in RRC as said in the first sub-bullet. The candidate values are from 0 to PF-1.
 |
| Lenovo/MotM | We think should at least including 0 to disable this feature, and there is no need additional RRC parameter to enable or disable start RB location hopping.- ~~This start RB location hopping is enabled or disabled by a RRC parameter.~~*FL’s response:* For this start RB hopping, either we can use a dedicated RRC parameter to disable it, or we can configure an all-zero pattern for as you suggested, e.g., for PF=4. No matter which detailed RRC signaling mechanism we adopt, this start RB hopping should be able to be enabled/disabled by RRC. Hence it’s better not to remove this sub-bullet. Instead I reword it to make it more general, which I believe can address your concern. |
| MediaTek | We are ok with the proposal in principle. One question for clarification. In proposal it says “*where is same for SRS occasions within an FH period but changes across FH periods*”, what is “*FH period*” means here? From 38.211, when FH enabled:where is given by Table 6.4.1.4.3-1,and is function of symbol index.Does FH period here means those symbols with **same or different** ? *FL’s response:* FH here means legacy frequence hopping. Then FH period is the period that the entire SRS BW is sounded with FH. Hence an FH period includes symbols with different n\_SRS. For a frequency resource (e.g., a subband with RBs) with SRS transmission, FH period includes all the symbols and occasions from one n\_SRS value to the next n\_SRS value where the same frequency resource is sounded. |
| Xiaomi | Fine with the FL proposal  |
| ZTE | Support the FL proposal. We believe this N\_offset hopping is beneficial to increase gNB channel estimation performance for regardless of whether PF value is large or small. |
| QC | Support in principle. Couple of points for clarifications:* It may be good to state or clarify the FH hopping as explained by FL’s response to MediaTek. In our understanding, it means that if repetition (R<Ns) is enabled a frequency hop, then repetition is applicable to PFS as well. Or in other words, would be same for the OFDM symbols with same value within the FH period.
* Why is it restricted to P/SP sets only?
* We prefer to have same pattern regardless of the value of PF.

*FL’s response:* * My understanding is that N\_offset is same not only for OFDM symbols with same n\_SRS but also for different n\_SRS within one FH period. I think it is clear based on the current formulation “ *is same for SRS occasions within an FH period but changes across FH periods*”. I further clarify this by adding “legacy” before “FH period”. While I believe it is sufficient, I’m open to any specific suggestions to make it even more clear.
* I don’t think it can always be applicable to aperiodic SRS as aperiodic SRS is just one shot. In most cases, there is no FH period as it seems not possible to sound a subband twice in just 12 or even 14 (not agreed yet) symbols. To be safe, I add “at least” for P and SP, and one FFS point for aperiodic SRS.
* I think PF = 4 and PF=2 are not strictly same pattern although the pattern for PF=2 can be a subset of PF=4. But anyway, I remove “for each PF” in this sub-bullet. Detailed pattern issues can be discussed later.
 |
| CATT | In our view, the start RB location (Noffset) hopping can occurs in a SRS frequency hopping period for RPFS, especially for an aperiodic SRS transmission. The motivation is that SRS can be transmitted in entire bandwidth through different sets of PRB on different symbols for RPFS, which avoids interpolation or extrapolation calculation to estimation UL channel.Whether the motivation of the start RB location is that entire channel bandwidth are estimated based on the received SRSs which are located on different sets of PRB? If so, we have a concern on the accuracy of UL channel estimation when start RB location is hopped in different SRS frequency hopping periods, especially for larger hopping periods, since the UL channel may be significantly changed across multiple hopping periods.For the second bullet, The start RB location hopping can be also enabled or disabled by MAC-CE or DCI other than RRC parameter. Thus, we suggest the bullet is revised as follows.*This start RB location hopping is enabled or disabled by a RRC parameter, MAC-CE or DCI indication.**FL’s response:* This FH period level approach is supported by most of the proponents of this feature. Based on the discussion in their papers, the reason is to facilitate gNB channel estimator design as the RB location does not change too dynamically. For your request of extend the support of start RB hopping even for SRS symbols within an FH period, I added an FFS point for it together with the FFS point for aperiodic SRS.For your request of using MAC CE and DCI to enable start RB hopping, I think it can be discussed later as I haven’t seen other companies proposing this. I add an FFS point for it. |
| CMCC | Generally fine with the proposal, as it could be seen that it is a majority view to support. The enabling of starting location hopping should be based on RRC configurations.  |
| Intel | Needs more clarification on the benefit to have the start position hopping. |

### 4.2.3 Applicable cases

Some companies discuss whether to restrict RPFS applicable to FH enabled case only. Companies’ views are summarized as follows.

