3GPP TSG RAN WG1 Meeting #104-e R1-2101917

**e-Meeting, Jan. 25th – Feb. 5th, 2021**

**Source: Moderator (ZTE)**

Title: FL summary #3 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#103e [2]-[25].

# Flexibility enhancements

## SRS triggering offset

### 2.1.1. Reference slot definition

Two options are given in last meeting’s agreement on the definition of reference slot. The following table summarizes companies’ views on three alternatives for SRS triggering offset enhancement.

Table 2-1

|  |  |  |
| --- | --- | --- |
|  | Number | Companies |
| Opt. 1 (Reference slot is the slot with the triggering DCI) | 11 | Nokia, NSB, Apple, NTT DOCOMO, ZTE, Futurewei, OPPO, Huawei, HiSilicon, LG, Spreadtrum, |
| Opt. 2 (Reference slot is the slot indicated by the legacy triggering offset) | 13 | NEC, CMCC, Xiaomi, Qualcomm, Ericsson, Sharp, InterDigital, CATT, vivo, MediaTek, Intel, Lenovo, MotM |

***FL Proposal 2-1:*** *For reference slot definition, support Opt 2 (Reference slot is the slot indicated by the legacy triggering offset).*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Apple | We are fine with the FL proposal  |
| Futurewei | We have pointed out issues about Opt 2, but for the sake of progress we can be ok with this proposal. |
| LGE | We still believe option 1 is more flexible solution, since option 2 cannot always schedule zero slot offset SRS. If the legacy triggering offset value is larger than 0 with option 2, the RRC reconfiguration is needed to enable zero slot offset triggering, or the minus value of t should be introduced. The former require RRC overhead and delay, and the latter require more candidate value of t and DCI payload overhead. |
| Samsung | Support FL’s proposal for the progress. |
| OPPO | We prefer Opt1. We share the same view as LGE that option 1 is more flexible. Moreover, Option 2 has more complexity compared to Option 1Option 2 has four steps: a. Determine the RRC-configured offset, b. determine the additional offset indicated by DCI, c. calculate the total offset (RRC-configured offset + additional offset, d. determine the occasion for real transmission. In contrast, Option 1 has only two steps: a’. determine the offset indicated by DCI, b’. determine the occasion for real transmission.  |
| vivo | Support the proposal |
| Huawei, HiSilicon | Not fine for the proposal. Shared the similar view with LGE.Obviously, the flexibility of A-SRS triggering for Option-1 is better than Option-2 when the slot-offset is more than 0.  |
| Spreadtrum | We support Opt.1. It is more flexible. We also adjust our position in Table 2-1. |
| Lenovo, MotM | Support FL proposal. |
| Nokia/NSB | O.K. with FL proposal for the progress |
| NEC | Support the proposal. |
| Intel | Support FL proposal.With Option 1, there is some issue when multiple SRS resource sets are triggered by the same DCI. If the reference slot is the slot carrying DCI, the multiple triggered SRS resource sets will be pointed to the same slot, resulting in collision.With Option 2, the gNB has the flexibility to configure different value of legacy slot offset for different SRS resource sets with the same trigger state. In this way, the multiple sets triggered by the same DCI will be distributed to different slot.Therefore, Option 2 is more flexible and preferred. |
| Ericsson | Support FL proposal. Agree with Intel on the issue with Option 1.  |
| Xiaomi | Support the proposal |
| InterDigital | Support FL’s proposal |
| QC | Support FL proposal. Similar views as Intel and Ericsson on the flexibility of option 2 and limitations of option 1. And want to clarify again that Rel-17 UE needs to support both legacy and enhanced SRS triggering mechanism. Option 2 is incremental enhancement based on current implementation based on legacy SlotOffset.  |
| NTT DOCOMO | We also think Opt. 1 is much flexible than Opt. 2, as we clarified in our previous comments and also as pointed out by several companies here. However, for the sake of progress we are fine with the proposal  |
| Huawei, HiSilicon2 | Not Support.To reply comments from Intel: Thanks raised the issue for multiple SRS sets cases. Since ‘t’ is configured per SRS resource set, different Set can be triggered by different available slot. **After analysis, there is no issue for Option-1 in the multiple SRS resource sets case, but actually there is collision of SRS transmission for Option-2.** Provided examples as follows:**For Option-1**, RRC configure: SRS set-1 is with candidate list ‘***t***’= {0, 1}, and SRS set-2 is with candidate list ‘***t***’ ={1, 2}. Then, the DCI triggering the first value, **0** available slot corresponding to SRS set-1, and **1** available slot corresponding to SRS set-2. Then, the two SRS sets transmitted in different available slot.C:\Users\z00221589\AppData\Roaming\eSpace_Desktop\UserData\z00583471\imagefiles\79C2E426-2C61-49DC-8A71-609F2EC01922.png**For Option-2**, RRC configure: SRS set-1 is with soltoffset=0 and candidate list ‘***t***’= {0, 1}, and SRS set-2 is with *slotoffset*=1 and the candidate list ‘***t***’ is {0, 1}. Then, DCI indicate ‘***t***’=0, then SRS set-1 is in the slot of the **0** available slot counting from the reference slot *slotoffset=0*, SRS set-2 is in the slot of the **0** available slot counting from the reference slot in *slotoffset=1*.If the reference slot in both *slotoffset=0 and 1* is the available slots for SRS transmission, then the same flexiblity as Option-1. However, **if the reference *slotoffset=0 or 1* is not an available slot for SRS transmission, then after counting of available slot, the two SRS sets will be collision**.C:\Users\z00221589\AppData\Roaming\eSpace_Desktop\UserData\z00583471\imagefiles\3CEE600C-4011-4D83-B68C-B21E4EB1A7AC.png |
| Samsung2 | We have strong view on these options but have a question to Huawei about your example above. If we compare two options having different ‘t’ values per SRS set, the following options also possibleOption 1) same as the above example* SRS set-1 with candidate list ‘***t***’= {0, 1}
* SRS set-2 with candidate list ‘***t***’ ={1, 2}

