**3GPP TSG RAN WG1 Meeting #105-e R1-21xxxxx**

**E-meeting, May 10th – May 27th, 2021**

**Agenda Item: 7.1**

**Source: Moderator (vivo)**

**Title: Summary of [105-e-NR-7.1CRs-10] Draft 38.212 CR on spreading factor for PUCCH format 4**

**Document for: Discussion and Decision**

# Introduction

This document is created to collect company views on the proposed changes in [1].

In addition, according to the collected comments in preparation phase, some companies think the discussion for clarifying the spreading factor of PUCCH format 2/3 in TS38.211 is also needed in Rel-16 NR. Some changes for TS38.211 are also provided in the document. Companies can also provide views on the changes.

# Background

In NR Rel-15, PUCCH format 4 supports multiplexing of different UEs in the same PUCCH resource via spreading, and the spreading factor can be either 2 or 4.

In NR Rel-16, for PUCCH format 2 and PUCCH format 3 with one interlace, multiplexing of different UEs in the same PUCCH resource via spreading can also be supported, and its spreading factor can be 1/2/4.

However, the description/name of spreading factor for PUCCH format 2/3/4 is not consistent among different specifications of TS38.211, TS38.212, TS38.213 and TS38.331.

# Problem description

For NR Rel-16, in TS38.331, *occ-Length* can be configured for PUCCH format 2/3/4, and the followings are captured TS38.331.

|  |
| --- |
| PUCCH-ResourceExt-r16 ::= SEQUENCE {  interlaceAllocation-r16 SEQUENCE {  rb-SetIndex INTEGER (0..4),  interlace0 CHOICE {  scs15 INTEGER (0..9),  scs30 INTEGER (0..4)  }  } OPTIONAL, --Need R  formatExt-v1610 CHOICE {  interlace1-v1610 INTEGER (0..9),  occ-v1610 SEQUENCE {  occ-Length-v1610 ENUMERATED {n2,n4} OPTIONAL, -- Need M  occ-Index-v1610 ENUMERATED {n0,n1,n2,n3} OPTIONAL -- Need M  }  } OPTIONAL, -- Need R  ...  }  PUCCH-format4 ::= SEQUENCE {  nrofSymbols INTEGER (4..14),  occ-Length ENUMERATED {n2,n4},  occ-Index ENUMERATED {n0,n1,n2,n3},  startingSymbolIndex INTEGER(0..10)  } |

The followings are captured in TS38.213.

|  |
| --- |
| 9.2.1 PUCCH Resource Sets *….*  If the *format* indicates *PUCCH-format2* or *PUCCH-format3*,the PUCCH format configured for a PUCCH resource is PUCCH format 2 or PUCCH format 3, respectively, where the PUCCH resource also includes a number of PRBs provided by *nrofPRBs*, a number of symbols for a PUCCH transmission provided by *nrofSymbols*, and a first symbol for the PUCCH transmission provided by *startingSymbolIndex*. If a UE is provided by *useInterlacePUCCH-PUSCH* in *BWP-UplinkDedicated,* and the *format* indicates *PUCCH-format2* or *PUCCH-format3* and *PUCCH-ResourceExt* is provided,the PUCCH resource also includes an index of a second interlace by *interlace1*, if provided; otherwise, if *interlace1* is not provided, the PUCCH resource also includes, if provided, an orthogonal cover code length by *occ-Length* and an orthogonal cover code index by *occ-Index*. If the *format* indicates *PUCCH-format3* and *PUCCH-ResourceExt* is provided, the UE assumes that the [4, TS38.211] PRBs with the lowest indexes within the first, and if configured, second interlace are used for PUCCH transmission.  If the *format* indicates *PUCCH-format4*, the PUCCH format configured for a PUCCH resource is PUCCH format 4, where the PUCCH resource also includes a number of symbols for a PUCCH transmission provided by *nrofSymbols*, an orthogonal cover code length by *occ-Length*, an orthogonal cover code index by *occ-Index*, and a first symbol for the PUCCH transmission provided by *startingSymbolIndex*.  *…* 9.2.5.2 UE procedure for multiplexing HARQ-ACK/SR/CSI in a PUCCH *…*  In the following  -  is a code rate given by *maxCodeRate* as in Table 9.2.5.2-1.  -  is a number of PRBs for PUCCH format 2, or PUCCH format 3, or PUCCH format 4, respectively, where  is provided by *nrofPRBs* in *PUCCH-format2* for PUCCH format 2 or by *nrofPRBs* in *PUCCH-format3* for PUCCH format 3, and  for PUCCH format 4  -  for PUCCH format 2 or, if the PUCCH resource with PUCCH format 2 includes an orthogonal cover code with length  provided by *occ-Length*, ,  for PUCCH format 3 or, if the PUCCH resource with PUCCH format 3 includes an orthogonal cover code with length  provided by *occ-Length*, , and  for PUCCH format 4, where  is a number of subcarriers per resource block [4, TS 38.211] |

