**3GPP TSG RAN WG1 #102e R1-2006710**

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

**Source: Moderator (NTT DOCOMO, INC.)**

**Title:** **Summary on UE features for URLLC/IIoT**

**Agenda Item:** **7.2.11**

**Document for:** **Discussion and Decision**

1. Introduction

This contribution summarizes the discussions and proposals in AI 7.2.11 regarding UE features for URLLC/IIoT.

Based on the discussions summarized in Section 2, followings are parts of the suggested email discussions/approvals for AI 7.2.11. It is suggested to have a separate email discussion on basic FG aspects after the completion of another email discussion according to the RAN guidance in RP-201284.

**FL proposal of email discussion/approval:**

**Email discussion/approval on UE features for URLLC/IIoT (17th – 20th August)**

* **Whether/how to define a new FG for “TB CRC for cancelled initial PUSCH with CBG based re-transmission”**
* **Whether/how to define FG11-3c/d/e/f/g and 11-4c/d/e/f/g/h/i**
* **Whether the component 3 of FG11-3 is kept, removed or replaced by another component**
* **Whether the component 4 of FG11-4/4a and the component 1 of FG12-1 are kept, removed or replaced by other component(s)**
* **Whether the component 6 of FG11-4/4a is kept, removed or modified, and what are candidate values for the component 6**
* **Whether to add licensed/unlicensed differentiation for FG11-6 or not**
* **Whether to change the reporting type of FG11-9/9a and FG12-2/2a to per UE with FR1/FR2 differentiation or not**
* **Whether to add components for the restriction on the number of monitoring occasions per slot/half-slot to FG11-2 or not**
* **Whether/how to add new FGs for the reference cell number for DC PDCCH BD/CCE limit**
* **Whether/how to add new FG for independent cancellation of the overlapping channels in an intra-band UL CA**

**Email discussion/approval on basic FGs for URLLC/IIoT (after the completion of above email discussion)**

* **Whether/how to define basic FG(s) for each of particular URLLC/IIoT scenarios based on completed FGs**

Companies are encouraged to check above FL proposal and to provide feedback if any in below.

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| Company | Comment |
| Qualcomm | We are fine with the scope of the first email discussion, except for 2.6; the reasons to have the signaling type as per band was discussed before.  We are not supportive of having the second email discussion; the need for defining for basic feature sets for URLLC was discussed before. In particular, given a wide spectrum of requirements for URLLC, it is not helpful at all to define some sub-features as for providing lower latency and some others for providing ultra reliability. There is also a connection between low latency and high reliability metrics. Hence, no basic feature group for URLLC is needed. |
| Intel | Fine with proposed scope for first email discussion as such. However, the list is a bit too long for a single thread.  We sympthasize with earlier comments on revisiting RAN1 agreements, and also share the same view as Qualcomm on aiming to define “basic feature sets” for URLLC. This was indeed discussed few meetings ago and we do not see a need to rediscuss now.  In view of the above, we would suggest to split the first email discussion into two threads for easier manageability. Splitting into **email discussion #1: first five items from current list** **in FL proposal** (these were discussed in the recently concluded email discussions); and **email discussion #2: last five items from current list** **in FL proposal** seems like a reasonable way forward here. |
| Apple | We are fine with the scope of the first email discussion except for 2.6. As a principle, we have strong concern with re-opening the previous agreements based on a single company’s preference. The agreements were made as a compromise among different companies’ views. If we re-open this discussion (especially there is no new point being brought up), we may risk a similar situation for many other discussion points. Therefore, we do not think this point should be discussed again.  We share the same view as Qualcomm and Intel that we do not see the need to define basic feature sets for URLLC given the wide range of requirements of different URLLC applications.  We are also fine with Intel’s suggestion of splitting the first email discussion into two. |
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1. Discussion on NR Rel-16 UE features for URLLC/IIoT
   1. New FG for “TB CRC for cancelled initial PUSCH with CBG based re-transmission”

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| 12-1x | TB CRC for cancelled initial PUSCH with CBG based re-transmission | PUSCH TB CRC calculated according to section 6.2.1 of TS38.212 for a re-transmission of a TB in case the initial transmission was cancelled and CBG-based re-transmission is configured | 5-25 | Yes | N/A |  | Per band | N/A | N/A |  | The cancellation could be due to support of ULCI and/or intra-UE prioritization | Optional with capability signaling |

Following proposals are made in contributions.

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| [2] | This issue was discussed in the scheduling and HARQ session [2], there are many solutions proposed to address the issue without introducing the FG. Therefore, we think the new FG is not needed.  In addition, our views for the TB CRC calculation is it is up to UE implementation to generate the TB CRC for the retransmission of the same TB. There is no need to mandate UE to always set TB CRC for the retransmission of the same TB as all zeros. If UE is capable to generate, the correct TB CRC can be sent. |
| [3] | FG 12-1x is intended for a UE capability of TB CRC update for CBG based re-transmission with cancelled initial transmission. In the RAN1#101-e meeting, RAN1 also discussed the possibility of addressing this issue by specification modification without introducing the new capability. As analyzed in our companion contribution [2], this issue can be avoided by gNB scheduling or leave to UE implementation. There is no need to define such UE capability. Whether it needs some specification modification or not can be further discussed in Rel-16 URLLC maintenance session.   |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | 12-1x | TB CRC for cancelled initial PUSCH with CBG based re-transmission | PUSCH TB CRC calculated according to section 6.2.1 of TS38.212 for a re-transmission of a TB in case the initial transmission was cancelled and CBG-based re-transmission is configured | 5-25 | Yes | N/A |  | Per band | N/A | N/A |  | The cancellation could be due to support of ULCI and/or intra-UE prioritization | Optional with capability signaling |   ***Proposal 2:*** *A new FG for “TB CRC for cancelled initial PUSCH with CBG based re-transmission” is not introduced.* |
| [4] | This issue is important for the UE implementation and should be solved either in UE feature or in the maintenance discussion. If no consensus is reached in the maintenance discussion, then we prefer to define the new FG in UE feature. In this case, for a UE not supporting this new FG, the gNB should not schedule a subset of the CBGs for retransmission if the initial PUSCH is partially or completely cancelled. |
| [5] | * + For the issue regarding TB CRC generation for retransmission of a canceled initial PUSCH transmission with CBGs, our views are presented in our companion paper as part of Rel-16 eURLLC/IIoT maintenance [3]. |
| [6] | For “TB CRC for cancelled initial PUSCH with CBG based re-transmission” RAN1 discussion for maintenance is first needed.  ***Proposal 3:*** *A new FG for “TB CRC for cancelled initial PUSCH with CBG based re-transmission” is not introduced.* |
| [9] | * We acknowledge the issue of re-transmission of partial TB in case initial transmission is cancelled. However, it should be addressed in RAN1 spec. |
| [11] | In our view, this issue does not belong to UE feature. Ongoing discussion can continue in Rel-16 maintenance. If a consensus is reached to address inappropriate CBG retransmissions, then this issue can be handled via a TP to the specification (e.g., 38.212).   1. Do not introduce New FG for TB CRC. Handle the issue as part of Rel-16 maintenance. |

**Discussion point #1**

* **Whether/how to define a new FG for “TB CRC for cancelled initial PUSCH with CBG based re-transmission”**
  1. FG[11-3c/d/e/f/g] and [11-4c/d/e/f/g/h/i]

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| 11.  NR\_L1enh\_URLLC | [11-3c] | 2 PUCCH of format 0 or 2 for a single 7\*2 subslot based HARQ-ACK codebook | 1) 2 PUCCH format 0/2 in different symbols and once per subslot for HARQ-ACK,  2) 2 PUCCH format 0 in different symbols and once per subslot for SR | 11-3 | Yes | N/A |  | TBD | TBD | TBD | TBD |  | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | [11-3d] | 2 PUCCH of format 0 or for a single 2\*7 subslot based HARQ-ACK codebook | 1) 2 PUCCH format 0/2 in different symbols and once per subslot for HARQ-ACK,  2) 2 PUCCH format 0 in different symbols and once per subslot for SR | 11-3 | Yes | N/A |  | TBD | TBD | TBD | TBD |  | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | [11-3e] | 1 PUCCH format 0 or 2 and 1 PUCCH format 1, 3 or 4 in the same subslot for a single 2\*7-symbol HARQ-ACK codebooks | If the UE supports a 2\*7-symbol subslot HARQ-ACK codebook, the UE also supports:  1) 1 PUCCH format 0 or 2 and 1 PUCCH format 1, 3 and 4 in the same subslot | 11-3 | Yes | N/A |  | TBD | TBD | TBD | TBD |  | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | [11-3f] | 2 PUCCH transmissions in the same subslot for a single 2\*7-symbol HARQ-ACK codebooks which are not covered by 11-3d and 11-3e | If the UE supports a 2\*7 subslot HARQ-ACK codebook, the UE also supports:  2 PUCCH transmissions in the same subslot for a single 2\*7-symbol HARQ-ACK codebooks which are not covered by 11-3d and 11-3e | 11-3 | Yes | N/A |  | TBD | TBD | TBD | TBD |  | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | [11-3g] | SR/HARQ-ACK multiplexing once per subslot using a PUCCH (or HARQ-ACK piggybacked on a PUSCH) when SR/HARQ-ACK are supposed to be sent with different starting symbols in a subslot | If a UE supports a subslot based HARQ-ACK codebook, the UE also supports:  Overlapping PUCCH resources with different starting symbols in a subslot | 11-3 | Yes | N/A |  | TBD | TBD | TBD | TBD |  | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | [11-4c] | 2 PUCCH of format 0 or 2 for Two HARQ-ACK codebooks with up to one 7\*2-symbol sub-slot based HARQ-ACK codebook | If the UE supports a 7\*2-symbol subslot HARQ codebook, the UE also supports:  1) 2 PUCCH format 0/2 in different symbols and once per subslot for HARQ-ACK,  2) 2 PUCCH format 0 in different symbols and once per subslot for SR | 11-4 | Yes | N/A |  | TBD | TBD | TBD | TBD |  | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | [11-4d] | 2 PUCCH of format 0 or 2 in consecutive symbols for two HARQ-ACK codebooks with up to one 2\*7-symbol sub-slot based HARQ-ACK codebook | If the UE supports a 2\*7-symbol subslot HARQ codebook, the UE also supports:  1) 2 PUCCH format 0/2 in different symbols and once per subslot for HARQ-ACK,  2) 2 PUCCH format 0 in different symbols and once per subslot for SR | 11-4 | Yes | N/A |  | TBD | TBD | TBD | TBD |  | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | [11-4e] | 2 PUCCH of format 0 or 2 for two subslot based HARQ-ACK codebooks | If the UE supports two subslot HARQ codebooks, the UE also supports:  1) 2 PUCCH format 0/2 in different symbols and once per subslot per codebook for HARQ-ACK,  2) 2 PUCCH format 0 in different symbols and once per subslot per codebook for SR | 11-4a | Yes | N/A |  | TBD | TBD | TBD | TBD |  | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | [11-4f] | 1 PUCCH format 0 or 2 and 1 PUCCH format 1, 3 or 4 in the same subslot for HARQ-ACK codebooks with up to one 2\*7-symbol subslot based HARQ-ACK codebook | If the UE supports a 2\*7 subslot HARQ-ACK codebook, the UE also supports:  1) 1 PUCCH format 0 or 2 and 1 PUCCH format 1, 3 and 4 in the same subslot of the codebook | 11-4 | Yes | N/A |  | TBD | TBD | TBD | TBD |  | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | [11-4g] | 1 PUCCH format 0 or 2 and 1 PUCCH format 1, 3 or 4 in the same subslot for two subslot based HARQ-ACK codebooks | If the UE supports two subslot HARQ-ACK codebooks both configured with 2\*7 symbols, the UE also supports:  1) 1 PUCCH format 0 or 2 and 1 PUCCH format 1, 3 and 4 in the same subslot of a codebook | 11-4a | Yes | N/A |  | TBD | TBD | TBD | TBD |  | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | [11-4h] | 2 PUCCH transmissions in the same subslot for two HARQ-ACK codebooks with up to one 2\*7-symbol subslot which are not covered by 11-4c and 11-4e | If the UE supports two HARQ-ACK codebooks with up to one subslot based codebook with 2\*7-symbol configuration, the UE also supports:  1) 2PUCCH transmissions in the same subslot of the codebook which are not covered by 11-4c and 11-4e | 11-4 | Yes | N/A |  | TBD | TBD | TBD | TBD |  | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | [11-4i] | 2 PUCCH transmissions in the same subslot for two subslot based HARQ-ACK codebooks  which are not covered by 11-4d and 11-4f | If the UE supports two HARQ-ACK codebooks both with 2\*7-symbol configuration, the UE also supports:  1) 2PUCCH transmissions in the same subslot of a codebook which are not covered by 11-4d and 11-4f | 11-4a | Yes | N/A |  | TBD | TBD | TBD | TBD |  | Optional with capability signalling |

Following proposals are made in contributions.

