**3GPP TSG-RAN WG1 Meeting #102-eR1-200xxxx**

**e-Meeting, August 17th – 28th, 2020**

**Agenda item:** **7.2.5.3**

**Source: Moderator (Apple Inc.)**

**Title: Feature lead summary #2 on PUSCH enhancements for NR eURLLC (AI 7.2.5.3)**

**Document for: Discussion and Decision**

# 1 Introduction

In this contribution, Sections 2 summarizes the issues raised in the contributions submitted under AI 7.2.5.3, PUSCH enhancements for NR Rel-16 URLLC. Companies’ views on the priorities of the issues are collected in Section 3. The agreed scope of email discussions is summarized in Section 4.

# 2 Issues

## Issue#1 Optimization regarding *numberInvallidSymbolsForDL-UL-Switching*

There was some discussion in RAN1#101-e regarding whether *numberInvallidSymbolsForDL-UL-Switching* should also apply to the symbols after SSB or CORESET#0. This was further considered by some companies in this meeting:

* Apply *numberInvallidSymbolsForDL-UL-Switching* to indicate the number of symbols after the last symbol that is indicated by *ssb-PositionsInBurst* in SIB1 or *ssb-PositionsInBurst* in *ServingCellConfigCommon* for reception of SS/PBCH block are invalid symbols for PUSCH repetition Type B transmission.
  + Yes: ZTE[2], CATT[4], WILUS[10]
  + No: Samsung[7]
    - Samsung[7]: A UE that is not required to receive an SSB can transmit a PUSCH Type B repetition starting from a first UL or flexible symbol after the SSB.
* Apply *numberInvallidSymbolsForDL-UL-Switching* to indicate the number of symbols after the last symbol that is indicated by *pdcch-ConfigSIB1* in *MIB* for a CORESET for Type0-PDCCH CSS set are invalid symbols for PUSCH repetition Type B transmission.
  + Yes: ZTE[2], CATT[4], WILUS[10]
  + No: Samsung[7]

## Issue#2 Peak rate restriction

Huawei/HiSi[5] and Apple[8] discussed the issues on the peak rate restrictions related to PUSCH repetition Type B. There are two aspects, one is the per-cell peak rate restriction, the other one is the aggregated data rate restriction. The corresponding TPs have been proposed.

Huawei/HiSi[5]:

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| **Proposal 1: Apply per-cell peak rate restriction for PUSCH repetition type B.**  The text proposal for 38.214 could be found in the following:  --------------------------------------------Start of text proposal-------------------------------------------------------- 6.1.4 Modulation order, redundancy version and transport block size determination \*\*\* Unchanged text is omitted \*\*\*  For a *j*-th serving cell, if higher layer parameter *processingType2Enabled* of *PUSCH-ServingCellConfig* is configured for the serving cell and set to *enable,* or if at least one *IMCS > W* for a PUSCH, where *W* = 28 for MCS tables 5.1.3.1-1 and 5.1.3.1-3, and *W* = 27 for MCS tables 5.1.3.1-2, 6.1.4.1-1, and 6.1.4.1-2, or if *PUSCHRepTypeIndicator-ForDCIFormat0\_1* is set to '*pusch-RepTypeB*' for PUSCH scheduled by DCI format 0\_1, or if *PUSCHRepTypeIndicator-ForDCIFormat0\_2* is set to '*pusch-RepTypeB*' for PUSCH scheduled by DCI format 0\_2, the UE is not required to handle PUSCH transmissions, if the following condition is not satisfied:  where  - is the number of symbols assigned to the PUSCH  - *M* is the number of TB in the PUSCH  - where μ is the numerology of the PUSCH  - for the *m*-th TB,  - *A* is the number of bits in the transport block as defined in Clause 6.2.1 [5, TS 38.212]  - *C* is the total number of code blocks for the transport block defined in Clause 5.2.2 [5, TS 38.212]  - is the number of scheduled code blocks for the transport block as defined in Clause 5.4.2.1 [5, TS 38.212]  - [Mbps] is computed as the maximum data rate for a carrier in the frequency band of the serving cell for any signaled band combination and feature set consistent with the serving cell, where the data rate value is given by the formula in Clause 4.1.2 in [13, TS 38.306], including the scaling factor *f(i).*  - each actual repetition for PUSCH repetition type B is treated as one PUSCH.  ---------------------------------------------End of text proposal-------------------------------------------------------- |

Apple[8]:

TP for TS 38.214 Clause 6.1.4:

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| Within a cell group, a UE is not required to handle PUSCH(s) transmissions in slot *sj* in serving cell-*j*, and for *j* = 0,1,2.. *J-1*, slot *sj* overlapping with any given point in time, if the following condition is not satisfied at that point in time:  ,  where  *- J* is the number of configured serving cells belong to a frequency range  - for the *j-th* serving cell,  *- M* is the number of TB(s) transmitted in slot-*sj*. For PUSCH repetition Type B, each actual repetition is counted separately.  *- Tslotμ(j)* =10-3/2*μ(j*), where *μ(j)* is the numerology for PUSCH(s) in slot *sj* of the *j*-th serving cell.  - for the *m*-th TB,  *- A* is the number of bits in the transport block as defined in Clause 6.2.1 [5, TS 38.212]  *- C* is the total number of code blocks for the transport block defined in Clause 5.2.2 [5, TS 38.212].  - is the number of scheduled code blocks for the transport block as defined in Clause 5.4.2.1 [5,38.212]  - [Mbps] is computed as the maximum data rate summed over all the carriers in the frequency range for any signaled band combination and feature set consistent with the configured servings cells, where the data rate value is given by the formula in Clause 4.1.2 in [13, TS 38.306], including the scaling factor *f(i).*  For a *j*-th serving cell, if higher layer parameter *processingType2Enabled* of *PUSCH-ServingCellConfig* is configured for the serving cell and set to *enable,* or if at least one *IMCS > W* for a PUSCH, where *W* = 28 for MCS tables 5.1.3.1-1 and 5.1.3.1-3, and *W* = 27 for MCS tables 5.1.3.1-2, 6.1.4.1-1, and 6.1.4.1-2, or if it is an actual repetition for PUSCH repetition Type B, the UE is not required to handle PUSCH transmissions, if the following condition is not satisfied:  where  - is the number of symbols assigned to the PUSCH  - *M* is the number of TB in the PUSCH  - where μ is the numerology of the PUSCH  - for the *m*-th TB,  - *A* is the number of bits in the transport block as defined in Clause 6.2.1 [5, TS 38.212]  - *C* is the total number of code blocks for the transport block defined in Clause 5.2.2 [5, TS 38.212]  - is the number of scheduled code blocks for the transport block as defined in Clause 5.4.2.1 [5, TS 38.212]  - [Mbps] is computed as the maximum data rate for a carrier in the frequency band of the serving cell for any signaled band combination and feature set consistent with the serving cell, where the data rate value is given by the formula in Clause 4.1.2 in [13, TS 38.306], including the scaling factor *f(i).* |

## Issue#3 Number of MIMO layers

vivo[1] discussed whether to introduce the restriction on the number of MIMO layers for PUSCH repetition Type B, and proposed:

* If *numberofrepetitions* is configured, in case the number of nominal repetitions >1, PUSCH is limited to a single transmission layer.

## Issue#4 UCI multiplexing

The following TP was agreed in RAN1#101-e:

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| TP for TS 38.213 Clause 9 9 UE procedure for reporting control information < Unchanged parts are omitted >  If a UE transmits a PUSCH with repetition Type B and the UE would transmit a PUCCH with HARQ-ACK and/or CSI information over a single slot that overlaps with the PUSCH transmission in one or more slots, the UE expects an earliest actual repetition of the PUSCH transmission [6, TS 38.214] that would overlap with the PUCCH transmission to fulfill the conditions in Clause 9.2.5 for multiplexing the HARQ-ACK and/or CSI information, and the UE multiplexes the HARQ-ACK and/or CSI information in the earliest actual PUSCH repetition with a duration of more than 1 symbol that would overlap with the PUCCH transmission. The UE does not expect that all the actual repetitions that would overlap with the PUCCH transmission have a duration of a single symbol.  < Unchanged parts are omitted > |

CATT[4] would like to clarify the following:

* If all the actual PUSCH repetitions that would overlap with the PUCCH transmission have a duration of a single symbol and all the actual repetitions are segmented from nominal repetitions with *L*>1, clarify the intended UE behaviour between the two understandings.
  + **Understanding 1:** It is an error case.
  + **Understanding 2:** All the actual PUSCH repetitions are omitted and PUCCH is transmitted.

## Issue#5 Large code rate for an actual repetition

OPPO[6] observed that PUSCH transmission with coding rate >948/1024 is not defined in spec, and proposed to clarify the procedure on actual PUSCH repetition with code rate>948/1024. It claimed that “Although there is an assumption on maximum coding rate in spec, however, the assumption does not work in rate matching procedure in spec. So it could be considered to relax assumption. To avoid impact on legacy UE, relaxing assumption could be applied for actual PUSCH repetition for Type B PUSCH repetition only.”

[*Feature lead’s comment: it is not clear why the assumption on maximum coding rate in spec does not work in rate matching procedure. Further elaboration is needed. There is a similar case even in Rel-15 when the resource allocation for HARQ retransmission is smaller than the initial HARQ transmission, and the code rate could also exceed 948/1024.*]

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| ------------------------------------ Start of TP 38.212 V16.2.0 section 5.4.2.1--------------------------------- 5.4.2.1 Bit selection The bit sequence after encoding  from Clause 5.3.2 is written into a circular buffer of length  for the -th coded block, where  is defined in Clause 5.3.2.  For the -th code block, let  if  and  otherwise, where, ,  is determined according to Clause 6.1.4.2 in [6, TS 38.214] for UL-SCH and Clause 5.1.3.2 in [6, TS 38.214] for DL-SCH/PCH, assuming the following:  - maximum number of layers for one TB for UL-SCH is given by X, where  - if the higher layer parameter *maxMIMO-Layers* of *PUSCH-ServingCellConfig* of the serving cell is configured, X is given by that parameter  - elseif the higher layer parameter *maxRank* of *pusch-Config* of the serving cell is configured, X is given by the maximum value of *maxRank* across all BWPs of the serving cell  - otherwise, X is given by the maximum number of layers for PUSCH supported by the UE for the serving cell  - maximum number of layers for one TB for DL-SCH/PCH is given by the minimum of X and 4, where  - if the higher layer parameter *maxMIMO-Layers* of *PDSCH-ServingCellConfig* of the serving cell is configured, X is given by that parameter  - otherwise, X is given by the maximum number of layers for PDSCH supported by the UE for the serving cell  - if the higher layer parameter *mcs-Table* given by a *pdsch-Config* for at least one DL BWP of the serving cell is set to 'qam256', maximum modulation order  is assumed for DL-SCH; otherwise a maximum modulation order  is assumed for DL-SCH;  - if the higher layer parameter *mcs-Table* or *mcs-TableTransformPrecoder* given by a *pusch-Config* or *configuredGrantConfig* for at least one UL BWP of the serving cell is set to 'qam256', maximum modulation order  is assumed for UL-SCH; otherwise a maximum modulation order  is assumed for UL-SCH  - maximum coding rate of 948/1024 for PDSCH/PUSCH except for actual PUSCH repetition for Type B PUSCH repetition  -  is given by Table 5.4.2.1-1, where the value of  for DL-SCH is determined according to the initial downlink bandwidth part if there is no other downlink bandwidth part configured to the UE;  - ;  -  is the number of code blocks of the transport block determined according to Clause 5.2.2.  ------------------------------------ End of TP 38.212 V16.2.0 section 5.4.2.1--------------------------------- |

Two options (with TP provided) are proposed to handle the issue:

* Option 1: Puncture redundancy data after rate matching
* Option 2: Skip encoding a transport block if the effective channel code rate is higher than 948/1024

## Issue#6 Number of modulation symbols for UCI multiplexing

In Samsung[7], the issue of how to determine the number of modulation symbols for UCI multiplexing on PUSCH repetition Type B was further discussed. The current specification has:

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| For HARQ-ACK transmission on an actual repetition of a PUSCH with repetition Type B with UL-SCH, the number of coded modulation symbols per layer for HARQ-ACK transmission, denoted as , is determined as follows:  …  For CSI part 1 transmission on an actual repetition of a PUSCH with repetition Type B with UL-SCH, the number of coded modulation symbols per layer for CSI part 1 transmission, denoted as , is determined as follows:  …  For CSI part 2 transmission on an actual repetition of a PUSCH with repetition Type B with UL-SCH, the number of coded modulation symbols per layer for CSI part 2 transmission, denoted as , is determined as follows: |

Samsung[7] claimed that “The above

1. are not according to agreements as UCI is multiplexed in only one repetition while is over repetitions (spectral efficiency of UL-SCH in one repetition is reduced by for a given BLER target – e.g. if BLER target is 10% and there are 4 self-decodable repetitions, BLER of a single repetition is ~50%) - the numerator needs to be scaled by to capture the PUSCH spectral efficiency in one repetition
2. would lead to either increased UCI BLER, with varying degrees as varies, or to a frequent over-dimensioning of resources and an inability to use the larger values of as currently it is effectively , and
3. would require different gNB implementation for UCI reception in a PUSCH depending on whether or not the PUSCH is with Type B repetitions.”

