3GPP TSG RAN WG1 Meeting #104b-e R1-2102674

**e-Meeting, Apr. 12th – 20th, 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) | 8 | Samsung (when ‘slotoffset’ is absent but a list of ‘t’ is configured), LG, ZTE, NTT DOCOMO, Huawei, HiSilicon, OPPO, Futurewei |
| Opt. 2 (Reference slot is the slot indicated by the legacy triggering offset) | 12 | Qualcomm, Samsung (when ‘slotoffset’ and a list of ‘t’ are configured), Ericsson, Sharp, NEC, InterDigital, vivo, CATT, MediaTek, Intel, CMCC, Xiaomi |

These issue has been discussed extensively in RAN1#104e without any conclusion. This is a necessary component to complete the Rel-17 feature of aperiodic SRS triggering offset enhancement. A compromised solution is needed given both two sides have strong views.

The following observation can be seen based on companies’ input to RAN1#104e and RAN1#104b-e.

* Opt. 1 is a subset of Opt. 2 (Opt. 1 and Opt. 2 is equivalent when the legacy triggering offset is configured as 0 in Opt. 2).
* Some companies claimed that Opt. 2 requires extra processing on top of Opt. 1 as UE needs to perform offset operation twice.

Based on the above, FL propose the following compromised direction to solve the dilemma ahead of us.

* Supports Opt. 2 for reference slot definition.
* The configuration of Opt. 1 is a basic feature if UE supports the Rel-17 enhancement on SRS triggering offset, and the other configurations in Opt. 2 is optional.

Based on the above spirit, the following FL proposal is given.

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

* *For a UE supporting the Rel-17 SRS triggering offset enhancement, configuring legacy triggering offset as 0 when using this enhancement is a basic feature, and configuring legacy triggering offset as non-zero values when using this enhancement is optional.*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| InterDigital | Support only the main proposal, and not the sub-bullet. We are not sure what is meant by basic feature, and why the sub-bullet is needed, as gNB can freely select a zero value for the legacy triggering offset |
| CATT | Similar views as InterDigital. The main bullet is agreeable. Some clarification is needed for the sub-bullet.  |
|  |  |

### 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** |
| Schemes | Companies |
| Introduce dropping rule when collision happens among aperiodic SRS resource sets | Qualcomm, ZTE (for SRS in different CCs), Ericsson, vivo (for SRS in different CCs or same CC) |
| Update collision handling rule for SRS colliding with other UL channel/signal | Futurewei (A/N and AP UL triggered later than R17 flexible A-SRS > R17 flexible A-SRS > other UL) |

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| CATT | We are not sure if dropping rule needs to be introduced. However the rule is defined, in the end what/how SRS are transmitted is definitively known to the gNB which can be similarly achieved by gNB scheduling. Leaving it to implementation seems feasible.  |
|  |  |
|  |  |

### 2.1.3 Determination on the value of t

**DCI indication mechanism**

Alternatives to indicate t values in DCI are listed in RAN1#104e’s agreements. Companies’ views in RAN1#104b-e are summarized in the following table.

Table 2-3

|  |
| --- |
| **DCI** |
| Cases | Alternatives | Number | Companies |
| Scheduling DCI (DCIs scheduling a PDSCH or PUSCH) | Alt 2-1: t is indicated by adding a new configurable DCI field | 11 | Apple, ZTE, NEC, NTT DOCOMO, Huawei, HiSilicon, Spreadtrum, vivo, MediaTek, IDC, CATT |
| Alt 2-2: t is indicated without adding DCI payload | 8 | Qualcomm (using aperiodic SRS trigger state), Samsung, Nokia, NSB (using aperiodic SRS trigger state), Ericsson, OPPO, Intel, Xiaomi |
| Non-scheduling DCI (DCI 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 | 11 | Apple, ZTE, NEC, NTT DOCOMO, Huawei, HiSilicon, OPPO, Spreadtrum, CATT, Intel, IDC |
| Alt 1-2: Re-purpose unused DCI field to indicate t | 9 | Qualcomm, ZTE, Samsung, Ericsson, NTT DOCOMO, vivo, MediaTek, CMCC, Xiaomi |
| 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 | 3 | Nokia, NSB, vivo |

We have agreed to strive for a unified solution for scheduling DCI and non-scheduling DCI. Hence FL proposes the following for offline/online discussion in RAN1#104b-e. Companies are encouraged to share your views on these two alternatives.

