3GPP TSG RAN WG1 Meeting #106-e R1-210xxxx

**e-Meeting, Aug. 16th – 27th, 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 issues with wide interest after the two rounds of discussion in RAN1#106e.

# Flexibility enhancements

## SRS triggering offset

### 2.1.1. Collision handling

***FL Proposal 2-2:*** *Introduce dropping rule when collision happens among multiple aperiodic SRS resource sets in a same CC or different CCs.*

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

The above proposal has been discussed in the first round. Companies’ views are summarized as given below.

Support: Qualcomm, ZTE, Ericsson, Intel, vivo, Futurewei, Huawei/HiSilicon, Spreadtrum, CATT, China Telecom, Nokia/NSB, NEC, NTT DOCOMO, Xiaomi, InterDigital

Concern: OPPO, LGE

FL would like to check whether companies with concern can follow majority view to address the issue when multiple SRS resource sets collide in time domain.

Companies’ further views are collected as follows.

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| Companies | Views |
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## Flexible DCI format

**Re-purpose**

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

Table 2-1

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

***FL Proposal 2-5:*** *Further discuss the issue of repurposing DCI field(s) for SRS parameter indication until RAN1#106bis-e, focused on the following:*

* *Reuse one or more existing DCI fields configured for data transmission for SRS parameter indication without changing the field bitwidths/parameters, e.g., TPC command field, bandwidth part indicator field, FDRA field*
* *Extend the number of DCI codepoints for aperiodic SRS trigger states*

*If no consensus can be achieved, conclude this issue as following.*

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

Support: Qualcomm, CATT, CMCC, Nokia/NSB, Lenovo/MotM, Samsung, OPPO, Apple, ZTE, Intel, Futurewei

This proposal is updated based on Futurewei’s comment in previous round. FL would like to thank Futurewei for the willingness to compromise. FL thinks it is a good compromise between the two alternative proposals in last round.

Companies’ further views are collected as follows.

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| Companies | Views |
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## Flexible antenna switching

***FL proposal 2-6:*** *Support gNB indicating the used SRS resources from the configured SRS resources in SRS resource set(s) for 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*
* *Support UE reporting of one preferred antenna switching configuration via MAC CE*
  + *This preferred antenna switching configuration is one of the supported antenna switching reported by UE capability signaling*
* *FFS whether DCI can be additional used to indicate the used antenna switching configuration*

Support: Qualcomm, Ericsson, Xiaomi, Huawei/HiSilicon, ZTE, Lenovo/MotM, Futurewei, InterDigital, NTT DOCOMO, Nokia/NSB, OPPO

Concern:

It seems companies begin to converge on the support of this functionality. If we only use MAC CE to do the indication and reporting, the rest of work in RAN1 is limited. FL would like to check whether the above proposal is acceptable to companies.

Companies’ further views are collected as follows.

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| Companies | Views |
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# Antenna switching up to 8Rx

## Extension for aperiodic SRS with <=4Rx

The following FL proposal has been discussed in the previous two rounds.

***FL Proposal 3-2:*** *For extension of antenna switching SRS configurations for <=4Rx, support N=4* *for 1T4R and N=2 for 1T2R/2T4R.*

Support: Ericsson, Xiaomi, Nokia/NSB, Huawei/HiSilicon, CATT, Intel, ZTE, NTT DOCOMO

Concern: OPPO, Lenovo/MotM, Apple, vivo

Companies’ further views are collected as follows.

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| Companies | Views |
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# Conclusion