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| [2] | Some typos should be corrected, such as delete the redundant “1)” in the component column for FG11-3c and “2” is missing in the title of this feature group, i.e. change it to “2 PUCCH of format 0 or 2 for a single 2\*7 subslot based HARQ-ACK codebook”. We are fine with those FGs are defined as “Per FS”. Different from Rel.15 that at most one PUCCH carrying HARQ-ACK in one slot, Rel.16 supports more than one PUCCH carrying the HARQ-ACK for sub-slot based HARQ-ACK feedback, the processing power the UE has to spend on preparing PUCCH has a relation with PDSCH processing power and that is related to number of carriers on which the UE has to process PDSCH. |
| [3] | There was a working assumption on support of FG11-3c/d/e/f/g and FG11-4c/d/e/f/g/h/i. The intention of these feature groups is to limit the maximum number of PUCCHs by following Rel-15 FG 4-2 and FG 4-22a with replacing slot PUCCH to sub-slot PUCCH. By these FGs, the maximum number of PUCCHs within a slot will be determined. However, component 3 of FG 11-3 and component 6 of FG 11-4/4a also targets to limit the the maximum number of PUCCHs within a slot. In this sense, it’s not rational to confirm the working assumption with keeping FG11-3/11-4/4a unchanged. Thus, there are basically two alternatives to go with.   * Alt1: Confirm the working assumption, and delete component 3 of FG 11-3 and component 6 of FG 11-4/4a. * Alt2: Do not confirm the working assumption, and keep component 3 of FG 11-3 and component 6 of FG 11-4/4a.   In our view, Alt2 is preferred since it is simpler for UE reporting and network handling.  ***Proposal 3:*** *Do not confirm the working assumption on support of FG11-3c/d/e/f/g and FG11-4c/d/e/f/g/h/i, and keep component 3 of FG 11-3 and component 6 of FG 11-4/4a.* |
| [4] | Both updated proposal 2 and part of the updated proposal 4 as above should be agreed. The updated proposal 2 (i.e. FG11-3c/d/e/f/gand FG11-4c/d/e/f/g/h/i) define the maximum number of actual PUCCH transmissions and PUCCH formats within a sub-slot, while component 6 in FG11-4/4a defines the restriction for the maximum number of actual PUCCH transmissions for HARQ-ACK within a slot. They are different things and both will have impact on UE complexity. Especially if component 3 under FG 11-3 is not included, then for sure component 6 should be kept here.  As to the reporting type for FG11-3c/d/e/f/g and FG11-4c/d/e/f/g/h/i, we are ok with “Per FS”. |
| [5] | * + We are supportive of the latest version of the updated Proposal 2 from the moderator. |
| [6] | All above FGs relate to limiting a number of PUCCH transmission within a slot. In Rel-15, similar restrictions were adopted for limiting the number of PUUCH transmissions within a slot. Therefore, component 3 of FG 11-3 is not necessary. In that sense, [11-4c to 4i] can be covered by [Supported maximum number of actual PUCCH transmissions for HARQ-ACK within a slot] for FG 11-4/4a, and [11-3c to 3g] can be covered by [Supported maximum number of actual PUCCH transmissions for HARQ-ACK within a slot] under FG 11-3 if component 3 of FG 11-3 is replaced by [Supported maximum number of actual PUCCH transmissions for HARQ-ACK within a slot].  ***Proposal 1:*** *Add component [Supported maximum number of actual PUCCH transmissions for HARQ-ACK within a slot] for FG 11-4/4a and FG 11-3.* |
| [7] | These are a set of FGs that are intended to address the limit of PUCCH transmissions with different formats associated with FG 11-3 and FGs 11-4/4a. These are necessary because otherwise the Rel-15 FGs would apply which put a limit of at most 2 PUCCHs per slot. We made the comment during the email discussion that “sub-slot” definition is not clear for the case with two sub-slot-based codebooks if the sub-slot configuration is different. But given the descriptions for these FGs define the limit as per sub-slot per codebook, there should not be any ambiguity. Therefore, no changes are necessary in this respect. However, “once per sub-slot” should be modified to avoid the misunderstanding that this means the UE needs to be able to handle the PUCCHs in every sub-slot.  **Proposal 2-4: Confirm working assumption on FG11-3c/d/e/f/g and FG11-4c/d/e/f/g/h/i by modifying “once per sub-slot” to “at most once per sub-slot”.**   * **Type of FG11-3c/d/e/f/g and FG11-4c/d/e/f/g/h/i is “Per FS”**   + **Per FS is selected because the processing power the UE has to spend on preparing PUCCH has a relation with PDSCH processing power and that is related to number of carriers on which the UE has to process PDSCH.** |
| [8] | * **11-3c/d/e/f/g and 11-4d/e/f/g/h/i:** FG11-4 component 6 seems capable to address the issues already, so there is no need to support these extra FGs. |
| [10] | * We propose to confirm the working assumption and to set the reporting type to per FS. * Per FS is chosen since the number of downlink carriers and the processing power needed for each PDSCH is different in different bands (considering BW of different carriers.) This impacts the number of PUCCHs that a UE can process. * It should be noted that these FGs cover al PUCCHs (not only those carrying HARQ-ACK); hence, using the components of other FGs to limit the number of PUCCHs carrying HARQ-ACK per slot does not achieve the same goal. * PUCCH formats that a UE can support in combination should be considered since different formats would require different processing effort. * Finally, reusing the Rel. 15 FGs and only replacing “per slot” with “per subslot” is not reasonable. The number of PUCCH trasmissions for slot based (1 or 2) and 7-symbol subslot PUCCH (2 or 4) and 2-symbol subslot PUCCH (7 or 14) are quite different. If we just replace slot with subslot, and if the UE wants to support 2 PUCCH transmissions per slot, then it has to support 14 PUCCH transmissions with a 2-symbol subslot HARQ-ACK codebook. |
| [11] | Two set of FGs [11-3c to 3g] and [11-4c to 4i] (see [1]) have been proposed for PUCCH transmission.  We don’t see the need to introduce these FGs, since Rel-15 already supports corresponding FG with interpretation of subs-lot instead of slot which is already agreed. What is additionally needed to do for Rel-16 is to put a cap for a slot when sub-slot is configured.  As an example, 11-3c is: “2 PUCCH of format 0 or 2 for a single 7\*2 subslot based HARQ-ACK codebook”. 11-3c is equivalent to Rel-15 FG 4-2: “2 PUCCH of format 0 or 2 in consecutive symbols”.  Thus, it is redundant to introduce FGs [11-3c to 3g] and [11-4c to 4i], which increases UE capability signaling overhead unnecessarily.   1. Do not introduce New FGs [11-3c to 3g] and [11-4c to 4i]. 2. Add a note “a UE supporting 11-3 is also expected to support FGs 4-1, 4-3, 4-4, 4-5, and 4-19 with a “slot” being replaced by a sub-slot of length 2 or 7 symbols for NCP and (2 and 6 symbols for ECP) for the PUCCH formats that can be accommodated in the corresponding sub-slot durations” for FG11-3. |

**Discussion point #2**

* **Whether/how to define FG11-3c/d/e/f/g and 11-4c/d/e/f/g/h/i** 
  1. FG11-3

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| 11.  NR\_L1enh\_URLLC | 11-3 | More than one PUCCH for HARQ-ACK transmission within a slot | 1. Supports sub-slot based HARQ-ACK feedback procedure.   • A UL slot consists of a number of sub-slots. No more than one transmitted PUCCH carrying HARQ-ACKs starts in a sub-slot.  • At least one sub-slot configuration for PUCCH can be UE specifically configured to a UE.  • Supports a single configuration for PUCCH resource for all sub-slots in a slot. The starting symbol of a PUCCH resource is defined with respect to the first symbol of sub-slot. Any sub-slot PUCCH resource is not across sub-slot boundaries.   1. Supported sub-slot configuration 2. [Supported combinations of (A, B), where A is the minimum gap between sub-slots containing actual PUCCH transmissions measured from beginning to beginning of the sub-slots, including across slots, and B is the sub-slot duration, with both A and B in units of symbols] |  | Yes | N/A |  | Per FS  Per FS is selected because in bands or BCs with large number of carriers or large BW, the UE’s processing power is spent on PDCCH/PDSCH decoding, and hence in some cases the support of the new codebook or some codebook configurations may not be possible | N/A | N/A | N/A | Candidate value set for component 2:  { 7-symbol\*2, 2-symbol\*7 and 7-symbol\*2} for NCP or { 6-symbol\*2, 2-symbol\*6 and 6-symbol\*2} for ECP  The number of PUCCHs for CSI reporting per slot is not impacted compared with Rel-15 by introducing the new HARQ-ACK CBs  A UE supporting 11-3 is also expected to support FGs 4-1, 4-3, 4-4, 4-5, and 4-19 with a “slot” being replaced by a sub-slot of length 2 or 7 symbols for NCP and (2 and 6 symbols for ECP) for the PUCCH formats that can be accommodated in the corresponding sub-slot durations  [Candidate value set for component 3):  (A, B) =  {(7, 7),  (4, 2) and (7, 7),  (2, 2) and (7, 7)}]  FFS: Whether to keep component 3) and accordingly the above note for component 3) | Optional with capability signalling |

Following proposals are made in contributions.