Table 4-3

|  |
| --- |
| **Whether to restrict the applicable cases for RPFS** |
| Views | Companies |
| Applicable at least for frequency hopping case | Qualcomm |
| Applicable for frequency hopping case only | CMCC, Intel, OPPO |
| Applicable for both frequency hopping and non-frequency hopping cases | Xiaomi, Huawei/HiSilicon, Futurewei, NEC, MediaTek |

***FL Proposal:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | For non-frequency hopping, we can have the same SRS transmission by proper configuration. Why do we need redundant feature? |
| NEC | We think this can be discussed after other details settled down, e.g. section 4.2.4. As we think the restriction on number of RBs may have impact on the final usage of partial frequency sounding. |
| LGE | If only RRC based Pf value and offset value is supported, same function can be achieved by RRC based SRS bandwidth reconfiguration for non-frequency hopping case. If we want to support non-frequency hopping case for RPFS, signaling method for Pf value and offset value should be enhanced for better flexibility. |
| Huawei, HiSilicon | No need to restrict the use case. Both should be supported. |
| Futurewei | Support both for higher flexibility. |
| QC | We don’t see the needs to support PFS non-frequency hopping.  |
| Spreadtrum | Both should be supported. |
| CATT | We support both, and have same view with LGE. |
| Intel | We don’t think it’s necessary to apply it for non-frequency hopping case. |

### 4.2.4 Further restriction on the number of RBs

One remaining issue is whether to further restrict the number of RBs for SRS transmission in RPFS. Companies’ views are summarized as follows.

Table 4-4

|  |
| --- |
| **Further restriction on the number of RBs for RPFS** |
| Alternatives | Companies |
| Alt 1: is an integer value | Ericsson, ZTE, Huawei/HiSilicon, Futurewei, Lenovo/MotM, Spreadtrum |
| Alt 2: is an integer value with minimum value 4 | Fraunhofer, NTT DOCOMO |
| Alt 3: is a multiple of 4 | Fraunhofer, Intel, Apple, LGE, Nokia/NSB, Spreadtrum, Samsung, CATT, OPPO, Qualcomm |
| Alt 4: Round to a multiple of 4 in case of Alt 1 or Alt 2 | Qualcomm, vivo, NEC, Xiaomi |

***FL Proposal:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | Support Alt.3 since it has no benefit to introduce some SRS bandwidths different from that of the current spec.  |
| Apple |  is limited to the number of SRS PRBs in the current specification 38.211. Alt 3 is still beyond what spec supports currently, we do not support all the integer multiple of 4 in Table 6.4.1.4.3-1 |
| NEC | We don’t support Alt 3, restriction the value to be a multiple of 4 will quite limit the usage of partial frequency sounding, as almost all possible values based on Alt 3 already supported by current spec (based on frequency hopping).Regarding Alt 1 and Alt 2, we think this has no benefit on multiplexing if the number of RBs is not a multiple of 4.So we think Alt 4 is a good solution, and meanwhile, the starting position of SRS subband should be aligned to boundary of a multiple of 4, otherwise, multiplexing can not be guaranteed.  |
| LGE | Support Alt 3. |
| Huawei, HiSilicon | No restriction is needed, since there is already sequence length is the same as legacy sequence length. Alt.3 are too restricted, only the SRS bandwidth is times 16 can be used for partial sounding.  |
| Futurewei | Both Alt 1 and Alt 2 are generally acceptable. The only difference between them is about how to handle a resulting bandwidth less than 4 PRBs. We note that the actual limitation is not directly on the number of PRBs but on the minimum sequence length. So it seems Alt 1 together with the restriction that “SRS sequence shorter than the minimum length supported in the current specification is not pursued” is the best choice.Alt 3 is very limiting, significantly restricting the potential PF values and usable SRS bandwidth configurations. Many of the SRS bandwidth values supported in the current standards cannot meet this requirement. Therefore, this is not preferred.Alt 4 assumes that UE should transmit SRS with bandwidth values as multiples of 4 only. It is unclear why this restriction has to be imposed. This is not preferred at least from a futureproof or SRS flexibility perspective. |
| Lenovo/MotM | Same view with Huawei. Support Alt.1 with that the sequence length is the same as legacy sequence length. |
| Xiaomi | We prefer alt.4 because the requirement for alt.3 is a bit too restricted. |
| ZTE | We support Alt 1. There is no need to introduce any further restriction. We have agreed that there will be no new sequence or new sequence length. This agreement is still valid even if we don’t agree on anything new. |
| QC | Support Alt 3 as well.  |
| Samsung | Support Alt3. |
| Spreadtrum | Slightly prefer Alt.3, but also OK with Alt.1.  |
| CATT | Support Alt 3.  |
| CMCC | Do not support the Alt 3. The Alt 3 will limit the using scenarios of partial frequency sounding. Only , which is the multiples of 8 or 16 PRBs could be used for this feature.  |
| Intel | Support Alt 3 to ensure no new sequence length. |