# Appendix

## Previous agreements

Table 6-1

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| **RAN1#102e**  **Agreement**  Enhance the determination of aperiodic SRS triggering offset, with at least one of the following alternatives   * + Alt 1: Delay the SRS transmission to an available slot later than the triggering offset defined in current specification, including possible re-definition of the triggering offset   + Alt 2: Indicate triggering offset in DCI explicitly or implicitly   + Alt 3: Update triggering offset in MAC CE   + Further consideration aspects may include the cost v.s. the total combinations PDCCH and SRS locations for gNB to choose, DCI overhead, multi-UE SRS multiplexing, CA aspect, whether to have multiple opportunities to transmit SRS, etc.   **Agreement**  Study the following two alternatives in the scope to enhance at least one DCI format for aperiodic SRS triggering   * + Alt 1: Use UE-specific DCI, e.g., extending DCI 0\_1 without uplink data and without CSI   + Alt 2: Use group-common DCI, e.g., extending DCI 2\_3 for cases other than carrier switching   + Further consideration aspects may include simultaneous or CC-specific SRS triggering for multiple CCs, dynamic indication of SRS frequency resources, etc..   **Agreement**  For SRS overhead reduction, study reusing same resources among multiple usages, at least for “codebook” and “antenna switching”. Study aspects include   * + Whether implementation approach based on legacy SRS configuration is sufficient     - If not, and if there are benefits other than RRC overhead reduction, study further on the case that antenna switching and PUSCH have different number of Tx antennas, whether UL BWP for different SRS usages is the same or different, whether and how to ensure UE to use same virtualization, the set of applicable usages, UE implementation complexity and overhead, etc..   **Agreement**  For SRS antenna switching up to 8Rx, study the configuration of {1T6R, 1T8R, 2T6R, 2T8R, 4T6R, 4T8R}.   * + Study points may include CSI latency, performance considering aspects like insertion loss, use cases, antenna structure, UE power saving, SRS resource configuration, etc..   **Agreement**  For SRS coverage/capacity enhancements, evaluate and, if needed, specify one or more from three categories based on the following definition.   * + Class 1 (Time bundling): Utilize relationship among two or more occasions of one or more SRS resources in one or more slots to enable joint processing within time domain.     - Study aspects include the issue of phase discontinuity, interruption of SRS transmission by other UL signals, etc..   + Class 2 (Increase repetition): Change the legacy SRS pattern in one resource and one occasion from time domain by increasing SRS symbols for repetition.     - Study aspects include to use TD-OCC to compensate the negative impact on SRS capacity, inter-cell interference randomization, whether these SRS symbols are in one slot or consecutive slots, etc..   + Class 3 (Partial frequency sounding): Support more flexibility on SRS frequency resources to allow SRS transmission on partial frequency resources within the legacy SRS frequency resources.     - Study aspects include the partial frequency resources are with RB level or subcarrier level (e.g., larger comb, partial bandwidth), PAPR issue, etc..   **RAN1#103e**  **Agreement**  A given aperiodic SRS resource set is transmitted in the (t+1)-th available slot counting from a reference slot, where t is indicated from DCI, or RRC (if only one value of t is configured in RRC), and the candidate values of t at least include 0. Adopt at least one of the following options for the reference slot.   * Opt. 1: Reference slot is the slot with the triggering DCI. * Opt. 2: Reference slot is the slot indicated by the legacy triggering offset. * FFS the detailed definition of “available slot” considering UE processing complexity and timeline to determine available slot, potential co-existence with collision handling, etc., e.g.,   + Based on only RRC configuration, “available slot” is the slot satisfying: there are UL or flexible symbol(s) for the time-domain location(s) for all the SRS resources in the resource set and it satisfies the minimum timing requirement between triggering PDCCH and all the SRS resources in the resource set * FFS explicit or implicit indication of t * FFS whether updating candidate triggering offsets in MAC CE may be beneficial   **Agreement**  Support at least DCI 0\_1 and 0\_2 to trigger aperiodic SRS without data and without CSI.   * FFS whether/how to re-purpose the unused fields, e.g., the triggering offset(s) and the frequency resources for triggering A-SRS on one or more component carriers, SFI-index, etc. * FFS UL/DL DCI with data for aperiodic SRS * FFS group common DCI   **Agreement**  In Rel-17 SRS coverage and capacity enhancement, support at least one scheme from Class 2 and Class 3, and deprioritize Class 1.   * Note: Extensions of Rel-15/16 frequency hopping are included in Classes 2 and 3, e.g. where UE hops once per symbol within a Rel-17 SRS resource.   **Agreement**  Candidate schemes for Class 2:   * Scheme 2-0: Increase the number of repetition symbols in one slot * Scheme 2-1: Inter-slot repetition on consecutive symbols or non-consecutive symbols across slots * Scheme 2-2: Repetition with TD-OCC * Scheme 2-3: Repetition with CS hopping   Candidate schemes for Class 3:   * Scheme 3-1: RB-level partial frequency sounding * Scheme 3-2: Subcarrier-level partial frequency sounding * Scheme 3-3: Subband-level partial frequency sounding * Scheme 3-4: Partial-frequency sounding schemes assisted with CSI-RS, where SRS is transmitted in a subset of RBs of the original SRS frequency resource * Scheme 3-5: Dynamic change of SRS bandwidth with RB-level subband size scaling * Note: Consider issues like gNB receiver complexity, PAPR, etc., with above schemes * Note: Joint operation between Class 2 and Class 3 schemes can be considered   **Agreement**  For antenna switching up to 8Rx, support SRS resource configurations for {1T6R, 1T8R, 2T6R, 2T8R, [4T6R], 4T8R}.  **RAN1#104e**  **Agreement**  For Rel-17 SRS capacity and coverage enhancement, support the following   * Increase the maximum number of repetition symbols in one slot and one SRS resource to S   + Support at least one S value from {8, 10, 12, 14}     - FFS other candidate values * Support to transmit SRS only in  contiguous RBs in one OFDM symbol, where  indicates the number of RBs configured by BSRS and CSRS   + Support at least one PF value from {2, [3], 4, 8}     - FFS other candidate values, e.g., non-integer values for PF   + Note: SRS sequence shorter than the minimum length supported in the current specification is not pursued.   + No new sequence including length is introduced   + FFS it is applicable to frequency hopping and non-frequency hopping   + FFS detailed signaling mechanism to determine PF and the location of the  RBs * Support Comb 8   + Note: SRS sequence shorter than the minimum length supported in the current specification is not pursued. * FFS whether and if needed, how to use harmonized approach to define the three supported schemes * Note: other schemes for SRS capacity and coverage enhancements are not supported in Rel-17.   **Agreement**   * For aperiodic antenna switching SRS, support to configure N <=N\_max resource sets, where totally K resources are distributed in the N resource sets flexibly based on RRC configuration.   + For 1T6R, K=6, N\_max = [4], and each resource has 1 port.   + For 1T8R, K=8, N\_max = [4], and each resource has 1 port.   + For 2T6R, K=3, N\_max = [3], and each resource has 2 ports.   + For 2T8R, K=4, N\_max = [4], and each resource has 2 ports.   + (Working Assumption) For 4T8R, K=2, N\_max = [2], and each resource has 4 ports.   + FFS the number of supported candidate values of N for each xTyR. * FFS extension to increase N\_max for 1T4R, 2T4R, T=R and 1T2R cases for aperiodic, periodic and semi-persistent SRS resources * FFS the number of resources and resource sets for semi-persistent and periodic antenna switching SRS * Note: SRS could be transmitted over the last 6 OFDM symbols, or over any OFDM symbols within the slot subject to UE capability.   **Agreement**  Further study whether and if needed, how to achieve further enhancements on aperiodic SRS triggering and resource management based on repurposing unused fields in DCI format 0\_1/0\_2 without data and without CSI. Consider the following examples   * CAT A: Time-domain parameters   + A-1: Indication of available slot position, i.e., the t values   + A-2: Indication of slot offset   + A-3: Indication of SRS symbol-level offset   + A-4: Indication of time-domain behavior for SRS transmission over multiple OFDM symbols, e.g., repetition, hopping, and/or splitting * CAT B: Frequency-domain parameters   + B-1: Indication of a group of CCs for SRS transmission   + B-2: Indication of frequency domain resource in a BWP for