It proposed to “Correct the number of UCI coded modulation symbols for PUSCH with repetition Type B by scaling the numerator by the number of repetitions K.”

## Issue#7 Consideration on PHY priorities

The following TP was proposed in QC[9].

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| **Modified clause (Section 11.1.1 of TS 38.213)** |

If a UE is configured by higher layers to transmit SRS, or PUCCH, or PUSCH, or PRACH in a set of symbols of a slot and the UE detects a DCI format 2\_0 with a slot format value other than 255 that indicates a slot format with a subset of symbols from the set of symbols as downlink or flexible, or the UE detects a DCI format 1\_0, DCI format 1\_1, or DCI format 0\_1, or DCI format 0\_2 or DCI format 1\_2, indicating to the UE to receive CSI-RS or PDSCH in a subset of symbols from the set of symbols, then

- the UE does not expect to receive a PDSCH scheduled or a CSI-RS triggered by a PDCCH where the *priority* indicator field in the corresponding DCI is either not configured or set to *0*, that overlaps with the transmission of a PUSCH corresponding to a configured grant with a *priority* set to *1* in *configuredGrantConfig*, or a PUCCH configured to carry HARQ-ACK for SPS PDSCH receptions with a *priority* set to *1* in *SPS-Config*

- the UE does not expect to cancel the transmission in symbols from the set of symbols that occur, relative to a last symbol of a CORESET where the UE detects the DCI format 2\_0 or the DCI format 1\_0 or the DCI format 1\_1 or the DCI format 0\_1, after a number of symbols that is smaller than the PUSCH preparation time  for the corresponding PUSCH processing capability [6, TS 38.214] assuming  and  corresponds to the smallest SCS configuration between the SCS configuration of the PDCCH carrying the DCI format 2\_0, DCI format 1\_0, DCI format 1\_1 or DCI format 0\_1 and the SCS configuration of the SRS, PUCCH, …

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| **End** |

[*Feature lead’s comment: should this belong to “intra-UE prioritization” discussion?*]

## Issue#8 PUSCH without a TB

In RAN1#101-e, the following was agreed in Rel-15 CR discussion.

**Agreement**

The following text proposal is endorsed in [R1-2005044](https://ericssonnam-my.sharepoint.com/personal/yufei_blankenship_ericsson_com/Documents/Documents_Yufei/3GPP_meetings/RAN1_meetings/2020/Docs/R1-2005044.zip) (TS38.214, Rel-15, CR#0105, Cat. F).

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| A UE shall upon detection of a DCI format scheduling a PUSCH ~~PDCCH with a configured DCI format 0\_0 or 0\_1~~ transmit the corresponding PUSCH ~~as indicated by that DCI.~~ unless the UE does not generate a transport block as described in [10, TS38.321] and there is no PUCCH with CSI/HARQ-ACK that overlaps in time with the PUSCH. In this release of the specification, the UE behavior is undefined if there would be a PUCCH with CSI/HARQ-ACK overlapping in time with a PUSCH scheduled by a DCI format and if the UE does not generate a transport block as described in [10, TS38.321] when *skipUplinkTxDynamic* provided by higher layers is set to true. |

In Ericsson[3], it was discussed that there could be cases where no TB is generated in Rel-16 URLLC, and the following TP was proposed:

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| **--------------------------- Text Proposal for 38.214 V16.2.0 Section 6.1 -------------------------------------------**  \*\*\* Unchanged text is omitted \*\*\*  A UE shall upon detection of a PDCCH with a configured DCI format 0\_0, 0\_1 or 0\_2 transmit the corresponding PUSCH as indicated by that DCI unless the UE does not generate a transport block as described in [10, TS38.321]. Upon detection of a DCI format 0\_1 or 0\_2 with "UL-SCH indicator" set to "0" and with a non-zero "CSI request" where the associated "reportQuantity" in *CSI-ReportConfig* set to "none" for all CSI report(s) triggered by "CSI request" in this DCI format 0\_1 or 0\_2, the UE ignores all fields in this DCI except the "CSI request" and the UE shall not transmit the corresponding PUSCH as indicated by this DCI format 0\_1 or 0\_2. When the UE is scheduled with multiple PUSCHs by a DCI, HARQ process ID indicated by this DCI applies to the first PUSCH, as described in clause 6.1.2.1, HARQ process ID is then incremented by 1 for each subsequent PUSCH(s) in the scheduled order, with modulo 16 operation applied. For any HARQ process ID(s) in a given scheduled cell, the UE is not expected to transmit a PUSCH that overlaps in time with another PUSCH. For any two HARQ process IDs in a given scheduled cell, if the UE is scheduled to start a first PUSCH transmission starting in symbol *j* by a PDCCH ending in symbol *i*, the UE is not expected to be scheduled to transmit a PUSCH starting earlier than the end of the first PUSCH by a PDCCH that ends later than symbol *i*. The UE is not expected to be scheduled to transmit another PUSCH by DCI format 0\_0, 0\_1 or 0\_2 scrambled by C-RNTI or MCS-C-RNTI for a given HARQ process until after the end of the expected transmission of the last PUSCH for that HARQ process.  \*\*\* Unchanged text is omitted \*\*\*  -**---------------------------------------------End of proposed TP ----------------------------------------------------** |

[*Feature lead’s comments: this is indeed an issue that should be addressed in Rel-16 CR. But it seems that this should be handled as a generic Rel-16 CR instead of URLLC-specific CR. It may be good to check with the chairman the best AI to handle this issue.*]

It was further proposed to discuss if/how to modify the following TP in RAN1#101-e to exclude the case that no TB was provided by MAC for a dynamically scheduled uplink grant (the highlighted parts below).

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| 6.1.2 Resource allocation  6.1.2.1 Resource allocation in time domain  < Unchanged parts are omitted >  For PUSCH repetition Type B, except for PUSCH transmitting CSI report(s) with no transport block, the number of nominal repetitions is given by *numberofrepetitions*. For the *n*-th nominal repetition, *n* = *0*, …, *numberofrepetitions* - 1,  - The slot where the nominal repetition starts is given by , and the starting symbol relative to the start of the slot is given by .  - The slot where the nominal repetition ends is given by , and the ending symbol relative to the start of the slot is given by .  < Unchanged parts are omitted >  For PUSCH repetition Type B, after determining the invalid symbol(s) for PUSCH repetition type B transmission for each of the *K* nominal repetitions, the remaining symbols are considered as potentially valid symbols for PUSCH repetition Type B transmission. If the number of potentially valid symbols for PUSCH repetition type B transmission is greater than zero for a nominal repetition, the nominal repetition consists of one or more actual repetitions, where each actual repetition consists of a consecutive set of potentially valid symbols that can be used for PUSCH repetition Type B transmission within a slot. An actual repetition with a single symbol is omitted except for the case of *L*=1. An actual repetition is omitted according to the conditions in Clause 11.1 of [6, TS38.213]. The redundancy version to be applied on the *n*th actual repetition (with the counting including the actual repetitions that are omitted) is determined according to table 6.1.2.1-2.  For PUSCH repetition Type B, when a UE receives a DCI that schedules aperiodic CSI report(s) or activates semi-persistent CSI report(s) on PUSCH with no transport block by a *CSI request* field on a DCI, the number of nominal repetitions is always assumed to be 1, regardless of the value of *numberofrepetitions*. When the UE is scheduled to transmit a PUSCH repetition Type B with no transport block and with aperiodic or semi-persistent CSI report(s) by a *CSI request* field on a DCI, the first nominal repetition is expected to be the same as the first actual repetition. For PUSCH repetition Type B carrying semi-persistent CSI report(s) without a corresponding PDCCH after being activated on PUSCH by a *CSI request* field on a DCI, if the first nominal repetition is not the same as the first actual repetition, the first nominal repetition is omitted; otherwise, the first nominal repetition is omitted according to the conditions in Clause 11.1 of [6, TS38.213].  For PUSCH repetition Type B, when a UE is scheduled to transmit a transport block and aperiodic CSI report(s) on PUSCH by a *CSI request* field on a DCI, the CSI report(s) is multiplexed only on the first actual repetition. The UE does not expect that the first actual repetition has a single symbol duration.  < Unchanged parts are omitted > |

[*Feature lead’s comments: This TP addresses the case where a UE is scheduled a dynamic PUSCH for A-CSI/SP-CSI purpose only without UL-SCH, so it is already clear there is no TB in this case. It seems that no further clarification is needed.*]

## Issue#9 Editorial changes

Some editorial changes were proposed in ZTE[2] section 3 to align on RRC parameter names.