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

* *Discuss and decide one of the following alternatives in RAN1#104b-e for both scheduling DCI and non-scheduling DCI*
	+ *Alt 1: t is indicated by adding a new configurable DCI field*
	+ *Alt 2: t values are associated with SRS triggering states*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| InterDigital | Support Alt1.As for Alt2, since t is agreed to be configured per SRS resource set, then we don’t see any benefit by relating it not to trigger states. We believe this reduces the flexibility of the configurations. |
| CATT | Support alt.1. According to current specs, only three trigger states can be used to trigger aperiodic SRS resource sets. From the perspective of overhead reduction, SRS resource sets for different usages are more likely to be configured with different trigger states. Hence to adequately address SRS triggering flexibility, it is desirable to have a dedicated DCI field.  |
|  |  |

**Size of t list**

We have agreed that a list of t values is configured per SRS resource set. The size of each list is to be determined. Companies’ views are summarized as follows.

Table 2-4

|  |
| --- |
| **Size of t list in each SRS resource set** |
| Alternatives | Number | Companies |
| Up to 2 | 1 | Qualcomm |
| At least up to 4 | 4 | Ericsson, NEC, ZTE, IDC, CATT |

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

Companies’ further views are collected as follows.

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

**Whether to support MAC CE update**

Another FFS point in previous 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 2-5

|  |
| --- |
| **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 | Qualcomm, Samsung, Nokia, NSB, NTT DOCOMO, MediaTek, Lenovo, MotM, Xiaomi, IDC |
| Deprioritize or do NOT support | 2 | CMCC, CATT |

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| CATT | Between using DCI to choose from a list of t values and using MAC-CE to update the t values, the first is preferable and sufficient. It does not seem necessary to have yet another MAC-CE for t value update, when dynamically choosing t value already can address this issue.  |
|  |  |
|  |  |

## Flexible DCI format

**Re-purpose**

In 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 re-purpose the unused fields. Companies’ views are summarized as follows.

Table 2-6

|  |
| --- |
| **Repurpose unused fields in DCI format 0\_1/0\_2 without data and without CSI** |
| Categories | Detailed aternatives | Companies |
| CAT-A (Time-domain parameters) * 13 supporting companies: Qualcomm, ZTE, Samsung, Ericsson, NTT DOCOMO, vivo, MediaTek, CMCC, Xiaomi, Nokia, NSB, Futurewei, LG
 | A-1: Indication of available slot position, i.e., the t values  | Qualcomm, ZTE, Samsung, Ericsson, NTT DOCOMO, vivo, MediaTek, CMCC, Xiaomi |
| A-2: Indication of slot offset  | Nokia, NSB, Ericsson, vivo, Futurewei |
| A-3: Indication of SRS symbol-level offset  | LG, Futurewei |
| A-4: Indication of time-domain behavior for SRS transmission over multiple OFDM symbols, e.g., repetition, hopping, and/or splitting  | vivo, Futurewei |
| CAT B (Frequency-domain parameters)* 6 supporting companies: Qualcomm, Futurewei, Xiaomi, Ericsson, LG, Intel
 | B-1: Indication of a group of CCs for SRS transmission | Qualcomm, Futurewei, Xiaomi |
| B-2: Indication of frequency domain resource in a BWP for SRS transmission | Ericsson, LG, Futurewei, Xiaomi |
| 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)* 6 supporting companies: Qualcomm (for each CC), Futurewei, Intel, Xiaomi, Huawei, HiSilicon
 | C-1: Re-purpose ‘TPC command for PUSCH’ as ‘TPC command for SRS’ | Qualcomm (for each CC), Futurewei, Intel, Xiaomi |
| C-2: Indication of open loop power control parameter e.g., p0. | Huawei, HiSilicon |
| Do not support this category | vivo |
| CAT D (Spatial-domain parameters, i.e., indication of SRS port and beamforming)* 1 supporting company: Futurewei
 | 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)* 5 supporting companies: Nokia, NSB, Futurewei, Intel, Xiaomi
 | Extend the number of DCI codepoints for aperiodic SRS trigger states | Nokia, NSB, Futurewei, Intel, Xiaomi |
| New functionalities | Re-purpose to indicate set usage | Spreadtrum |
| No or deprioritize | - | Apple, OPPO, CATT |

The majority of companies have interest in CAT A, while the other categories do not attract major interest. Hence the following is proposed by FL.