Option2)* SRS set-1 with slotoffset=0 and candidate list ‘***t***’= {0, 1}
* SRS set-2 with slotoffset=1 and candidate list ‘***t***’ ={1, 2}

 (option 1) (option 2)In this case, conflict is not occurred in option 2.Otherwise, if we go with majority view of option 2, one can set the legacy Slotoffset=0 for all SRS sets for using the benefit of the option 1. In addition, we also have similar view as Qualcomm that Rel-17 UE needs to support both legacy and enhanced SRS triggering mechanism. |
| NEC | Support the FL proposal, we share similar view with Qualcomm that option 2 is an incremental enhancement.In Rel-15/16, the slot offset for SRS triggering can be 0-32, while the issue is lack of flexibility. The main target is to find an available slot if the RRC configured slot offset is not available. Any candidate values of 0-32 for slot offset configuration is useful, just adjusting the transmission slot based on legacy offset is enough.Taking slot offset = 5 for example.In case of Option 1, if candidate list “t” is 0, 1, the SRS triggered by the slots are all localized in two slots (slot 7 and 8). Besides, for SRS triggered in slot 6, the offset may not meet the minimum requirement for SRS transmission, where the triggering may be dropped. On the contrary, to meet the requirement, the value of “t” may be set to be 2,3, but in this case, for SRS triggering in slot 0,1,2,3, there is no need to wait so many slots for SRS transmission.And in case of option 2, with slotoffset = 5, and candidate list “t” with 0, 1, the SRS triggered by the slots can be distributed. For option 1, to achieve same flexibility, more values of “t” are needed (e.g. 0,1,2,3), which costs extra overhead.Furthermore, any candidate values of 0-32 in Rel-15/15 for slot offset configuration is useful, network can schedule the SRS transmission flexibly. With option 1, to achieve similar flexibility, the value for candidate list “t” needs to be counted considering the slot format configuration and the triggering slot position. In other words, in different triggering slots, the values of “t” are different, and with different slot format configurations, the values of “t” are different. We can not exhaustively list any value of “t” based on the various slot format configurations and triggering slot positions. |
| CATT | Support FL’s proposal. Don’t agree there is no issue for Option 1 in the multiple SRS resource sets case. Assume that the configurations of SRS for option 1 are the same as that for option 2 in HW’s example, i.e. SRS Set-1 is with soltoffset=0 and candidate list ‘***t***’= {0, 1}, and SRS set-2 is with *slotoffset*=1 and the candidate list ‘***t***’ is {0, 1}. Then, if the DCI triggering the first value, **0** available slot corresponding to SRS set-1, and **0** available slot corresponding to SRS set-2. The two SRS sets will be collision for option 1.  |
| CMCC | Support FL’s proposal  |
| Nokia/NSB | Still O.K. with FL proposal for the progress. But we echo to Huawei or CATT that option 1 has restriction which option 2 does not have. Considering multiple SRS resource sets, we may not see collision always, but it should be true that gNB should be more careful on configuring slot offset value, and it should be also true that there is restriction on triggering A-SRS, e.g., which set to be transmitted earlier than other set.  |
| Intel2 | Response to Huawei’s comment. Thanks for the interesting discussion.In your example, the ‘t’ configuration for resource sets are different for two Options. If gNB configure the same values of ‘t’ for the same trigger state, then there will be collision for Option 1. For Option 2, as also observed by Samsung in your example, for different value of ‘t’, there is no collision.As mentioned by CATT, we don’t know yet whether gNB should indicate set-common value of ‘t’ or set-specific value of ‘t’ via the same DCI. Therefore, we think it’s better to go with Option 2 at this stage. |