**----------------------------Text Proposal 2 for Section 6 in TS 38.214 [3]-------------------------------**

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| 6 Physical uplink shared channel related procedure 6.1 UE procedure for transmitting the physical uplink shared channel  PUSCH transmission(s) can be dynamically scheduled by an UL grant in a DCI, or the transmission can correspond to a configured grant Type 1 or Type 2. The configured grant Type 1 PUSCH transmission is semi-statically configured to operate upon the reception of higher layer parameter of *configuredGrantConfig* including *rrc-ConfiguredUplinkGrant* without the detection of an UL grant in a DCI. The configured grant Type 2 PUSCH transmission is semi-persistently scheduled by an UL grant in a valid activation DCI according to Clause 10.2 of [6, TS 38.213] after the reception of higher layer parameter *configuredGrantConfig* not including *rrc-ConfiguredUplinkGrant*. If *ConfiguredGrantConfigToAddModList-r16* is configured, more than one configured grant configuration of configured grant Type 1 and/or configured grant Type 2 may be active at the same time on an active BWP of a serving cell.  For the PUSCH transmission corresponding to a Type 1 configured grant or a Type 2 configured grant activated by DCI format 0\_0 or 0\_1, the parameters applied for the transmission are provided by *configuredGrantConfig* except for *dataScramblingIdentityPUSCH*, *txConfig*, *codebookSubset*, *maxRank*, *scaling* of *UCI-OnPUSCH,* which are provided by *pusch-Config*. For the PUSCH transmission corresponding to a Type 2 configured grant activated by DCI format 0\_2, the parameters applied for the transmission are provided by *configuredGrantConfig* except for *dataScramblingIdentityPUSCH*, *txConfig*, *codebookSubsetForDCI-Format0-2-r16*, *maxRankForDCI-Format0-2-r16*, *scaling* of *UCI-OnPUSCH*, *resourceAllocationType1GranularityForDCI-Format0-2-r16* provided by *pusch-Config*.If the UE is provided with *transformPrecoder* in *configuredGrantConfig*, the UE applies the higher layer parameter *tp-pi2BPSK*, if provided in *pusch-Config*, according to the procedure described in Clause 6.1.4 for the PUSCH transmission corresponding to a configured grant.  ...  6.1.2 Resource allocation  6.1.2.1 Resource allocation in time domain  When the UE is scheduled to transmit a transport block and no CSI report, or the UE is scheduled to transmit a transport block and a CSI report(s) on PUSCH by a DCI, the *Time domain resource assignment* field value *m* of the DCI provides a row index *m* + 1to an allocated table. The determination of the used resource allocation table is defined in Clause 6.1.2.1.1. The indexed row defines the slot offset *K2*, the start and length indicator *SLIV*, or directly the start symbol *S* and the allocation length *L*, the PUSCH mapping type, and the number of repetitions (if *numberOfRepetitions-r16* is present in the resource allocation table) to be applied in the PUSCH transmission.  When the UE is scheduled to transmit a PUSCH with no transport block and with a CSI report(s) by a *CSI request* field on a DCI, the *Time domain resource assignment* field value *m* of the DCI provides a row index *m* + 1to the allocated table as defined in Clause 6.1.2.1.1. The indexed row defines the start and length indicator SLIV, or directly the start symbol *S* and the allocation length *L*, and the PUSCH mapping type to be applied in the PUSCH transmission and the *K2* value is determined as , where  are the corresponding list entries of the higher layer parameter  - *reportSlotOffsetListForDCI-Format0-2-r16*, if PUSCH is scheduled by DCI format 0\_2 and *reportSlotOffsetListForDCI-Format0-2-r16* is configured;  - *reportSlotOffsetListForDCI-Format0-1-r16*, if PUSCH is scheduled by DCI format 0\_1 and *reportSlotOffsetListForDCI-Format0-1-r16* is configured;  - *reportSlotOffsetList*, otherwise;  ...  for PUSCH scheduled by DCI format 0\_1, if *pusch-RepTypeIndicatorForDCI-Format0-1-r16* is set to '*pusch-RepTypeB*', the UE applies PUSCH repetition Type B procedure when determining the time domain resource allocation. For PUSCH scheduled by DCI format 0\_2, if *pusch-RepTypeIndicatorForDCI-Format0-2-r16* is set to '*pusch-RepTypeB*', the UE applies PUSCH repetition Type B procedure when determining the time domain resource allocation. Otherwise, the UE applies PUSCH repetition Type A procedure when determining the time domain resource allocation for PUSCH scheduled by PDCCH.  ...  For PUSCH repetition Type B, the starting symbol *S* relative to the start of the slot, and the number of consecutive symbols *L* counting from the symbol *S* allocated for the PUSCH are provided by *startSymbol-r16* and *length-r16* of the indexed row of the resource allocation table, respectively.  ...  For PUSCH repetition Type A, when transmitting PUSCH scheduled by DCI format 0\_1 or 0\_2 in PDCCH with CRC scrambled with C-RNTI, MCS-C-RNTI, or CS-RNTI with NDI=1, the number of repetitions *K* is determined as  - if *numberOfRepetitions-r16* is present in the resource allocation table, the number of repetitions K is equal to *numberOfRepetitions-r16*;  - elseif the UE is configured with *pusch-AggregationFactor*, the number of repetitions *K* is equal to *pusch-AggregationFactor*;  - otherwise *K=1*.  ...  For PUSCH repetition Type B, except for PUSCH transmitting CSI report(s) with no transport block, the number of nominal repetitions is given by *numberOfRepetitions-r16*. For the *n*-th nominal repetition, *n* = *0*, …, *numberOfRepetitions-r16* - 1,  ...  For PUSCH repetition Type B, the UE determines invalid symbol(s) for PUSCH repetition Type B transmission as follows:  - A symbol that is indicated as downlink by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationDedicated* is considered as an invalid symbol for PUSCH repetition Type B transmission.  - For operation in unpaired spectrum, symbols indicated by *ssb-PositionsInBurst* in SIB1 or *ssb-PositionsInBurst* in *ServingCellConfigCommon* for reception of SS/PBCH blocks are considered as invalid symbols for PUSCH repetition Type B transmission.  - For operation in unpaired spectrum, symbol(s) indicated by *pdcch-ConfigSIB1* in *MIB* for a CORESET for Type0-PDCCH CSS set are considered as invalid symbol(s) for PUSCH repetition Type B transmission.  - For operation in unpaired spectrum, if *numberOfInvalidSymbolsForDL-UL-Switching-r16* is configured, *numberOfInvalidSymbolsForDL-UL-Switching-r16* symbol(s) after the last symbol that is indicated as downlink in each consecutive set of all symbols that are indicated as downlink by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationDedicated* are considered as invalid symbol(s) for PUSCH repetition Type B transmission. The symbol(s) given by *numberOfInvalidSymbolsForDL-UL-Switching-r16* are defined using the reference SCS configuration *referenceSubcarrierSpacing* provided in *tdd-UL-DL-ConfigurationCommon*.  - The UE may be configured with the higher layer parameter *InvalidSymbolPattern-r16*, which provides a symbol level bitmap spanning one or two slots (higher layer parameter *symbols-r16* given by *InvalidSymbolPattern-r16*). A bit value equal to 1 in the symbol level bitmap *symbols-r16* indicates that the corresponding symbol is an invalid symbol for PUSCH repetition Type B transmission. The UE may be additionally configured with a time-domain pattern (higher layer parameter *periodicityAndPattern-r16* given by *InvalidSymbolPattern-r16*), where each bit of *periodicityAndPattern-r16* corresponds to a unit equal to a duration of the symbol level bitmap *symbols-r16*, and a bit value equal to 1 indicates that the symbol level bitmap *symbols-r16* is present in the unit. The *periodicityAndPattern-r16* can be {1, 2, 4, 5, 8, 10, 20 or 40} units long, but maximum of 40ms. The first symbol of *periodicityAndPattern-r16* every 40ms/P periods is a first symbol in frame 𝑛𝑓 mod 4 = 0, where P is the duration of *periodicityAndPattern-r16* in units of ms. When *periodicityAndPattern-r16* is not configured, for a symbol level bitmap spanning two slots, the bits of the first and second slots correspond respectively to even and odd slots of a radio frame, and for a symbol level bitmap spanning one slot, the bits of the slot correspond to every slot of a radio frame. If *InvalidSymbolPattern-r16* is configured, when the UE applies the invalid symbol pattern is determined as follows:  - if the PUSCH is scheduled by DCI format 0\_1, or corresponds to a Type 2 configured grant activated by DCI format 0\_1, and if *invalidSymbolPatternIndicatorForDCI-Format0-1-r16* is configured,  - if invalid symbol pattern indicator field is set 1, the UE applies the invalid symbol pattern;  - otherwise, the UE does not apply the invalid symbol pattern;  - if the PUSCH is scheduled by DCI format 0\_2, or corresponds to a Type 2 configured grant activated by DCI format 0\_2, and if *invalidSymbolPatternIndicatorForDCI-Format0-2-r16* is configured,  - if invalid symbol pattern indicator field is set 1, the UE applies the invalid symbol pattern;  - otherwise, the UE does not apply the invalid symbol pattern;  - otherwise, the UE applies the invalid symbol pattern.  6.1.2.2 Resource allocation in frequency domain  ...  If the scheduling DCI is configured to indicate the uplink resource allocation type as part of the *Frequency domain resource* assignment field by setting a higher layer parameter r*esourceAllocation* in *pusch-Config* to 'dynamicSwitch', for DCI format 0\_1 or setting a higher layer parameter *resourceAllocationForDCI-Format0-2-r16* in *pusch-Config* to 'dynamicswitch' for DCI format 0\_2, the UE shall use uplink resource allocation type 0 or type 1 as defined by this DCI field. Otherwise the UE shall use the uplink frequency resource allocation type as defined by the higher layer parameter *resourceAllocation* for DCI format 0\_1 or the higher layer parameter *resourceAllocationForDCI-Format0-2-r16* for DCI format 0\_2. The UE shall assume that when the scheduling PDCCH is received with DCI format 0\_1 and *useInterlacePUCCH-PUSCH* in *BWP-UplinkDedicated* is configured, uplink type 2 resource allocation is used.  ...  6.1.2.2.2 Uplink resource allocation type 1  When the scheduling grant is received with DCI format 0\_2, an uplink type 1 resource allocation field consists of a resource indication value (*RIV*) corresponding to a starting resource block group *RBGstart*=0, 1, …, *NRBG*-1 and a length in terms of virtually contiguously allocated resource block groups *LRBGs*=1, …, *NRBG*, where the resource block groups are defined as in 6.1.2.2.1 with *P* defined by *resourceAllocationType1GranularityForDCI-Format0-2-r16* if the UE is configured with higher layer parameter *resourceAllocationType1GranularityForDCI-Format0-2-r16*, and *P*=1 otherwise*.* The resource indication value is defined by |

# 3 Companies’ Views on Priorities

Issue #1 (Optimization regarding *numberInvallidSymbolsForDL-UL-Switching*) was discussed in RAN1#101-e without conclusion, and the assumption is that we will continue the discussion and conclude on the topic (i.e., **issue #1 will be included in the email discussion**). Please comment if you have a different view.

For the remaining issue, please provide the view on the priorities (high/med/low/no need) in the table below.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Company | Issue #2  Peak rate restriction | Issue #3  Number of MIMO layers | Issue #4  UCI multiplexing | Issue #5  Large code rate for an actual repetition | Issue #6  Number of mod symbols for UCI multiplexing | Issue #7  PHY priorities | Issue #8  PUSCH without a TB | Issue #9  Editorial changes |
| CATT | high | medium | medium | high | medium | low | No need | low |
| Sony | high | medium | low | low | high | low | No need | low |
| Nokia, NSB | high | Low | Low / no need | high | Low | Low / no need | No need | low |
| vivo | High | High | Low | Low | Low | To be discussed in 7.2.5.4 | To be discussed in 7.1 for Rel-16 CR | Medium |
| ZTE | high | medium | low | low | low | No need | No need | Medium |
| Huawei, HiSilicon | high | medium | Low | medium | Low | Low | No need | low |
| Intel | medium | medium | low | low | low | low | low | low |
| DOCOMO | High | Medium | Low | Medium | Low | Low | No need | Low |
| Samsung | high | Medium | Low/no need | high | high | No need | No need | Low |
| Apple | High | Medium | Low/no need  We think the spec is clear that it is an error case. | Low  The issue is not clear to us. | No need  It is non-essential. | Low  Should be discussed with intra-UE prioritization if needed | Handled in AI7.1 for Rel-16 CR | Low |

Please provide detailed comments, if any.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| CATT | For issue#8, it should be handled together with Rel-16 CR under AI 7.1. |
| Sony | Agree with FL issue#8 can be treated in Rel-16 CR maintenance. |
| Nokia, NSB | * On issue #6, in contrast to Samsung to our view the summation of the size of the codeblock Kr over the number of codeblocks C\_UL\_SCH within the TB (which is independent on the number of actual or nominal repetitions, this is just the total number of bits within the TB), but is not related to any repetition factor there!?? * On issues #7, clearly the new DCI formats need to be added, but no need for further restrictions. And agree with FL, if to handle such restriction then maybe better to handle this as part of the prioritization discussions * Agree with FL issue#8 can be treated in Rel-16 CR maintenance. * Issue #9 (RRC parameters) could be handled by editors CR |
| vivo | For issue 3, it is not clear in current spec for the number of MIMO layers for PUSCH repetition Type B. Similar to PUSCH repetition type A, single transmission layer is applied for PUSCH repetition type B.  For issue 4, it is already clear for current spec, i.e. it is an error case if all the actual repetitions that would overlap with the PUCCH transmission have a duration of a single symbol.  For issue 5, the motivation to restrict the code rate for actual repetition of PUSCH repetition type B not exceed 948/1024 is not clear.  For issue 6, in Rel.15, there is a similar case for PUSCH repetition type A with UCI multiplexing where the number of UCI coded modulation symbols for PUSCH with repetitions is not scaled by the number of repetitions K.  For issue 7, it is related to processing order of intra-UE multiplexing and prioritization. It can be discussed in 7.2.5.4.  For issue 8, it is a general issue for PUSCH with UL skipping, which will be discussed in 7.1 for Rel.16 CR, see Yonsun’s suggestion in R1-2006958 for 7.1 CR handling. So better to wait for the decision made in AI 7.1 first mainly focus on PUSCH with repetition Type A (Rel.15 PUSCH Type). |
| ZTE | Issue 7 can be discussed in 7.2.5.4 and issue 8 in 7.1. |
| Huawei, HiSilicon | 1. Issue 4 : We think the spec defines that actual transmission with single symbol will not be transmitted, therefore gNB should know not to schedule with all actual repetitions with single symbol ? 2. Issue 7 is low priority for PUSCH agenda, can be disucssed under 7.2.5.4. However, if the workload is already much under 7.2.5.4, probably can be considered here. 3. Issue #9 (RRC parameters) could be handled by editors CR |
| Intel | For issue #5 it needs to be checked whether the CR restriction is before rate matching to the actual repetition or after. If it is defined before the rate matching, then no change is needed.  For issue #6 agree with Nokia |
| DOCOMO | Issue 4: optimization. Current spec should follow the understanding 1, i.e. error case.  Issue 9: agree with Huawei. The issue is valid but it could be handled by editors CR. |
| Samsung | Issue 5: we support to clarify this.  Issue 6: The current formula for UCI is against the agreement from Rel-15. It should be trivial to understand that for a given BLER, the spectral efficiency of a PUSCH transmitted in 1 slot is higher by an equivalent of ~6 dB (at least for low SINRs/code rates) than the spectral efficiency of a PUSCH transmitted over 4 slots. The current formula uses the smaller spectral efficiency for UCI as if UCI (like UL-SCH) is over 4 slots. In the example, the UCI BLER would be the one for 6 dB lower SINR, when the SINR is already low. Not only is UCI reliability difficult to achieve by multiplexing it in only a single slot while repetitions are needed for data, the current formula practically guarantees that UCI is unreliable. We prefer to further discuss this in this meeting and avoid discussion in a later CR.  Issue 8: should be discussed in in Rel-16 CR |