***FL Proposal:*** *Support enhancement on aperiodic SRS time-domain resource management based on repurposing unused fields in DCI format 0\_1/0\_2 without data and without CSI, by at least one of the following alternatives:*

* *Alt A-1: Indication of available slot position, i.e., the t values*
* *Alt A-2: Indication of legacy slot offset*
* *Alt A-3: Indication of SRS symbol-level offset*
* *Alt A-4: Indication of time-domain behavior for SRS transmission over multiple OFDM symbols, e.g., repetition, hopping, and/or splitting*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| InterDigital | Support Alt A-1 |
| CATT | We prefer to deprioritize the discussion until an agreement on how to configure and indicate “*t*” is achieved. |
|  |  |

**Group-common DCI**

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 | 5 | Qualcomm, Samsung, vivo, Futurewei, Xiaomi |
| No or deprioritize | 1 | OPPO |

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

Companies’ further views are collected as follows.

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

## Usage/overhead reduction

One remaining issue is whether to specification enhancement on reusing SRS resource(s) for multiple usages. Table 2-8 summarize companies’ views.

Table 2-8

|  |
| --- |
| **Whether to support configuring one SRS resource set with multiple usages explicitly** |
|  | 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 | 5 | Apple, ZTE, Ericsson, NTT DOCOMO, CATT |
| Action 2: Add a RRC parameter to turn on/off the UE behavior in Action 1 | 4 | Apple, Ericsson, NTT DOCOMO, CATT |
| Action 3: Have a conclusion to clarify same virtualization is used if SRS resource(s) for antenna switching also belong to a set for codebook | 3 | Ericsson, ZTE, CATT |
| None of the above actions is needed | 6 | Samsung, Huawei, HiSilicon, Futurewei, Intel, IDC |

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

Companies’ further views are collected as follows.

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

## 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

|  |
| --- |
| **Update Tx/Rx antennas for SRS antenna switch in dynamic signaling** |
|  | Number | Companies | Other comments |
| Support indicating the number of Tx/Rx antennas for SRS antenna switching via MAC CE or DCI | 9 | Apple, Qualcomm (MAC CE), Ericsson (MAC CE), Huawei, HiSilicon (MAC CE), Lenovo, MotM, Xiaomi, ZTE | **UE reporting**Apple, Xiaomi: Support UE reporting of the preferred antenna switching configuration**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#104b-e.

***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 |
| InterDigital | We need further discussion on this. |
| CATT | Need further discussion. |
|  |  |

## Others

The following issues are discussed by one company.

|  |  |
| --- | --- |
| Support single scheduling DCI to trigger simultaneous AP SRS transmission across multiple component carriers | Qualcomm |
| Support triggering multiple SRS resource sets and/or triggering multi-shot SRS by a single DCI | LG |
| Reuse parameters from a co-scheduled/associated PDSCH/PUSCH for AP SRS | Futurewei |
| Allow non-contiguous/almost contiguous sounding | Futurewei |