### 2.1.2. Available slot definition

Void

### 2.1.3 Determination on the value of t

Based on last meeting’s agreement, candidate values of t are configured by RRC and indicated further in DCI. Detailed mechanism is still to be decided. Companies’ views are summarized in the following table.

Table 2-3

|  |
| --- |
| **DCI** |
| Cases | Alternatives | Number | Companies |
| Non-scheduling DCI (DCI 0\_1/0\_2 without data and without CSI request) | Alt 1-1: Add a new configurable DCI field to indicate t | 4 | Apple, Huawei, HiSilicon, CATT |
| Alt 1-2: Re-purpose unused DCI field to indicate t | 8 | CMCC (TDRA), Qualcomm, ZTE (TDRA), Futurewei (TDRA), vivo, LG, Ericsson, DOCOMO |
| Scheduling DCI (DCI that schedules a PDSCH or PUSCH) | Alt 2-1: Add a new configurable DCI field to indicate t | 8 | Nokia, NSB, Apple, Futurewei, Huawei, HiSilicon, vivo, CATT |
| Alt 2-2: t is indicated without adding DCI payload | 10 | CMCC, Qualcomm, ZTE, OPPO, Intel, Ericsson, Xiaomi, Lenovo, MotM, DOCOMO |

***FL Proposal 2-3:*** *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.*
* *FFS: The number of RRC configured t values per SRS resource set and DCI bit field size.*