SRS transmission   + B-3: Indication of whether DL/UL BWP is applied for SRS transmission * CAT C: Power control parameters   + C-1: Re-purpose ‘TPC command for PUSCH’ as ‘TPC command for SRS’     - FFS impact on power control, impact from triggering a group of CCs for SRS   + C-2: Indication of open loop power control parameter e.g., p0. * CAT D: Spatial-domain parameters, i.e., indication of SRS port and beamforming * CAT E: Extend the number of DCI codepoints for aperiodic SRS trigger states * Other examples are not precluded   **Agreement**  A list of t values is configured in RRC for each SRS resource set. Adopt at least one of the following for DCI indication of t.   * In DCI format 0\_1/0\_2 without data and without CSI request,   + Alt 1-1: Reuse the same scheme used for DCI format 0\_1/0\_2/1-1/1-2 that schedules a PDSCH or PUSCH   + Alt 1-2: Re-purpose unused DCI field to indicate t   + Alt 1-3: t is indicated by a configurable DCI field, where the DCI field may contain bits from unused fields and additional bits configured by gNB     - FFS design details with other potential field(s)   + FFS: whether t can be slot offset * In DCI format 0\_1/0\_2/1-1/1-2 that schedules a PDSCH or PUSCH   + Alt 2-1: t is indicated by adding a new configurable DCI field   + Alt 2-2: t is indicated without adding DCI payload * Note: The size of DCI payload does not change dynamically * Note: RAN1 should strive for unified solution for different DCI formats. * FFS: The number of RRC configured t values per SRS resource set and DCI bit field size.   **Agreement**  Confirm the following working assumption with modifications  An “available slot” is a slot satisfying there are UL or flexible symbol(s) for the time-domain location(s) for all the SRS resources in the resource set and it satisfies UE capability on the minimum timing requirement between triggering PDCCH and all the SRS resources in the resource set.   * From the first symbol carrying the SRS request DCI and the last symbol of the triggered SRS resource set, UE does not expect to receive SFI indication, UL cancellation indication or dynamic scheduling of DL channel/signal(s) on flexible symbol(s) that may change the determination of “available slot”. * Note: Collision handling between the triggered SRS and any other UL channel/signal is performed after the determination of available slot. * FFS: Rules to handle the case of multiple SRS resource sets with overlapping symbols and/or triggered by a same DCI   **RAN1#104bis-e**  **Agreement**  For increased repetition in Rel-17, support the following N\_symbol (number of OFDM symbols in one SRS resource) and R (repetition factor) values   * N\_symbol = 8, R = {1, 2, 4, 8} * N\_symbol = 12, R = {1, 2, [3], 4, 6, 12} * FFS the following configurations   + N\_symbol = 10, R = {1, 2, 5, 10}   + N\_symbol = 14, R = {1, 2, 7, 14} * FFS options to reduce SRS BW for R>1   **Agreement**  On aperiodic SRS configuration for antenna switching with > 4Rx, support the following N\_max values   * 1T6R: N\_max = 3 * 1T8R: N\_max = 4 * 2T6R: N\_max = 3 * 2T8R: N\_max = 4 * [4T8R: N\_max = 2] * The support of N\_max value does not imply the support of N value that is smaller than N\_max. This is FFS. * FFS whether further enhancement for single-DCI or multi-DCI based MTRP is needed   **Agreement**  For RB-level partial frequency sounding (RPFS) in Rel-17   * The start RB index of the RBs in the RBs is , where kF = {0, …, PF-1}   + FFS support start RB location (Noffset) hopping in different SRS occasions, symbols or frequency hopping periods, and if supported, detailed hopping pattern * Support to determine PF and Noffset at least via RRC configuration per SRS resource.   + FFS whether to introduce DCI and/or MAC CE in addition   **Working Assumption**  For DCI indication of “t” in Rel-17 SRS triggering offset enhancement   * For both DCI that schedules a PDSCH/PUSCH and DCI 0\_1/0\_2 without data and without CSI request   + t is indicated by adding a new configurable DCI field (up to 2 bits)     - Applies only when there are multiple candidate values of t configured   + No further enhancement to indicate “t” for DCI 0\_1/0\_2 without data and without CSI request at least when the new DCI field is configured   **Agreement**  On supported values of N for Rel-17 aperiodic SRS antenna switching with >4Rx, down-select at least one of the following alternatives in RAN1#105e   * Alt 1: All the non-zero integer values <= N\_max are supported for N * Alt 2: Support