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

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

# Antenna switching up to 8Rx

## Aperiodic SRS configurations for >4Rx

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

**N\_max values**

Table 3-1

|  |
| --- |
| **N\_max** |
| xTyR | Value | Companies |
| 1T6R | N\_max = 2 | 1 company: OPPO |
| N\_max = 3 | 9 companies: Qualcomm, Nokia, NSB, NTT DOCOMO, Spreadtrum, Lenovo, MotM, CMCC, ZTE |
| N\_max = 4 | 4 companies: Samsung, Ericsson, CATT, Xiaomi |
| N\_max = 6 | 1 company: Spreadtrum |
| 1T8R | N\_max = 2 | 2 companies: OPPO, Spreadtrum |
| N\_max = 4 | 13 companies: Qualcomm, Samsung, ZTE, Nokia, NSB, Ericsson, NTT DOCOMO, Spreadtrum, CATT, Lenovo, MotM, CMCC, Xiaomi |
| 2T6R | N\_max = 1 | 1 company: Spreadtrum |
| N\_max = 2 | 5 companies: Qualcomm, OPPO, Lenovo, MotM, CMCC |
| N\_max = 3 | 9 companies: Samsung, ZTE, Nokia, NSB, Ericsson, NTT DOCOMO, Spreadtrum, CATT, Xiaomi |
| 2T8R | N\_max = 2 | 6 companies: Qualcomm, OPPO, Spreadtrum, Lenovo, MotM, CMCC |
| N\_max = 4 | 9 companies: Samsung, ZTE, Nokia, NSB, Ericsson, NTT DOCOMO, Spreadtrum, CATT, Xiaomi |
| 4T8R | Confirm the WA with | N\_max = 1 | 3 companies: Qualcomm, Spreadtrum, CMCC |
| N\_max = 2 | 10 companies: Samsung, ZTE, Ericsson, NTT DOCOMO, OPPO, Spreadtrum, CATT, Lenovo, MotM, Xiaomi |
| Update the WA with * For *fullAndPartialAndNonCoherent* UEs, K=2, N\_max = [4], and each resource has 4 ports
* For *partialAndNonCoherent* and *nonCoherent* UEs, K=4, N\_max = [2], and each resource has 2 ports
 | 1 company: InterDigital |

Clear majority view has formed for each xTyR. Hence FL propose the following on N\_max.

***FL Proposal:*** *On aperiodic SRS configuration for > 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*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| InterDigital | * Do not support the case for *4T8R: N\_max = 2*

For 4T8R, based on our evaluation that is shared in our contribution, there will be a significant performance loss if SRS transmission occur over all TX chains in a partially coherent UE. Therefore, our proposal is that to apply FL proposal only for fully coherent 4T8R UEs, and then use SRS configuration of 2T8R case for partially coherent 4T8R UEs.* For *fullAndPartialAndNonCoherent* UEs, K=2, N\_max = [4], and each resource has 4 ports
* For *partialAndNonCoherent* UEs, K=4, N\_max = [2], and each resource has 2 ports
 |
| CATT | OK with the table.  |
|  |  |

**N values**

Table 3-2

|  |
| --- |
| **N** |
| Alternatives | Sub-alternatives | Companies |
| Alt 1: All the non-zero integer values <= N\_max are supported for N | - | 6 supporting companies: Samsung, ZTE, Ericsson, CATT, Lenovo, MotM |
| Alt 2: Support N=N\_max only | - | 1 supporting company: vivo |
| Alt 3: Support specific N values | 1T6R | N={2, 3} | Nokia, NSB, CMCC (if only the last 6 symbols can transmit SRS) |
| N=2 | CMCC (if all the symbols can transmit SRS) |
| 1T8R | N={2, 4} | Nokia, NSB |
| N={3, 4} | CMCC (if only the last 6 symbols can transmit SRS) |
| N=2 | CMCC (if all the symbols can transmit SRS) |
| 2T6R | N={1, 3} | Nokia, NSB |
| N={1, 2} | CMCC (if only the last 6 symbols can transmit SRS) |
| N=1 | CMCC (if all the symbols can transmit SRS) |
| 2T8R | N={1, 2, 4} | Nokia, NSB |
| N=2 | CMCC (if only the last 6 symbols can transmit SRS) |
| 4T8R | N=1 | CMCC |

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| CATT | According to current specs, at least 1 symbol is required for the guard period. Therefore up to 7 SRS resources for antenna switching can be transmitted in a slot, and at least 2 aperiodic SRS resource sets are needed for 1T8R. We prefer that:- for 1T8R, 2 <= N <=N\_max; - for other cases, 1 <= N <=N\_max. |
|  |  |
|  |  |