***FL Proposal 2-3 (rev):***

*On the determination of t value(s)*

* *RRC Configuration: A list of t values is configured for each SRS resource set*
* *DCI indication: adopt at least one of the following*
	+ *Alt 1-1: t is indicated by adding bits in current DCI format*
		- *Alt 1-1-1: t is indicated by adding a new configurable DCI field*
		- *Alt 1-1-2: t is indicated by a configurable DCI field, where the DCI field may contain additional bits configured by gNB and bits from fields other than SRS request field*
			* *FFS design details with other potential field(s)*
	+ *Alt 1-2: t is indicated without adding DCI payload*
		- *Alt 1-2-1: Re-purpose bits in DCI field(s) other than SRS request field to indicate t*
		- *Alt 1-2-2: t is indicated by SRS trigger state*
	+ *Note: The size of DCI payload does not change dynamically*
	+ *FFS: whether t can be slot offset*
	+ *FFS considerations on scheduling DCI (DCI format that schedules a PDSCH or PUSCH) or non-scheduling DCI (DCI format 0\_1/0\_2 without data and without CSI request)*
	+ *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*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Apple | We do not think we need to treat DCI format 0\_1/0\_2 without data and without CSI request differently. We just reuse the solution for “DCI format 0\_1/0\_2/1-1/1-2 that schedules a PDSCH or PUSCH” |
| Futurewei | Support Alt 2-1 and Alt 1-2. We think the difference between Alt 1-1 and Alt 1-2 is inessential. t is indicated by some bits in the DCI, and as long as these bits are configured on any unused location within the DCI, the functionality is achieved. The location may be decided as part of the design in Sec. 2.2. So we suggest Alt 1-3:*Alt 1-3: t is indicated by a configurable DCI field; FFS design details with other potential field(s)* |
| LGE | Generally OK with FL proposal. |
| Samsung | We have similar thinking with Apple about common solution and Futurewei about configurability of DCI. We prefer to use an existing field in the DCI that is not used for other SRS triggering purpose in both cases. |
| OPPO | Share the same view as Apple and we prefer to have a common solution for different DCI formats. |
| vivo | Ok with the proposal, for DCI format 0\_1/0\_2 without data and without CSI request, t can be slot offset rather than available slot offset  |
| Huawei, HiSilicon | We can accept the proposal. Similar view as Apple that reusing the solution for the “with data” case for “without data” case to guarantee no dynamic change on the DCI payload size. In our understanding, “with data” case need to be discussed first, since there is no existing bits can be reused, then new DCI field is the way to go. |
| Spreadtrum | Fine with the proposal.Share the same view with other companies. One unified solution for DCI w/ and w/o scheduling data is preferred to keep consistent DCI payload size. |
| Lenovo, MotM | Support FL proposal.Prefer to have a unified solution for both cases that “with date” and “without date”.  |
| Nokia/NSB | Support FL proposal. We are also O.K. with unified solution proposed by multiple companies.  |
| NEC | Fine with the proposal. |
| Intel | Only support the second bullet. Similar view as Apple, we think the solution for DCI scheduling data could be also used for DCI without scheduling data.We think the first bullet should be removed. |
| Ericsson | We are fine with the proposal and prefer a unified solution for the triggering enhancement.  |
| Xiaomi | Fine with the proposal and prefer a unified solution as Apple,intel,E/// mentioned |
| OPPO | For the first bullet, the listed alternatives don’t cover all the potential solutions for DCI format 0\_1/0\_2/1-1/1-2 that schedules a PDSCH or PUSCH. In order to provide the possibility that the 1st bullet and 2nd bullet can have a common design, we proposed to revise Alt.1-1 as below ( or add a new alternative 1-x)***FL Proposal 2-3:*** *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: ~~t is indicated by adding a new configurable DCI field~~ 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*
 |
| InterDigital | Support FL’s proposal |
| QC | Support the proposal. For next meeting discussion, suggest adding FFS on the list size for the number t-values (e.g., 2 or 4 values) and the bit field size for indication the value of t.* *FFS: The number of RRC configured t values per SRS resource set and DCI bit field size.*
 |
| NTT DOCOMO | Support FL’s proposal. Further, we also prefer a unified solution for indication of *t* within DCI with/without data scheduling. |
| CATT | We suggest to delete “*A list of t values is configured in RRC for each SRS resource set.*”. If option 2 of the reference slot is adopted, set-common *t* can be considered (i.e., the *t* indicated by DCI applies to all SRS resource sets triggered by the DCI), then SRS resource set-specific indication of *t* is not needed.Besides, we prefer a unified solution for DCI formats with/without data. |
| CMCC | Support FL’s proposal. It seems that a unified solution for DCI format with/without data have majority support. We are fine with it.  |
| Nokia/NSB | We are generally O.K. with FL proposal. But we wonder what this note means:* *Note: RAN1 should strive for unified solution.*

If RAN1 strives so, why we need separated discussion?  |
| Intel2 | We still have concern on the first bullet. As explained in previous discussion, we can just use the same solution for DCI format with and without scheduling data. |

Another FFS point in last meeting’s agreement is whether to support MAC CE as an inter-mediate step to update candidate values of t. Companies’ views are summarized as follows.

Table 2-4

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| **Whether to support MAC CE as an inter-mediate step** |
| Alternatives | Number | Companies |
| Support using MAC CE to update the candidate values of t | 10 | Nokia, NSB, Samsung, Qualcomm, NTT DOCOMO, MotM, Lenovo, MediaTek, InterDigital, Xiaomi |
| Deprioritize or do NOT support | 9 | CMCC, Futurewei, OPPO, Ericsson, CATT, vivo, Huawei, HiSilicon, Intel |

***FL Proposal 2-4:*** *Further discuss in future meetings*

### 2.1.4 Collision handling among the triggered SRS resource sets

Two companies discuss the issue of supporting a mechanism to handle potential collision among the triggered SRS resource sets in the available slot, if multiple resource sets are triggered by one DCI. Their views are summarized as follows.