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| [2] | 3. About whether/how to define following component 3 in FG11-3 of “More than one PUCCH for HARQ-ACK transmission within a slot”  “3. [Supported combinations of (A, B), where A is the minimum gap between sub-slots containing actual PUCCH transmissions measured from beginning to beginning of the sub-slots, including across slots, and B is the sub-slot duration, with both A and B in units of symbols]”  Component 3 is proposed to support the case to allow 3 PUCCHs with the combination of (A, B) = (4, 2) to reduce the latency if the UE cannot support 7 PUCCHs. However, introduce the component for such optimization seems not necessary from the latency perspective given only 3 symbol difference compared to the support of 2\*7-symbol sub-slot configuration. Therefore, we are fine to remove it from the FG11-3. |
| [3] | It is still pending on whether/how to keep component 3 of FG 11-3. As discussed above, if the working assumption on support of FG11-3c/d/e/f/g and FG11-4c/d/e/f/g/h/i is not confirmed, we would be fine to keep component 3 here. But, the current form is too restrictive. It artificially introduces a gap between every two PUCCHs within a slot, while there is even no such restriction in Rel-15. Similar to component 6 of FG 11-4/4a, we suggest changing component 3 to ‘Supported maximum number of actual PUCCH transmissions for HARQ-ACK within a slot’.  ***Proposal 4:*** *Component 3 of FG 11-3 should be changed to ‘Supported maximum number of actual PUCCH transmissions for HARQ-ACK within a slot’.* |
| [4] | During the email discussion, whether to keep component 3 under FG 11-3 was discussed and no consensus was achieved. We still prefer to keep component 3.  While FG 11-3c to 3g define the maximum number of actual PUCCH transmissions within a sub-slot and component 6 in FG 11-4/4a defines the restriction for the maximum number of actual PUCCH transmissions for HARQ-ACK within a slot, this component 3 defines the gap that can be allowed between two actual PUCCH transmissions. The gap between actual PUCCH transmissions is important for UE capability, because we also need to consider the processing that the UE needs to do from receiving the PDSCH until the transmission of the PUCCH, not just the PUCCH transmission itself. Supporting back-to-back PUCCHs will have impact on the processing pipeline, which will result in difficulties to handle the processing with one unit and to use more processing units will increase the UE complexity. This is similar as what we did for PUSCH in Rel-15, where FG5-33 introduces a gap for two unicast PUSCHs. |
| [5] | * + We are supportive of the proposal to remove Component #3 from FG 11-3. With the restrictions from Rel-15 on scheduling and HARQ timings in place, there is no adverse impact to pipelining due to the absence of component #3 from FG 11-3. This is similar to PUSCH scheduling with multiple PUSCHs per slot, where it has not been necessary since Rel-15 to introduce any additional constraints enforcing gaps between two consecutive PUCCHs. |
| [6] | All above FGs relate to limiting a number of PUCCH transmission within a slot. In Rel-15, similar restrictions were adopted for limiting the number of PUUCH transmissions within a slot. Therefore, component 3 of FG 11-3 is not necessary. In that sense, [11-4c to 4i] can be covered by [Supported maximum number of actual PUCCH transmissions for HARQ-ACK within a slot] for FG 11-4/4a, and [11-3c to 3g] can be covered by [Supported maximum number of actual PUCCH transmissions for HARQ-ACK within a slot] under FG 11-3 if component 3 of FG 11-3 is replaced by [Supported maximum number of actual PUCCH transmissions for HARQ-ACK within a slot].  ***Proposal 1:*** *Add component [Supported maximum number of actual PUCCH transmissions for HARQ-ACK within a slot] for FG 11-4/4a and FG 11-3.* |
| [7] | One open issue for FG 11-3 is whether to introduce component 3(“[Supported combinations of (A, B), where A is the minimum gap between sub-slots containing actual PUCCH transmissions measured from beginning to beginning of the sub-slots, including across slots, and B is the sub-slot duration, with both A and B in units of symbols]”). It defines certain minimum gap between PUCCHs which helps with the 2-symbol sub-slot implementation. We support introducing this component because it would allow UEs to implement the feature with reduced complexity, similar to the span pattern that has been introduced for PDCCH. From performance point of view, supporting 2-symbol sub-slot allows fast HARQ-ACK feedback for reduced latency at least with a single PDSCH. Introducing the gap degrades the HARQ-ACK latency only if there are two back-to-back 2-symbol PDSCH transmissions that requires HARQ-ACK feedback, but this does not seem to be a compelling use case. Therefore, introducing the 2-symbol gap should not have much impact in practical sense, but could provide relaxation for UE implementation.  However, it should be clarified whether PUCCH transmissions here include the ones that include UCI other than HARQ-ACK. From UE complexity point of view, it makes sense to include all PUCCH transmissions in the definition given that all PUCCH transmissions are confined within sub-slots in this case.  **Proposal 2-1: Include component 3 in FG 11-3 by modifying it to the following: “Supported combinations of (A, B), where A is the minimum gap between sub-slots containing actual PUCCH transmissions carrying any UCI measured from beginning to beginning of the sub-slots, including across slots, and B is the sub-slot duration, with both A and B in units of symbols”.**  There is a note for FG 11-3 that: “A UE supporting 11-3 is also expected to support FGs 4-1, 4-3, 4-4, 4-5, and 4-19 with a “slot” being replaced by a sub-slot of length 2 or 7 symbols for NCP and (2 and 6 symbols for ECP) for the PUCCH formats that can be accommodated in the corresponding sub-slot durations”. These FGs 4-x defines the frequency of PUCCH as once per slot. When “slot” is replaced by “sub-slot”, the frequency of PUCCH becomes once per sub-slot. However, this is somewhat conflicting with the intention of Proposal 2-1 which may limit the maximum total number of PUCCHs per slot when sub-slot based HARQ-ACK feedback is enabled. Therefore, we think it is more appropriate to re-interpret these FGs 4-x as the UE capability “in a sub-slot”, but not necessarily in every sub-slot. The wording can be changed accordingly. This is also aligned with Proposal 2-4 below.  **Proposal 2-2: Modify the note for FG 11-3 as follows: “A UE supporting 11-3 is also expected to support FGs 4-1, 4-3, 4-4, 4-5, and 4-19 with a “slot” being replaced by a sub-slot of length 2 or 7 symbols for NCP ~~and~~ (and 2 or ~~and~~ 6 symbols for ECP) for the PUCCH formats that can be accommodated in the corresponding sub-slot durations”, and “once per slot” being replaced by “at most once per sub-slot”.** |
| [8] | * **11-3, component 3**: no need for the component, can be removed. |
| [10] | * We are proposing to keep component 3 and its corresponding note; the gap between the consecutive PUCCHs has an impact on the UE’s processing. |

**Discussion point #3**

* **Whether the component 3 of FG11-3 is kept, removed or replaced by another component**
  1. FG11-4/4a and FG12-1

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| 11.  NR\_L1enh\_URLLC | 11-4 | Two HARQ-ACK codebooks with up to one sub-slot based HARQ-ACK codebook (i.e. slot-based + slot-based, or slot-based + sub-slot based) simultaneously constructed for supporting HARQ-ACK codebooks with different priorities at a UE | 1. Supports two HARQ-ACK codebooks with different priorities to be simultaneously constructed with the restriction up to one sub-slot based HARQ-ACK codebook. 2. Supports separate PUCCH configuration for different HARQ-ACK codebooks 3. Supports 2-level priority of HARQ-ACK for dynamically scheduled PDSCH and SPS PDSCH. 4. [Supports a DCI format (from the formats 1\_1/1\_2) scheduling PDSCH with different HARQ-ACK priorities when only DCI format 0\_1/1\_1 is configured or only DCI format 0\_2/1\_2 is configured per BWP] 5. Supports separate configuration of parameters PDSCH-HARQ-ACK-Codebook, UCI-OnPUSCH and ‘codeBlockGroupTransmission” for different HARQ-ACK codebooks. 6. [Supported maximum number of actual PUCCH transmissions for HARQ-ACK within a slot] 7. Support intra-UE multiplexing/prioritization of UL overlapping channels/signals with two priority levels for HARQ-ACK |  | Yes | N/A |  | Per FS  Per FS is selected because in bands or BCs with large number of carriers or large BW, the UE’s procesing power is spent on PDCCH/PDSCH decoding, and hence in some cases the support of the new codebook or some codebook configurations may not be possible | N/A | N/A | N/A | If a UE reports both 11-3 and 11-4, it can support two slot-based HARQ-ACK codebooks, and one slot-based and one-sub-slot-based HARQ-ACK codebooks. If a UE reports 11-4 but not 11-3, it can only support two slot-based HARQ-ACK codebooks.  The number of PUCCHs for CSI reporting per slot is not impacted compared with Rel-15 by introducing the new HARQ-ACK CBs | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | 11-4a | Two sub-slot based HARQ-ACK codebooks simultaneously constructed for supporting HARQ-ACK codebooks with different priorities at a UE | 1. Supports two sub-slot based HARQ-ACK codebooks with different priorities to be simultaneously constructed. 2. Supports separate PUCCH configuration for different HARQ-ACK codebooks 3. Supports 2-level priority of HARQ-ACK for dynamically scheduled PDSCH and SPS PDSCH. 4. [Supports a DCI format (from the formats /1\_1/1\_2) scheduling PDSCH with different HARQ-ACK priorities when only DCI format 0\_1/1\_1 is configured or only DCI format 0\_2/1\_2 is configured in USS per BWP] 5. Supports separate configuration of parameters PDSCH-HARQ-ACK-Codebook, UCI-OnPUSCH and ‘codeBlockGroupTransmission” for different HARQ-ACK codebooks. 6. [Supported maximum number of actual PUCCH transmissions for HARQ-ACK within a slot] | 11-3 and 11-4 | Yes | N/A |  | Per FS  Per FS is selected because in bands or BCs with large number of carriers or large BW, the UE’s procesing power is spent on PDCCH/PDSCH decoding, and hence in some cases the support of the new codebook or some codebook configurations may not be possible | N/A | N/A | N/A | The number of PUCCHs for CSI reporting per slot is not impacted compared with Rel-15 by introducing the new HARQ-ACK CBs | Optional with capability signalling |
| 12. NR\_IIOT | 12-1 | UL intra-UE multiplexing/prioritization of overlapping channel/signals with two priority levels in physical layer | Support intra-UE multiplexing/prioritization of overlapping PUCCH/PUCCH and PUCCH/PUSCH with two priority levels in physical layer (PHY)   1. [Configuration of PHY priority level for CG PUSCH and SR, and dynamic indication of priority level for dynamic PUSCH with a single DCI format] 2. Multiplexing/prioritization between UL channels/signals with the same PHY priority level 3. Prioritization between UL channels/signals with different PHY priority levels 4. Additional number of symbols (d1) needed beyond the PUSCH preparation time for cancelling a low priority UL transmission. 5. Additional number of symbols (d2) needed beyond the PUSCH preparation time for scheduling a high priority UL transmission that cancels a low priority UL transmission |  | Yes | N/A |  | Per FS  Per FS is selected because this FG involves various kinds of prioritization/cancellation/multiplexing, it is very processing intensive, and hence it is important to have finer granularity so that the UE does not have to under-report based on the worst band/band combination | N/A | N/A | N/A | Candidate value set for component 4: {0, 1, 2}  Candidate value set for component 5: {0, 1, 2}  The relationship between this feature and the feature of up to two HARQ-ACK codebooks of 11-4 and 11-4xshould be further discussed. | Optional with capability signaling |

Following proposals are made in contributions.