## Extension for aperiodic SRS with <=4Rx

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

Table 3-3

|  |
| --- |
| **Whether to support increasing N\_max for 1T4R, 2T4R, T=R and 1T2R cases** |
|  | Number | Companies |
| Yes | 5 | Ericsson (Support N=4 for 1T4R and N=2 for 1T2R/2T4R), Xiaomi (Support N=4 for 1T4R and N=2 for 1T2R/2T4R), CATT (Support N = 1 for 1T4R), Intel, ZTE |
| No or deprioritize | 2 | Qualcomm, CMCC |

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

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| CATT | When SRS starting at any OFDM symbol within a slot is supported, N =1 can be supported for 1T4R. N =1 for 1T4R is expected to be supported to have less latency. |
|  |  |
|  |  |

## Configurations for periodic and semi-persistent SRS

Table 3-4

|  |
| --- |
| **Number of resource sets for periodic or semi-persistent SRS** |
|  | Number | Companies |
| Alt 1: Support only one SRS resource set for either periodic or semi-persistent SRS | 6 | Qualcomm, ZTE, vivo, CATT, CMCC, Xiaomi |
| Alt 2: Support at least one resource set for periodic SRS and at least two SRS resource sets for semi-persistent SRS | 2 | Huawei, HiSilicon |

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

Companies’ further views are collected as follows.

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

## Configured time-domain types

Multiple companies discuss enhancing the number of configured time-domain types to more than one for antenna switching SRS.

Table 3-5

|  |
| --- |
| **Number of configured time-domain types** |
|  | Number | Companies |
| Alt 1: Only one time-domain type (periodic, semi-persistent or aperiodic) can be configured (same as Rel-15) |  |  |
| Alt 2: Support configuring more than one time-domain types (periodic, semi-persistent or aperiodic) for antenna switching SRS | 3 | ZTE, Huawei, HiSilicon |

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

Companies’ further views are collected as follows.

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

## Guard period

Multiple companies discuss whether to remove some always-on guard symbols between two adjacent SRS resources for antenna switching.

Table 3-6

|  |
| --- |
| **Whether to remove some always-on guard symbols between two adjacent SRS resources for antenna switching** |
|  | Number | Companies |
| Alt 0: Guard symbols are always-on, which is same as Rel-15 |  |  |
| Alt 1: Make the present of guard symbols configurable | 1 | Ericsson |
| Alt 2: Remove some of the guard symbols based on certain conditions | 2 | vivo, Sony, IDC |

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

Companies’ further views are collected as follows.

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

## Whether 4T6R is supported

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

Table 3-7

|  |
| --- |
| **Whether to support 4T6R SRS antenna switching** |
|  | Number | Companies |
| Yes | 8 | Qualcomm, NEC, InterDigital, Spreadtrum, Lenovo, MotM, CMCC, Xiaomi |
| No or deprioritize | 4 | Ericsson, Futurewei, Huawei, HiSilicon |

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

Companies’ further views are collected as follows.

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

## 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 |
| 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 |
| Consideration on antenna switching for multi-panel UEs | Sony, vivo |
| Further study SRS resource/resource set configurations for multi-TRP | Intel |

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

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

# Coverage and capacity enhancements

## Increased repetition

The major remaining issue on increased repetition is the supported number of repetition symbols, which impacts the configuration on N\_symbol (number of OFDM symbols in one SRS resource) and R (repetition factor). Companies views on this are summarized as follows.

Table 4-1

|  |
| --- |
| **Supported N\_symbol and R values** |
| N\_symbol | R |
| N\_symbol = 8* Qualcomm, ZTE, Huawei, HiSilicon, OPPO, vivo, Futurewei, Intel, CMCC, Xiaomi, Apple, Ericsson, Sharp, Fraunhofer IIS, Fraunhofer HHI
 | R = {1, 2, 4, 8}* Qualcomm, ZTE, vivo
 |
| N\_symbol = 10* Qualcomm, ZTE, vivo, Futurewei, Xiaomi, Apple, Ericsson, Sharp
 | R = {1, 2, 10}* Qualcomm, ZTE

R = {1, 2, 5, 10}* vivo
 |
| N\_symbol = 12* Qualcomm, ZTE, Huawei, HiSilicon, OPPO, vivo, Futurewei, Xiaomi, Apple, Ericsson, Sharp, LG
 | R={1, 2, 4, 6, 12}* Qualcomm, ZTE, vivo
 |
| N\_symbol = 14* Qualcomm, ZTE, vivo, Futurewei, Xiaomi, Apple, Sharp, LG
 | R = {1, 2, 14}* Qualcomm, ZTE

R = {1, 2, 7, 14} * vivo
 |

It can be observed that all these 4 values of N\_symbol have good support from companies, and there is no particular reason to preclude any of them. Hence FL proposal the following.