Table 2-5

|  |  |
| --- | --- |
|  | Companies |
| Support a mechanism to handle potential collision among triggered SRS resources in the same or different CCs in an available slot | vivo (an ordering principle of increased or decreased SRS resource set ID), Ericsson (details FFS) |

***FL Proposal 2-5:*** *Further discuss in future meetings.*

## Flexible DCI format

Last meeting we have agreed to support DCI format 0\_1/0\_2 to trigger SRS without data and without CSI request. One remaining issue is whether to repurpose the unused fields. Companies’ views are summarized as follows.

Table 2-6

|  |
| --- |
| **Whether to repurpose unused fields in DCI format 0\_1/0\_2 without data and without CSI** |
| Alternatives | Detailed functionality | Companies |
| Yes | Indication of available slot position (cf. Section 2.1.3) | CMCC, Qualcomm, ZTE, Futurewei, LG |
| Indication of slot offset (cf. Section 2.1.3) | vivo |
| Indication of a group of CCs for SRS transmission | Qualcomm, ZTE |
| TPC command for each CC | Qualcomm |
| Indication of resource blocks for SRS transmission | Ericsson, Futurewei |
| Indication of SRS port and beamforming | Futurewei |
| No | - | Apple, Huawei, HiSilicon |

***FL Proposal 2-6:*** *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*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Futurewei | We support “Indication of resource blocks for SRS transmission” and “Indication of SRS port and beamforming”. The indication of RBs may be achieved by indication of subbands, RBGs, $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$, *PF* value(s),etc.The time-domain behavior of repetition / hopping / non-hopping / splitting over multiple symbols may also be indicated.“Indication of slot offset” should also be included here, and “Indication of available slot position” is no longer needed. “Indication of a group of CCs for SRS transmission” is generally supported by GC DCI and may be considered there. |
| LGE | Support. And, can we add one more sub-bullet as follows? The motivation is to avoid SRS symbol-level collision with the other UL channel/RS within the indicated “available slot”. SRS symbol-level position can be anywhere within a slot for a UE with corresponding UE capability from Rel-16, and as we have discussed in this agenda we are trying to increase the max number of configurable SRS symbols for an SRS resource. We think these are quite relevant to the collision between SRS and the other UL channel/RS.* *Indication of SRS symbol-level offset*
 |
| OPPO | We think repurpose unused fields in DCI format 0\_1/0\_2 without data and without CSI is a lower priority issue.  |
| vivo | On indication of resource block for SRS , propose to revise as  *Indication of frequency domain resource ~~blocks~~ for SRS transmission* |
| Huawei, HiSilicon | Add a new bullet for further study:* *Indication of open loop power control parameter e.g., p0.*

In current spec, open loop power control parameters are configured by RRC, repurposing unused fields for open loop power control parameters can adjust SRS power dynamically according to channel condition, which is more flexible. |
| Spreadtrum | Fine to further study, but should be low priority. |
| Lenovo, MotM | We just want to clarify that all the list bullets may be discussed, and more other proposals may be added in the future? |
| Nokia/NSB | Support in principle. But we do not prefer all the possible issues to be listed and to be discussed. ***FL Proposal 2-6:*** *Further study whether and if needed, how to achieve further enhancements on aperiodic SRS triggering and resource management ~~the following functionalities~~ based on repurposing unused fields in DCI format 0\_1/0\_2 without data and without CSI. Consider following examples* |
| NEC | Fine with the proposal. |
| Intel | 1. For DCI 0\_1/0\_2 without scheduling PUSCH, we think the field of ‘TPC command for PUSCH’ should be repurposed as ‘TPC command for SRS’, since SRS is not triggered together with PUSCH. In addition, we think the impact on power control should be further studied, because SRS triggered by DCI 0\_1/0\_2 without data is a new feature and it is not considered in current power control design.2. Currently the number of DCI codepoint for available trigger states for aperiodic SRS is just 3. But there might be a lot of aperiodic SRS resource sets configured for the UE. For example, for 1T8R antenna switching, there might be 4 aperiodic SRS resource sets. For multi-TRP, there might be two aperiodic SRS resource sets for codebook/non-codebook. And the UE can also be configured with aperiodic SRS resource sets for beam management. Thus, it’s possible that multiple SRS resource sets with different usages are configured with the same trigger state, which means different usages might be always triggered together.In order to increase the flexibility, some un-used fields for DCI 0\_1/0\_2 without data could be re-purposed to extend the number of DCI codepoints for trigger states.3. In TDD, the bandwidth for DL BWP and UL BWP may be different. In order to determine the DL precoder, it’s better to transmit SRS over the DL BWP. Thus some un-used field in DCI 0\_1/0\_2 could be re-purposed to indicate whether DL/UL BWP is applied for SRS transmission.Therefore, we suggest adding the following bullets to the FL proposal* *Re-purpose ‘TPC command for PUSCH’ as ‘TPC command for SRS’. FFS impact on power control*
* *Extend the number of DCI codepoints for aperiodic SRS trigger states*
* *Indication of whether DL/UL BWP is applied for SRS transmission*
 |
| Ericsson | Support. We think the flexibility to select the RB for AP-SRS transmission dynamically is important for future use cases with different verticals co-existing in the same BWP. |
| InterDigital | Support FL’s proposal |
| QC | Support the study.  |
| Futurewei2 | Support the proposal.We’d like to further elaborate our comment on time-domain behavior before. When the DCI indicates multiple symbols for the SRS, different time-domain behaviors may be possible. For example, the SRS transmissions may be repeated on these symbols; for another instance, frequency hopping may be performed on these symbols; alternatively, the indicated frequency-domain resources may be split over these symbols; furthermore, combinations of repetition/hopping/splitting may also be considered. Note that splitting may also be used if the frequency-domain resources are non-contiguous: for example, if subband 2 and subband 15 are indicated with 2 OFDM symbols, then subband 2 may be transmitted on the first symbol and subband 15 may be transmitted on the second symbol. So we suggest to add a sub-bullet:* + *B-4: Indication of time-domain behavior for SRS transmission over multiple OFDM symbols, e.g., repetition, hopping, and/or splitting*
 |
| NTT DOCOMO | Support FL’s proposal |
| Nokia/NSB | Support in principle |

