3GPP TSG RAN WG1 #104-e R1-21xxxxx

e-Meeting, Janurary 25th – Feburary 5th, 2021

**Source: Moderator (Sharp)**

**Title: FL Summary#1 on Enhancements on PUSCH repetition type A**

**Agenda Item: 8.8.1.1**

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

# Introduction

This document is intended to facilitate view exchange and discussions for the following assigned email discussion.

[104-e-NR-CovEnh-01] Email discussion on enhancements on PUSCH repetition type A – Toshi (Sharp)

* 1st check point: Jan 28
* 2nd check point: Feb 2
* 3rd check point: Feb 4

# Increasing the maximum number of repetitions

The discussions in this section are based on the following objective in the Coverage Enhancement WID.

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| The detailed objectives of the work item are as follows:   * Specification of PUSCH enhancements [RAN1, RAN4]   + Specify the following mechanisms for enhancements on PUSCH repetition type A [RAN1]     - **Increasing the maximum number of repetitions up to a number to be determined during the course of the work.**     - The number of repetitions counted on the basis of available UL slots. |

# The maximum number of repetitions

In Rel-15/16, RRC parameter *pusch-AggregationFactor* configures the number of repetitions for PUSCH, where the candidate value set of *pusch-AggregationFactor* = {2, 4, 8}. TRDA based dynamic repetition number indication introduced in Rel-16 is applied when configured, where the candidate value set of *numberOfRepetitions-r16* = {1, 2, 3, 4, 7, 8, 12, 16}.

13 companies (ZTE, OPPO, CATT, vivo, Intel, China Telecom, NEC, Panasonic, Xiaomi, Sierra Wireless, Apple, Qualcomm, NTT DOCOMO) provided their views that the maximum number of repetitions should be increased to 32. One major reason is it enables 8 actual repetitions in DDDDDDDSUU slot structure. Two companies (CMCC, Samsung) also accepted increasing it to 32.

2 companies (Huawei, HiSilicon) mentioned that the currently supported maximum number of repetition being 16 is sufficient to meet the coverage requirement.

1 company (Sharp) proposed considering the maximum number of repetitions of 36 which enables 8 actual repetitions in DDDSU slot structure.

1 company (IITH) preferred increasing of the maximum number of repetitions to 128.

1 company (Ericsson) proposed that assuming FDD for determination of the maximum number of repetitions without postponement justifies an increase to 20. Values greater than 20 needs confirmation that the corresponding data rates support vocoder operation with sufficient quality and low enough higher layer overhead.

2 companies (Nokia, Nokia Shanghai Bell) provided their views that specification changes on TDRA should be avoided for the Rel-17 enhancements on PUSCH repetition type A.

1st round discussion

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| **FL observation 1-1:**  Clear majority supports 32 as the maximum number of repetitions.  **Question 1-1:**  Companies are invited to provide technical reasoning / technical concern to the majority’s view. | |
| **Company** | **Comment** |
| Samsung | If a number larger than 16 is agreed, the maximum size of the TDRA table remains unchanged (64 rows, 6 bits in DCI for the indication) as a UE’s coverage condition is slowly varying and the TDRA table can be adjusted by RRC. |
| Qualcomm | Support increasing maximum number of repetitions to 32 for both RRC configured PUSCH and dynamic TDRA-based PUSCH grants. This aids VoIP traffic where one aggregated packet is generated every 40 ms and the resulting packet can be repeated a large number of times. Allowing large number of repetitions is also useful from an NTN perspective where retransmissions may not be feasible due to large time delays. |
| Apple | We supports 32 as the maximum repetition number, other values and indication can discuss later. |

# Other candidate values for configured number of repetitions

3 companies (CATT, vivo, China Telecom) discussed that, on top of adding 32, additional values for a value set of the number of repetitions (e.g. also adding {20, 24, 28}) with finer granularity improve performance. 1 company (ZTE) discussed increasing of the number of candidate repetition factors from 8 to 16.

1st round discussion

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| **FL proposal 1-2:**  Additional candidate values for configured number of repetitions are discussed after concluding the discussion on the maximum number of repetitions. This is also affected by outcomes from Question 1-4.  **Question 1-2:**  Any views on the above suggestion? | |
| **Company** | **Comment** |
| Qualcomm | Candidate repetition factors can include {20,24,28,32}. |
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# Repetitions for configured grant

In Rel-15/16, RRC parameter *repK* applies to both Type 1 and Type 2 configured grant transmissions, where the candidate value set of *repK* = {1, 2, 4, 8}. TRDA based dynamic repetition number indication introduced in Rel-16 is applicable to Type 2 configured grant transmission, where the candidate value set of *numberOfRepetitions-r16* = {1, 2, 3, 4, 7, 8, 12, 16}.