# 4 Scope of email discussions

Based on companies’ input, majority view is that the following issues do not need to be discussed here:

* Issue #4: the specification should be clear that it is an error case if all the actual repetitions that would overlap with the PUCCH transmission have a duration of a single symbol.
* Issue #7: if needed, this should be discussed together with intra-UE prioritization (AI 7.2.5.4).
* Issue #8: this is to be discussed in AI 7.1 for Rel-16 CR.
* Issue #9: can be handled by editor’s CR

It is proposed that we have the following two email discussions:

* Email discussion #1
  + Issue #1: Optimization regarding *numberInvallidSymbolsForDL-UL-Switching*
  + Issue #3: Number of MIMO layers
* Email discussion #2
  + Issue #2: Peak rate restriction
  + Issue #5: Large code rate for an actual repetition

# References

1. R1-2005349 PUSCH enhancements for URLLC vivo
2. R1-2005415 Remaining issues on PUSCH enhancements for NR URLLC ZTE
3. R1-2005508 Remaining Issue of PUSCH Enhancements for NR URLLC Ericsson
4. R1-2005674 Remaining issues on PUSCH enhancements CATT
5. R1-2005793 Corrections on PUSCH enhancement Huawei, HiSilicon
6. R1-2006053 PUSCH enhancements for URLLC OPPO
7. R1-2006111 Remaining issues for PUSCH enhancement Samsung
8. R1-2006489 Remaining Issues on PUSCH enhancements for eURLLC Apple
9. R1-2006776 Remaining issues on PUSCH enhancements for URLLC Qualcomm Incorporated
10. R1-2006883 Remaining issues on PUSCH enhancement for NR URLLC WILUS Inc.

# Appendix A: Previous agreements on potential enhancements for PUSCH

### RAN1#94bis (Oct. 2018)

Agreements**:**

* One PUSCH transmission instance is not allowed to cross the slot boundary at least for grant-based PUSCH.

### RAN1#95 (Nov. 2018)

Agreements**:**

Support at least one of the following for one TB:

* One UL grant scheduling two or more PUSCH repetitions that can be in one slot, or across slot boundary in consecutive available slots
* One UL grant scheduling two or more PUSCH repetitions in consecutive available slots, with one repetition in each slot with possibly different starting symbols and/or durations
* N (N>=2) UL grants scheduling N PUSCH repetitions on consecutive available slots, with one repetition in each slot, and the i-th UL grant can be received before the end of the PUSCH transmission scheduled by the (i-1)th UL grant.
* FFS the definition of available slots

### RAN1 AH#1901 (Jan. 2019)

Agreements:

At least for scheduled PUSCH, for the option “One UL grant scheduling two or more PUSCH repetitions that can be in one slot, or across slot boundary in consecutive available slots” (also called as “mini-slot based repetitions”), if supported, it further consists of:

* Time domain resource determination
  + The time domain resource assignment field in the DCI indicates the resource for the first repetition.
  + The time domain resources for the remaining repetitions are derived based at least on the resources for the first repetition and the UL/DL direction of the symbols.
    - FFS the detailed interaction with the procedure of UL/DL direction determination
  + Each repetition occupies contiguous symbols.
  + FFS whether/how to handle “orphan” symbols (the # of UL symbols is not sufficient to carry one full repetition)
* Frequency hopping (at least 2 hops)
  + Support at least inter-PUSCH-repetition hopping and inter-slot hopping
  + FFS other FH schemes
  + FFS number of hops larger than 2
* FFS dynamic indication of the number of repetitions
* FFS DMRS sharing
* FFS TBS determination (e.g. based on the whole duration, or based on the first repetition)

Agreements:

At least for scheduled PUSCH, for the option “One UL grant scheduling two or more PUSCH repetitions in consecutive available slots, with one repetition in each slot with possibly different starting symbols and/or durations” (also called as “~~two~~multi-segment transmission”), if supported, it further consists of:

* Time domain resource determination
  + The time domain resource assignment field in the DCI indicates the starting symbol and the transmission duration of all the repetitions.
    - FFS multiple SLIVs indicating the starting symbol and the duration of each repetition
    - FFS details of SLIV, including the possibility of modifying SLIV to support the cases with S+L>14.
  + FFS the interaction with the procedure of UL/DL direction determination
* For the transmission within one slot,
  + If there are more than one UL period within a slot (where each UL period is the duration of a set of contiguous symbols within a slot for potential UL transmission as determined by the UE)
    - ~~Alt1: One repetition spans across more than one UL periods.~~
      * ~~This implies that DMRS is required for each UL period.~~
      * ~~Note: it is agreed in previous meetings that one PUSCH instance is not across a slot boundary~~
      * ~~Each repetition occupies contiguous symbols available for potential UL transmission across one or more UL periods~~
    - ~~Alt2:~~ One repetition is within one UL period.
      * FFS if more than one UL period is used for the transmission (If more than one UL period is used, this would override the previous definition of this option.)
      * Each repetition occupies contiguous symbols
  + Otherwise, a single PUSCH repetition is transmitted within a slot following Rel-15 behavior.
* ~~FFS Transmission of the repetitions spanning across more than two slots is not supported.~~
* Frequency hopping
  + Support at least inter-slot FH
  + FFS other FH schemes
* FFS TBS determination (e.g. based on the whole duration, or based on the first repetition, overhead assumption)

Agreements:

* Down-select between “mini-slot based repetitions” and “two-segment transmission”, aiming in RAN1#96
* FFS the option of using separate grants to schedule PUSCH repetitions in consecutive available slots

Agreements**:**

Companies are encouraged to provide more details in RAN1#96 at least for the following for potential enhancements of PUSCH:

* Details of the time domain resource determination, including the interaction with the DL/UL direction of the symbols
* Details of TBS determination
* What is different for scheduled PUSCH and configured grant?
  + E.g. for configured grant, should the transmission be allowed to postpone when conflicting with DL symbols?
* Comparison between the two schemes, including the potential performance evaluation/analysis (including latency, reliability, etc), complexity, overhead, etc.

### RAN1#96 (Feb. 2019)

Agreements**:**

* Capture the descriptions of option 1 to 6 (see R1-1903797 and previous agreements) in the TR.

Here is the description of Option 4 from TR 38.824:

*One or more actual PUSCH repetitions in one slot, or two or more actual PUSCH repetitions across slot boundary in consecutive available slots, is supported using one UL grant for dynamic PUSCH, and one configured grant configuration for configured grant PUSCH. It further consists of:*

* *The number of the repetitions signaled by gNB represents the “nominal” number of repetitions. The actual number of repetitions can be larger than the nominal number.*
  + *FFS dynamically or semi-statically signalled for dynamic PUSCH and type 2 configured grant PUSCH*
* *The time domain resource assignment (TDRA) field in the DCI or the TDRA parameter in the type 1 configured grant indicates the resource for the first “nominal” repetition.*
* *The time domain resources for the remaining repetitions are derived based at least on the resources for the first repetition and the UL/DL direction of the symbols.*
  + *FFS the detailed interaction with the procedure of UL/DL direction determination*
* *If a “nominal” repetition goes across the slot boundary or DL/UL switching point, this “nominal” repetition is splitted into multiple PUSCH repetitions, with one PUSCH repetition in each UL period in a slot.*
  + *Handling of the repetitions under some conditions, e.g., when the duration is too small due to splitting, is to be further investigated in the WI phase.*
* *No DMRS sharing across multiple PUSCH repetitions*
* *The maximum TBS size is not increased compared to Rel-15.*
* *FFS: L > 14*
* *S+L can be larger than 14*
* *FFS: The bitwidth for TDRA is up to 4 bits.*
* *Note: different repetitions may have the same or different RV.*

**Conclusion**:

* Finalize the details regarding how to use “option 1” vs. “option 2” during the WI phase using option 4, 5, and 6 (as in R1-1903797) as a starting point.

Agreements**:**

* Capture the simulation results in Section 3 in the TR.

### RAN1#96bis (Apr. 2019)

Agreements**:**

* Option 5 is not considered further as part of PUSCH enhancements.

Agreements**:**

For option 4, dynamic indication of the nominal number of repetitions in the DCI scheduling dynamic PUSCH is supported for PUSCH enhancements. The dynamic indication can be enabled or disabled by the gNB.

* FFS the exact signaling method
* FFS the exact DCI format(s)
* FFS the exact mechanism to enable or disable
* FFS the DCI activating type 2 configured grant PUSCH

Agreements:

For option 6,

* For dynamic PUSCH
  + For semi-static DL symbol(s), to down-select
    - Option 1: it is not expected that the resource allocation has conflict with semi-static DL symbol(s).
    - Option 2: if the resource allocation has conflict with semi-static DL symbol(s), the repetition is not transmitted.
  + For dynamically indicated DL symbol(s) (via format 2\_0), it is not expected at the UE that the resource allocation has conflict with dynamically indicated DL symbol(s).
    - Note: this is the same as Rel-15 behavior.
* For configured grant PUSCH,
  + For type 1 configured grant PUSCH, and PUSCH other than the first PUSCH (including all repetitions) associated with the type 2 configured grant activation,
    - If a repetition conflicts with semi-static DL symbol(s), the repetition is not transmitted.
    - FFS: If a repetition conflicts with dynamically indicated DL symbol(s) (via format 2\_0), the repetition is not transmitted.
  + FFS For the first PUSCH (including all repetitions) associated with the type 2 configured grant activation, follow the same handling as dynamic PUSCH.

Agreements:

* For option 6, at least for dynamic grants, it is not expected that one repetition (i.e., one SLIV) spans across slot boundary.

Agreements:

For both option 4 and 6, frequency hopping is supported

* FFS details

### RAN1#97 (May 2019)

Agreements:

* Adopt option 4 with the following update:
* The time domain resource assignment (TDRA) field in the DCI or the TDRA parameter in the type 1 configured grant indicates the resource for the first “nominal” repetition.
  + FFS the detailed interaction with the procedure of UL/DL direction determination

### RAN1#98 (Aug. 2019)

Agreements:

In terms of how to interpret L and K for all PUSCH transmissions, down-select between the following two:

* Alt 1: The time window within which valid symbols are used for transmission is L\*K.
  + FFS the definition of “valid symbols”
* Alt 2: The time window within which valid symbols are used for transmission can be longer than L\*K symbols, and it is extended at least in case of semi-static DL symbols.
  + FFS extension of the time window in case of dynamic DL symbols and/or semi-static flexible symbols and/or reserved symbols (if defined) and/or SSB symbols and/or type-0 CSS in CORESET#0 (as indicated by MIB)
  + FFS the definition of “valid symbols”
  + FFS whether to define a maximum time window size and if so, details

**Conclusion:**

In terms of how to handle the interaction of enhanced PUSCH with DL/UL directions, consider the following options:

* For DG PUSCH
  + If dynamic SFI is not configured,
    - Semi-static flexible symbols are used for PUSCH. Segmentation occurs only around semi-static DL symbols.
  + If dynamic SFI is configured
    - Option 1: behavior not dependent on dynamic SFI
      * Option 1-1: Semi-static flexible symbols are used for PUSCH. Segmentation occurs only around semi-static DL symbols.
        + FFS whether the conflict between dynamic SFI and symbols used for PUSCH transmission is considered as an error case, e.g.