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

Table 2-7

|  |
| --- |
| **Whether group-common DCI enhancement is supported additionally** |
| Alternatives | Number | Companies |
| Yes | 7 | Xiaomi, Samsung, Qualcomm, Sharp, Futurewei, vivo, Intel |
| No | 8 | Nokia, NSB, Huawei, HiSilicon, CATT, Lenovo, MotM, LG |

***FL Proposal 2-7:*** *Further discuss in future meetings*

## Usage/overhead reduction

One remaining issue is whether to support configuring one SRS resource set with multiple usages explicitly in specification. Table 2-8 summarize companies’ views.

Table 2-8

|  |
| --- |
| **Whether to support configuring one SRS resource set with multiple usages explicitly** |
|  | Number | Companies |
| Support specification change | 6 | Nokia, NSB, Apple, Ericsson, vivo, DOCOMOEricsson: Further support antenna selection for PUSCH with ceil(n/m)-bit SRI field. |
| Implementation can solve the issue | 8 | Xiaomi, Futurewei, OPPO, Huawei, HiSilicon, CATT, Lenovo, MotM |

***FL proposal 2-8:*** *Further discuss in future meetings*

## 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 2-9

|  |  |  |
| --- | --- | --- |
|  | Number | Companies |
| Support indicating the number of Tx/Rx antennas for SRS antenna switching via MAC CE or DCI | 6 |  Qualcomm, Ericsson, ZTE, MotM, Lenovo, Intel |
| UE Report the preferred Tx or Rx antenna number together with other CSI contents to the gNB to trigger the change or degradation of the SRS antenna switching configurations. | 1 | Xiaomi |

***FL proposal 2-9:*** *Study L1 or L2 based adaptation on the number of Tx and/or Rx antennas for SRS antenna switching based on the indicated UE capability of supported SRS-TxPortSwitch*