N=N\_max only * Alt 3: Support specific N values <= N\_max * FFS whether different alternatives may be selected for the same xTyR configuration subject to the UE capability on maximum number of symbols that can be used for SRS in a slot * FFS: whether different alternatives may be selected for different xTyR configuration   **Agreement**  Study the maximum number of cyclic shifts for Comb-8 in Rel-17, with the following alternatives as starting points   * Alt 1: The maximum number of CSs for Comb-8 is 6 * Alt 2: The maximum number of CSs for Comb-8 is 12, and introduce a rule to restrict applicable CSs when SRS sequence is shorter than the maximum number of CSs   **Agreement**   * Up to 4 “t” values can be configured per SRS resource set.   **Agreement**   * For RPFS in Rel-17, support PF = {2, 4}. * FFS 3, 8, 12, 16 or fractional numbers * Support at least one of the following alternatives (to be decided in RAN1#105-e)   + Alt 1: is an integer value   + Alt 2: is an integer value with minimum value 4   + Alt 3: is a multiple of 4   + Alt 4: Round to a multiple of 4 in case of Alt 1 or Alt 2   **Agreement**  On aperiodic SRS configuration for antenna switching with 4T8R, support N\_max = 2  **Agreement**  For RPFS SRS in Rel-17, adopt one of the following alternatives for sequence generation, where no new sequence length other than the ones supported in the current spec is introduced (to be decided in RAN1#105-e)   * Alt 1: Generate length- ZC sequence * Alt 2: Truncate from legacy length- sequence according to the location of RPFS SRS   **Agreement**  For antenna switching, support one of the following   * Alt 1: Support maximum one SRS resource set for periodic SRS and maximum one SRS resource set for semi-persistent SRS * Alt 2: Support up to two semi-persistent SRS resource sets in addition to a periodic SRS resource set   + Note: the two SP-SRS resource sets are not activated at the same time. * FFS whether further enhancement for single-DCI or multi-DCI based MTRP is needed * FFS whether configurations on SRS repetitions have impact * FFS relevant UE capability design   **RAN1#106-e**  **Agreement**  Confirm the following WA.  For DCI indication of “t” in Rel-17 SRS triggering offset enhancement   * For both DCI that schedules a PDSCH/PUSCH and DCI 0\_1/0\_2 without data and without CSI request   + t is indicated by adding a new configurable DCI field (up to 2 bits)     - Applies only when there are multiple candidate values of t configured   + No further enhancement to indicate “t” for DCI 0\_1/0\_2 without data and without CSI request at least when the new DCI field is configured   **Agreement**  Support start RB location (*Noffset*) hopping in different SRS frequency hopping periods for RPFS and at least periodic/semi-persistent SRS, where *Noffset* is the start RB index of the RBs in the RBs.   * For a given SRS transmission occasion, , where is same for all SRS occasions within a legacy FH period but changes across legacy FH periods, kF and PF are at least configured by RRC signaling (kF = {0, 1, …, PF-1}).   + Support at least one pattern for in time domain, FFS detailed pattern   + Note: the legacy FH period is the period to sound the full SRS hopping bandwidth across the different subbands of RBs each. * This start RB location hopping is enabled or disabled by RRC signaling.   + FFS whether MAC CE or DCI can be additionally used   + When this start RB location hopping is disabled, is fixed to be 0 for all SRS symbols * This start RB location hopping is UE optional. * FFS whether start RB location hopping is also applicable on SRS occasion(s) within one FH period (e.g., when R>1) and/or on aperiodic SRS, if so, how   **Agreement**  For aperiodic xTyR antenna switching SRS, where xTyR is from {1T6R, 1T8R, 2T6R, 2T8R, 4T8R}, support all the non-zero integer values N<=N\_max except N=1 for 1T8R   * For each xTyR configuration, UE does not expect multiple SRS resource sets are configured or triggered in one slot * UE does not expect that the OFDM symbols contained in one SRS resource set exceed UE capability on which OFDM symbols can be used for SRS taking guard period into account   **Agreement**  Support Opt. 2: Reference slot is the slot indicated by the legacy triggering offset.   * If DCI is transmitted in slot n, and k is the legacy triggering offset, reference slot is slot n+k. * Note: the legacy triggering offset can be 0, if slotOffset is absent.   **Conclusion**  Do not support MAC CE for t value update in Rel-17. |