2 companies (ZTE, Apple) discussed that the maximum repetition number for PUSCH transmission with configured grant is currently 8, and it should be increased, too.

1st round discussion

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| **FL observation 1-3:**  Only few companies have explicitly shown their views on increase of the maximum number of repetitions for configured grant.  **Question 1-3:**  Any views on increasing the maximum number of repetitions for configured grant? | |
| **Company** | **Comment** |
| Samsung | Apply same conclusion as for DG-PUSCH. |
| Qualcomm | Apply same maximum for both DG and CG PUSCH. |
| Apple | Agree with Samsung and Qualcomm. In addition, to align the objective of this WI, the proposal should clarify for PUSCH repetition type A with a configured grant. |

# RRC parameters to be extended

In GTW session, there was a discussion on which RRC parameters should be extended to support more repetitions.

1st round discussion

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| **FL observation 1-4:**  There are 3 RRC parameters which are possibly extended so as to increase the maximum number of repetitions.   * *pusch-AggregationFactor* * *numberOfRepetitions* * *repK*   **Question 1-4:**  Companies are invited to provide their views on which RRC parameter(s) is extended to increase the maximum number of repetitions. | |
| **Company** | **Comment** |
| Samsung | If the maximum number of repetitions in the TDRA table is increased above 16, *pusch-AggregationFactor* and *repK* should also be increased. |
| Qualcomm | All three parameters can be extended to accommodate up to 32 repetitions. |
| Apple | Which parameter needs to extend the value is related to indication the repetition number semi-statically or dynamically. If we agree repetition number is 32 or more. Semi-statically indication is less the flexibility and resource utilization is not so efficient. From this point, parameter *numberOfRepetitions* and *repK* can be increased. |

# The number of repetitions counted on the basis of available slots for the PUSCH transmissions

The discussions in this section are based on the following objective in the Coverage Enhancement WID.

1st round discussion

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| The detailed objectives of the work item are as follows:   * Specification of PUSCH enhancements [RAN1, RAN4]   + Specify the following mechanisms for enhancements on PUSCH repetition type A [RAN1]     - Increasing the maximum number of repetitions up to a number to be determined during the course of the work.     - **The number of repetitions counted on the basis of available UL slots.** |

# Basic postponement mechanism

In Rel-15/16 the number of repetitions for a PUSCH repetition type A is counted at every slot regardless of whether the slot has sufficient available resources for UL transmissions or not.

4 companies (CATT, Panasonic, Qualcomm, NTT DOCOMO) mentioned that the number of repetitions counted on the basis of available resources for UL transmissions is already supported by Rel-15/16 PUCCH repetition and it can be reused for Rel-17 PUSCH repetition.

2 companies (ZTE, Ericsson) mentioned that definition of “available UL resource” can follow Rel-15/16 rules (i.e. reuse of legacy PUSCH omitting rules).

2 companies (OPPO, vivo) discussed that UE should postpone the transmission in a slot if the slot cannot transmit the repetition of a TB, where the postponing applies until the configured number of the repetition is achieved.

1st round discussion

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| **FL observation 2-1:**  Most of the companies share the views on postponement mechanism as the following:   * If a slot is determined as available for a scheduled PUSCH, the slot is counted in the PUSCH repetition. Otherwise, the slot is not counted in the PUSCH repetition and the repetition is postponed to the next slot. * Adopt one of the following:   + Alt 1: The above step is repeated until the count reaches the configured/indicated number of repetitions.   + Alt 2: The above step is repeated until the count reaches the configured/indicated number of repetitions N, or until the duration of the PUSCH transmission is K slots and the count is not larger than N.   + Note: additional dropping on the actual repetitions is not precluded (See FL proposal 2-2a).   **Question 2-1:**  Any views on the above observation? | |
| **Company** | **Comment** |
| Samsung | Postponing has the drawback of increasing latency (and resources), and complicating the gNB scheduler as resources are reserved in advance. How much postponing can be done by a UE needs to be controlled by the gNB. We suggest the following change in red:   * The above step is repeated until the count reaches the configured/indicated number of repetitions N, or until the duration of the PUSCH transmission is K slots and the count is not larger than N. |
| Qualcomm | Postponing and on-the-fly determination of slots available for repetition can lead to unpredictable latency and scheduling complications.  We prefer to reuse methodology used for PUCCH repetitions. No postponements are allowed. All slots for repetition are identified **right at the beginning** of the transmission and not revised later on.    This framework is also critical to enabling DMRS bundling, which is being studied in a separate sub-agenda. UE and gNB need to plan in advance for DMRS bundling/joint channel estimation.  Note further that typically PUSCH repetitions may be slightly over-provisioned to account for the fact that some repetitions may get dropped. It is therefore not necessary to specify a complicated mechanism of identifying slots for repetition.  Request FL to add an alternative to not allow postponing before discussing Alt 1 or Alt 2:  **Alt A:** If a slot is determined as available for a scheduled PUSCH prior to the beginning of the first transmission, the slot is counted in the PUSCH repetition. Otherwise, the slot is not counted in the PUSCH repetition. Once slots for repetition are identified they are not revised.  **Alt B:** If a slot is determined as available for a scheduled PUSCH, the slot is counted in the PUSCH repetition. Otherwise, the slot is not counted in the PUSCH repetition and the repetition is postponed to the next slot.  Adopt one of the following:   * + Alt 1: The above step is repeated until the count reaches the configured/indicated number of repetitions.   + Alt 2: The above step is repeated until the count reaches the configured/indicated number of repetitions N, or until the duration of the PUSCH transmission is K slots and the count is not larger than N.   + Note: additional dropping on the actual repetitions is not precluded (See FL proposal 2-2a). |
| Apple | Alt. 1 seems straightforward, gNB could control the repetition and delay if the PUSCH is scheduling. |