* *Consider this adaption is applicable to which type(s) of SRS ( aperiodic SRS, periodic SRS, or semi-persistent SRS)*
* *Consider use cases like UE power saving, NW overhead saving, multi-panel UEs, etc.*
* *FFS via MAC CE or DCI*
* *FFS whether to consider dynamic DL MIMO layer adaptation together*
* *FFS UE reporting of the preferred Tx/Rx antenna number*
* *FFS potential enhancements on CSI measurement to solve issues (if any) caused by this dynamic adaption*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Apple | The only reason we support L1 or L2 based adaptation if because UE can report its preferred Tx/Rx, otherwise, we would not agree for gNB to randomly change our Tx/Rx configuration that dynamically  |
| Futurewei | We described a CSI issue for antenna switching. That is, when the UE antenna configuration changes, the wireless channels and hence CSI change abruptly. Based on all the inputs, it seems the only way to resolve this is to adopt time-domain measurement restriction / reset. Therefore, the following should be included (other suggestions are also welcome), otherwise we are not sure if this scheme can work:* *Define time-domain CSI measurement restriction / reset for antenna switching*
 |
| LGE | Regarding this issue, as we commented in Round 0 we are not convinced yet why the proposal is needed. |
| OPPO | Not support since the use case and benefit are not justified so far.  |
| vivo | Same as in previous comment, we do not support this proposal |
| Huawei, HiSilicon | We are not positive for the proposal, since RRC based changing is already supported in current spec.If company think it is beneficial for power saving, we do hope it is only restricted for periodic and semi-persistent cases, and MAC-CE based change, while dynamic change based solution will require UE’s complexity. |
| Spreadtrum | Fine with the proposal. At least it is beneficial for UE power saving. |
| Lenovo, MotM | We can support this proposal with MAC CE based approach.This mechanism is useful for multi-panel UE, where the UE panels may be activated semi-statically. Another purpose is for power saving, especially for UE with 1T6R and 1T8R capability in poor channel conditional.  |
| Nokia/NSB | Support in principle.  |
| Intel | Fine with FL proposal. |
| Ericsson | Support the proposal. |
| Xiaomi | Support the proposal, and agree that CSI issues should be considered also  |
| InterDigital | Support FL’s proposal for study. |
| QC | Support the study. In our understanding, this mechanism is helpful to enable faster adaptation of SRS resources for antenna switching. This is not related to UE power savings and/or the adaptation of UE actual number of Rx antennas. Agree with Apple, that adaptation should be based on UE reporting of its preferred Tx/Rx or antenna switching configuration (1T8R, 1T6R. etc.). Suggest the following wording:*L1 or L2 based adaptation on the number of Tx and/or Rx antennas for SRS antenna switching* based on the indicated UE capability of supported SRS-TxPortSwitch. |
| CATT | Since the proposal is “Study…”, shall we revise the following bullet* “*This adaptation is applicable for at least one of the following*
	+ *Case 1: Aperiodic SRS*
	+ *Case 2: Periodic and semi-persistent SRS”*

to be“*Consider this adaption is applicable to which type(s) of SRS( aperiodic SRS, periodic SRS, or semi-persistent SRS)*”? |
| CMCC | From the perspective of UE power saving and NW overhead reduction, we do not see benefits of dynamic change from 2T4R (as an example) to 1T2R and then go back to 2T4R. We should be careful with the design of dynamic indication. We are open for this topic. And more view and discussions are preferred.  |
| Nokia/NSB | Support FL proposal |

## Others

The following are proposed by one company.

|  |  |
| --- | --- |
| Support CC-specific SRS triggering in carrier aggregation | Intel |
| Support flexible trigger state configuration for multiple SRS resource sets with different usages in multi-TRP | Intel |
| Support one usage of SRS with multiple time-domain types | CMCC |
| Support to trigger aperiodic SRS by non-scheduled DCI format 1-1 and 1-2 | vivo, LG |
| Support update the association between aperiodic SRS resource set(s) and aperiodic SRS triggering states by MAC CE | Lenovo, MotM |

# Antenna switching up to 8Rx

## Resource set configurations

Void

## Whether 4T6R is supported

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

Table 3-2

|  |
| --- |
| **Whether to support 4T6R SRS antenna switching** |
|  | Number | Companies |
| Yes | 13 | NEC, Nokia, NSB, CMCC, Xiaomi, Samsung, Qualcomm, NTT DOCOMO, InterDigital, Spreadtrum, Lenovo, MotM, MediaTek |
| No or deprioritize | 5 | Ericsson, Futurewei, Huawei, HiSilicon, vivo |