The followings are captured in TS38.212.

|  |
| --- |
| 1. 6.3.1.4 Rate matching   For PUCCH formats 2/3/4, the total rate matching output sequence length  is given by Table 6.3.1.4-1, where  , , and  are the number of symbols carrying UCI for PUCCH formats 2/3/4 respectively;  and  are the number of PRBs that are determined by the UE for PUCCH formats 2/3 transmission respectively according to Clause 9.2 of [5, TS38.213]; and , , and  are the spreading factors for PUCCH format 2, PUCCH format 3, and PUCCH format 4, respectively.   1. 6.3.1.6 Multiplexing of coded UCI bits to PUCCH   …  For PUCCH format 3, set , where  is the number of PRBs that is determined by the UE for PUCCH format 3 transmission according to Clause 9.2 of [5, TS 38.213], and is the spreading factor for PUCCH format 3 [4, TS 38.211].  For PUCCH format 4, set , where  is the spreading factor for PUCCH format 4.  Find the smallest such that . |

The followings are captured in TS38.211.

|  |
| --- |
| 6.3.2.5 PUCCH format 2 6.3.2.5.2A Spreading  Spreading shall be applied according to  resulting in a block of complex-valued symbols .  If the higher layer parameter *interlace1* is not configured, and the higher-layer parameter *OCC-Length* is configured,  - is given by the higher-layer parameter *OCC-Length*;  - is given by Tables 6.3.2.5A-1 and 6.3.2.5A-2 where , the quantity is the index of the orthogonal sequence to use given by the higher-layer parameter *OCC-Index*, and is the interlaced resource block number as defined in clause 4.4.4.6 within the interlace given by the higher-layer parameter *Interlace0*.  otherwise and 6.3.2.6 PUCCH formats 3 and 4 6.3.2.6.3 Block-wise spreading  For both PUCCH format 3 and 4, with representing the bandwidth of the PUCCH in terms of resource blocks according to clauses 9.2.3, 9.2.5.1 and 9.2.5.2 of [5, TS 38.213] and shall for non-interlaced mapping fulfil    where  is a set of non-negative integers and . For interlaced mapping, if a single interlace is configured and if two interlaces are configured.  For PUCCH format 3, if interlaced mapping is not configured, no block-wise spreading is applied and    where is given by clauses 9.2.3, 9.2.5.1 and 9.2.5.2 of [5, TS 38.213] and .  For PUCCH format 3 with interlaced mapping and PUCCH format 4, block-wise spreading shall be applied according to  where  - for PUCCH format 3 with interlaced mapping, if a single interlace is configured and , if two interlaces are configured;  - for PUCCH format 4,,;  and  is given by Tables 6.3.2.6.3-1 and 6.3.2.6.3-2 for where is the index of the orthogonal sequence to use according to clause 9.2.1 of [5, TS 38.213]. |

Based on the above quoted current specifications, it can be found that there is some insistency regarding the description of spreading factor for PUCCH format 2/3/4. For TS 38.212, current specification does not have detail on how the spreading factor for PUCCH format 2/3/4 is determined.