Option 1-1a: The UE does not expect any semi-static flexible symbol to be indicated as DL within the PUSCH transmission time window.

Option 1-1b: No error case is defined and in general all semi-static flexible symbols are used for PUSCH within the PUSCH transmission time window.

* + - * Option 1-2: Semi-static DL/flexible symbols are not used for PUSCH. Segmentation occurs around semi-static DL/flexible symbols.
      * Option 1-3: Dynamic indication in UL grant on which set of semi-static flexible symbols are used for PUSCH. Segmentation occurs around semi-static DL and the dynamically indicated invalid symbols.
      * Option 1-4: Pre-defined rules to determine which set of semi-static flexible symbols are used for PUSCH. Segmentation occurs around semi-static DL and the invalid symbols as defined in the rules.
    - Option 2: the UE uses SFI to determine the symbols to transmit
      * In case SFI is configured and received
        + Option 2-1: Segmentation occurs around semi-static DL symbols and dynamic DL/flexible symbols
        + Option 2-2: Dynamic flexible symbols are used for PUSCH. Segmentation occurs around semi-static DL symbols and dynamic DL symbols
        + Option 2-3: Dynamic flexible symbols are used for PUSCH. A repetition is not transmitted if it conflicts with a dynamic DL symbol.
        + Option 2-4: A repetition is not transmitted if it conflicts with a dynamic DL/flexible symbol
      * In case SFI is configured and not received
        + A repetition is not transmitted if it conflicts with a semi-static flexible symbol.
* For CG PUSCH other than the first Type 2 CG PUSCH (including all the repetitions) activated by an UL grant
  + If dynamic SFI is not configured,
    - Semi-static flexible symbols are used for PUSCH. Segmentation occurs only around semi-static DL symbols.
  + If dynamic SFI is configured
    - Option 1: behavior not dependent on dynamic SFI
      * ~~Option 1-1: Semi-static flexible symbols are used for PUSCH. Segmentation occurs only around semi-static DL symbols.~~
        + *~~This does not seem to make much sense for CG. If semi-static flexible symbols are always used for CG PUSCH, the gNB can essentially configure these symbols as UL in semi-static configuration. – no need for this option?~~*
      * Option 1-2: Semi-static DL/flexible symbols are not used for PUSCH. Segmentation occurs around semi-static DL/flexible symbols.
      * *~~Option 1-3 from DG is not applicable for CG.~~*
      * Option 1-4: Pre-defined rules to determine which set of semi-static flexible symbols are used for PUSCH. Segmentation occurs around semi-static DL and the invalid symbols as defined in the rules.
    - Option 2: the UE uses SFI to determine the symbols to transmit
      * In case SFI is configured and received
        + Option 2-1: Segmentation occurs around semi-static DL symbols and dynamic DL/flexible symbols
        + *~~Option 2-2 does not make sense for CG. (Dynamic flexible symbols are used for PUSCH. Segmentation occurs around semi-static DL symbols and dynamic DL symbols)~~*
        + *~~Option 2-3 does not make sense for CG. (Dynamic flexible symbols are used for PUSCH. A repetition is not transmitted if it conflicts with a dynamic DL symbol.)~~*
        + Option 2-4: a repetition is not transmitted if it conflicts with a semi-static DL symbol and a dynamic DL/flexible symbol
      * In case SFI is configured and not received
        + A repetition is not transmitted if it conflicts with a semi-static flexible symbol.
* For the first Type 2 CG PUSCH (including all the repetitions) activated by an UL grant,
  + Alt 1: same behavior as DG PUSCH
  + Alt 2: same behavior as CG PUSCH without an associated UL grant
  + …
* FFS: in case of a repetition not being transmitted (as in the above bullets), whether a repetition is a nominal repetition or a repetition after segmentation due to semi-static DL symbol(s)/slot boundary
* FFS: whether to postpone or not, and if yes, under what condition(s)
* FFS: whether/how guard period is handled
* Note that segmentation at slot boundary is always performed, even though it is not explicitly mentioned in the bullets above.
* FFS: the handling of conflict with SSB/PRACH symbols, the handling of conflict with semi-statically configured DL reception, etc.
* Other options are not precluded

### RAN1#98bis (Oct. 2019)

Agreements:

* Do not support PUSCH mapping type A for Option 4.

Agreements:

* Rel-16 enhanced PUSCH scheme (including dynamic indication of the number of repetitions) is supported for DCI format 0\_1 and new UL DCI format (for DG and type 2 CG).
* Rel-16 enhanced PUSCH scheme is not supported for DCI format 0\_0 for DG and type 2 CG

Agreements:

For the dynamic indication of the number of repetitions for dynamic grant:

* Jointly coded with SLIV in TDRA table, by adding an additional column for the number of repetitions in the TDRA table
  + The maximum TDRA table size is increased to 64
  + No other spec impact is expected

Agreements:

* Support dynamic indication of the number of repetitions for Rel-15 PUSCH with slot aggregation using DCI formats 0\_1 & the new UL DCI format
  + The dynamic indication is done by using the same Rel-16 mechanism (Jointly coding the number of repetitions with SLIV in TDRA table)

Agreements:

For frequency hopping for Rel-16 PUSCH, the number of actual hopping locations in frequency is 2.

Agreements:

In case frequency hopping is enabled for Rel-16 PUSCH, to determine the frequency locations of the two hops, reuse Rel-15 RRC parameters and equations for format 0\_1, and introduce new RRC parameters (same as those of Rel-15) for new DCI UL format.

* FFS time domain hopping pattern

Agreements:

In terms of how to interpret L and K for Rel-16 PUSCH transmissions (for both DG & CG), Alt. 1 is adopted.

* That is, for the Rel-16 PUSCH with enhanced repetition transmission, the time window within which valid symbols are used for transmission is L\*K, starting from the first symbol indicated by the SLIV in TDRA field.

**Conclusion:**

Definitions:

* “Rel-16 PUSCH transmission scheme”: Option 4
* “Rel-15 PUSCH transmission scheme”: the transmission is done according to Rel-15 behavior, either with or without slot aggregation. With slot aggregation, the number of repetitions can be either semi-statically configured (as in Rel-15) or dynamically indicated (as agreed for Rel-16).

Agreements:

For DG and retransmission of CG, introduce one RRC parameter for each of the DCI format 0\_1 and the new UL DCI format, to indicate whether UE follows the behavior for “Rel-16 PUSCH transmission scheme” or the behavior for “Rel-15 PUSCH transmission scheme”.

* FFS: whether to restrict that “Rel-16 PUSCH transmission scheme” cannot be enabled for both DCI formats simultaneously

For Type 1 CG, introduce an RRC parameter per CG configuration to indicate whether UE follows the behavior for “Rel-16 PUSCH transmission scheme” or the behavior for “Rel-15 PUSCH transmission scheme”.

Agreements:

For Type 2 CG, UE uses the PUSCH transmission scheme (“Rel-16 PUSCH transmission scheme” or “Rel-15 PUSCH transmission scheme”) associated with the activating DCI format.

Agreements:

For the interaction with DL/UL directions, if dynamic SFI is configured, Option 1-4 is not further considered for both DG and CG

For the interaction with DL/UL directions, if dynamic SFI is configured, Option 1-2 is not further considered for DG.

Agreements:

For the interaction with DL/UL directions, if dynamic SFI is configured, Option 2-2 and 2-3 is not further considered for DG.

Agreements:

* For both DG and CG with “Rel-16 PUSCH transmission scheme”, if dynamic SFI is not configured, semi-static flexible symbols are used for PUSCH. Segmentation occurs at least around semi-static DL symbols.
  + FFS segmentation also around dynamically indicated invalid symbols for UL transmissions in the UL grant (if supported for DG and/or Type 2 CG) and/or semi-statically configured invalid symbols for UL transmissions (if supported)
  + FFS how to handle the conflict with dynamic DL transmission for CG

### RAN1#99 (Nov. 2019)

Agreements:

* For the initial Type 2 CG PUSCH transmission, the TDRA table follows the activating DCI.
* For the initial Type 2 CG PUSCH transmission with PUSCH repetition type A or B, the number of repetitions is provided by the activating DCI via *numberofrepetitions* if it is present in the corresponding TDRA table; otherwise, the number of repetitions is provided by *repK*.

Agreements:

* For the initial Type 1 CG PUSCH transmission with PUSCH repetition type B,
  + If one and only one of DCI formats 0\_1 and 0\_2 is configured with PUSCH repetition type B, the TDRA table corresponding to the DCI format (0\_1 or 0\_2) configured with PUSCH repetition type B is used.
  + If both 0\_1 and 0\_2 are configured with PUSCH repetition type B, the TDRA table corresponding to DCI format 0\_1 is used.
  + Note: For the initial Type 1 CG PUSCH transmission with PUSCH repetition type B, the case of none of the DCI formats 0\_1 and 0\_2 is configured with PUSCH repetition type B is an error case
* For the initial Type 1 CG PUSCH transmission, if it is configured with PUSCH repetition type A, use the TDRA table for USS in Rel-15.
* For the initial Type 1 CG PUSCH transmission with PUSCH repetition, the number of repetitions is provided via *numberofrepetitions* if it is present in the corresponding TDRA table; otherwise, the number of repetitions is provided by repK.
* FFS the value range of repK is extended for R16 repetition type A and/or type B

Agreements:

* For PUSCH repetition type B, L<=14

Agreements:

For PUSCH repetition type B, support the following frequency hopping:

* Inter-PUSCH-repetition FH
  + Details FFS
* Inter-slot FH
* FFS Intra-PUSCH-repetition FH

Agreements**:**

The column on the number of repetitions *numberofrepetitions* is always present in *PUSCH-TimeDomainResourceAllocationList-ForDCIformat0\_1* and *PUSCH-TimeDomainResourceAllocationList-ForDCIformat0\_2*.

* For DG with PUSCH repetition type A, if *numberofrepetitions* is present in the corresponding TDRA table, the number of repetitions is given by *numberofrepetitions*. Elseif the UE is configured with pusch-AggregationFactor, the number of repetitions is given by pusch-AggregationFactor. Otherwise the number of repetitions is 1.
* For DG with PUSCH repetition type B, the number of repetitions is given by *numberofrepetitions*.
  + Note that pusch-TimeDomainAllocationList-ForDCIformat0\_1/2 needs to be configured for PUSCH repetition type B.

Agreements:

For PUSCH repetition type A and type B, the number of bits to indicate *numberofrepetitions* is 3.

* {1, 2, [3], 4, [6], 7, [8], 12, 16} are supported.
* FFS whether to have a limit on the number of nominal repetitions in a slot

Agreements:

For how to indicate S and L in the TDRA table for PUSCH repetition type B, S and L are separately indicated (4-bit for S and 4-bit for L).

* S is from 0 and [13], L is from [1] to 14.
  + Note: The additional restrictions for a particular waveform and/or DMRS mapping type from R15 are still applicable

Agreements:

For both DG and CG with PUSCH repetition type B, the TBS is determined based on *L* indicated in TDRA table entry reusing Rel-15 mechanism.

Agreements:

For Type 1 CG with PUSCH repetition type B, introduce a new RRC parameter *frequencyHopping-PUSCHRepTypeB* per CG configuration to indicate the frequency hopping scheme, and reuse Rel-15 parameter *frequencyHoppingOffset* to determine the frequency locations.

* For Type 1 CG with PUSCH repetition type B, if *frequencyHopping-PUSCHRepTypeB* is not configured, frequency hopping is not enabled.

Agreements

Introduce a new RRC parameter frequencyHopping-ForDCIFormat0\_1.

* This parameter can only be configured when *PUSCHRepTypeIndicator-ForDCIFormat0\_1* is set to ‘*pusch-RepTypeB*’.