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| --- | --- |
| [2] | [Component 4] for FG11-4/4a as well as [component 1] for FG12-1 should be kept, this is based on the working assumption agreed in RAN1 #99 meeting below for when only one DCI format is configured to support scheduling the traffic with different priorities. When both DCI formats (DCI formats 0\_1/0\_2 and 1\_1//1\_2) are configured, how to support scheduling the traffic with different priorities are still under the maintenance discussions.  Working assumption:  When a single PDSCH/PUSCH processing timeline is configured in the carrier, at least when only DCI format 0\_1/1\_1 is configured or only DCI format 0\_2/1\_2 is configured in USS per BWP, a DCI format (from the formats 0\_1/1\_1/0\_2/1\_2) can be used to schedule PDSCH with different HARQ-ACK priorities or PUSCH with different priorities.  For [component 6] that [Supported maximum number of actual PUCCH transmissions for HARQ-ACK within a slot], it has relations with FG 11-3c to 3g and 11-4c to 4i, for example, for the case of (slot-based + sub-slot based HARQ-ACK codebook), the maximum number of actual PUCCH transmissions for HARQ-ACK within a slot is defined by FG11-4c, FG-114d, FG-114f and FG11-4h; for the case of (sub-slot based + sub-slot based HARQ-ACK codebook), it is defined by FG 11-4e/FG11-4g/FG-11-4i. |
| [3] | There was a working assumption on support of FG11-3c/d/e/f/g and FG11-4c/d/e/f/g/h/i. The intention of these feature groups is to limit the maximum number of PUCCHs by following Rel-15 FG 4-2 and FG 4-22a with replacing slot PUCCH to sub-slot PUCCH. By these FGs, the maximum number of PUCCHs within a slot will be determined. However, component 3 of FG 11-3 and component 6 of FG 11-4/4a also targets to limit the the maximum number of PUCCHs within a slot. In this sense, it’s not rational to confirm the working assumption with keeping FG11-3/11-4/4a unchanged. Thus, there are basically two alternatives to go with.   * Alt1: Confirm the working assumption, and delete component 3 of FG 11-3 and component 6 of FG 11-4/4a. * Alt2: Do not confirm the working assumption, and keep component 3 of FG 11-3 and component 6 of FG 11-4/4a.   In our view, Alt2 is preferred since it is simpler for UE reporting and network handling.  ***Proposal 3:*** *Do not confirm the working assumption on support of FG11-3c/d/e/f/g and FG11-4c/d/e/f/g/h/i, and keep component 3 of FG 11-3 and component 6 of FG 11-4/4a.* |
| [4] | Both updated proposal 2 and part of the updated proposal 4 as above should be agreed. The updated proposal 2 (i.e. FG11-3c/d/e/f/gand FG11-4c/d/e/f/g/h/i) define the maximum number of actual PUCCH transmissions and PUCCH formats within a sub-slot, while component 6 in FG11-4/4a defines the restriction for the maximum number of actual PUCCH transmissions for HARQ-ACK within a slot. They are different things and both will have impact on UE complexity. Especially if component 3 under FG 11-3 is not included, then for sure component 6 should be kept here.  As to the reporting type for FG11-3c/d/e/f/g and FG11-4c/d/e/f/g/h/i, we are ok with “Per FS”. |
| [5] | * + Component #4 for FG 11-4/4a and Component 1 for FG 12-1 should be kept. These components are a direct consequence of the following WA from RAN1 #99:  |  | | --- | | Working assumption:  *When a single PDSCH/PUSCH processing timeline is configured in the carrier, at least when only DCI format 0\_1/1\_1 is configured or only DCI format 0\_2/1\_2 is configured in USS per BWP, a DCI format (from the formats 0\_1/1\_1/0\_2/1\_2) can be used to schedule PDSCH with different HARQ-ACK priorities or PUSCH with different priorities.*   * *1-bit field in DCI can be configured as the PHY identification of the priority* * *No indication of different priorities by DCI formats 0\_0/1\_0* |   Without these components it could be interpreted that these components by themselves are mandatory (since they are not captured in UE features, but in RAN1 specifications), and such outcome would be quite undesirable and unfortunate.   * On the other hand, the FFS bullet on introducing yet another UE feature based on a new behaviour, yet to agreed, and with questionable benefits at this late stage of Rel-16 maintenance, should not be pursued. Further details are provided in our companion paper as part of Rel-16 eURLLC/IIoT maintenance [4].   + On Component #6 for FG 11-4a, while it is indeed true that FG11-3c/d/e/f/g and FG11-4c/d/e/f/g/h/i in Proposal 2 (from moderator) provide certain limits on the numbers of PUCCHs in a slot for different combinations, these limits include PUCCH carrying different UCIs, and not just HARQ-ACK. Defining some limits on max number of PUCCHs with HARQ-ACK in a slot for FG 11-4a can be beneficial to UE implementation considering the case when both HARQ-ACK CBs are sub-slot based, especially, if both follow the 2-symbol\*7 sub-slot configuration.     - However, such restrictions for FG 11-4, with one slot and another sub-slot based HARQ-ACK CB do not seem essential in light of the FGs as part of Proposal 2 (from moderator). |
| [6] | 1. **FG 11-3c/d/e/f/g and FG11-4c/d/e/f/g/h/I & component 3 of FG 11-3 & Component 6 of FG 11-4/4a**   All above FGs relate to limiting a number of PUCCH transmission within a slot. In Rel-15, similar restrictions were adopted for limiting the number of PUUCH transmissions within a slot. Therefore, component 3 of FG 11-3 is not necessary. In that sense, [11-4c to 4i] can be covered by [Supported maximum number of actual PUCCH transmissions for HARQ-ACK within a slot] for FG 11-4/4a, and [11-3c to 3g] can be covered by [Supported maximum number of actual PUCCH transmissions for HARQ-ACK within a slot] under FG 11-3 if component 3 of FG 11-3 is replaced by [Supported maximum number of actual PUCCH transmissions for HARQ-ACK within a slot].  ***Proposal 1:*** *Add component [Supported maximum number of actual PUCCH transmissions for HARQ-ACK within a slot] for FG 11-4/4a and FG 11-3.*   1. **FG 11-4, FG 11-4a, FG 12-1a**   It has been agreed that use of a priority indicator for determining a priority of a PUSCH or PUCCH transmission is an optional feature. It has also been agreed that the priority indicator field in configurable – i.e. it’s use is not needed to operate a UE mixed traffic.  Component 4 is against the above and intends to only enable scheduling of a UE with mixed traffic using a single DCI format based on the priority indicator. There are fundamental problems with such as approach.  First, what would the size of the single DCI format be? Would it be the very compact DCI format x\_2 that was introduced for URLLC and is highly inappropriate for eMBB or would it be the ~100-bit DCI format x\_1 that is highly inappropriate for URLLC? Or would it be something in the middle that is a poor choice for both eMBB and URLLC? In general, that would contradict how DCI formats, intented for substantially different purposes, have been used in LTE/NR including in Rel-16 where a new DCI format was introduce in order for a gNB to separately schedule a UE on sidelink and on Uu link.  Second, use of a single DCI format to support both eMBB traffic and URLLC traffic is not supported by specifications as the configuration of several parameters is based on the DCI format and not on the priority indicator. For example, the MCS table is associated with the DCI format, not with the priority indicator. There is no way for a network to indicate use of a high spectral efficiency MCS table (Table 1 or 2 in TS 38.214) for eMBB and a low spectral efficiency MCS table (Table 3 in TS 38.214) for URLLC using a same DCI format. For example, HARQ-ACK timing is defined by *dl-DatatoUL-ACK* and by *dl-DataToUL-ACK-ForDCI-Format1-2* and it is not possible to indicate different values for HARQ-ACK slot timing (slot or sub-slot) using a same DCI format. The same applies to several other configurations such as the reference SLIV or the number of cells for CA with Rel-15/Rel-16 PDCCH monitoring.  There are additional issues, such as an inefficient search space set configuration as different numbers of PDCCH candidates per CCE aggregation level are required for different target BLERs corresponding to different traffic types, but detailed discussion can occur later, if needed, as it should be clear that, both for operational reasons and reasons related to specification support, use of single DCI format to schedule both eMBB and URLLC is not practically possible.  ***Observation 1:*** *Use of a single DCI format to schedule mixed traffic (eMBB and URLLC) for a UE is not feasible, both due to deployment considerations and due to absence of specification support.*  Currently, FGs 11-4, 11-4a, and 11-4b include support for mixed traffic based on an optional feature and on a field that the gNB is not mandated to configure. Combined with the above infeasibility to support mixed traffic using a single DCI format, Component 4 should be removed from FGs 11-4, 11-4a and Component 1 should be removed from FG 12-1 and should be replaced by the baseline operation of using DCI formats 0\_1/1\_1 for priority 0 (eMBB) and DCI formats 0\_2/1\_2 for priority 1.  ***Proposal 2:***  *For FGs 11-4 and 11-4a:*  *replace “Supports a DCI format (from the formats 1\_1/1\_2) scheduling PDSCH with different HARQ-ACK priorities when only DCI format 0\_1/1\_1 is configured or only DCI format 0\_2/1\_2 is configured per BWP”*  *with “Supports DCI format 1\_1 scheduling PDSCH with HARQ-ACK priority 0 and DCI format 1\_2 scheduling PDSCH with HARQ-ACK priority 1 per BWP”.*  *For FG 12-1:*  *replace “Configuration of PHY priority level for CG PUSCH and SR, and dynamic indication of priority level for dynamic PUSCH with a single DCI format”*  *with “Configuration of PHY priority level for CG PUSCH and SR, and indication of priority level 0 by using DCI format 0\_1 and of priority level 1 by using DCI format 0\_2 for dynamic PUSCH”.* |
| [7] | Component 6 for FG 11-4/4a is “[Supported maximum number of actual PUCCH transmissions for HARQ-ACK within a slot]”. We think it is important to allow the UE to report such a limit, otherwise a UE may need to support up to 14 PUCCHs in a slot, which could be unnecessarily demanding for the UE implementation. In addition, if a low-priority PUCCH is cancelled, it should be counted towards the limit because the UE may still need to process it before being cancelled.  In addition, the description current says PUCCH transmissions for HARQ-ACK. However, there still could be SR and CSI on PUCCH, and limiting the number of PUCCHs for HARQ-ACK only does not effectively reflect the UE complexity. For example, for the 2-symbol sub-slot case, the UE can report up to 3 PUCCHs per slot for HARQ-ACK, but according to the specifications, there could still be up to 7 SRs in a slot, plus CSI on PUCCH. So, the reporting is not very useful for the UE. Therefore, we propose to change it to include PUCCHs carrying any UCI.  **Proposal 2-3: Component 6 is kept for FG 11-4/4a by replacing “actual PUCCH transmissions for HARQ-ACK” with “actual PUCCH transmissions for any UCI”.**   * **Candidate values for the component 6 of FG11-4 is: For slot-based + sub-slot based, {2, 3, 4} for 7-symbol\*2 sub-slot configuration, and {2, 3, 4, 5, 6, 7} for 2-symbol\*7 sub-slot configuration.** * **Candidate values for the component 6 of FG11-4a is: {2, 3, 4} for 7-symbol\*2 sub-slot configuration, and {2, 3, 4, 5, 6, 7} if at least one of them has 2-symbol\*7 sub-slot configuration.** * **Add a note that “A low-priority PUCCH that is cancelled by a high-priority transmission is counted towards the limit”.** |
| [8] | * **11-4:**    + **Component 4**: as discussed already during RAN1#101-e, component 4 is an integral part of the functionality, it is very well aligned with the existing agreements and working assumptions in RAN1, and it is already captured in specifications. Hence, it needs to be kept in FG11-4.   + **Component 6**: OK to keep it as it addresses the issue corresponding to proposed FGs 11-3c/d/e/f/g and 11-4d/e/f/g/h/i. * **12-1, component 1:** to be kept, similar reasons as for 11-4 component 4 above. |
| [9] | * Regarding component 4 for FG11-4/4a, current text should be kept as it is aligned with WA in RAN1#99. If additional agreement for the case when a UE is configured with both sets of formats 0\_1/1\_1 and 0\_2/1\_2 but does not support FG11-4b is obtained in Rel.16 maintenance, new text/component can be added. |
| [10] | **FG 11-4/FG11-4a:**   * We are fine to keep component 4 if another component describing the UE capability in case two sets of DCI formats are configured is added; the value range for this component could be {dynamic switching of priority using each DCI format, a fixed priority using a given DCI format}. * We are fine to keep component 6.   **FG 12-1:**   * Component 1 needs to also account for the priority of PUCCH carrying SPS HARQ-ACK. * Regarding the note, FG 12-1 and the feature to support two HARQ-ACK codebooks should be considered independent. A UE may support one or both or none. A gNB can select a reasonable configuration according to the UE’s reported capability. |
| [11] | In our view, Component 4 is kept for FG11-4/4a (and Component 1 is kept for FG12-1). These components correctly reflect the Working Assumption made in RAN1#99 (copied below).   |  | | --- | | Working assumption: (RAN1#99)  When a single PDSCH/PUSCH processing timeline is configured in the carrier, at least when only DCI format 0\_1/1\_1 is configured or only DCI format 0\_2/1\_2 is configured in USS per BWP, a DCI format (from the formats 0\_1/1\_1/0\_2/1\_2) can be used to schedule PDSCH with different HARQ-ACK priorities or PUSCH with different priorities.   * 1-bit field in DCI can be configured as the PHY identification of the priority * No indication of different priorities by DCI formats 0\_0/1\_0 |   Regarding Component 6 of FG11-4/4a), component 6 should be considered together with FG11-3c/d/e/f/g and FG11-4c/d/e/f/g/h/i.   * If FG11-3c/d/e/f/g and FG11-4c/d/e/f/g/h/i are not introduced, then we support keeping Component 6 in FG11-4a. If Component 6 is kept, candidate values for the component 6 of FG11-4a is as follows.   + {2, 3, 4} if both HARQ-ACK codebooks use 7-symbol\*2 sub-slot configuration (See Figure 1), and   + {7} if at least one of HARQ-ACK codebooks use 2-symbol\*7 sub-slot configuration (see Figure 2). For this scenario, candidate value smaller than 7 are not included, since the UE should support at least one PUCCH per sub-slot, resulting in 7 PUCCH in a slot. Figure 2 shows that the candidate value 2, for example, is too limiting for the scheduler, hence not included. * On the other hand, if FG11-3c/d/e/f/g and FG11-4c/d/e/f/g/h/i are introduced, then we do not see the need of keeping Component 6 in FG11-4/4a. It’s true that component 6 is about actual PUCCH within a slot (i.e., not sub-slot). However, we do not see the need to additionally introduce component 6, since per-sub-slot UE capability is provided in detail. Together with sub-slot configuration, this naturally gives the limit of actual PUCCH transmission within a slot.     Figure 1. The exemplary PUCCHs for two HARQ-ACK codebooks, both with 7-symbol\*2 sub-slot configuration    Figure 2. The exemplary PUCCHs for two HARQ-ACK codebooks, with at least one of HARQ-ACK codebooks use 2-symbol\*7 sub-slot configuration.   1. Keep Component 4 for FG11-4/4a. 2. Consider Component 6 for FG11-4/4a together with FG11-3c/d/e/f/g and FG11-4c/d/e/f/g/h/i.   **~**  In our view, Component 1 should be kept for FG12-1. Similar to Component 4 of FG11-4/4a, Component 1 of FG12-1 correctly reflect the Working Assumption made in RAN1#99 (as copied earlier).   1. Keep Component 1 for FG12-1. |

