3GPP TSG RAN WG1 Meeting #99 **R1-1912239**
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Agenda Item:	7.2.4.1
Source:	TCL Communication
Title:	Physical Layer Structure for Sidelink
Document for:	Discussion and Decision

1 Introduction

Based on the results of the V2X SI [1], the corresponding WI [2] has been approved in RAN Plenary #83. In the following we discuss the physical layer aspects and solutions to enable sidelink unicast, groupcast and broadcast transmission for V2X services.

2 Resource Pool

The following agreements have been reached:

Agreements: **RAN1 #98b**

- A slot is the time-domain granularity for resource pool configuration.
  - To down-select:
    - Alt 1. Slots for a resource pool is (pre-)configured with bitmap, which is applied with periodicity
    - Alt 2. Slots for a resource pool is (pre-)configured, where the slots are applied with periodicity.
  - FFS: signaling details
  - FFS: how to apply the above bitmap signaling, e.g., to all slots or only to a set of slots
  - FFS: symbols for sidelink in the slot, how to indicate for the case when not all symbols are for SL

Agreements: **RAN1 #98b**

- Support (pre-)configuration of a resource pool consisting of contiguous PRBs only

Agreements: **RAN1 #98b**

- Support $\{10, 15, 20, 25, 50, 75, 100\}$ PRBs for possible sub-channel size.
  - FFS other values (e.g., 4, 5, 6, etc.)
- One value of the above set is (pre)configured for the sub-channel size for the resource pool.
- Size of PSCCH: X
  - $X \leq N$, where N is the number of PRBs of the subchannel
  - X is (pre)-configurable with values FFS, X

2.1 Time-domain Granularity of Resource Pool Configuration

In the last meeting it has been agreed that a slot is the time-domain granularity. Concerning the configuration of the time-domain resources, we prefer Alt. 1 where SL slots are selected via a bitmap which has a certain periodicity. This bitmap should be applied to all available physical slots. Moreover, given the guidelines, it is preferable to only select full slots for SL, i.e. all symbols within the slot are available for SL. Mechanism on how to use and signal partial slots can be considered in a future release.

Proposal 1: Support Alt.1 where slots for a resource pool are (pre-)configured with a bitmap, which is applied with periodicity.

Proposal 2: Only use slots where all symbols are available for SL.

3 Physical Sidelink Shared Channel (PSSCH)

In this section we discuss the design of the SL data channel.

3.1 DMRS Design

The following agreement on reference symbol design for PSSCH has been reached in the last meetings:

Agreements: **RAN1 #98**

- (Pre-)configuration of one or more PSSCH DMRS pattern(s) in time domain per a resource pool is supported.
- Exact DMRS pattern is indicated by SCI
  - FFS details, including whether or not to have the indication bit in case of one (pre)configured DMRS pattern
- For Mode 2, DMRS pattern is chosen by the transmitter UE from the (pre)configured patterns for the resource pool.
  - FFS: case for Mode 1
  - FFS: whether/how to use restrictions for choice of DMRS pattern
- FFS on details on time-domain pattern
- FFS the number of possible DMRS patterns
- Note: it is not intended to specify DM-RS based resource pool selection

In meeting RAN1#98 it has been agreed to support multiple DMRS patterns in time-domain per resource pool and that the exact DMRS pattern is signaled in the SCI. If only a single DMRS pattern is configured no signaling in the SCI is necessary. Moreover, the indication in the SCI should be limited to 2 bits.

Proposal 3: The signaling of the DMRS pattern in time-domain should not exceed 2 bits. If there is no ambiguity, no signaling is required.

In our view, the transmitter UE chooses the DMRS pattern from a set of (pre)configured patterns for both Mode 1 and Mode 2 since it has always better knowledge of the channel conditions than the gNB. Restricting the choice of DMRS patterns at the UE is certainly useful if there is a large number of different DMRS patterns configured. However, it is unclear why there would be a large number of DMRS time-domain patterns, in NR UL there are at most 4 DMRS symbols in a slot, regardless of the MCS.

Proposal 4: The TX-UE chooses the DMRS pattern, from the (pre)configured patterns for the resource pool, for both Mode 1 and Mode 2.

3.1.1 Time-domain DMRS pattern

A similar approach as in Uu can be utilized, where front-loaded DMRS are present and the number of additional DMRS symbols is configured semi-statically or dynamically. Due to high mobility environments more than 3 additional DMRS symbols can be considered. The PDSCH single-symbol DMRS positions can serve as a starting point. The exact placement of the additional DMRS symbols depends on the slot structure, in particular AGC and Tx-Rx switching symbols.