Agreement (RRC impact)

For DG PUSCH with PUSCH repetition type B, if dynamic SFI is configured, introduce a first RRC parameter that indicates one pattern for invalid symbols for PUSCH transmission repetition type B applicable to both DCI format 0\_1 and 0\_2, and introduce a second RRC parameter for each of DCI format 0\_1 and 0\_2 to indicate the presence of an additional bit in the DCI to indicate whether the pattern applies or not.

* If the first RRC parameter is not configured, semi-static flexible symbols are used for PUSCH. Segmentation occurs only around semi-static DL symbols.
* If the first RRC parameter is configured and the additional bit exists in a DCI,
  + Value ‘0’ means semi-static flexible symbols are used for PUSCH, and segmentation occurs only around semi-static DL symbols.
  + Value ‘1’ means that segmentation occurs around semi-static DL symbols and invalid symbols in the pattern, and the remaining symbols are used for PUSCH.
* If the first RRC parameter is configured and the additional bit does not exist in a DCI, segmentation occurs around semi-static DL symbols and invalid symbols in the pattern, and the remaining symbols are used for PUSCH.
* The first RRC parameter reuses the pattern definition of *rateMatchPattern* in time domain for PDSCH.

Note: Qualcomm has concerns over the above feature in terms of UE complexity. Majority of companies do not see this issue.

Agreement

For CG PUSCH with PUSCH repetition type B, if dynamic SFI is configured, segmentation occurs at least around semi-static DL symbols, which results in actual repetitions.

* If dynamic SFI is received for the entire duration of an actual repetition, an actual repetition is not transmitted if it conflicts with a dynamic DL/flexible symbol.
* If dynamic SFI is not received for at least one symbol of an actual repetition, an actual repetition is not transmitted if it conflicts with a semi-static flexible symbol.
* FFS the handling of semi-statically configured invalid symbols for PUSCH repetition type B transmissions (if supported)

Note that the cancellation behavior is the same as Rel-15, including Rel-15 cancellation timeline

Agreement

For DG PUSCH with PUSCH repetition type B, the RV for the first repetition is provided by DCI, and RV cycling is done across the repetitions using the RV sequence of {0, 2, 3, 1}.

* ~~FFS~~ “repetition” means ~~nominal or~~ actual repetition
  + ~~FFS In case “repetition” means nominal repetition, whether the same RV applies to all the actual repetitions corresponding to a nominal repetition.~~

Agreements:

For CG PUSCH with PUSCH repetition type B, RV cycling is done across repetition following the sequence in *repK-RV*,

* the first repetition uses the first value in repK-RV
* “repetition” means actual repetition

### RAN1#100-e (Feb. 2020)

**[100e-NR-L1enh\_URLLC-PUSCH\_Enh-01]**

Agreements:

For *numberofrepetitions* for PUSCH repetition type A and type B, {3, 8} are additionally supported. That is, {1, 2, 3, 4, 7, 8, 12, 16} are supported for *numberofrepetitions*. (RRC impact)

Agreements:

The value range for repK remains the same as in Rel-15.

Agreements:

For PUSCH repetition Type B, S is from 0 to 13, and L is from 1 to 14. (RRC impact)

Agreements: (RRC impact)

Introduce *reportSlotOffsetList-r16-ForDCIFormat0\_1* and *reportSlotOffsetList-r16-ForDCIFormat0\_2* and update TS 38.214 accordingly

* FFS whether or not to always assume the number of nominal repetitions is equal to 1 when PUSCH with repetition Type B carries A-CSI/SP-CSI only.

Agreements:

For PUSCH repetition Type B, PUSCH transmit power is determined based on the nominal repetition duration.

**Agreements:**

Adopt the following TP to TS 38.214:

|  |
| --- |
| **TP to TS 38.214, Sec. 5.2.1.4 and Sec. 6.1.2.1**  **5.2.1.4 Reporting configurations**  **<**Unchanged text is omitted>  For a semi-persistent or aperiodic CSI report on PUSCH, the allowed slot offsets are configured by the following higher layer parameters:  -     if triggered/activated by DCI format 0\_2 and the higher layer parameter reportSlotOffsetListForDCI-Format0-2 is configured, the allowed slot offsets are configured by ~~the higher layer parameter~~ reportSlotOffsetListForDCI-Format0-2 ~~reportSlotOffsetList-r16-ForDCIFormat0\_2~~, and  -     if triggered/activated by DCI format 0\_1 and the higher layer parameter reportSlotOffsetListForDCI-Format0-1 ~~reportSlotOffsetList-r16-ForDCIFormat0\_1~~ is configured, the allowed slot offsets are configured by ~~the higher layer parameter~~ reportSlotOffsetListForDCI-Format0-1 ~~reportSlotOffsetList-r16-ForDCIFormat0\_1~~, and  -     otherwise, the allowed slot offsets are configured~~]~~ by the higher layer parameter reportSlotOffsetList.  The offset is selected in the activating/triggering DCI.  **<**Unchanged text is omitted>    **6.1.2.1 Resource allocation in time domain**  **<**Unchanged text is omitted>  When the UE is scheduled to transmit a PUSCH with no transport block and with a CSI report(s) by a CSI request field on a DCI, the Time domain resource assignment field value m of the DCI provides a row index m + 1 to ~~an~~ the allocated table as defined in Clause 6.1.2.1.1 ~~which is defined by the higher layer configured pusch-TimeDomainAllocationList in pusch-Config~~. The indexed row defines the start and length indicator SLIV, and the PUSCH mapping type to be applied in the PUSCH transmission and the K2 value is determined as , where  are the corresponding list entries of the higher layer parameter  -     ~~[~~reportSlotOffsetListForDCI-Format0-2 ~~reportSlotOffsetList-r16-ForDCIFormat0\_2~~, if PUSCH is scheduled by DCI format 0\_2 and reportSlotOffsetListForDCI-Format0-2 is configured;  -     reportSlotOffsetListForDCI-Format0-1 ~~reportSlotOffsetList-r16-ForDCIFormat0\_1~~, if PUSCH is scheduled by DCI format 0\_1 and reportSlotOffsetListForDCI-Format0-1 ~~reportSlotOffsetList-r16-ForDCIFormat0\_1~~  is configured~~]~~;  -     reportSlotOffsetList, ~~[~~otherwise;~~]~~  in CSI-ReportConfig for the  triggered CSI Reporting Settings and  is the (m+1)th entry of .  **<**Unchanged text is omitted> |

**[100e-NR-L1enh\_URLLC-PUSCH\_Enh-02]**

**Conclusion on how FH is enabled/disabled for Type 2 CG** **with DCI format 0\_1** **in Rel-15**:

* For Type 2 CG in Rel-15 activated by DCI format 0\_1, if frequencyHopping in configuredGrantConfig is not configured, FH is disabled. If frequencyHopping in configuredGrantConfig is configured, FH for Type 2 CG is enabled if the frequency hopping flag field in the activation DCI is set to 1, and FH is disabled if the frequency hopping flag field in the activation DCI is set to 0.

Agreements:

For Type 2 CG PUSCH activated by a DCI format configured with PUSCH repetition Type B, the frequency hopping enabling/disabling and the frequency offset follows the indication in the activation DCI, and the frequency hopping scheme follows the corresponding RRC parameter for the activation DCI format. (RRC impact)

Agreements:

For PUSCH with repetition Type B, with inter-repetition FH, frequency hopping occurs for each nominal repetition.

Agreements:

For PUSCH repetition Type B, intra-PUSCH-repetition frequency hopping is not supported. (RRC impact)

Agreements:

Adopt the following TP to TS 38.212 (changes in red):

|  |
| --- |
| **TP to TS 38.212, Sec. 7.3.1.1.2** 7.3.1.1.2 Format 0\_1 **<**Unchanged text is omitted>  - Frequency hopping flag – 0 or 1 bit:  - 0 bit if only resource allocation type 0 is configured, or if ~~both~~ the higher layer parameter *frequencyHopping* is not configured and the higher layer parameter *~~frequencyHopping-ForDCIFormat0\_1~~* pusch-RepTypeIndicatorForDCI-Format0-1-r16 is ~~are~~ not configured to  ‘pusch-RepTypeB’, or if the higher layer parameter frequencyHoppingForDCI-Format0-1-r16 is not configured and pusch-RepTypeIndicatorForDCI-Format0-1-r16 is configured to ‘pusch-RepTypeB’, or if only resource allocation type 2 is configured;  - 1 bit according to Table 7.3.1.1.1-3 otherwise, only applicable to resource allocation type 1, as defined in Clause 6.3 of [6, TS 38.214].  **<**Unchanged text is omitted> |

**Agreements:**

Adopt the following TP to TS 38.214 (changes in red):

|  |
| --- |
| **TP to TS 38.214, Sec. 6.3.2**  6.3.2       Frequency hopping for PUSCH repetition Type B  For PUSCH repetition Type B (as determined according to procedures defined in Clause 6.1.2.1 for scheduled PUSCH, or Clause 6.1.2.3 for configured PUSCH), a UE is configured for frequency hopping by the higher layer parameter frequencyHopping-ForDCIFormat0\_2 in pusch-Config for PUSCH transmission scheduled by DCI format 0\_2, by frequencyHopping-ForDCIFormat0\_1 provided in pusch-Config for PUSCH transmission scheduled by DCI format 0\_1, and by frequencyHopping-PUSCHRepTypeB provided in rrc-ConfiguredUplinkGrant ~~configuredGrantConfig~~ for ~~[~~Type 1~~]~~ configured PUSCH transmission. ~~[~~The frequency hopping mode for Type 2 configured PUSCH transmission follows the configuration of the activating DCI format~~]~~. One of two frequency hopping modes can be configured:  -     Inter-repetition frequency hopping  -     Inter-slot frequency hopping  In case of resource allocation type 1, whether or not transform precoding is enabled for PUSCH transmission, the UE may perform PUSCH frequency hopping, if the frequency hopping field in a corresponding detected DCI format is set to 1, or if for a Type 1 PUSCH transmission with a configured grant the higher layer parameter frequencyHopping- PUSCHRepTypeB is provided, otherwise no PUSCH frequency hopping is performed. When frequency hopping is enabled for PUSCH, the RE mapping is defined in clause 6.3.1.6 of [4, TS 38.211].  **<**Unchanged text is omitted> |

**Agreements:**

Adopt the following TP to TS 38.214 (changes in red):

|  |
| --- |
| **TP to TS 38.214, Sec. 6.3.2**  6.3.2       Frequency hopping for PUSCH repetition Type B  **<**Unchanged text is omitted>  In case of inter-repetition frequency hopping, ~~[details to be added when agreements become available].~~ the starting RB for an actual repetition within the n-th nominal repetition (as defined in Clause 6.1.2.1) is given by:  A picture containing hanging  Description automatically generated,  where  is the starting RB within the UL BWP, as calculated from the resource block assignment information of resource allocation type 1 (described in Subclause 6.1.2.2.2) and is the frequency offset in RBs between the two frequency hops.  In case of inter-slot frequency hopping, the starting RB during slot  follows that of inter-slot frequency hopping for PUSCH Repetition Type A in Clause 6.3.1. |

**[100e-NR-L1enh\_URLLC-PUSCH\_Enh-03]**

Agreements:

The semi-static and dynamic indication of invalid symbols (related to *InvalidSymbolPattern*) for DG PUSCH repetition Type B in case dynamic SFI is not configured follows the same behaviour as for DG PUSCH repetition Type B in case dynamic SFI is configured.

Agreements:

For Type 1 CG PUSCH with repetition Type B, regardless of whether dynamic SFI is configured or not, if *InvalidSymbolPattern* is configured, the configured pattern is applied (that is, segmentation occurs around semi-static DL symbols and invalid symbols indicated by *InvalidSymbolPattern*).

Agreements:

For the first Type 2 CG PUSCH with repetition Type B (including all repetitions) after activation, regardless of whether dynamic SFI is configured or not, if *InvalidSymbolPattern* is configured, whether the configured pattern is applied follows the same procedure as specified for DG PUSCH according to the activation DCI.