***FL Proposal:*** *For increased repetition supported 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 = 10, R = {1, 2, 5, 10}*
* *N\_symbol = 12, R = {1, 2, 4, 6, 12}*
* *N\_symbol = 14, R = {1, 2, 7, 14}*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| InterDigital | Support FL’s proposal |
|  |  |
|  |  |

## RB-level partial frequency sounding (RPFS)

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

### 4.2.1 Issues related to PF

**Supported PF values**

Table 4-2

|  |
| --- |
| **Supported PF values** |
| Values | Companies |
| PF = {2, 4} | 13 supporting companies* Qualcomm, ZTE, Sony, Nokia, NSB, Ericsson, Sharp, Fraunhofer IIS, Fraunhofer HHI, Huawei, HiSilicon, OPPO, vivo
 |
| PF = 8 | 9 supporting companies* Qualcomm, ZTE, Sony, Nokia, NSB, Sharp, Fraunhofer IIS, Fraunhofer HHI, vivo
 |
| PF = 3 | 2 supporting companies* Sony, vivo

3 companies have concern* Nokia, NSB, Spreadtrum
 |
| Other values | PF = {12, 16} | 2 supporting companies* Fraunhofer IIS, Fraunhofer HHI
 |
| Fractional values | 1 supporting company* Futurewei

1 company has concern* CMCC
 |
| **How to avoid fractional values for** $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$**, e.g., in the case of PF = 8** |
| Alternatives | Number | Companies |
| Alt 1: Restrict that $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ is an integer value | 7 | Qualcomm, ZTE, Samsung, Sony, Huawei, HiSilicon, OPPO |
| Alt 2: Introduce a rule to round $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ | 1 | vivo |

Following majority views shown in the above table, FL has the following proposal.

***FL Proposal:*** *For RB-level partial frequency sounding (RPFS) in Rel-17, support PF = {2, 4, 8}*

* *In the case of PF = 8,* $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ *shall be an integer value.*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| InterDigital | Support FL’s proposal |
|  |  |
|  |  |

### 4.2.2 RB location

Another remaining issue is the start RB location of the $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ RBs in the $m\_{SRS, B\_{SRS}}$ RBs. Companies’ views are summarize as follows.

Table 4-3

|  |
| --- |
| **Supported N\_offset value, which is the start RB index of the** $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ **RBs in the** $m\_{SRS, B\_{SRS}}$ **RBs** |
| Values | Companies |
| $\frac{k\_{F}}{P\_{F}}m\_{SRS, B\_{SRS}}$, where kF = {0, …, PF-1} | 9 supporting companies* Apple, ZTE, Qualcomm, Huawei, HiSilicon, OPPO, CATT, MediaTek, Futurewei
 |
| **Whether to support hopping of start RB location** |
| Views | Companies |
| Support start RB location hopping in different SRS occasions or symbols | 8 supporting companies* Qualcomm, ZTE, Ericsson, Huawei, HiSilicon, vivo, MediaTek, Spreadtrum
 |

Based on companies’ input, the following FL proposal is given

***FL Proposal:*** *For Rel-17 RPFS, the start RB index of the* $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ *RBs in the* $m\_{SRS, B\_{SRS}}$ *RBs is* $N\_{offset}=\frac{k\_{F}}{P\_{F}}m\_{SRS, B\_{SRS}}$*, where kF = {0, …, PF-1}*

* *Support start RB location (*$N\_{offset}$*) hopping in different SRS occasions or symbols*
	+ *FFS detailed hopping pattern*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| InterDigital | Support FL’s proposal |
| CATT | Support FL’s proposal |
|  |  |
|  |  |

### 4.2.3 Applicable cases

On the FFS point of applicable cases for RPFS, the following table summarize companies’ views.