**Discussion point #4**

* **Whether the component 4 of FG11-4/4a and the component 1 of FG12-1 are kept, removed or replaced by other component(s)**

**Discussion point #5**

* **Whether the component 6 of FG11-4/4a is kept, removed or modified, and what are candidate values for the component 6**
  1. FG11-6

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| 11.  NR\_L1enh\_URLLC | 11-6 | PUSCH repetition Type A | 1. PUSCH transmission with Rel-15 behavior with or without slot aggregation.   • With slot aggregation, the number of repetitions can be dynamically indicated (as agreed for Rel-16).  • When dynamically indicated, the number of repetitions is jointly coded with SLIV in TDRA table, by adding an additional column for the number of repetitions in the TDRA table. | One of {5-16, 5-17] | Yes | N/A |  | Per UE | No | No | N/A |  | Optional with capability signalling |

Following proposals are made in contributions.

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| [2] | We are not sure this FG needs FR1 and FR2 differentiation. Clarification is needed. |
| [10] | **FG 11-6:**   * PUSCH repetition with dynamic indication is also supported in unlicensed bands. Hence, we propose to add a licensed/unlicensed differentiation for this FG. |

**Discussion point #6**

* **Whether to add licensed/unlicensed differentiation for FG11-6 or not**
  1. FG11-9/9a and FG12-2/2a

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| 11.  NR\_L1enh\_URLLC | 11-9 | Multiple active configured grant configurations for a BWP of a serving cell | 1. Supports up to 12 configured/active configured grant configurations in a BWP of a serving cell.   • Separate RRC parameters for different configured grant configurations  • Separate activation for different configured grant Type 2 configurations  • Separate release for different configured grant Type 2 configurations   1. Supported maximum number of configured/active configured grant configurations in a BWP of a serving cell   Candidate values for component 2: {1, 2, 4, 8, 12}   1. Supported maximum number of configured/active configured grant configurations across all serving cells   Candidate values for component 3: {2, …, 32} | One of {5-19, 5-20} | Yes | N/A |  | Per band | N/A | N/A | N/A | For component 3: Total number in FR1 is not greater than X value reported for FR1. Total number in FR2 is not greater than X value reported for FR2.Total number across FR1 and FR2 is not greater than the larger of the FR1 and FR2 values | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | 11-9a | Joint release in a DCI for two or more configured grant Type 2 configurations for a given BWP of a serving cell | 1. M<=4 bits indication in the Release DCI is used for indicating which CG configuration(s) is/are released, where the association between each state indicated by the indication and the CG configuration(s) is   • Up to 2^M states are higher layer configurable, where each of the state can be mapped to a single or multiple CG configurations to be released  • In case of no higher layer configured state(s), separate release is used where the release corresponds to the CG configuration index indicated by the indication | 11-9 | Yes | N/A |  | Per band | N/A | N/A | N/A |  | Optional with capability signalling |
| 12. NR\_IIOT | 12-2 | Multiple SPS configurations | 1. Support of up to 8 configured SPS configurations in a BWP of a serving cell and up to 32 configured SPS configurations in a cell group, including separate RRC parameters and separate activation/release for different SPS configurations 2. The max number of active SPS configurations in a BWP of a serving cell 3. The max number of active SPS configurations across all serving cells 4. The related HARQ-ACK enhancements to support multiple active SPS configurations | 5-18 DL SPS | Yes | N/A |  | Per band | N/A | N/A | N/A | Component-2, candidate value set is {1, 2, …, 8}  Component-3, candidate value set is [{2, …, 32}] | Optional with capability signaling |
| 12. NR\_IIOT | 12-2a | Joint release in a DCI for two or more SPS configurations for a given BWP of a serving cell | 1. M<=4 bits indication in the Release DCI is used for indicating which SPS configuration(s) is/are released, where the association between each state indicated by the indication and the SPS configuration(s) is   • Up to 2^M states are higher layer configurable, where each of the state can be mapped to a single or multiple SPS configurations to be released  • In case of no higher layer configured state(s), separate release is used where the release corresponds to the SPS configuration index indicated by the indication   1. The related HARQ-ACK enhancements to support joint release | 12-2 | Yes | N/A |  | Per band | N/A | N/A | N/A |  | Optional with capability signaling |

In [2], following proposal is made.

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| For the reporting type and differentiation of the TDD/FDD and FR1/FR2, same decision can be applied for UL CG and DL SPS. We think those FGs can be per UE without TDD/FDD differentiation. We are OK with FR1/FR2 differentiation as compromise.  ***Proposal 3.8: For FG11-9, 11-9a, 12-2 and 12-2a, reporting type is per UE without FDD/TDD differentiation and with FR1/FR2 differentiation.*** |

**Discussion point #7**

* **Whether to change the reporting type of FG11-9/9a and FG12-2/2a to per UE with FR1/FR2 differentiation or not**
  1. FG11-2

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 11.  NR\_L1enh\_URLLC | 11-2 | Rel-16 PDCCH monitoring capability | 1. Supported combination(s) of (X, Y, μ). For each reported combination, the UE supports the limit C on the maximum number of non-overlapped CCEs for channel estimation per PDCCH monitoring span and the limit M on the maximum number of monitored PDCCH candidates per PDCCH monitoring span 2. Maximum number of DL and UL unicast DCI formats in a span   For the set of monitoring occasions which are within the same span:   * Processing one unicast DCI scheduling DL and one unicast DCI scheduling UL per scheduled CC across this set of monitoring occasions for FDD * Processing one unicast DCI scheduling DL and two unicast DCI scheduling UL per scheduled CC across this set of monitoring occasions for TDD * Processing two unicast DCI scheduling DL and one unicast DCI scheduling UL per scheduled CC across this set of monitoring occasions for TDD |  | Yes | N/A |  | Per FS for component 1  Note: Indicating support of this capability in a band in a BC implies that only rel-16 monitoring can be configured in a CA configuration for the BC if the CA configuration includes the band and if rel-16 monitoring is configured for the band | N/A | N/A | N/A | This capability is signaled for SCS 15 kHz and 30 kHz.  For μ=0 and 1, candidate value set for (X, Y, μ): {(7, 3, μ), (4, 3, μ), (2, 2, μ)}  For component 1, a list of separate UE capabilities (X, Y, μ)for processing capability #1;  For component 1, a list of separate UE capabilities (X, Y, μ)for processing capability #2; | Optional with capability signalling |

In [4], following proposal is made.

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| --- | --- | --- | --- | --- |
| In RAN1#101-2 meeting, it was agreed to remove FG3-5b from prerequisite feature groups for FG11-2. The main reason is that the motivations to introduce spans in Rel-15 and in Rel-16 are different. Since FG 3-5b is not the prerequisite of FG 11-2 anymore, we think the restriction on the number of monitoring occasions per slot defined in FG 3-5b should be included in FG 11-2 also. Without this restriction, UE may end up with up to 14 monitoring occasions per slot, which is extremely complicated for the UE implementation.   |  |  |  |  | | --- | --- | --- | --- | | 11.  NR\_L1enh\_URLLC | 11-2 | Rel-16 PDCCH monitoring capability | 1. Supported combination(s) of (X, Y, μ). For each reported combination, the UE supports the limit C on the maximum number of non-overlapped CCEs for channel estimation per PDCCH monitoring span and the limit M on the maximum number of monitored PDCCH candidates per PDCCH monitoring span 2. Maximum number of DL and UL unicast DCI formats in a span   For the set of monitoring occasions which are within the same span:   * Processing one unicast DCI scheduling DL and one unicast DCI scheduling UL per scheduled CC across this set of monitoring occasions for FDD * Processing one unicast DCI scheduling DL and two unicast DCI scheduling UL per scheduled CC across this set of monitoring occasions for TDD * Processing two unicast DCI scheduling DL and one unicast DCI scheduling UL per scheduled CC across this set of monitoring occasions for TDD  1. The number of different start symbol indices of PDCCH monitoring occasions per slot including PDCCH monitoring occasions of FG-3-1, is no more than 7. 2. The number of different start symbol indices of PDCCH monitoring occasions per half-slot including PDCCH monitoring occasions of FG-3-1 is no more than 4 in SCell. | |

**Discussion point #8**

* **Whether to add components for the restriction on the number of monitoring occasions per slot/half-slot to FG11-2 or not**
  1. New FGs for DC

Following proposals are made in contributions.