Agreements:

For Type 2 CG PUSCH with repetition Type B (excluding the first Type 2 CG PUSCH, with all repetitions, after activation), regardless of whether dynamic SFI is configured or not, if *InvalidSymbolPattern* is configured, whether the configured pattern is applied follows the activation DCI.

Agreements:

For PUSCH repetition Type B, a UE is not expected to be indicated with an antenna port configuration that is invalid for the duration of any actual repetition.

Agreements:

For PUSCH with repetition Type B, an actual repetition with a single symbol is not transmitted.

**Agreements:**

Adopt the following TP to TS 38.214:

|  |
| --- |
| **TP to TS 38.214, Sec. 6.1.2.1**  6.1.2       Resource allocation  6.1.2.1            Resource allocation in time domain  <unchanged text omitted>  For PUSCH repetition Type B, the UE determines invalid symbol(s) for PUSCH repetition Type B transmission as follows:  -     A symbol that is indicated as downlink by *tdd-UL-DL-ConfigurationCommon* or *tdd-UL-DL-ConfigurationDedicated* is considered as an invalid symbol for PUSCH repetition Type B transmission.  -     ~~[If a UE is configured with higher layer parameter~~ *~~SlotFormatInficator,~~* ~~the]~~ The UE may be configured with the higher layer parameter *InvalidSymbolPattern*, which provides a symbol level bitmap spanning one or two slots (higher layer parameter *symbols* given by *InvalidSymbolPattern*). A bit value equal to 1 in the symbol level bitmap *symbols* indicates that the corresponding symbol is an invalid symbol for PUSCH repetition Type B transmission. The UE may be additionally configured with a time-domain pattern (higher layer parameter *periodicityAndPattern* given by *InvalidSymbolPattern*), where each bit of *periodicityAndPattern* corresponds to a unit equal to a duration of the symbol level bitmap *symbols*, and a bit value equal to 1 indicates that the symbol level bitmap *symbols* is present in the unit. The *periodicityAndPattern* can be {1, 2, 4, 5, 8, 10, 20 or 40} units long, but maximum of 40ms. The first symbol of *periodicityAndPattern* every 40ms/P periods is a first symbol in frame 𝑛𝑓 mod 4 = 0, where P is the duration of *periodicityAndPattern* in units of ms. When *periodicityAndPattern* is not configured, for a symbol level bitmap spanning two slots, the bits of the first and second slots correspond respectively to even and odd slots of a radio frame, and for a symbol level bitmap spanning one slot, the bits of the slot correspond to every slot of a radio frame. If *InvalidSymbolPattern* is configured, when the UE applies the invalid symbol pattern is determined as follows:  -     ~~if~~ *~~InvalidSymbolPatternIndicator-ForDCIFormat0\_1~~* ~~is configured when the PUSCH is scheduled by DCI format 0\_1, or if~~ *~~InvalidSymbolPatternIndicator-ForDCIFormat0\_2~~* ~~is configured when the PUSCH is scheduled by DCI format 0\_2,~~  ~~-     if [invalid symbol pattern indicator] field is set 1, the UE applies the invalid symbol pattern;~~  ~~-     otherwise, the UE does not apply the invalid symbol pattern;~~  -     If the PUSCH is scheduled by DCI format 0\_1, or corresponds to a Type 2 configured grant activated by DCI format 0\_1, and if *InvalidSymbolPatternIndicator-ForDCIFormat0\_1* is configured,  -     if invalid symbol pattern indicator field is set 1, the UE applies the invalid symbol pattern;  -     otherwise, the UE does not apply the invalid symbol pattern;  -     If the PUSCH is scheduled by DCI format 0\_2, or corresponds to a Type 2 configured grant activated by DCI format 0\_2, and if *InvalidSymbolPatternIndicator-ForDCIFormat0\_2* is configured,  -     if invalid symbol pattern indicator field is set 1, the UE applies the invalid symbol pattern;  -     otherwise, the UE does not apply the invalid symbol pattern;  -     otherwise, the UE applies the invalid symbol pattern.  For PUSCH repetition Type B, after determining the invalid symbol(s) for PUSCH repetition type B transmission for each of the *K* nominal repetitions, the remaining symbols are considered as potentially valid symbols for PUSCH repetition Type B transmission. ~~[~~If the number of potentially valid symbols for PUSCH repetition type B transmission is greater than zero for a nominal repetition, the nominal repetition consists of one or more actual repetitions, where each actual repetition consists of a consecutive set of potentially valid symbols that can be used for PUSCH repetition Type B transmission within a slot.~~]~~ An actual repetition is omitted according to the conditions in Clause 11.1 of [6, TS38.213]. The redundancy version to be applied on the *n*th actual repetition (with the counting including the actual repetitions that are omitted) is determined according to table 6.1.2.1-2. |

**Agreements:**

Adopt the following TP to TS 38.214:

|  |
| --- |
| **TP to TS 38.214, Sec. 6.1.2.1**  6.1.2       Resource allocation  6.1.2.1            Resource allocation in time domain  <unchanged text omitted>  For PUSCH repetition Type B, after determining the invalid symbol(s) for PUSCH repetition type B transmission for each of the K nominal repetitions, the remaining symbols are considered as potentially valid symbols for PUSCH repetition Type B transmission. [If the number of potentially valid symbols for PUSCH repetition type B transmission is greater than zero for a nominal repetition, the nominal repetition consists of one or more actual repetitions, where each actual repetition consists of a consecutive set of potentially valid symbols that can be used for PUSCH repetition Type B transmission within a slot.] An actual repetition with a single symbol is omitted except for the case of L =1. An actual repetition is omitted according to the conditions in Clause 11.1 of [6, TS38.213]. The redundancy version to be applied on the nth actual repetition (with the counting including the actual repetitions that are omitted) is determined according to table 6.1.2.1-2. |

**Agreements:**

Adopt the following TP to TS 38.214:

|  |
| --- |
| **TP to TS 38.214, Sec. 6.2.2**  6.2.2 UE DM-RS transmission procedure  <unchanged text omitted>  For PUSCH repetition Type B, the DM-RS transmission procedure is applied for each actual repetition separately based on the allocation duration of the actual repetition. A UE is not expected to be indicated with an antenna port configuration that is invalid for the allocated duration of any actual repetition. |

### RAN1#100bis-e (April. 2020)

**[100b-e-NR-L1enh-URLLC-PUSCH-01]**

**Agreements:**

Adopt the following TP to TS 38.213:

|  |
| --- |
| **TP to TS 38.213, Sec. 7**  7 Uplink Power control  Uplink power control determines a power for PUSCH, PUCCH, SRS, and PRACH transmissions.  A UE does not expect to simultaneously maintain more than four pathloss estimates per serving cell for all PUSCH/PUCCH/SRS transmissions as described in Clauses 7.1.1, 7.2.1, and 7.3.1, except for SRS transmissions configured by IE *SRS-Positioning-Config* as described in Clause 7.3.1.  A PUSCH/PUCCH/SRS/PRACH transmission occasion  is defined by a slot index  within a frame with system frame number , a first symbol  within the slot, and a number of consecutive symbols . For PUSCH with repetition Type B, a PUSCH transmission occasion is a nominal repetition, as described in [6, TS 38.214 Clause 6.1.2].  7.1 Physical uplink shared channel  <omitted text>  7.1.1 UE behaviour  If a UE transmits a PUSCH on active UL BWP  of carrier  of serving cell  using parameter set configuration with index  and PUSCH power control adjustment state with index , the UE determines the PUSCH transmission power  in PUSCH transmission occasion  as  [dBm]  where,  <omitted text>  -  for  and  for  where  is provided by *deltaMCS* for each UL BWP  of each carrier  and serving cell . If the PUSCH transmission is over more than one layer [6, TS 38.214], .  and , for active UL BWP  of each carrier  and each serving cell , are computed as below  -  for PUSCH with UL-SCH data and  for CSI transmission in a PUSCH without UL-SCH data, where  -  is a number of transmitted code blocks,  is a size for code block , and  is a number of resource elements determined as , where  is a number of symbols for PUSCH transmission occasion on active UL BWP  of carrier  of serving cell,  is a number of subcarriers excluding DM-RS subcarriers and phase-tracking RS samples [4, TS 38.211] in PUSCH symbol  (assuming no segmentation for a nominal repetition in case of PUSCH repetition type B), , and ,  are defined in [5, TS 38.212]  <omitted text> |

**[100b-e-NR-L1enh-URLLC-PUSCH-02]**

**Agreements:**

In case of PUCCH overlapping with PUSCH with repetition Type B,

* **Option A**: Multiplexing timeline conditions in Clause 9.2.5 of TS 38.213 shall be satisfied for all the overlapping actual repetitions. Otherwise it is considered as an error case.

**Agreements:**

In case PUCCH overlaps with multiple repetitions of PUSCH repetition Type B that satisfy the multiplexing timeline conditions, UCI is multiplexed on only one actual repetition (including the case where a PUCCH overlaps with a PUSCH with repetition Type B in multiple slots). ~~To determine which actual repetition, down-select from the following 3 options:~~

* Option 1: the first overlapping actual repetition ~~in the first overlapping slot~~ that satisfies the multiplexing timeline

**Conclusion:**

The number of possible indices for beta offset that dynamic-ForDCIFormat0\_2 can indicate is not increased.

**[100b-e-NR-L1enh-URLLC-PUSCH-03]**

**Agreements:**

For operation in unpaired spectrum, symbols that are indicated by ssb-PositionsInBurst in SIB1 or ssb-PositionsInBurst in ServingCellConfigCommon for reception of SS/PBCH blocks are considered invalid symbols for PUSCH repetition Type B, and segmentation occurs around these invalid symbols.

**Agreements:**

For operation in unpaired spectrum, symbols indicated to a UE by *pdcch-ConfigSIB1*in *MIB*for a CORESET for Type0-PDCCH CSS are considered as invalid symbols for PUSCH repetition Type B, and segmentation occurs around these symbols.

**Agreements:**

For operation in unpaired spectrum, introduce a new RRC parameter *numberInvallidSymbolsForDL-UL-Switching* to indicate the number of symbols after the last semi-static DL symbol that are invalid symbols for PUSCH repetition Type B.

* The candidate values include {1, 2, 3, 4}.
* If not configured, it means no symbols are explicitly defined for DL-to-UL switching.

**Agreements:**

Adopt the following TP for TS 38.213:

|  |
| --- |
| TP for TS 38.213 Section 8.1  8.1 Random access preamble  < Unchanged parts are omitted >  For single cell operation or for operation with carrier aggregation in a same frequency band, a UE does not transmit PRACH and PUSCH/PUCCH/SRS in a same slot or when a gap between the first or last symbol of a PRACH transmission in a first slot is separated by less than  symbols from the last or first symbol, respectively, of a PUSCH/PUCCH/SRS transmission in a second slot where  for  or ,  for  or , and  is the SCS configuration for the active UL BWP. This applies to each actual repetition for PUSCH repetition Type B (as described in [6, TS 38.214 Clause 6.1.2])  < Unchanged parts are omitted > |

**[100b-e-NR-L1enh-URLLC-PUSCH-04]**

**Agreements:**

Adopt the following TP for TS 38.214:

|  |
| --- |
| TP for TS 38.214  6.1.2.1 Resource allocation in time domain  When the UE is scheduled to transmit a transport block and no CSI report, or the UE is scheduled to transmit a transport block and a CSI report(s) on PUSCH by a DCI, the *Time domain resource assignment* field value *m* of the DCI provides a row index *m* + 1to an allocated table. The determination of the used resource allocation table is defined in Clause 6.1.2.1.1. The indexed row defines the slot offset *K2*, the start and length indicator *SLIV*, or directly the start symbol *S* and the allocation length *L*, the PUSCH mapping type, and the number of repetitions (if *numberofrepetitions* is present in the resource allocation table) to be applied in the PUSCH transmission.  When the UE is scheduled to transmit a PUSCH with no transport block and with a CSI report(s) by a *CSI request* field on a DCI, the *Time domain resource assignment* field value *m* of the DCI provides a row index *m* + 1to the allocated table as defined in Clause 6.1.2.1.1. The indexed row defines the start and length indicator SLIV, or directly the start symbol *S* and the allocation length *L*, and the PUSCH mapping type to be applied in the PUSCH transmission and the *K2* value is determined as , where  are the corresponding list entries of the higher layer parameter  - *reportSlotOffsetListForDCI-Format0-2*, if PUSCH is scheduled by DCI format 0\_2 and *reportSlotOffsetListForDCI-Format0-2* is configured;  - *reportSlotOffsetListForDCI-Format0-1*, if PUSCH is scheduled by DCI format 0\_1 and *reportSlotOffsetListForDCI-Format0-1* is configured;  - *reportSlotOffsetList*, otherwise;  < Unchanged parts are omitted > |