In [1], some changes are proposed for TS38.212 to clarify that the value of PUCCH spreading factor is determined by a higher parameter (*occ-Length*). And the exact changes are quoted as following for convenience.

## Proposed CR in R1-2105456

### For Rel-15:

6.3.1.4 Rate matching

For PUCCH formats 2/3/4, the total rate matching output sequence length  is given by Table 6.3.1.4-1, where  , , and  are the number of symbols carrying UCI for PUCCH formats 2/3/4 respectively;  and  are the number of PRBs that are determined by the UE for PUCCH formats 2/3 transmission respectively according to Subclause 9.2 of [5, TS38.213]; and  is the spreading factor provided by *OCC-Length* for PUCCH format 4.

**Table 6.3.1.4-1: Total rate matching output sequence length **

|  |  |  |
| --- | --- | --- |
| ***PUCCH format*** | ***Modulation order*** | |
| QPSK | π/2-BPSK |
| PUCCH format 2 |  | N/A |
| PUCCH format 3 |  |  |
| PUCCH format 4 |  |  |

6.3.1.6 Multiplexing of coded UCI bits to PUCCH

If CSI of two parts are transmitted on a PUCCH, the coded bits corresponding to UCI bit sequence  is denoted by and the coded bits corresponding to UCI bit sequence  is denoted by . The coded bit sequence , where , is generated according to the following.

**Table 6.3.1.6-1: PUCCH DMRS and UCI symbols**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| PUCCH duration (symbols) | PUCCH DMRS symbol indices | Number of UCI symbol indices sets | 1st UCI symbol indices set | 2nd UCI symbol indices set | 3rd UCI symbol indices set |
| 4 | {1} | 2 | {0,2} | {3} | - |
| 4 | {0,2} | 1 | {1,3} | - | - |
| 5 | {0, 3} | 1 | {1, 2, 4} | - | - |
| 6 | {1, 4} | 1 | {0, 2, 3, 5} | - | - |
| 7 | {1, 4} | 2 | {0, 2, 3, 5} | {6} | - |
| 8 | {1, 5} | 2 | {0, 2, 4, 6} | {3, 7} | - |
| 9 | {1, 6} | 2 | {0, 2, 5, 7} | {3, 4, 8} | - |
| 10 | {2, 7} | 2 | {1, 3, 6, 8} | {0, 4, 5, 9} | - |
| 10 | {1, 3, 6, 8} | 1 | {0,2,4,5,7,9} | - | - |
| 11 | {2, 7} | 3 | {1,3,6,8} | {0,4,5,9} | {10} |
| 11 | {1,3,6,9} | 1 | {0,2,4,5,7,8,10} | - | - |
| 12 | {2, 8} | 3 | {1,3,7,9} | {0,4,6,10} | {5, 11} |
| 12 | {1,4,7,10} | 1 | {0,2,3,5,6,8,9,11} | - | - |
| 13 | {2, 9} | 3 | {1,3,8,10} | {0,4,7,11} | {5,6,12} |
| 13 | {1,4,7,11} | 2 | {0,2,3,5,6,8,10,12} | {9} | - |
| 14 | {3, 10} | 3 | {2,4,9,11} | {1,5,8,12} | {0,6,7,13} |
| 14 | {1,5,8,12} | 2 | {0,2,4,6,7,9,11,13} | {3, 10} | - |

Denote  as UCI OFDM symbol index. Denote  as the number of elements in UCI symbol indices set  for , where  and  are given by Table 6.3.1.6-1 according to the PUCCH duration and the PUCCH DMRS configuration. Denote  as the number of OFDM symbols carrying UCI in the PUCCH. Denote  as the modulation order of the PUCCH.

For PUCCH format 3, set  , where  is the number of PRBs that is determined by the UE for PUCCH format 3 transmission according to Subclause 9.2 of [5, TS 38.213].

For PUCCH format 4, set , where  is the spreading factor provided by *OCC-Length*for PUCCH format 4.

Find the smallest such that .