3.1.2 Frequency-domain DMRS pattern

The WI [2] considers that *multi-rank PSSCH transmission is supported with up to two antenna ports*. Therefore, single-symbol DMRS type 1 is sufficient to support spatial multiplexing for sidelink of up to 2 layers. Adapting the frequency density to increase resource efficiency requires accurate sidelink channel information at the transmitter which, given the dynamic propagation environment and aperiodic traffic, seems difficult to obtain and exploit. Moreover, a single pattern in frequency domain reduces the signaling overhead, which is particularly important if the DMRS pattern is signaled dynamically in the SCI.

Proposal 5: Only support PDSCH single-symbol DMRS type 1 for PSSCH.

3.2 Channel Coding and Modulation

Working Assumption: **RAN1 #96b**

- Transmission of 1 TB with up to 2 layers in a PSSCH is supported.

Agreements: **RAN1 #98b**

- 256QAM is supported for SL.
  - Support of 256QAM by a UE is FFS between mandatory vs. based on UE capability from the Rx perspective
  - Support of 256QAM is based on UE capability from the Tx perspective

- 64QAM is mandatory

Agreements: **RAN1 #98b**

- Three MCS tables supported in Rel-15 NR Uu CP-OFDM are also used for SL.
  - Support of the the low-spectral efficiency 64QAM MCS table is an optional UE feature in SL as in the Uu link
- For each resource pool, at least one MCS table is (pre)-configured
  - FFS whether or not to introduce a case where the MCS table can be overwritten by PC5 RRC or indicated in SCI
- Each resource pool is only configured with one 1st stage SCI PSCCH format

In our view, it is better to transmit 1 TB with up to two layers. This is in line with Uu and will avoid signaling overhead in both control and feedback channel.

Proposal 6: Confirm working assumption to support 1 TB per PSSCH.

3.3 Transmission schemes

For unicast transmission it is desirable to use multiple antenna ports for spatial multiplexing. However, short-term channel feedback is likely unreliable because of the aperiodic feedback and dynamic propagation environment. Therefore, transmission schemes that are robust to errors in the channel state information at the transmitter should be considered in a first instance, e.g. transmit diversity schemes or open-loop spatial multiplexing schemes. Specific scenarios, e.g. platooning, may allow for closed-loop spatial multiplexing since channel conditions are more stable.

Proposal 7: For PSSCH, consider transmission schemes that are robust to errors in channel state information at the transmitter.

4 Physical Sidelink Control Channel (PSCCH)

This section discusses the design of the sidelink control channel.

Conclusion: **RAN1 #97**

- If two-stage SCI is supported, the following details are used.
  - Information related to channel sensing is carried on 1st-stage.
  - 2nd-stage is decoded by using PSSCH DMRS.
  - Polar coding used for PDCCH is applied to 2nd-stage
  - Payload size for 1st-stage in two-stage SCI case is the same for unicast, groupcast, and broadcast in a resource pool.
  - After decoding the 1st-stage, the receiver does not need to perform blind decoding of 2nd-stage.
  - FFS other details

Agreements: **RAN1 #98**

- Support 2-stage SCI
  - 1st SCI is carried in PSCCH.
  - FFS: other details

Agreements: **RAN1 #98b**

- PSCCH for 1st stage SCI with 2 and 3 symbols is supported in Rel-16.
  - FFS: other length(s) of symbols (e.g., all symbols)
  - The number of symbols above excludes AGC symbols if any
- The number of PSCCH symbols is explicitly (pre-)configured per Tx/Rx resource pool

Agreements: **RAN1 #98b**

- The 2nd stage SCI is carried within the resource of the corresponding PSSCH.
- Scrambling operation for the 2nd stage SCI is applied separately with PSSCH