### 4.2.5 SRS sequence generation

Some companies discuss how to generate SRS sequence for RPFS. The following two alternatives are discussed.

Table 4-5

|  |
| --- |
| **How to generate SRS sequence for RPFS** |
| Alternatives | Companies |
| Alt 1: Generate length- ZC sequence | Qualcomm, ZTE, MediaTek, Ericsson, Apple, NTT DOCOMO, Nokia/NSB, vivo, Lenovo/MotM, Spreadtrum, CATT, NEC, OPPO |
| Alt 2: Truncate from legacy length- sequence according to the location of RPFS SRS | Intel (when SRS is multiplexed with legacy UE), Huawei/HiSilicon, Futurewei |

Given super majority view has formed, FL recommends the following.

***FL Proposal:*** *For RPFS SRS sequence generation, support Alt 1: Generate length- ZC sequence.*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | Support FL proposal |
| Apple | Support FL proposal  |
| NEC  | Support the FL proposal. |
| LGE | Support the proposal. |
| Huawei, HiSilicon | Not support. Alt2 can achieve flexible multiplexing between partial SRS and legacy SRS, which is important in the case where both R15 UE and R17 UE coexist in one cell. |
| Futurewei | Even with SRS transmission not exactly carrying a complete ZC sequence, the PAPR increase is quite limited, as shown in evaluation results in our tdoc. Therefore, the PAPR increase is not really an issue for the truncated SRS sequence, especially the partial frequency sounding provides a significant power boosting. In addition, generating SRS sequences based on the partial bandwidth reduces the multiplexing benefit which is a key objective for this enhancement. Therefore, Alt 2 is preferred. |
| Lenovo/MotM | Support the FL proposal. |
| MediaTek | Support FL proposal |
| Xiaomi | Support the FL proposal  |
| ZTE | Support FL proposal. We think Alt 2 violates previous agreement on no new sequence, and it has PAPR issue. |
| QC | Support the FL proposal.  |
| Samsung | Support FL proposal |
| Spreadtrum | Support FL proposal |
| CATT | Support FL proposal |
| Ericsson | Support FL proposal |
| Intel | Do not support. With Alt 1, how to multiplex with legacy UEs? |

### 4.2.6 Dynamic signaling to determine PF and kF

It has been agreed that RRC signaling is used to indicate PF and kF. The following is to discuss whether more dynamic signaling, e.g., MAC CE or DCI can also be used to update these two values.

Table 4-6

|  |
| --- |
| **Signaling to determine PF and kF** |
| Alternatives | Companies |
| Use MAC CE to update P\_F and/or k\_F | CMCC, NTT DOCOMO, Lenovo/MotM, CATT |
| Use DCI to indicate k\_F | LGE, NTT DOCOMO, Lenovo, CATT, Futurewei |
| Do not support to use MAC CE or DCI | Nokia/NSB, Huawei/HiSilicon, vivo, Spreadtrum, OPPO, Apple, Qualcomm |