Table 4-4

|  |
| --- |
| **Whether to restrict the applicable cases for RPFS** |
| Views | Number | Companies |
| RPFS is applicable only for frequency hopping case | 6 | Qualcomm, OPPO, Spreadtrum, vivo, Intel, CMCC |
| RPFS is applicable for both frequency hopping and non-frequency hopping cases | 6 | Nokia, NSB, NEC, Huawei, HiSilicon, Xiaomi |

The common ground between the above two alternatives is RPFS is applicable at least for frequency hopping. Hence the following is proposed.

***FL Proposal:*** *Rel-17 RPFS is applicable at least for frequency hopping case*

* *FFS non-frequency hopping case*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| InterDigital | Support FL’s proposal |
|  |  |
|  |  |
|  |  |

### 4.2.4 Issues related to SRS sequence

**How to restrict sequence length**

RAN1#104e agreement restricts that no new sequence or length is introduced. How to achieve this restriction is discussed by companies. The follow table shows companies’ views.

Table 4-5

|  |
| --- |
| **How to restrict SRS sequence length for RPFS** |
| Alternatives | Number | Companies |
| Alt 1: Restrict that the final SRS sequence (i.e., the number of SRS subcarriers) is a multiple of 6, which has been supported by the current specification | 5 | ZTE, Sony, Ericsson, Sharp, OPPO |
| Alt 2: Restrict that the minimum number of RBs given by $\frac{1}{P\_{F}}m\_{SRS, B\_{SRS}}$ is 4 | 3 | Qualcomm, Huawei, HiSilicon |

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

Companies’ further views are collected as follows.

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

**Sequence generation**

Some companies discuss how to generate SRS sequence for RPFS. The following two alternatives can be identified.

Table 4-6

|  |
| --- |
| **How to generate SRS sequence for RPFS** |
| Alternatives | Number | Companies |
| Alt 1: Generate length-$\frac{\frac{12}{P\_{F}}m\_{SRS, B\_{SRS}}}{Comb}$ ZC sequence | 1 | ZTE |
| Alt 2: Truncate from legacy length-$\frac{12⋅m\_{SRS, B\_{SRS}}}{Comb}$ sequence according to the location of RPFS SRS | 2 | Huawei, HiSilicon |

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

Companies’ further views are collected as follows.

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

### 4.2.5 Signaling to determine PF and Noffset

The signaling to indicate PF and Noffset also needs to be addressed. The following alternatives are identified.

Table 4-7

|  |
| --- |
| **Signaling to determine PF and Noffset** |
| Alternatives | Number | Companies |
| Alt 1: Determine PF value and Noffset value by RRC configuration per SRS resource | 7 | ZTE, Huawei, HiSilicon, CATT, MediaTek, Apple, Ericsson |
| Alt 2: Configure multiple P\_F and N\_offset values in RRC, and update the used one in MAC CE | 3 | CMCC, Lenovo, MotM |

Alt 1 is the majority view, and both alternatives require determining PF and Noffset by RRC. Hence FL proposes the following.

***FL Proposal:*** *For Rel-17 RPFS, support to determine PF and Noffset at least via RRC configuration per SRS resource.*

Companies’ further views are collected as follows.

|  |  |
| --- | --- |
| Companies | Views |
| InterDigital | Support FL’s proposal |
|  |  |
|  |  |

## Comb-8

The major remaining issue on Comb-8 is the maximum number of supported cyclic shifts. The following table summarizes companies’ views.

Table 4-8

|  |
| --- |
| **The maximum number of supported cyclic shifts** |
| Alternatives | Number | Companies |
| Alt 1: The maximum number of CSs for Comb-8 is 6 | 2 | Huawei, HiSilicon |
| 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 | 1 | Ericsson |

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

Companies’ further views are collected as follows.

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

## Others

The following issue is discussed by two 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 $\frac{1}{P\_{F}}m\_{SRS,B\_{SRS}}$ contiguous RBs in one OFDM symbol, where$m\_{SRS,B\_{SRS}}$  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 $\frac{1}{P\_{F}}m\_{SRS,B\_{SRS}}$ 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
 |

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