<unchanged part omitted>

### For Rel-16:

6.3.1.4 Rate matching

For PUCCH formats 2/3/4, the total rate matching output sequence length  is given by Table 6.3.1.4-1, where  , , and  are the number of symbols carrying UCI for PUCCH formats 2/3/4 respectively;  and  are the number of PRBs that are determined by the UE for PUCCH formats 2/3 transmission respectively according to Clause 9.2 of [5, TS38.213]; and , , and  are the spreading factors for PUCCH format 2, PUCCH format 3, provided by *occ-Length-v1610* or equalled to 1 if *occ-Length-v1610* is not provided, and for PUCCH format 4, provided by *occ-Length*, respectively.

**Table 6.3.1.4-1: Total rate matching output sequence length **

|  |  |  |
| --- | --- | --- |
| ***PUCCH format*** | ***Modulation order*** | |
| QPSK | π/2-BPSK |
| PUCCH format 2 |  | N/A |
| PUCCH format 3 |  |  |
| PUCCH format 4 |  |  |

6.3.1.6 Multiplexing of coded UCI bits to PUCCH

If CSI of two parts are transmitted on a PUCCH, the coded bits corresponding to UCI bit sequence  is denoted by and the coded bits corresponding to UCI bit sequence  is denoted by . The coded bit sequence , where , is generated according to the following.

**Table 6.3.1.6-1: PUCCH DMRS and UCI symbols**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| PUCCH duration (symbols) | PUCCH DMRS symbol indices | Number of UCI symbol indices sets | 1st UCI symbol indices set | 2nd UCI symbol indices set | 3rd UCI symbol indices set |
| 4 | {1} | 2 | {0,2} | {3} | - |
| 4 | {0,2} | 1 | {1,3} | - | - |
| 5 | {0, 3} | 1 | {1, 2, 4} | - | - |
| 6 | {1, 4} | 1 | {0, 2, 3, 5} | - | - |
| 7 | {1, 4} | 2 | {0, 2, 3, 5} | {6} | - |
| 8 | {1, 5} | 2 | {0, 2, 4, 6} | {3, 7} | - |
| 9 | {1, 6} | 2 | {0, 2, 5, 7} | {3, 4, 8} | - |
| 10 | {2, 7} | 2 | {1, 3, 6, 8} | {0, 4, 5, 9} | - |
| 10 | {1, 3, 6, 8} | 1 | {0,2,4,5,7,9} | - | - |
| 11 | {2, 7} | 3 | {1,3,6,8} | {0,4,5,9} | {10} |
| 11 | {1,3,6,9} | 1 | {0,2,4,5,7,8,10} | - | - |
| 12 | {2, 8} | 3 | {1,3,7,9} | {0,4,6,10} | {5, 11} |
| 12 | {1,4,7,10} | 1 | {0,2,3,5,6,8,9,11} | - | - |
| 13 | {2, 9} | 3 | {1,3,8,10} | {0,4,7,11} | {5,6,12} |
| 13 | {1,4,7,11} | 2 | {0,2,3,5,6,8,10,12} | {9} | - |
| 14 | {3, 10} | 3 | {2,4,9,11} | {1,5,8,12} | {0,6,7,13} |
| 14 | {1,5,8,12} | 2 | {0,2,4,6,7,9,11,13} | {3, 10} | - |

Denote  as UCI OFDM symbol index. Denote  as the number of elements in UCI symbol indices set  for , where  and  are given by Table 6.3.1.6-1 according to the PUCCH duration and the PUCCH DMRS configuration. Denote  as the number of OFDM symbols carrying UCI in the PUCCH. Denote  as the modulation order of the PUCCH.

For PUCCH format 3, set , where  is the number of PRBs that is determined by the UE for PUCCH format 3 transmission according to Clause 9.2 of [5, TS 38.213], and is the spreading factor for PUCCH format 3 [4, TS 38.211] provided by *occ-Length-v1610* or equalled to 1 if *occ-Length-v1610* is not provided.