***FL Proposal:*** *TBD*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | Not support MAC CE/DCI to update any of them |
| Apple  | Prefer not to support MAC-CE or DCI based |
| LGE | Support DCI indication for offset value, for aperiodic SRS. |
| Huawei, HiSilicon | Not support MAC-CE and DCI. RRC is sufficient for PF and kF, it’s no need to introduce other signaling. |
| Futurewei | Support DCI approach for higher flexibility.  |
| QC | We don’t see the need for DCI or MAC-CE mechanism for indicating or updating the PFS parameters.  |
| Samsung | Share same view as OPPO and Apple |
| Spreadtrum | Not support MAC-C/DCI. |
| CATT | At present, there are two candidate PF values and PF candidate KF values. Assume that the estimation UL channel for an UE become worse due to channel variation. The larger PF value can be indicated to UE though MAC-CE or DCI for SRS coverage enhancement, which does not require RRC reconfiguration. For K*F*, DCI is used to flexibly change the location of RPFS for avoiding the collision between SRS and other UL signals transmission. In addition, DCI can be used to indicate whether the start RB location (Noffset) hopping is enable or disable, as discussed in 4.2.2. |
| Intel | RRC configuration is sufficient. No need to update via MAC-CE or DCI. |

## Comb-8

The only remaining issue for Comb 8 is the maximum supported number of CSs. Companies’ views are summarized as follows.

Table 4-7

|  |
| --- |
| **The maximum number of supported cyclic shifts** |
| Alternatives | Companies |
| Alt 1: The maximum number of CSs for Comb-8 is 6 | Apple, Nokia/NSB, Huawei/HiSilicon, ZTE, vivo, Samsung, Futurewei, NEC, OPPO, Spreadtrum |
| Alt 2: The maximum number of CSs for Comb-8 is 12, and introduce a rule to restrict applicable CSs when SRS sequence is shorter than the maximum number of CSs | Qualcomm, Ericsson, Lenovo/MotM, CATT |

Based on that the majority view is to support max CS = 6, FL recommends the following.

***FL Proposal:*** *For comb-8 SRS in Rel-17, the maximum number of CSs is 6.*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| OPPO | Support FL summary |
| Apple | Support DL proposal  |
| NEC | Support the FL proposal. |
| LGE | Support the proposal. |
| Huawei, HiSilicon | Support |
| Futurewei | Support |
| Lenovo/MotM | Do not support since it does not work for SRS resource with 4 antenna ports. |
| ZTE | Support. 4 ports can be supported with max CS=6 as we have 8 comb offset values to distribute these 4 ports. |
| QC | As pointed out by Ericsson and Lenovo, the equation for computing CS index doesn’t work for 4 antenna ports for Alt 1 (max CS = 6),Also, we did some evaluation and observed similar performance for both max CS = 6,8 while max CS = 12 has minimal performance loss. Not sure on what basis the proponent support max CS = 6 which has similar SRS capacity or multiplexing gain compared to comb 4.We support the maximum number of CSs is >6. |
| Samsung | Support FL proposal |
| Spreadtrum | Support |
| CATT | The orthogonality among SRS sequences for four SRS ports in a SRS resource may not be kept when the maximum number of CSs is 6. Thus, we prefer Alt 2. |
| Ericsson | Do not support. Same view as Lenovo/MotM, QC, there is an issue for 4 ports.  |
| Intel | Support FL proposal |

## Others

The following issue is discussed by one companies.

|  |  |
| --- | --- |
| Support different repetition factors/SRS bandwidths for different symbols within one SRS resource | Nokia/NSB |

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
|  |  |
|  |  |
|  |  |

# Conclusion

# Appendix

## Previous agreements

Table 6-1

|  |
| --- |
| **RAN1#102e****Agreement**Enhance the determination of aperiodic SRS triggering offset, with at least one of the following alternatives* + Alt 1: Delay the SRS transmission to an available slot later than the triggering offset defined in current specification, including possible re-definition of the triggering offset
	+ Alt 2: Indicate triggering offset in DCI explicitly or implicitly
	+ Alt 3: Update triggering offset in MAC CE
	+ Further consideration aspects may include the cost v.s. the total combinations PDCCH and SRS locations for gNB to choose, DCI overhead, multi-UE SRS multiplexing, CA aspect, whether to have multiple opportunities to transmit SRS, etc.

**Agreement**Study the following two alternatives in the scope to enhance at least one DCI format for aperiodic SRS triggering * + Alt 1: Use UE-specific DCI, e.g., extending DCI 0\_1 without uplink data and without CSI
	+ Alt 2: Use group-common DCI, e.g., extending DCI 2\_3 for cases other than carrier switching
	+ Further consideration aspects may include simultaneous or CC-specific SRS triggering for multiple CCs, dynamic indication of SRS frequency resources, etc..