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| [6] | There are UE capabilities for the reference cell number for CA PDCCH BD/CCE limit for rel-16 monitoring and mixed monitoring as FG 11-2a and 11-2c. In the last meeting, similar to rel-15, UE capabilities related to DC PDCCH BD/CCE limit were agreed, but they are not reflected in the current UE feature table. Hence, we propose the addition of those capabilities as described below.  ***Proposal 4:*** *Adopt the addition of UE capabilities related to DC PDCCH BD/CCE limit as described below.*   |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | 11.  NR\_L1enh\_URLLC | 11-2d | Capability on the number of CCs for monitoring a maximum number of BDs and non-overlapped CCEs per span for MCG and for SCG when configured with NR-NR DC with Rel-16 PDCCH monitoring capability on all the serving cells | 1. Supported combination of (*pdcch-BlindDetectionMCG-UE-r16*, *pdcch-BlindDetectionSCG-UE-r16*)    * Candidate values for *pdcch-BlindDetectionMCG-UE-r16* is 1 to *pdcch-BlindDetectionCA-r16*-1    * Candidate values for *pdcch-BlindDetectionSCG-UE-r16* is 1 to *pdcch-BlindDetectionCA-r16*-1 | 11-2 | Yes | N/A |  | Per BC | N/A | N/A | N/A |  | Optional with capability signalling | | 11.  NR\_L1enh\_URLLC | 11-2e | Number of carriers for CCE/BD scaling for MCG and for SCG when configured with NR-NR DC with mix of Rel. 16 and Rel. 15 PDCCH monitoring capabilities on different carriers | 1. Supported combination(s) of (*pdcch-BlindDetectionMCG-UE-r15*, *pdcch-BlindDetectionSCG-UE-r15, pdcch-BlindDetectionMCG-UE-r16*, *pdcch-BlindDetectionSCG-UE-r16*)    * Candidate values for *pdcch-BlindDetectionMCG-UE-r15* is 0 to *pdcch-BlindDetectionCA-r15*    * Candidate values for *pdcch-BlindDetectionSCG-UE-r15* is 0 to *pdcch-BlindDetectionCA-r15*    * Candidate values for *pdcch-BlindDetectionMCG-UE-r16* is 0 to *pdcch-BlindDetectionCA-r16*    * Candidate values for *pdcch-BlindDetectionSCG-UE-r16* is 0 to *pdcch-BlindDetectionCA-r16* | 11-2b | Yes | N/A |  | Per BC | N/A | N/A | N/A | One combination of (*pdcch-BlindDetectionMCG-UE-r15, pdcch-BlindDetectionSCG-UE-r15, pdcch-BlindDetectionMCG-UE-r16, pdcch-BlindDetectionSCG-UE-r16*) corresponds to one combination of (*pdcch-BlindDetectionCA-r15, pdcch-BlindDetectionCA-r16*) | Optional with capability signalling | |
| [10] | **FG 11-2d and FG 11-2e (new FGs for Rel. 16 PDCCH with NR-DC):**   * Added in the URLLC section. |

**Discussion point #9**

* **Whether/how to add new FGs for the reference cell number for DC PDCCH BD/CCE limit**
  1. New FG for independent cancellation of the overlapping channels in an intra-band UL CA

In [7], following proposal is made.

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| For inter-UE UL cancellation, we introduced FG11-7b to handle the phase discontinuity issue for intra-band CA. In fact, a similar issue exists for intra-UE prioritization when a high priority channel cancels a low priority channel with a potential change of transmit power and duration. Therefore, we propose to add a new FG which has a pre-requisite of either 11-4 or 12-1.  **Proposal 2-5: Introduce a new FG to handle phase discontinuity issue for intra-band CA in case of intra-UE prioritization:**   |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | 12. NR\_IIOT | 12-1b | Independent cancellation of the overlapping channels in an intra-band UL CA | 1. For a UE indicating the capability of pa-PhaseDiscontinuityImpacts, and if the PUCCH or PUSCH on at least one serving cell is cancelled due to the overlapping with a high priority PUCCH or PUSCH transmission, the UE may cancel the (repetition of the) PUSCHs transmission on all other intra-band serving cell(s). The cancellation of the (repetition of the) PUSCH transmission on the set of intra-band serving cell(s) includes all symbols from the earliest symbol that is overlapping with the first cancelled symbol of the PUSCH on the serving cell. | 6-23, one of {11-4, 12-1} | Yes | N/A |  | Per band | N/A | N/A | N/A | If UE indicates 6-23 but does not support this FG, UE is not expected to be scheduled simultaneous PUCCH/PUSCHs on multiple carriers but receiving cancellation only for subset of carriers in intra-band carriers. | Optional with capability signaling | |

**Discussion point #10**

* **Whether/how to add new FG for independent cancellation of the overlapping channels in an intra-band UL CA**
  1. Basic feature groups for URLLC/IIoT

In [4], following proposal is made.

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| --- |
| An informal discussion on the definition of basic feature groups during RAN#87-E is summarized and the key points are as below:   * In case that a set of feature groups/components is necessary to be supported by UE (and NW) for a certain purpose,   + There are at least two possible approaches below to define the set of feature groups for a purpose.     - Approach 1: A basic feature group(s), which is a set of components that are viewed necessary to provide a minimum level of support for the feature. Defining a basic feature group(s) is not always possible or necessary for a given feature.     - Approach 2: A set(s) of feature groups necessary to be supported for the purpose is defined somewhere in specification(s).   In our understanding, defining the basic feature group(s) for URLLC/IIoT is very beneficial to speed up the basic URLLC support in vertical industry, thus making some effort here is worthwhile. In general all the feature groups in the list can contribute to both low latency and high reliability to some extent. The more feature groups the UE and the gNB support, the tougher requirements can be met. Some companies seem to have the concern on UE implementation if many feature groups are required to be implemented from the beginning. To leave some flexibility for the UE implementation, at this stage we can consider to define basic feature group(s) only for a single purpose first, e.g. to define basic feature groups for achieving low latency and to define basic feature groups for achieving high reliability. Then later, if needed, some UE with higher capability can support the combination of basic feature groups to meet tighter requirements in terms of both low latency and high reliability. In addition, in this way there is some flexibility to tailor it for a specific use case considering potential different requirements for different use cases, while speed up the support. Therefore, we would prefer to follow approach 1 above for URLLC/IIoT. However, based on the previous discussion and considering the position from companies, for progress we can consider to go to approach 2.  **Proposal URLLC-2: Adopt approach 2 in RP-200502 to define a set of feature groups necessary to be supported for achieving high reliability and a set of feature groups necessary to be supported for achieving low latency.**  To help the discussion of defining basic UE feature groups following approach 2, we can identify “a set of feature groups **more helpful** for achieving low latency” and “a set of feature groups **more helpful** for achieving high reliability” first. One example is as below:   * *Feature groups more helpful for achieving high reliability: FG 11-1, FG 11-8, FG 11-9* * *Feature groups more helpful for achieving low latency: FG 11-2, FG 11-3, FG 11-4/4a, FG 11-5, FG 11-7, FG 12-1, FG 12-2, FG 12-6*   + *FG 11-4 and FG 12-1 are applied to a UE supporting both eMBB and URLLC*   + *FG 11-7 is applied to a UE supporting eMBB* |

**Discussion point #11**

* **Whether/how to define basic FG(s) for each of particular URLLC/IIoT scenarios based on completed FGs**

Reference

[1] R1-2006462 Updated RAN1 UE features list for Rel-16 NR Moderators (AT&T, NTT DOCOMO, INC.)

[2] R1-2005361 Remaining issues on Rel-16 UE features vivo

[3] R1-2005423 Discussion on NR Rel-16 UE Features ZTE

[4] R1-2005814 Remaining details of Rel-16 NR UE features Huawei, HiSilicon

[5] R1-2005857 Rel-16 UE feature Intel Corporation

[6] R1-2006124 Remaining issues on NR Rel-16 UE features Samsung

[7] R1-2006482 Discussions on NR Rel-16 UE features Apple

[8] R1-2006677 Remaining aspects of Rel-16 UE features Nokia, Nokia Shanghai Bell

[9] R1-2006703 Discussion on NR Rel-16 UE features NTT DOCOMO, INC.

[10] R1-2006788 Discussion on NR Rel-16 UE features Qualcomm Incorporated

[11] R1-2006874 Remaining details of Rel-16 NR UE features Ericsson

Appendix: UE features list for URLLC/IIoT in [1]