For PUCCH format 4, set , where  is the spreading factor for PUCCH format 4 provided by *occ-Length*.

<unchanged part omitted>

In addition, some changes are also provided for TS38.211 based on the comments in preparation phase.

## Proposed changes for TS 28.211

### For Rel-15:

6.3.2.6 PUCCH formats 3 and 4

6.3.2.6.3 Block-wise spreading

For both PUCCH format 3 and 4, with representing the bandwidth of the PUCCH in terms of resource blocks according to subclauses 9.2.3, 9.2.5.1 and 9.2.5.2 of [5, TS 38.213] and shall fulfil



where  is a set of non-negative integers and .

For PUCCH format 3, no block-wise spreading is applied and



where is given by subclauses 9.2.3, 9.2.5.1 and 9.2.5.2 of [5, TS 38.213] and .

For PUCCH format 4, block-wise spreading shall be applied according to



where , is given by the higher-layer parameter *occ-Length* and  are given by Tables 6.3.2.6.3-1 and 6.3.2.6.3-2 where is the index of the orthogonal sequence to use according to subclause 9.2.1 of [5, TS 38.213].

**Table 6.3.2.6.3-1: Orthogonal sequences  for PUCCH format 4 when .**

|  |  |
| --- | --- |
|  |  |
| 0 |  |
| 1 |  |

**Table 6.3.2.6.3-2: Orthogonal sequences  for PUCCH format 4 when .**

|  |  |
| --- | --- |
|  |  |
| 0 |  |
| 1 |  |
| 2 |  |
| 3 |  |

### For Rel-16:

#### 6.3.2.5 PUCCH format 2

6.3.2.5.2A Spreading

Spreading shall be applied according to

resulting in a block of complex-valued symbols .

If the higher layer parameter *interlace1* is not configured, and the higher-layer parameter *occ-Length-v1610* is configured,

- is given by the higher-layer parameter *occ-Length-v1610*;

- is given by Tables 6.3.2.5A-1 and 6.3.2.5A-2 where , the quantity is the index of the orthogonal sequence to use given by the higher-layer parameter *OCC-Index*, and is the interlaced resource block number as defined in clause 4.4.4.6 within the interlace given by the higher-layer parameter *Interlace0*.

otherwise and

**Table 6.3.2.5A-1: Orthogonal sequences for PUCCH format 2 when .**

|  |  |
| --- | --- |
|  |  |
| 0 |  |
| 1 |  |

**Table 6.3.2.5A-2: Orthogonal sequences for PUCCH format 2 when .**

|  |  |
| --- | --- |
|  |  |
| 0 |  |
| 1 |  |
| 2 |  |
| 3 |  |

#### 6.3.2.6 PUCCH formats 3 and 4

##### 6.3.2.6.3 Block-wise spreading

For both PUCCH format 3 and 4, with representing the bandwidth of the PUCCH in terms of resource blocks according to clauses 9.2.3, 9.2.5.1 and 9.2.5.2 of [5, TS 38.213] and shall for non-interlaced mapping fulfil



where  is a set of non-negative integers and . For interlaced mapping, if a single interlace is configured and if two interlaces are configured.

For PUCCH format 3, if interlaced mapping is not configured, no block-wise spreading is applied and



where is given by clauses 9.2.3, 9.2.5.1 and 9.2.5.2 of [5, TS 38.213] and .

For PUCCH format 3 with interlaced mapping and PUCCH format 4, block-wise spreading shall be applied according to

where

- for PUCCH format 3 with interlaced mapping, if a single interlace is configured and , if two interlaces are configured; is given by the higher-layer parameter *occ-Length-v1610*, otherwise, *.*

- for PUCCH format 4,, is given by the higher-layer parameter *occ-Length*;

and  is given by Tables 6.3.2.6.3-1 and 6.3.2.6.3-2 for where is the index of the orthogonal sequence to use according to clause 9.2.1 of [5, TS 38.213].