**Agreement**For SRS overhead reduction, study reusing same resources among multiple usages, at least for “codebook” and “antenna switching”. Study aspects include* + Whether implementation approach based on legacy SRS configuration is sufficient
		- If not, and if there are benefits other than RRC overhead reduction, study further on the case that antenna switching and PUSCH have different number of Tx antennas, whether UL BWP for different SRS usages is the same or different, whether and how to ensure UE to use same virtualization, the set of applicable usages, UE implementation complexity and overhead, etc..

**Agreement**For SRS antenna switching up to 8Rx, study the configuration of {1T6R, 1T8R, 2T6R, 2T8R, 4T6R, 4T8R}.* + Study points may include CSI latency, performance considering aspects like insertion loss, use cases, antenna structure, UE power saving, SRS resource configuration, etc..

**Agreement**For SRS coverage/capacity enhancements, evaluate and, if needed, specify one or more from three categories based on the following definition. * + Class 1 (Time bundling): Utilize relationship among two or more occasions of one or more SRS resources in one or more slots to enable joint processing within time domain.
		- Study aspects include the issue of phase discontinuity, interruption of SRS transmission by other UL signals, etc..
	+ Class 2 (Increase repetition): Change the legacy SRS pattern in one resource and one occasion from time domain by increasing SRS symbols for repetition.
		- Study aspects include to use TD-OCC to compensate the negative impact on SRS capacity, inter-cell interference randomization, whether these SRS symbols are in one slot or consecutive slots, etc..
	+ Class 3 (Partial frequency sounding): Support more flexibility on SRS frequency resources to allow SRS transmission on partial frequency resources within the legacy SRS frequency resources.
		- Study aspects include the partial frequency resources are with RB level or subcarrier level (e.g., larger comb, partial bandwidth), PAPR issue, etc..

**RAN1#103e****Agreement**A given aperiodic SRS resource set is transmitted in the (t+1)-th available slot counting from a reference slot, where t is indicated from DCI, or RRC (if only one value of t is configured in RRC), and the candidate values of t at least include 0. Adopt at least one of the following options for the reference slot.* Opt. 1: Reference slot is the slot with the triggering DCI.
* Opt. 2: Reference slot is the slot indicated by the legacy triggering offset.
* FFS the detailed definition of “available slot” considering UE processing complexity and timeline to determine available slot, potential co-existence with collision handling, etc., e.g.,
	+ Based on only RRC configuration, “available slot” is the slot satisfying: there are UL or flexible symbol(s) for the time-domain location(s) for all the SRS resources in the resource set and it satisfies the minimum timing requirement between triggering PDCCH and all the SRS resources in the resource set
* FFS explicit or implicit indication of t
* FFS whether updating candidate triggering offsets in MAC CE may be beneficial

**Agreement**Support at least DCI 0\_1 and 0\_2 to trigger aperiodic SRS without data and without CSI.* FFS whether/how to re-purpose the unused fields, e.g., the triggering offset(s) and the frequency resources for triggering A-SRS on one or more component carriers, SFI-index, etc.
* FFS UL/DL DCI with data for aperiodic SRS
* FFS group common DCI

**Agreement**In Rel-17 SRS coverage and capacity enhancement, support at least one scheme from Class 2 and Class 3, and deprioritize Class 1.* Note: Extensions of Rel-15/16 frequency hopping are included in Classes 2 and 3, e.g. where UE hops once per symbol within a Rel-17 SRS resource.

**Agreement**Candidate schemes for Class 2:* Scheme 2-0: Increase the number of repetition symbols in one slot
* Scheme 2-1: Inter-slot repetition on consecutive symbols or non-consecutive symbols across slots
* Scheme 2-2: Repetition with TD-OCC
* Scheme 2-3: Repetition with CS hopping

Candidate schemes for Class 3:* Scheme 3-1: RB-level partial frequency sounding
* Scheme 3-2: Subcarrier-level partial frequency sounding
* Scheme 3-3: Subband-level partial frequency sounding
* Scheme 3-4: Partial-frequency sounding schemes assisted with CSI-RS, where SRS is transmitted in a subset of RBs of the original SRS frequency resource
* Scheme 3-5: Dynamic change of SRS bandwidth with RB-level subband size scaling
* Note: Consider issues like gNB receiver complexity, PAPR, etc., with above schemes
* Note: Joint operation between Class 2 and Class 3 schemes can be considered