Agreements: **RAN1 #98b**

- Support 1st stage SCI in PSCCH in one subchannel only.
  - Within one subchannel, there is at most one 1st stage SCI, except for spatial re-use
- For RE mapping of the 2nd stage SCI, frequency-first mapping within the PSSCH is used. To down-select:
  - Alt 1. The REs for the 2nd SCI are not interlaced with (localized in) PSSCH data RE.
    - Alt 1-1. only RBs in the subchannel having the corresponding 1st stage SCI can be possibly used for mapping the 2nd stage SCI
    - Alt 1-2. only RBs in the all sub-channels for the scheduled PSSCH can be possibly used for mapping the 2nd stage SCI.
  - Alt 2. The REs for the 2nd stage SCI can be interlaced with (distributed in) PSSCH data RE.
  - Whether to allow mapping with the same symbol of PSSCH DMRS
- For modulation order of the 2nd stage SCI, to down-select:
  - Alt 1. Fixed as QPSK
  - Alt 2. Same as PSSCH
- The same PSSCH DM-RS port(s) is used for transmitting the 2nd stage SCI.
  - When PSSCH is 2-layer, FFS how to map the 2nd stage SCI modulation symbols to the two layers, to down-select:
    - Alt 1: when PSSCH is 2-layer, the same modulation symbol of the 2nd stage SCI is mapped to the two layers
    - Alt 2: when PSSCH is 2-layer, different modulation symbols of the 2nd stage SCI are mapped to the two layers
    - A combination thereof

The first-stage SCI should be of a small, fixed size and transmitted with a (pre-)configured suitable aggregation level to minimize the number of blind decoding attempts.

Proposal 8: The first-stage SCI is transmitted with a (pre-)configured aggregation level per resource pool.

Concerning the 2nd stage SCI, a frequency-first resource mapping has been agreed. One

remaining point is, if the REs for the 2nd stage SCI can be interlaced with the REs of PSSCH. An advantage of interlacing is the potential diversity gain. However, an interlacing may also result in the 2nd stage SCI being spread over more symbols which will delay decoding. Hence, we think that interlacing should not be supported, Alt. 1. Moreover, RBs in all sub-channeles of the scheduled PSSCH can be used for mapping the 2nd stage SCI to exploit frequency diversity and allow for fast decoding.

Proposal 9: Support Alt 1 and Alt 1-2, where REs of 2nd stage SCI are mapped to all sub-channels of corresponding PSSCH without interlacing.

It has been agreed that the 2nd stage SCI will be decoded with PSSCH DMRS. Therefore, it can be mapped to symbols containing PSSCH DMRS.

Proposal 10: Allow mapping of 2nd stage SCI to symbols with PSSCH DMRS.

Another open issue is the modulation order used for the 2nd stage SCI. We think the modulation order should be restricted to QPSK to ensure robustness of the control information.

Proposal 11: The modulation order of the 2nd stage SCI is fixed to QPSK, Alt 1.

It is agreed that the 2nd stage SCI is transmitted through the same DMRS port(s) as the PSSCH. In case of a 2-layer PSSCH transmission, we think that the *same* modulation symbols of the 2nd stage SCI should be mapped to both layers to ensure robustness in case one layer has low SINR, e.g. due to sub-optimal precoding.

4.1 Transmission schemes

Broadcast transmission requires that all UEs are capable of decoding the PSCCH. To keep the number of blind decoding attempts low, only receiver-transparent single-antenna port transmission should be considered.

Proposal 12: Only consider receiver transparent single-antenna port transmission schemes for PSCCH.

First stage SCI can occupy a fraction of the PRBs in a sub-channel. To fulfill different QoS requirements in different channel conditions, multiple sizes for the transmission of 1st stage SCI should be supported. Each resource pool is configured with the suitable size for the 1st stage SCI to avoid any blind decodes.

Proposal 13: Multiple sizes for the transmission of 1st stage SCI are supported. A resource pool is configured with the 1st stage SCI size to be used in this resource pool.

It would be interesting to investigate the pros and cons of configuring more than one size for the 1st stage SCI transmissions. On the downside, it increases the blind decoding complexity. On the upside, it improves resource and power efficiency by combining the knowledge of QoS and link conditions.

5 Physical Sidelink Feedback Channel (PSFCH)

This section discussed the sidelink feedback channel.

Agreements: **RAN1 #95**

- Physical sidelink feedback channel (PSFCH) is defined and it is supported to convey SFCI for unicast and groupcast via PSFCH.

Agreements: **RAN1 #96**

- At least for sidelink HARQ feedback, NR sidelink supports at least a PSFCH format which uses last symbol(s) available for sidelink in a slot.

Work Item Description: **[2]**

- In sidelink, CSI is delivered using PSSCH (including PSSCH containing CSI only) using the resource allocation procedure for data transmission.

Agreements: **RAN1 #97**

- A sequence-based PSFCH format with one symbol (not including AGC training period) is supported.