**Table 6.3.2.6.3-1: Orthogonal sequences  for PUCCH format 3 with interlaced mapping and PUCCH format 4 when .**

|  |  |
| --- | --- |
|  |  |
| 0 |  |
| 1 |  |

**Table 6.3.2.6.3-2: Orthogonal sequences  for PUCCH format 3 with interlaced mapping and PUCCH format 4 when .**

|  |  |
| --- | --- |
|  |  |
| 0 |  |
| 1 |  |
| 2 |  |
| 3 |  |

# Company views

**Q1: Do you agree with proposed changes for TS28.212 for Rel-15? If not, why?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Agree or not** | **Comment** |
| OPPO | More on NO side. | Firstly, we think the issue (if any) would be editorial, given the current spec text does not give a second technical interpretation.  Secondly, if certain editorial improvement (e.g. to further clarify where the parameter should come from) is indeed desired for the long-time stable Rel-15 spec, besides the proposed change, the current terminology in 38.212, “spreading factor”, is better to be changed to “orthogonal cover code length” in order to align with 38.213 and 38.331, or to be simply removed to avoid giving two different PHY names for the same higher layer parameter. |
| QC | leaning towards NO | Similar view as OPPO, this is editorial change. We admit the CR beautifies the spec and improves the readability of the spec. But current spec is good enough. I don’t think it can be interpreted in a different/wrong way. |
| Apple |  | Same view as OPPO and QC |
| Intel |  | We share similar view as other companies that this is mainly editorial change. Even without such change, there would not have different interpretations.  Some of the changes in the proposed CR are not correct, i.e., *OCC-Length* should be *occ-Length, occ-Length-v1610* should be *occ-Length.*  We can be okay to leave to editor to make the change. |
|  |  |  |

**Q2: Do you agree with proposed changes for TS28.212 for Rel-16? If not, why?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Agree or not** | **Comment** |
| OPPO | More on NO side. | Our comments under Q1 apply to Q2 as well.  In addition, occ-Length and occ-Length-v1610 are defined in 38.331 per single PUCCH resource, and each PUCCH resource would not be configured with both occ-Length and occ-Length-v1610. Therefore it does not seem necessary to distinguish in RAN1 spec between occ-Length and occ-Length-v1610 --- “if occ-Length [of occ-Length-v1610] is provided” means the same as “if occ-Length is provided for the concerned PUCCH resource”. The existing RAN1 spec does not seem to propagate the parameter suffix of “-v16xx” quite much. This discussed CR should follow the same way.  On the other hand, we agree it is good to add some text for the case where occ-Length is not configured for PUCCH formats 2 and 3. |
| QC | Leaning toward No | Similar view as OPPO, this is editorial change. We admit the CR beautifies the spec and improves the readability of the spec. But current spec is good enough. I don’t think it can be interpreted in a different/wrong way. |
| Apple |  | Similar view as OPPO and QC |
| Intel |  | Same comments as above. |
|  |  |  |

**Q3: Do you agree with the proposed changes for TS28.211 for Rel-15? If not, why?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Agree or not** | **Comment** |
| OPPO | No. | The change does not seem to be essential because the current spec text does not generate any technical issues, and the same math notation is explained in 38.212. |
| QC | NO | Similar view as OPPO, this is editorial change. We admit the CR beautifies the spec and improves the readability of the spec. But current spec is good enough. I don’t think it can be interpreted in a different/wrong way. |
| Apple | No | Similar view as OPPO and QC |
| Intel |  | Same comment as above |
|  |  |  |

**Q4: Do you agree with the proposed changes for TS28.211 for Rel-16? If not, why?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Agree or not** | **Comment** |
| OPPO | No. | As explained in our comments for Q1, we do not see a reason to change current wording of occ-Length to occ-Length-v1610. The other changes are not essential because the current spec text does not generate any technical issues. |
| QC | NO | Same comment as for previous question |
| Apple | No |  |
| Intel |  | Same comment as above |
|  |  |  |

# Conclusions

To be updated based on the discussion

# References

1. R1-2105456, “Draft 38.212 CR on spreading factor for PUCCH format 4”, vivo