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Features | Index | Feature group | Components | Prerequisite feature groups | Need for the gNB to know if the feature is supported | Applicable to the capability signalling exchange between UEs (V2X WI only)”. | **Consequence if the feature is not supported by the UE** | **Type**  **( 1) Per UE or 2) Per Band or 3) Per BC or 4) Per FS or 5) Per FSPC)** | Need of FDD/TDD differentiation | Need of FR1/FR2 differentiation | Capability interpretation for mixture of FDD/TDD and/or FR1/FR2 | Note | Mandatory/Optional |
| 11.  NR\_L1enh\_URLLC | 11-1 | Monitoring DCI format 1\_2 and DCI format 0\_2 | 1. Supports monitoring DCI format 1\_2 for DL scheduling 2. Supports monitoring DCI format 0\_2 for UL scheduling |  | Yes | N/A |  | Per UE | No | No | N/A |  | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | 11-1a | Monitoring both DCI format 0\_1/1\_1 and DCI format 0\_2/1\_2 in the same search space | 1. Supports monitoring both DCI format 0\_1/1\_1 and DCI format 0\_2/1\_2 in the same search space | 11-1 | Yes | N/A |  | Per UE | No | No | N/A |  | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | 11-1b | Type 1 HARQ-ACK codebook support for relative TDRA for DL | 1. Support Type 1 HARQ-ACK codebook for TDRA using the starting symbol of the PDCCH monitoring occasion in which the DL assignment is detected as the reference of the SLIV | 11-1 | Yes | N/A |  | Per UE | No | Yes  Note: Differentiation is from the perspective of the scheduled carrier | N/A |  | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | 11-2 | Rel-16 PDCCH monitoring capability | 1. Supported combination(s) of (X, Y, μ). For each reported combination, the UE supports the limit C on the maximum number of non-overlapped CCEs for channel estimation per PDCCH monitoring span and the limit M on the maximum number of monitored PDCCH candidates per PDCCH monitoring span 2. Maximum number of DL and UL unicast DCI formats in a span   For the set of monitoring occasions which are within the same span:   * Processing one unicast DCI scheduling DL and one unicast DCI scheduling UL per scheduled CC across this set of monitoring occasions for FDD * Processing one unicast DCI scheduling DL and two unicast DCI scheduling UL per scheduled CC across this set of monitoring occasions for TDD * Processing two unicast DCI scheduling DL and one unicast DCI scheduling UL per scheduled CC across this set of monitoring occasions for TDD |  | Yes | N/A |  | Per FS for component 1  Note: Indicating support of this capability in a band in a BC implies that only rel-16 monitoring can be configured in a CA configuration for the BC if the CA configuration includes the band and if rel-16 monitoring is configured for the band | N/A | N/A | N/A | This capability is signaled for SCS 15 kHz and 30 kHz.  For μ=0 and 1, candidate value set for (X, Y, μ): {(7, 3, μ), (4, 3, μ), (2, 2, μ)}  For component 1, a list of separate UE capabilities (X, Y, μ)for processing capability #1;  For component 1, a list of separate UE capabilities (X, Y, μ)for processing capability #2; | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | 11-2a | Capability on the number of CCs for monitoring a maximum number of BDs and non-overlapped CCEs per span when configured with DL CA with Rel-16 PDCCH monitoring capability on all the serving cells | 1. Capability on the number of CCs for monitoring a maximum number of BDs and non-overlapped CCEs per span when configured with DL CA with Rel-16 PDCCH monitoring capability on all the serving cells    * Candidate value for the component: {2, 3, …, 16} 2. Supported span arrangement for CA    * Candidate value for the component: {aligned spans only, aligned spans and non-aligned spans} | 11-2 | Yes | N/A |  | Per BC | N/A | N/A | N/A |  | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | 11-2b | Mix of Rel. 16 PDCCH monitoring capability and Rel. 15 PDCCH monitoring capability on different carriers | 1. Support Rel-15 monitoring capability and Rel-16 monitoring capability on different serving cells | 11-2 | Yes | N/A |  | Per FS  Note: Per FS is selected because same type with 3-5b is preferred | N/A | N/A | N/A |  | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | 11-2c | Number of carriers for CCE/BD scaling with DL CA with mix of Rel. 16 and Rel. 15 PDCCH monitoring capabilities on different carriers | 1. Supported combination(s) of (pdcch-BlindDetectionCA-R15, pdcch-BlindDetectionCA-R16)    * Candidate values for pdcch-BlindDetectionCA-R15 is 1 to 15    * Candidate values for pdcch-BlindDetectionCA-R16 is 1 to 15 2. Supported span arrangement for CA    * Candidate value for the component: {aligned spans only, aligned spans and non-aligned spans} | 11-2b | Yes | N/A |  | Per BC | N/A | N/A | N/A | The minimum of the summation of capability on the number of CCs with Rel-15 PDCCH monitoring capability and the capability on the number of CCs with Rel-16 PDCCH monitoring capability is 3 | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | 11-3 | More than one PUCCH for HARQ-ACK transmission within a slot | 1. Supports sub-slot based HARQ-ACK feedback procedure.   • A UL slot consists of a number of sub-slots. No more than one transmitted PUCCH carrying HARQ-ACKs starts in a sub-slot.  • At least one sub-slot configuration for PUCCH can be UE specifically configured to a UE.  • Supports a single configuration for PUCCH resource for all sub-slots in a slot. The starting symbol of a PUCCH resource is defined with respect to the first symbol of sub-slot. Any sub-slot PUCCH resource is not across sub-slot boundaries.   1. Supported sub-slot configuration 2. [Supported combinations of (A, B), where A is the minimum gap between sub-slots containing actual PUCCH transmissions measured from beginning to beginning of the sub-slots, including across slots, and B is the sub-slot duration, with both A and B in units of symbols] |  | Yes | N/A |  | Per FS  Per FS is selected because in bands or BCs with large number of carriers or large BW, the UE’s processing power is spent on PDCCH/PDSCH decoding, and hence in some cases the support of the new codebook or some codebook configurations may not be possible | N/A | N/A | N/A | Candidate value set for component 2:  { 7-symbol\*2, 2-symbol\*7 and 7-symbol\*2} for NCP or { 6-symbol\*2, 2-symbol\*6 and 6-symbol\*2} for ECP  The number of PUCCHs for CSI reporting per slot is not impacted compared with Rel-15 by introducing the new HARQ-ACK CBs  A UE supporting 11-3 is also expected to support FGs 4-1, 4-3, 4-4, 4-5, and 4-19 with a “slot” being replaced by a sub-slot of length 2 or 7 symbols for NCP and (2 and 6 symbols for ECP) for the PUCCH formats that can be accommodated in the corresponding sub-slot durations  [Candidate value set for component 3):  (A, B) =  {(7, 7),  (4, 2) and (7, 7),  (2, 2) and (7, 7)}]  FFS: Whether to keep component 3) and accordingly the above note for component 3) | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | [11-3c] | 2 PUCCH of format 0 or 2 for a single 7\*2 subslot based HARQ-ACK codebook | 1) 2 PUCCH format 0/2 in different symbols and once per subslot for HARQ-ACK,  2) 2 PUCCH format 0 in different symbols and once per subslot for SR | 11-3 | Yes | N/A |  | TBD | TBD | TBD | TBD |  | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | [11-3d] | 2 PUCCH of format 0 or for a single 2\*7 subslot based HARQ-ACK codebook | 1) 2 PUCCH format 0/2 in different symbols and once per subslot for HARQ-ACK,  2) 2 PUCCH format 0 in different symbols and once per subslot for SR | 11-3 | Yes | N/A |  | TBD | TBD | TBD | TBD |  | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | [11-3e] | 1 PUCCH format 0 or 2 and 1 PUCCH format 1, 3 or 4 in the same subslot for a single 2\*7-symbol HARQ-ACK codebooks | If the UE supports a 2\*7-symbol subslot HARQ-ACK codebook, the UE also supports:  1) 1 PUCCH format 0 or 2 and 1 PUCCH format 1, 3 and 4 in the same subslot | 11-3 | Yes | N/A |  | TBD | TBD | TBD | TBD |  | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | [11-3f] | 2 PUCCH transmissions in the same subslot for a single 2\*7-symbol HARQ-ACK codebooks which are not covered by 11-3d and 11-3e | If the UE supports a 2\*7 subslot HARQ-ACK codebook, the UE also supports:  2 PUCCH transmissions in the same subslot for a single 2\*7-symbol HARQ-ACK codebooks which are not covered by 11-3d and 11-3e | 11-3 | Yes | N/A |  | TBD | TBD | TBD | TBD |  | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | [11-3g] | SR/HARQ-ACK multiplexing once per subslot using a PUCCH (or HARQ-ACK piggybacked on a PUSCH) when SR/HARQ-ACK are supposed to be sent with different starting symbols in a subslot | If a UE supports a subslot based HARQ-ACK codebook, the UE also supports:  Overlapping PUCCH resources with different starting symbols in a subslot | 11-3 | Yes | N/A |  | TBD | TBD | TBD | TBD |  | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | 11-4 | Two HARQ-ACK codebooks with up to one sub-slot based HARQ-ACK codebook (i.e. slot-based + slot-based, or slot-based + sub-slot based) simultaneously constructed for supporting HARQ-ACK codebooks with different priorities at a UE | 1. Supports two HARQ-ACK codebooks with different priorities to be simultaneously constructed with the restriction up to one sub-slot based HARQ-ACK codebook. 2. Supports separate PUCCH configuration for different HARQ-ACK codebooks 3. Supports 2-level priority of HARQ-ACK for dynamically scheduled PDSCH and SPS PDSCH. 4. [Supports a DCI format (from the formats 1\_1/1\_2) scheduling PDSCH with different HARQ-ACK priorities when only DCI format 0\_1/1\_1 is configured or only DCI format 0\_2/1\_2 is configured per BWP] 5. Supports separate configuration of parameters PDSCH-HARQ-ACK-Codebook, UCI-OnPUSCH and ‘codeBlockGroupTransmission” for different HARQ-ACK codebooks. 6. [Supported maximum number of actual PUCCH transmissions for HARQ-ACK within a slot] 7. Support intra-UE multiplexing/prioritization of UL overlapping channels/signals with two priority levels for HARQ-ACK |  | Yes | N/A |  | Per FS  Per FS is selected because in bands or BCs with large number of carriers or large BW, the UE’s procesing power is spent on PDCCH/PDSCH decoding, and hence in some cases the support of the new codebook or some codebook configurations may not be possible | N/A | N/A | N/A | If a UE reports both 11-3 and 11-4, it can support two slot-based HARQ-ACK codebooks, and one slot-based and one-sub-slot-based HARQ-ACK codebooks. If a UE reports 11-4 but not 11-3, it can only support two slot-based HARQ-ACK codebooks.  The number of PUCCHs for CSI reporting per slot is not impacted compared with Rel-15 by introducing the new HARQ-ACK CBs | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | 11-4a | Two sub-slot based HARQ-ACK codebooks simultaneously constructed for supporting HARQ-ACK codebooks with different priorities at a UE | 1. Supports two sub-slot based HARQ-ACK codebooks with different priorities to be simultaneously constructed. 2. Supports separate PUCCH configuration for different HARQ-ACK codebooks 3. Supports 2-level priority of HARQ-ACK for dynamically scheduled PDSCH and SPS PDSCH. 4. [Supports a DCI format (from the formats /1\_1/1\_2) scheduling PDSCH with different HARQ-ACK priorities when only DCI format 0\_1/1\_1 is configured or only DCI format 0\_2/1\_2 is configured in USS per BWP] 5. Supports separate configuration of parameters PDSCH-HARQ-ACK-Codebook, UCI-OnPUSCH and ‘codeBlockGroupTransmission” for different HARQ-ACK codebooks. 6. [Supported maximum number of actual PUCCH transmissions for HARQ-ACK within a slot] | 11-3 and 11-4 | Yes | N/A |  | Per FS  Per FS is selected because in bands or BCs with large number of carriers or large BW, the UE’s procesing power is spent on PDCCH/PDSCH decoding, and hence in some cases the support of the new codebook or some codebook configurations may not be possible | N/A | N/A | N/A | The number of PUCCHs for CSI reporting per slot is not impacted compared with Rel-15 by introducing the new HARQ-ACK CBs | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | 11-4b | DL priority indication in DCI with mixed DCI formats | 1. Support of priority indicator field configured in DCI formats 1\_1 and 1\_2 in a BWP when configured to monitor both DCI formats 1\_1 and 1\_2 in the BWP | 11-1, 11-4 | Yes | N/A |  | Per UE | No | No | N/A |  | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | [11-4c] | 2 PUCCH of format 0 or 2 for Two HARQ-ACK codebooks with up to one 7\*2-symbol sub-slot based HARQ-ACK codebook | If the UE supports a 7\*2-symbol subslot HARQ codebook, the UE also supports:  1) 2 PUCCH format 0/2 in different symbols and once per subslot for HARQ-ACK,  2) 2 PUCCH format 0 in different symbols and once per subslot for SR | 11-4 | Yes | N/A |  | TBD | TBD | TBD | TBD |  | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | [11-4d] | 2 PUCCH of format 0 or 2 in consecutive symbols for two HARQ-ACK codebooks with up to one 2\*7-symbol sub-slot based HARQ-ACK codebook | If the UE supports a 2\*7-symbol subslot HARQ codebook, the UE also supports:  1) 2 PUCCH format 0/2 in different symbols and once per subslot for HARQ-ACK,  2) 2 PUCCH format 0 in different symbols and once per subslot for SR | 11-4 | Yes | N/A |  | TBD | TBD | TBD | TBD |  | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | [11-4e] | 2 PUCCH of format 0 or 2 for two subslot based HARQ-ACK codebooks | If the UE supports two subslot HARQ codebooks, the UE also supports:  1) 2 PUCCH format 0/2 in different symbols and once per subslot per codebook for HARQ-ACK,  2) 2 PUCCH format 0 in different symbols and once per subslot per codebook for SR | 11-4a | Yes | N/A |  | TBD | TBD | TBD | TBD |  | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | [11-4f] | 1 PUCCH format 0 or 2 and 1 PUCCH format 1, 3 or 4 in the same subslot for HARQ-ACK codebooks with up to one 2\*7-symbol subslot based HARQ-ACK codebook | If the UE supports a 2\*7 subslot HARQ-ACK codebook, the UE also supports:  1) 1 PUCCH format 0 or 2 and 1 PUCCH format 1, 3 and 4 in the same subslot of the codebook | 11-4 | Yes | N/A |  | TBD | TBD | TBD | TBD |  | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | [11-4g] | 1 PUCCH format 0 or 2 and 1 PUCCH format 1, 3 or 4 in the same subslot for two subslot based HARQ-ACK codebooks | If the UE supports two subslot HARQ-ACK codebooks both configured with 2\*7 symbols, the UE also supports:  1) 1 PUCCH format 0 or 2 and 1 PUCCH format 1, 3 and 4 in the same subslot of a codebook | 11-4a | Yes | N/A |  | TBD | TBD | TBD | TBD |  | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | [11-4h] | 2 PUCCH transmissions in the same subslot for two HARQ-ACK codebooks with up to one 2\*7-symbol subslot which are not covered by 11-4c and 11-4e | If the UE supports two HARQ-ACK codebooks with up to one subslot based codebook with 2\*7-symbol configuration, the UE also supports:  1) 2PUCCH transmissions in the same subslot of the codebook which are not covered by 11-4c and 11-4e | 11-4 | Yes | N/A |  | TBD | TBD | TBD | TBD |  | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | [11-4i] | 2 PUCCH transmissions in the same subslot for two subslot based HARQ-ACK codebooks  which are not covered by 11-4d and 11-4f | If the UE supports two HARQ-ACK codebooks both with 2\*7-symbol configuration, the UE also supports:  1) 2PUCCH transmissions in the same subslot of a codebook which are not covered by 11-4d and 11-4f | 11-4a | Yes | N/A |  | TBD | TBD | TBD | TBD |  | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | 11-5 | PUSCH repetition Type B | 1. For a transport block, one dynamic UL grant or one configured grant schedules two or more PUSCH repetitions that can be in one slot, or across slot boundary in consecutive available slots. 2. Dynamic indication of the nominal number of repetitions in the DCI scheduling dynamic PUSCH. 3. 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. 4. PUSCH repetition type B is supported for DCI format 0\_1 and DCI format 0\_2 (for DG and type 2 CG). 5. S and L are separately indicated (4-bit for S and 4-bit for L). L <= 14. 6. Handling of interaction with DL/UL directions depending on whether dynamic SFI is configured or not, including both cases with and without higher layer parameter InvalidSymbolPattern configured 7. Supported maximum number of PUSCH transmissions within a slot for all TB(s), where each actual repetition for PUSCH repetition type B is counted as 1 PUSCH transmission, separately reported for UE processing capability 1 and for UE processing capability 2 if UE supports both processing capabilities   Note: Number of TBs are based on reported Rel-15 capability on number of TBs, and reported value for component 7 cannot be smaller than the reported value of the number of TBs   1. Supported PUSCH hopping scheme |  | Yes | N/A |  | Per FS  Note: Per FS is selected to follow Rel-15 reporting type for number of TBs to be supported | N/A | N/A | N/A | Candidate value for component 7: {2, 3, 4, 7, 8, 12}  Candidate value for component 8: {Inter-slot hopping, Inter-repetition hopping, both Inter-slot hopping and Inter-repetition hopping}  PUSCH repetition type B with configured grant is applied only if UE reports the support of FG 5-19 or FG 5-20, and subjected to the capability of FG 5-19 and FG 5-20  The case that both dynamic SFI and InvalidSymbolPattern are configured is applied only if UE reports the support of FG3-6 | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | 11-6 | PUSCH repetition Type A | 1. PUSCH transmission with Rel-15 behavior with or without slot aggregation.   • With slot aggregation, the number of repetitions can be dynamically indicated (as agreed for Rel-16).  • When dynamically indicated, the number of repetitions is jointly coded with SLIV in TDRA table, by adding an additional column for the number of repetitions in the TDRA table. | One of {5-16, 5-17] | Yes | N/A |  | Per UE | No | No | N/A |  | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | 11-7 | UL cancelation scheme for self-carrier | 1. Supports group common DCI (i.e. DCI format 2\_4) for cancelation indication on the same DL CC as that scheduling PUSCH or SRS 2. UL cancelation for PUSCH  * Cancellation is applied to each PUSCH repetition individually in case of PUSCH repetitions  1. UL cancelation for SRS symbols that overlap with the cancelled symbols |  | Yes | N/A |  | Per FS  Per FS is selected because the FG is very demanding in UE processing, considering that this can be a UE with processing capability 1 but required to be able to cancel according to processing capability 2, and hence it is important to take into account the BC information for dimensioning purpose | N/A | N/A | N/A | More than one monitoring occasion for DCI format 2\_4 per slot is applied only if the UE reports to support FG 3-5 or FG 3-5a or FG 3-5b or 11-2 or 11-2a | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | 11-7a | UL cancelation scheme for cross-carrier | 1. Supports group common DCI (i.e. DCI format 2\_4) for cancelation indication on a different DL CC than that scheduling PUSCH or SRS 2. UL cancelation for PUSCH  * Cancellation is applied to each PUSCH repetition individually in case of PUSCH repetitions  1. UL cancelation for SRS symbols that overlap with the cancelled symbols |  | Yes | N/A |  | Per FS  Per FS is selected because the FG is very demanding in UE processing, considering that this can be a UE with processing capability 1 but required to be able to cancel according to processing capability 2, and hence it is important to take into account the BC information for dimensioning purpose | N/A | N/A | N/A | More than one monitoring occasion for DCI format 2\_4 per slot is applied only if the UE reports to support FG 3-5 or FG 3-5a or FG 3-5b or 11-2 or 11-2a | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | 11-7b | Independent cancellation of the overlapping PUSCHs in an intra-band UL CA | 1. For a UE indicating the capability of pa-PhaseDiscontinuityImpacts, and if the PUSCH on at least one serving cell is cancelled, the UE may cancel the (repetition of the) PUSCHs transmission on all other intra-band serving cell(s). The cancellation of the (repetition of the) PUSCH transmission on a the set of intra-band serving cell(s) includes all symbols from the earliest symbol that is overlapping with the first cancelled symbol of the PUSCH on the serving cell for which the DCI format 2\_4 is applicable to. | 6-23, 11-7 | Yes | N/A |  | Per band | N/A | N/A | N/A | If UE indicates 6-23 but does not support this FG, UE is not expected to be scheduled simultaneous PUSCHs on multiple carriers but receiving UL CI only for subset of carriers in intra-band carriers | Optional with capability signaling |
| 11.  NR\_L1enh\_URLLC | 11-8 | Enhanced UL power control scheme | 1. For DG-PUSCH, one bit (separately from SRI) in UL grant is used to indicate the P0 value if SRI is present in the UL grant, and 1 or 2 bits is used to indicate the P0 value if SRI is not present in the UL grant |  | Yes | N/A |  | Per UE | No | Yes  Note: Differentiation is from the perspective of the scheduled carrier | N/A |  | Optional with capability signaling |
| 11.  NR\_L1enh\_URLLC | 11-9 | Multiple active configured grant configurations for a BWP of a serving cell | 1. Supports up to 12 configured/active configured grant configurations in a BWP of a serving cell.   • Separate RRC parameters for different configured grant configurations  • Separate activation for different configured grant Type 2 configurations  • Separate release for different configured grant Type 2 configurations   1. Supported maximum number of configured/active configured grant configurations in a BWP of a serving cell   Candidate values for component 2: {1, 2, 4, 8, 12}   1. Supported maximum number of configured/active configured grant configurations across all serving cells   Candidate values for component 3: {2, …, 32} | One of {5-19, 5-20} | Yes | N/A |  | Per band | N/A | N/A | N/A | For component 3: Total number in FR1 is not greater than X value reported for FR1. Total number in FR2 is not greater than X value reported for FR2.Total number across FR1 and FR2 is not greater than the larger of the FR1 and FR2 values | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | 11-9a | Joint release in a DCI for two or more configured grant Type 2 configurations for a given BWP of a serving cell | 1. M<=4 bits indication in the Release DCI is used for indicating which CG configuration(s) is/are released, where the association between each state indicated by the indication and the CG configuration(s) is   • Up to 2^M states are higher layer configurable, where each of the state can be mapped to a single or multiple CG configurations to be released  • In case of no higher layer configured state(s), separate release is used where the release corresponds to the CG configuration index indicated by the indication | 11-9 | Yes | N/A |  | Per band | N/A | N/A | N/A |  | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | 11-10 | Type 2 configured grant release by DCI format 0\_1 | 1. Support of type 2 configured grant release by DCI format 0\_1 | 5-20 | Yes | N/A |  | Per UE | No | No | N/A | A UE supporting this feature and 11-1 (DCI format 0\_2/1\_2) shall also support 11-11 (Type 2 configured grant release by DCI format 0\_2). | Optional with capability signalling |
| 11.  NR\_L1enh\_URLLC | 11-11 | Type 2 configured grant release by DCI format 0\_2 | 1. Support of type 2 configured grant release by DCI format 0\_2 | 5-20, 11-1 | Yes | N/A |  | Per UE | No | No | N/A | A UE supporting this feature shall also support 11-10 (Type 2 configured grant release by DCI format 0\_1). | Optional with capability signalling |