- This is applicable for unicast and groupcast including options 1/2.
- Sequence of PUCCH format 0 is the starting point.
- FFS: 1 PRB or multiple PRBs is/are used for this PSFCH format
- FFS: feasible number of HARQ-ACK bits, mapping of HARQ-ACK bit

- FFS whether to support the following formats
  - X-symbol PSFCH format with a repetition of the one-symbol PSFCH format (not including AGC training period).
    - E.g. $X = 2$
  - A PSFCH format based on PUCCH format 2
  - A PSFCH format spanning all available symbols for sidelink in a slot

Agreements: **98b-NR-09**

- For the agreed sequence-based PSFCH format with onesymbol (not including AGC training period),
  - 1 PRB is used.
  - Only 1 bit can be carried for the case of $N = 1$, where N denotes the periodof slot having PSFCH resource in a resource pool,
  - FFS: for the case of $N = 2, 4$

Note: Each company is encouraged to discuss on howto handle AGC issue for the agreed sequence-based PSFCH format with onesymbol (not including AGC training period) to decide whether/how to support 2-symbol PSFCH format.

It has been agreed to adopt a sequence-based PSFCH format and to consider PUCCH format 0 as a starting point. PUCCH format 0 carries at most 2 bits and spans one PRB in frequency domain and one or two symbols in time domain. In accordance with the guidelines, we propose to reuse PUCCH format 0 as much as possible.

The PSFCH resources per resource pool consist of a certain number of consecutive symbols in a slot and PSFCH needs to be transmitted on *all* of those symbols to maintain an approximately constant PSD. Thus, if a X-symbol ($X > 1$) PSFCH format is supported it applies to all feedback in the resource pool even if some transmissions only require 1-symbol PSFCH transmission for successful detection. However, we believe that

a multi-symbol PSFCH format is only necessary if there are issues with coverage.

Proposal 14: A 1-symbol PSFCH format is the baseline. More symbols can be considered if there are issues with coverage compared to PSCCH.

With regards to the payload, we think that up to two bits should be adopted as in PUCCH format 0 if $N > 1$, which allows a UE to acknowledge two transport blocks and increases PSFCH resource utilization. A periodicity of $N = 4$ would require a payload of 4 bits which is not supported by PUCCH format 0. At this point additional standardization effort should be avoided and PSFCH formats with larger payload can be considered for a future release.

Proposal 15: Support a PSFCH payload size of up to 2 HARQ-ACK bits, i.e. same as PUCCH format 0.

6 Conclusion

In this contribution the following proposals and observations have been made:

Proposal 1: Support Alt.1 where slots for a resource pool are (pre-)configured with a bitmap, which is applied with periodicity.

Proposal 2: Only use slots where all symbols are available for SL.

Proposal 3: The signaling of the DMRS pattern in time-domain should not exceed 2 bits. If there is no ambiguity, no signaling is required.

Proposal 4: The TX-UE chooses the DMRS pattern, from the (pre)configured patterns for the resource pool, for both Mode 1 and Mode 2.

Proposal 5: Only support PDSCH single-symbol DMRS type 1 for PSSCH.

Proposal 6: Confirm working assumption to support 1 TB per PSSCH.

Proposal 7: For PSSCH, consider transmission schemes that are robust to errors in channel state information at the transmitter.

Proposal 8: The first-stage SCI is transmitted with a (pre-)configured aggregation level per resource pool.

Proposal 9: Support Alt 1 and Alt 1-2, where REs of 2nd stage SCI are mapped to all sub-channels of corresponding PSSCH without interlacing.

Proposal 10: Allow mapping of 2nd stage SCI to symbols with PSSCH DMRS.

Proposal 11: The modulation order of the 2nd stage SCI is fixed to QPSK, Alt 1.

Proposal 12: Only consider receiver transparent single-antenna port transmission schemes for PSCCH.

Proposal 13: Multiple sizes for the transmission of 1st stage SCI are supported. A resource pool is configured with the 1st stage SCI size to be used in this resource pool.

Proposal 14: A 1-symbol PSFCH format is the baseline. More symbols can be considered if there are issues with coverage compared to PSCCH.

Proposal 15: Support a PSFCH payload size of up to 2 HARQ-ACK bits, i.e. same as PUCCH format 0.

References

[1] TSG RAN, "Study on NR Vehicle-to-Everything (V2X)," 3GPP TR 38.885 V2.0.0, Tech. Rep., Mar. 2019.

[2] ——, "Revised WID on 5G V2X with NR sidelink," 3GPP RP-190984, Tech. Rep., Jun. 2019.

[3] TSG RAN1, "LS on NR V2X resource pool configuration and selection," 3GPP R1-1908004, Tech. Rep., Sep. 2019.