**Agreements:**

For PUSCH repetition Type B, S is from 0 to 11, and L is from 1 to 12 for extended cyclic prefix. Adopt the following TP for Section 6.1.2.1 in TS 38.214:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| TP for TS 38.214  6.1.2.1 Resource allocation in time domain  < Unchanged parts are omitted >  - For PUSCH repetition Type B, the starting symbol *S* relative to the start of the slot, and the number of consecutive symbols *L* counting from the symbol *S* allocated for the PUSCH are provided by *startSymbol* and *length* of the indexed row of the resource allocation table, respectively.  - For PUSCH repetition Type A, the PUSCH mapping type is set to Type A or Type B as defined in Clause 6.4.1.1.3 of [4, TS 38.211] as given by the indexed row.  - For PUSCH repetition Type B, the PUSCH mapping type is set to Type B.  The UE shall consider the *S* and *L* combinations defined in table 6.1.2.1-1 as valid PUSCH allocations  **Table 6.1.2.1-1: Valid *S* and *L* combinations**   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | **PUSCH mapping type** | **Normal cyclic prefix** | | | **Extended cyclic prefix** | | | | ***S*** | ***L*** | ***S+L*** | ***S*** | ***L*** | ***S+L*** | | Type A | 0 | {4,…,14} | {4,…,14} (repetition\_Type A only) | 0 | {4,…,12} | {4,…,12} | | Type B | {0,…,13} | {1,…,14} | {1,…,14} for repetition Type A, {1,…,27} for repetition Type B | {0,…, 11} | {1,…  ,12} | {1,…,12} for repetition Type A, {1,...,23} for repetition Type B | |
| < Unchanged parts are omitted > |

**Agreements:**

Adopt the following TP for TS 38.214:

|  |
| --- |
| TP for TS 38.214  6.1.2.1 Resource allocation in time domain  < Unchanged parts are omitted >  For PUSCH repetition Type B, after determining the invalid symbol(s) for PUSCH repetition type B transmission for each of the *K* nominal repetitions, the remaining symbols are considered as potentially valid symbols for PUSCH repetition Type B transmission. If the number of potentially valid symbols for PUSCH repetition type B transmission is greater than zero for a nominal repetition, the nominal repetition consists of one or more actual repetitions, where each actual repetition consists of a consecutive set of all potentially valid symbols that can be used for PUSCH repetition Type B transmission within a slot. An actual repetition with a single symbol is omitted except for the case of *L*=1. An actual repetition is omitted according to the conditions in Clause 11.1 of [6, TS38.213]. The redundancy version to be applied on the *n*th actual repetition (with the counting including the actual repetitions that are omitted) is determined according to table 6.1.2.1-2.  < Unchanged parts are omitted > |

**Agreements:**

Adopt the following TP for TS 38.214:

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| --- |
| TP for TS 38.214  6.1.4.2 Transport block size determination  < Unchanged parts are omitted >  The UE shall first determine the number of REs (*NRE*) within the slot:  - A UE first determines the number of REs allocated for PUSCH within a PRB  by  - , where is the number of subcarriers in the frequency domain in a physical resource block,  is the number of symbols *L* of the PUSCH allocation according to Clause 6.1.2.1 for scheduled PUSCH or Clause 6.1.2.3 for configured PUSCH,  is the number of REs for DM-RS per PRB in the allocated duration including the overhead of the DM-RS CDM groups without data, as described for PUSCH with a configured grant in Clause 6.1.2.3 or as indicated by DCI format 0\_1 or DCI format 0\_2 or as described for DCI format 0\_0 in Clause 6.2.2, and  is the overhead configured by higher layer parameter *xOverhead* in *PUSCH-ServingCellConfig*. If the  is not configured (a value from 6, 12, or 18), the  is assumed to be 0. For Msg3 transmission the  is always set to 0. In case of PUSCH repetition Type B,  is determined assuming a nominal repetition with the duration of *L* symbols without segmentation.  < Unchanged parts are omitted > |

# Appendix B: Related Rel-15 RRC parameters

PUSCH-Config ::= SEQUENCE {

dataScramblingIdentityPUSCH INTEGER (0..1023) OPTIONAL, -- Need S

txConfig ENUMERATED {codebook, nonCodebook} OPTIONAL, -- Need S

dmrs-UplinkForPUSCH-MappingTypeA SetupRelease { DMRS-UplinkConfig } OPTIONAL, -- Need M

dmrs-UplinkForPUSCH-MappingTypeB SetupRelease { DMRS-UplinkConfig } OPTIONAL, -- Need M

pusch-PowerControl PUSCH-PowerControl OPTIONAL, -- Need M

frequencyHopping ENUMERATED {intraSlot, interSlot} OPTIONAL, -- Need S

frequencyHoppingOffsetLists SEQUENCE (SIZE (1..4)) OF INTEGER (1.. maxNrofPhysicalResourceBlocks-1)

OPTIONAL, -- Need M

resourceAllocation ENUMERATED { resourceAllocationType0, resourceAllocationType1, dynamicSwitch},

pusch-TimeDomainAllocationList SetupRelease { PUSCH-TimeDomainResourceAllocationList } OPTIONAL, -- Need M

pusch-AggregationFactor ENUMERATED { n2, n4, n8 } OPTIONAL, -- Need S

mcs-Table ENUMERATED {qam256, qam64LowSE} OPTIONAL, -- Need S

mcs-TableTransformPrecoder ENUMERATED {qam256, qam64LowSE} OPTIONAL, -- Need S

transformPrecoder ENUMERATED {enabled, disabled} OPTIONAL, -- Need S

codebookSubset ENUMERATED {fullyAndPartialAndNonCoherent, partialAndNonCoherent,nonCoherent}

OPTIONAL, -- Cond codebookBased

maxRank INTEGER (1..4) OPTIONAL, -- Cond codebookBased

rbg-Size ENUMERATED { config2} OPTIONAL, -- Need S

uci-OnPUSCH SetupRelease { UCI-OnPUSCH} OPTIONAL, -- Need M

tp-pi2BPSK ENUMERATED {enabled} OPTIONAL, -- Need S

...

}

ConfiguredGrantConfig ::= SEQUENCE {

frequencyHopping ENUMERATED {intraSlot, interSlot} OPTIONAL, -- Need S

cg-DMRS-Configuration DMRS-UplinkConfig,

mcs-Table ENUMERATED {qam256, qam64LowSE} OPTIONAL, -- Need S

mcs-TableTransformPrecoder ENUMERATED {qam256, qam64LowSE} OPTIONAL, -- Need S

uci-OnPUSCH SetupRelease { CG-UCI-OnPUSCH } OPTIONAL, -- Need M

resourceAllocation ENUMERATED { resourceAllocationType0, resourceAllocationType1, dynamicSwitch },

rbg-Size ENUMERATED {config2} OPTIONAL, -- Need S

powerControlLoopToUse ENUMERATED {n0, n1},

p0-PUSCH-Alpha P0-PUSCH-AlphaSetId,

transformPrecoder ENUMERATED {enabled, disabled} OPTIONAL, -- Need S

nrofHARQ-Processes INTEGER(1..16),

repK ENUMERATED {n1, n2, n4, n8},

repK-RV ENUMERATED {s1-0231, s2-0303, s3-0000} OPTIONAL, -- Need R

periodicity ENUMERATED {

sym2, sym7, sym1x14, sym2x14, sym4x14, sym5x14, sym8x14, sym10x14, sym16x14, sym20x14,

sym32x14, sym40x14, sym64x14, sym80x14, sym128x14, sym160x14, sym256x14, sym320x14, sym512x14,

sym640x14, sym1024x14, sym1280x14, sym2560x14, sym5120x14,

sym6, sym1x12, sym2x12, sym4x12, sym5x12, sym8x12, sym10x12, sym16x12, sym20x12, sym32x12,

sym40x12, sym64x12, sym80x12, sym128x12, sym160x12, sym256x12, sym320x12, sym512x12, sym640x12,

sym1280x12, sym2560x12

},

configuredGrantTimer INTEGER (1..64) OPTIONAL, -- Need R

rrc-ConfiguredUplinkGrant SEQUENCE {

timeDomainOffset INTEGER (0..5119),

timeDomainAllocation INTEGER (0..15),

frequencyDomainAllocation BIT STRING (SIZE(18)),

antennaPort INTEGER (0..31),

dmrs-SeqInitialization INTEGER (0..1) OPTIONAL, -- Need R

precodingAndNumberOfLayers INTEGER (0..63),

srs-ResourceIndicator INTEGER (0..15) OPTIONAL, -- Need R

mcsAndTBS INTEGER (0..31),

frequencyHoppingOffset INTEGER (1.. maxNrofPhysicalResourceBlocks-1) OPTIONAL, -- Need R

pathlossReferenceIndex INTEGER (0..maxNrofPUSCH-PathlossReferenceRSs-1),

...

} OPTIONAL, -- Need R

...

}

CG-UCI-OnPUSCH ::= CHOICE {

dynamic SEQUENCE (SIZE (1..4)) OF BetaOffsets,

semiStatic BetaOffsets

}

-- ASN1START

-- TAG-DMRS-UPLINKCONFIG-START

DMRS-UplinkConfig ::= SEQUENCE {

dmrs-Type ENUMERATED {type2} OPTIONAL, -- Need S

dmrs-AdditionalPosition ENUMERATED {pos0, pos1, pos3} OPTIONAL, -- Need S

phaseTrackingRS SetupRelease { PTRS-UplinkConfig } OPTIONAL, -- Need M

maxLength ENUMERATED {len2} OPTIONAL, -- Need S

transformPrecodingDisabled SEQUENCE {

scramblingID0 INTEGER (0..65535) OPTIONAL, -- Need S

scramblingID1 INTEGER (0..65535) OPTIONAL, -- Need S

...

} OPTIONAL, -- Need R

transformPrecodingEnabled SEQUENCE {

nPUSCH-Identity INTEGER(0..1007) OPTIONAL, -- Need S

sequenceGroupHopping ENUMERATED {disabled} OPTIONAL, -- Need S

sequenceHopping ENUMERATED {enabled} OPTIONAL, -- Need S

...

} OPTIONAL, -- Need R

...

}

-- TAG-DMRS-UPLINKCONFIG-STOP

-- ASN1STOP

# Appendix C: PUSCH prioritization rules for UCI multiplexed on PUSCH

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| Conclusion (RAN1#97)  For the issue raised in the draft CR [R1-1906302](x-msg://31/R1-1906302.zip), the intended UE behavior per specification is commonly understood as follows:   * For UCI multiplexing, within a PUCCH group, on PUSCH, the following two steps are performed with step 1 first, then followed by step 2:   + Step 1: UCI in overlapped PUCCH transmissions is multiplexed into one PUCCH resource (resource Z). This step is done per PUCCH slot.   + Step 2: UCI, that doesn’t include SR, in Z is multiplexed into one PUSCH, if Z overlaps with at least one PUSCH, following the priorities (sequentially from high to low) as listed below.     - First priority: PUSCH with A-CSI as long as it overlaps with Z     - Second priority: earliest PUSCH slot(s) based on the start of the slot(s)     - If there are still multiple PUSCHs overlap with Z in the earliest PUSCH slot(s), follow the following priorities (sequentially from high to low)       * Third priority: Dynamic grant PUSCHs > PUSCHs configured by respective ConfiguredGrantConfig or semiPersistentOnPUSCH       * Fourth priority: PUSCHs on serving cell with smaller serving cell index > PUSCHs on serving cell with larger serving cell index       * Fifth priority: Earlier PUSCH transmission > later PUSCH transmission   Note: The clarification applies to both cases with the same (except the second priority part) and different numerologies among PUCCH and PUSCHs. |