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| Features | Index | Feature group | Components | Prerequisite feature groups | Need for the gNB to know if the feature is supported | Applicable to the capability signalling exchange between UEs (V2X WI only)”. | **Consequence if the feature is not supported by the UE** | **Type**  **( 1) Per UE or 2) Per Band or 3) Per BC or 4) Per FS or 5) Per FSPC)** | Need of FDD/TDD differentiation | Need of FR1/FR2 differentiation | Capability interpretation for mixture of FDD/TDD and/or FR1/FR2 | Note | Mandatory/Optional |
| 12. NR\_IIOT | 12-1 | UL intra-UE multiplexing/prioritization of overlapping channel/signals with two priority levels in physical layer | Support intra-UE multiplexing/prioritization of overlapping PUCCH/PUCCH and PUCCH/PUSCH with two priority levels in physical layer (PHY)   1. [Configuration of PHY priority level for CG PUSCH and SR, and dynamic indication of priority level for dynamic PUSCH with a single DCI format] 2. Multiplexing/prioritization between UL channels/signals with the same PHY priority level 3. Prioritization between UL channels/signals with different PHY priority levels 4. Additional number of symbols (d1) needed beyond the PUSCH preparation time for cancelling a low priority UL transmission. 5. Additional number of symbols (d2) needed beyond the PUSCH preparation time for scheduling a high priority UL transmission that cancels a low priority UL transmission |  | Yes | N/A |  | Per FS  Per FS is selected because this FG involves various kinds of prioritization/cancellation/multiplexing, it is very processing intensive, and hence it is important to have finer granularity so that the UE does not have to under-report based on the worst band/band combination | N/A | N/A | N/A | Candidate value set for component 4: {0, 1, 2}  Candidate value set for component 5: {0, 1, 2}  The relationship between this feature and the feature of up to two HARQ-ACK codebooks of 11-4 and 11-4xshould be further discussed. | Optional with capability signaling |
| 12. NR\_IIOT | 12-1a | UL priority indication in DCI with mixed DCI formats | Support of priority indicator field configured in DCI formats 0\_1 and 0\_2 in a BWP when configured to monitor both DCI formats 0\_1 and 0\_2 in the BWP | 12-1 and 11-1 | Yes | N/A |  | Per UE | No | No | N/A |  | Optional with capability signalling |
| 12. NR\_IIOT | 12-2 | Multiple SPS configurations | 1. Support of up to 8 configured SPS configurations in a BWP of a serving cell and up to 32 configured SPS configurations in a cell group, including separate RRC parameters and separate activation/release for different SPS configurations 2. The max number of active SPS configurations in a BWP of a serving cell 3. The max number of active SPS configurations across all serving cells 4. The related HARQ-ACK enhancements to support multiple active SPS configurations | 5-18 DL SPS | Yes | N/A |  | Per band | N/A | N/A | N/A | Component-2, candidate value set is {1, 2, …, 8}  Component-3, candidate value set is [{2, …, 32}] | Optional with capability signaling |
| 12. NR\_IIOT | 12-2a | Joint release in a DCI for two or more SPS configurations for a given BWP of a serving cell | 1. M<=4 bits indication in the Release DCI is used for indicating which SPS configuration(s) is/are released, where the association between each state indicated by the indication and the SPS configuration(s) is   • Up to 2^M states are higher layer configurable, where each of the state can be mapped to a single or multiple SPS configurations to be released  • In case of no higher layer configured state(s), separate release is used where the release corresponds to the SPS configuration index indicated by the indication   1. The related HARQ-ACK enhancements to support joint release | 12-2 | Yes | N/A |  | Per band | N/A | N/A | N/A |  | Optional with capability signaling |
| 12. NR\_IIOT | 12-3 | SPS release by DCI format 1\_1 | Support of SPS release by DCI format 1\_1 | 5-18 DL SPS | Yes | N/A |  | Per UE | No | No | N/A |  | Optional with capability signaling |
| 12. NR\_IIOT | 12-3a | SPS release by DCI format 1\_2 | Support of SPS release by DCI format 1\_2 | 5-18 DL SPS and 11-1 | Yes | N/A |  | Per UE | No | No | N/A |  | Optional with capability signaling |
| 12. NR\_IIOT | 12-5 | Configuration of aggregation factor per SPS configuration | Support of configurable PDSCH aggregation factor ({1, 2, 4, 8}) per DL SPS configuration | 5-18 DL SPS | Yes | N/A |  | Per UE | No | Yes | N/A |  | Optional with capability signaling |
| 12. NR\_IIOT | 12-6 | Support of SPS periodicity shorter than 10 ms | Support of SPS periodicity shorter than 10 ms | 5-18 DL SPS | Yes | N/A |  | Per UE | No | Yes | N/A |  | Optional with capability signalling |