***FL Proposal 3-2:*** *Support antenna switching SRS with 4T6R in NR Rel-17*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| Futurewei | We are already supporting a large number of antenna switching schemes. As there are still concerns on 4T6R, we suggest to deprioritize it. |
| OPPO | We are ok with the proposal.  |
| vivo | Deprioritize this proposal |
| Huawei, HiSilicon | Not support. We have already agreed so many cases for antenna switching in Rel-17 for specification. For 4T6R, we do not see there is practical antenna structures and switching solutions from proposals, while considering the insertion loss, imbalanced power transmission issues, antennas mapping, etc. |
| Spreadtrum | Fine with the proposal.  |
| Lenovo, MotM | We support FL proposal. |
| Nokia/NSB | Support |
| NEC | Support the proposal. |
| Intel | Fine with FL proposal |
| Ericsson | Deprioritize the proposal.  |
| Xiaomi | Support the proposal |
| InterDigital | Support FL’s proposal  |
| QC | Support FL’s proposal.We ask companies who have technical concerns to further clarify. In our tdoc, we showed how 4T6R antenna switching configuration can be supported including.* + Physical mapping between Tx chains to antenna ports for different SRS configuration
	+ Symmetrical insertion loss across all antenna ports.
 |
| NTT DOCOMO | Support FL’s proposal |
| Huawei, HiSilicon2 | Not support. We do have concerns on the antenna switching for 4T6R. For QC’s Tdoc and results, we have the following comments:1. Could you clarify the exact mapping between antennas and Tx chain with switches, since in the Tdoc, the mapping part is a black box. What’s the switches look like, especially for the best performance case: 4+4+4?2. Please clarify the insertion loss modeling in the evaluation. In our understanding, with special antenna switches mapping may be with different insertion loss/modeling, which need to study. 3. It seems in the evaluation 4+4+4 for 4T6R is with best performance, but we already have the antenna switching solution for 2T6R, what’s the benefits compared to 2T6R? Actually, the same periodicity, but 2T6R may beneficial on less overhead and also each port is with much more transmit power (beneficial for channel estimation).4. In the simulation provided by QC, although we do not know the exact antenna mapping and not sure the insertion loss modeling for the special cases, but some results show the gain of 1T6R and 2T6R are already better performance than 4T6R, e.g., Figure 3-7.  |
| CMCC | We are fine with the proposal. |

## Others

The following is proposed by one company.

|  |  |
| --- | --- |
| Enhance SRS resource set configuration for 1T2R, 1T4R and 2T4R | Ericsson |
| Need to consider UE coherence capability, especially for 4T8R | InterDigital |

# Coverage and capacity enhancements

Void

# 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}. |

# References

1. RP-193133, New WID: Further enhancements on MIMO for NR, Samsung
2. R1-2100042, Enhancements on SRS flexibility, coverage and capacity, FUTUREWEI
3. R1-2100068 , Flexible SRS Transmission and Antenna Switching, InterDigital, Inc.
4. R1-2100123, Enhancements on SRS flexibility, coverage and capacity, OPPO
5. R1-2100213 , Enhancements on SRS for Rel-17, Huawei, HiSilicon
6. R1-2100277, Enhancements on SRS, Lenovo, Motorola Mobility
7. R1-2100290, Enhancements on SRS flexibility, coverage and capacity, ZTE
8. R1-2100348, Discussion on SRS enhancement for Rel-17 , CATT
9. R1-2100426, Further discussion on SRS enhancement, vivo
10. R1-2100590 , Enhancements on SRS flexibility, coverage and capacity, MediaTek Inc.
11. R1-2100623 , Enhancements on SRS flexibility, coverage and capacity, LG Electronics
12. R1-2100641 , Discussion on SRS enhancements, Intel Corporation
13. R1-2100788, Considerations on SRS enhancement, Spreadtrum Communications
14. R1-2100849 , Considerations on SRS flexibility, coverage and capacity, Sony
15. R1-2100953, Discussion on SRS enhancement, NEC
16. R1-2101010, Enhancements on SRS flexibility, coverage and capacity, Nokia, Nokia Shanghai Bell
17. R1-2101037, Enhancements on SRS flexibility, coverage and capacity, CMCC
18. R1-2101096 , Discussion on SRS enhancements, Xiaomi
19. R1-2101191, Enhancements on SRS, Samsung
20. R1-2101355 , Views on Rel-17 SRS enhancement, Apple
21. R1-2101451 , Enhancements on SRS flexibility, coverage and capacity, Qualcomm Incorporated
22. R1-2101519 , SRS Performance and Potential Enhancements, Ericsson
23. R1-2101538, Enhancements on SRS flexibility, coverage and capacity, Sharp
24. R1-2101602, Discussion on SRS enhancement, NTT DOCOMO, INC.
25. R1-2101684 , Enhancements on SRS for coverage and capacity, Fraunhofer IIS, Fraunhofer HHI