**Agreement**For antenna switching up to 8Rx, support SRS resource configurations for {1T6R, 1T8R, 2T6R, 2T8R, [4T6R], 4T8R}.**RAN1#104e****Agreement**For Rel-17 SRS capacity and coverage enhancement, support the following* Increase the maximum number of repetition symbols in one slot and one SRS resource to S
	+ Support at least one S value from {8, 10, 12, 14}
		- FFS other candidate values
* Support to transmit SRS only in  contiguous RBs in one OFDM symbol, where  indicates the number of RBs configured by BSRS and CSRS
	+ Support at least one PF value from {2, [3], 4, 8}
		- FFS other candidate values, e.g., non-integer values for PF
	+ Note: SRS sequence shorter than the minimum length supported in the current specification is not pursued.
	+ No new sequence including length is introduced
	+ FFS it is applicable to frequency hopping and non-frequency hopping
	+ FFS detailed signaling mechanism to determine PF and the location of the  RBs
* Support Comb 8
	+ Note: SRS sequence shorter than the minimum length supported in the current specification is not pursued.
* FFS whether and if needed, how to use harmonized approach to define the three supported schemes
* Note: other schemes for SRS capacity and coverage enhancements are not supported in Rel-17.

**Agreement*** For aperiodic antenna switching SRS, support to configure N <=N\_max resource sets, where totally K resources are distributed in the N resource sets flexibly based on RRC configuration.
	+ For 1T6R, K=6, N\_max = [4], and each resource has 1 port.
	+ For 1T8R, K=8, N\_max = [4], and each resource has 1 port.
	+ For 2T6R, K=3, N\_max = [3], and each resource has 2 ports.
	+ For 2T8R, K=4, N\_max = [4], and each resource has 2 ports.
	+ (Working Assumption) For 4T8R, K=2, N\_max = [2], and each resource has 4 ports.
	+ FFS the number of supported candidate values of N for each xTyR.
* FFS extension to increase N\_max for 1T4R, 2T4R, T=R and 1T2R cases for aperiodic, periodic and semi-persistent SRS resources
* FFS the number of resources and resource sets for semi-persistent and periodic antenna switching SRS
* Note: SRS could be transmitted over the last 6 OFDM symbols, or over any OFDM symbols within the slot subject to UE capability.

**Agreement**Further study whether and if needed, how to achieve further enhancements on aperiodic SRS triggering and resource management based on repurposing unused fields in DCI format 0\_1/0\_2 without data and without CSI. Consider the following examples* CAT A: Time-domain parameters
	+ A-1: Indication of available slot position, i.e., the t values
	+ A-2: Indication of slot offset
	+ A-3: Indication of SRS symbol-level offset
	+ A-4: Indication of time-domain behavior for SRS transmission over multiple OFDM symbols, e.g., repetition, hopping, and/or splitting
* CAT B: Frequency-domain parameters
	+ B-1: Indication of a group of CCs for SRS transmission
	+ B-2: Indication of frequency domain resource in a BWP for SRS transmission
	+ B-3: Indication of whether DL/UL BWP is applied for SRS transmission
* CAT C: Power control parameters
	+ C-1: Re-purpose ‘TPC command for PUSCH’ as ‘TPC command for SRS’
		- FFS impact on power control, impact from triggering a group of CCs for SRS
	+ C-2: Indication of open loop power control parameter e.g., p0.
* CAT D: Spatial-domain parameters, i.e., indication of SRS port and beamforming
* CAT E: Extend the number of DCI codepoints for aperiodic SRS trigger states
* Other examples are not precluded

**Agreement**A list of t values is configured in RRC for each SRS resource set. Adopt at least one of the following for DCI indication of t.* In DCI format 0\_1/0\_2 without data and without CSI request,
	+ Alt 1-1: Reuse the same scheme used for DCI format 0\_1/0\_2/1-1/1-2 that schedules a PDSCH or PUSCH
	+ Alt 1-2: Re-purpose unused DCI field to indicate t
	+ Alt 1-3: t is indicated by a configurable DCI field, where the DCI field may contain bits from unused fields and additional bits configured by gNB
		- FFS design details with other potential field(s)
	+ FFS: whether t can be slot offset
* In DCI format 0\_1/0\_2/1-1/1-2 that schedules a PDSCH or PUSCH
	+ Alt 2-1: t is indicated by adding a new configurable DCI field
	+ Alt 2-2: t is indicated without adding DCI payload
* Note: The size of DCI payload does not change dynamically
* Note: RAN1 should strive for unified solution for different DCI formats.
* FFS: The number of RRC configured t values per SRS resource set and DCI bit field size.

