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) | 10 | Nokia, NSB, Apple, NTT DOCOMO, ZTE, Futurewei, OPPO, Huawei, HiSilicon, LG |
| Opt. 2 (Reference slot is the slot indicated by the legacy triggering offset) | 14 | NEC, CMCC, Xiaomi, Qualcomm, Ericsson, Sharp, InterDigital, CATT, vivo, MediaTek, Intel, Spreadtrum, 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.  |

### 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: t is indicated by a new configurable DCI field*
	+ *Alt 1-2: Re-purpose unused DCI field to indicate t*
* *In DCI format 0\_1/0\_2/1-1/1-2 that schedules a PDSCH or PUSCH*
	+ *Alt 2-1: t is indicated by 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*

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. |

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

|  |
| --- |
| **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, ~~vivo~~, 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 the following functionalities based on repurposing unused fields in DCI format 0\_1/0\_2 without data and without CSI*

* *Indication of available slot position*
* *Indication of slot offset*
* *Indication of SRS symbol-level offset*
* *Indication of a group of CCs for SRS transmission*
* *TPC command for each CC*
* *Indication of resource blocks for SRS transmission*
* *Indication of SRS port and beamforming*

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.  |

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:*** *Support L1 or L2 based adaptation on the number of Tx and/or Rx antennas for SRS antenna switching*

* *This adaptation is applicable for at least one of the following*
	+ *Case 1: Aperiodic SRS*
	+ *Case 2: Periodic and semi-persistent SRS*
* *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*

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.  |

## 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.  |
|  |  |

## 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