**Agreement**Confirm the following working assumption with modificationsAn “available slot” is a slot satisfying there are UL or flexible symbol(s) for the time-domain location(s) for all the SRS resources in the resource set and it satisfies UE capability on the minimum timing requirement between triggering PDCCH and all the SRS resources in the resource set.* From the first symbol carrying the SRS request DCI and the last symbol of the triggered SRS resource set, UE does not expect to receive SFI indication, UL cancellation indication or dynamic scheduling of DL channel/signal(s) on flexible symbol(s) that may change the determination of “available slot”.
* Note: Collision handling between the triggered SRS and any other UL channel/signal is performed after the determination of available slot.
* FFS: Rules to handle the case of multiple SRS resource sets with overlapping symbols and/or triggered by a same DCI

**RAN1#104bis-e****Agreement**For increased repetition in Rel-17, support the following N\_symbol (number of OFDM symbols in one SRS resource) and R (repetition factor) values* N\_symbol = 8, R = {1, 2, 4, 8}
* N\_symbol = 12, R = {1, 2, [3], 4, 6, 12}
* FFS the following configurations
	+ N\_symbol = 10, R = {1, 2, 5, 10}
	+ N\_symbol = 14, R = {1, 2, 7, 14}
* FFS options to reduce SRS BW for R>1

**Agreement**On aperiodic SRS configuration for antenna switching with > 4Rx, support the following N\_max values* 1T6R: N\_max = 3
* 1T8R: N\_max = 4
* 2T6R: N\_max = 3
* 2T8R: N\_max = 4
* [4T8R: N\_max = 2]
* The support of N\_max value does not imply the support of N value that is smaller than N\_max. This is FFS.
* FFS whether further enhancement for single-DCI or multi-DCI based MTRP is needed

**Agreement**For RB-level partial frequency sounding (RPFS) in Rel-17* The start RB index of the RBs in the RBs is , where kF = {0, …, PF-1}
	+ FFS support start RB location (Noffset) hopping in different SRS occasions, symbols or frequency hopping periods, and if supported, detailed hopping pattern
* Support to determine PF and Noffset at least via RRC configuration per SRS resource.
	+ FFS whether to introduce DCI and/or MAC CE in addition

**Working Assumption**For DCI indication of “t” in Rel-17 SRS triggering offset enhancement* For both DCI that schedules a PDSCH/PUSCH and DCI 0\_1/0\_2 without data and without CSI request
	+ t is indicated by adding a new configurable DCI field (up to 2 bits)
		- Applies only when there are multiple candidate values of t configured
	+ No further enhancement to indicate “t” for DCI 0\_1/0\_2 without data and without CSI request at least when the new DCI field is configured

**Agreement**On supported values of N for Rel-17 aperiodic SRS antenna switching with >4Rx, down-select at least one of the following alternatives in RAN1#105e* Alt 1: All the non-zero integer values <= N\_max are supported for N
* Alt 2: Support N=N\_max only
* Alt 3: Support specific N values <= N\_max
* FFS whether different alternatives may be selected for the same xTyR configuration subject to the UE capability on maximum number of symbols that can be used for SRS in a slot
* FFS: whether different alternatives may be selected for different xTyR configuration

**Agreement**Study the maximum number of cyclic shifts for Comb-8 in Rel-17, with the following alternatives as starting points* Alt 1: The maximum number of CSs for Comb-8 is 6
* Alt 2: The maximum number of CSs for Comb-8 is 12, and introduce a rule to restrict applicable CSs when SRS sequence is shorter than the maximum number of CSs

**Agreement*** Up to 4 “t” values can be configured per SRS resource set.

**Agreement*** For RPFS in Rel-17, support PF = {2, 4}.
* FFS 3, 8, 12, 16 or fractional numbers
* Support at least one of the following alternatives (to be decided in RAN1#105-e)
	+ Alt 1: is an integer value
	+ Alt 2: is an integer value with minimum value 4
	+ Alt 3: is a multiple of 4
	+ Alt 4: Round to a multiple of 4 in case of Alt 1 or Alt 2

**Agreement**On aperiodic SRS configuration for antenna switching with 4T8R, support N\_max = 2**Agreement**For RPFS SRS in Rel-17, adopt one of the following alternatives for sequence generation, where no new sequence length other than the ones supported in the current spec is introduced (to be decided in RAN1#105-e)* Alt 1: Generate length- ZC sequence
* Alt 2: Truncate from legacy length- sequence according to the location of RPFS SRS

**Agreement**For antenna switching, support one of the following * Alt 1: Support maximum one SRS resource set for periodic SRS and maximum one SRS resource set for semi-persistent SRS
* Alt 2: Support up to two semi-persistent SRS resource sets in addition to a periodic SRS resource set
	+ Note: the two SP-SRS resource sets are not activated at the same time.
* FFS whether further enhancement for single-DCI or multi-DCI based MTRP is needed
* FFS whether configurations on SRS repetitions have impact
* FFS relevant UE capability design
 |

# References

|  |  |  |  |
| --- | --- | --- | --- |
| [1] | RP-193133 | New WID: Further enhancements on MIMO for NR | Samsung |
| [2] | [R1-2106468](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106468.zip) | Enhancements on SRS in Rel-17 | Huawei, HiSilicon |
| [3] | [R1-2106546](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106546.zip) | Enhancements on SRS flexibility, coverage and capacity | ZTE |
| [4] | [R1-2106576](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106576.zip) | Further discussion on SRS enhancement | vivo |
| [5] | [R1-2106645](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106645.zip) | Remaining Issues on SRS Enhancements | InterDigital, Inc. |
| [6] | [R1-2106670](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106670.zip) | Enhancements on SRS | Lenovo, Motorola Mobility |
| [7] | [R1-2106690](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106690.zip) | Considerations on SRS enhancements | Spreadtrum Communications |
| [8] | [R1-2106793](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106793.zip) | Considerations on SRS flexibility, coverage and capacity | Sony |
| [9] | [R1-2106870](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106870.zip) | Enhancements on SRS | Samsung |
| [10] | [R1-2106940](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2106940.zip) | Discussion on SRS enhancements for Rel-17 | CATT |
| [11] | [R1-2107083](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107083.zip) | Enhancements on SRS flexibility, coverage and capacity | FUTUREWEI |
| [12] | [R1-2107147](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107147.zip) | Discussion on SRS enhancement | NEC |
| [13] | [R1-2107208](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107208.zip) | Enhancements on SRS flexibility, coverage and capacity | OPPO |
| [14] | [R1-2107328](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107328.zip) | Enhancements on SRS flexibility, coverage and capacity | Qualcomm Incorporated |
| [15] | [R1-2107395](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107395.zip) | Enhancements on SRS flexibility, coverage and capacity | CMCC |
| [16] | [R1-2107467](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107467.zip) | Enhancements on SRS for coverage and capacity  | Fraunhofer IIS, Fraunhofer HHI |
| [17] | [R1-2107489](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107489.zip) | Enhancements on SRS flexibility, coverage and capacity | MediaTek Inc. |
| [18] | [R1-2107558](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107558.zip) | SRS Performance and Potential Enhancements | Ericsson |
| [19] | [R1-2107575](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107575.zip) | Discussion on SRS enhancements | Intel Corporation |
| [20] | [R1-2107723](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107723.zip) | Views on Rel-17 SRS enhancement | Apple |
| [21] | [R1-2107788](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107788.zip) | Enhancements on SRS | Sharp |
| [22] | [R1-2107819](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107819.zip) | Enhancements on SRS flexibility, coverage and capacity | LG Electronics |
| [23] | [R1-2107843](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107843.zip) | Discussion on SRS enhancement | NTT DOCOMO, INC. |
| [24] | [R1-2107898](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2107898.zip) | Discussion on SRS enhancements | Xiaomi |
| [25] | [R1-2108057](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_106-e/Docs/R1-2108057.zip) | Enhancements on SRS flexibility, coverage and capacity | Nokia, Nokia Shanghai Bell |