# Definition of available slots for PUSCH repetitions

Several companies (vivo, Apple) discussed that dynamic SFI, CI and higher priority transmissions can lead to repetition transmission resource to be unavailable and not to be counted for determination of relevant repetitions, so that “available UL slots” should correspond to the slots where UL repetition is actually transmitted.

7 companies (Intel, Panasonic, Qualcomm, Ericsson, WILUS, Nokia, Nokia Shanghai Bell) discussed that a slot is determined for a PUSCH transmission if the allocated symbols for the PUSCH according to TDRA do not partly or fully overlap with DL symbols or invalid symbols (e.g. SS/PBCH block symbols). In other words, the same number of PUSCH symbols should be kept in every repetition.

7 companies (Intel, China Telecom, NEC, CMCC, Qualcomm, Sharp, WILUS) discussed that only semi-static configuration is referred to for determination of relevant repetitions, and dynamic signaling (e.g. dynamic SFI, CI) is not referred to.

2 companies (OPPO, Sharp) proposed that only symbols semi-statically configured as UL are used for determination of slots for PUSCH repetition.

1 company (CMCC) mentioned that confliction between PUSCH repetitions and other UL transmission (e.g. SRS) should be further clarified. One company (WILUS) mentioned that PUSCH repetition should be postponed when conflicting with a PUCCH repetition.

In current specification, UE does not expect to detect a DCI, indicating a PUCCH resource for HARQ-ACK in a later slot, if UE detects a DCI scheduling a PUSCH transmission in a previous slot and the HARQ-ACK information be multiplexed on the PUSCH transmission. 1 company (vivo) discussed that this timeline restriction should be removed by allowing puncturing of some PUSCH symbols.

1 company (Qualcomm) proposed that all slots for a PUSCH repetition shall be identified prior to the start of the first PUSCH transmission.

1 company (Intel) discussed that a time window can/limitation of postponing can be configured so that an excessive postponement is avoided. For the same purpose, several companies (Lenovo, Motorola Mobility) discussed that a repetition span can be configured in TDRA table so that an excessive postponement is avoided. One company (Samsung) also discussed that limitation on the number of postponing can be configured separately from TDRA.

1 company (LG) discussed adopting early stop of PUSCH repetition mechanism such as indication in DCI (e.g. New Data Indication and HARQ process ID), introduction of maximum time duration for PUSCH repetition, and dynamic indication of number of PUSCH repetition in addition to semi-static configuration.

2 companies (Panasonic, Xiaomi) discussed that early termination of the repetition should be considered, and DFI mechanism as in Rel-16 NR-U can be a starting point.

1 company (InterDigital) proposed supporting enhancement to enable fixed number of repetitions for a TB over one or more bundles.

1st round discussion

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| **FL observation 2-2:**  There seems to be several views on how to determine a given slot as available for PUSCH repetitions. E.g.,   * Only semi-static configurations are referred to for determination of whether or not a given slot as available for PUSCH repetitions for a postpone mechanism, * Dynamic signaling is also referred to for determination of whether or not a given slot as available for PUSCH repetitions for a postpone mechanism.   **FL proposal 2-2:**  For further discussions on definition of available slots for PUSCH repetitions for the postpone mechanism, the following terminology is used   * *Counted repetitions for a PUSCH repetition*: A set of the slots which are considered as available and counted according to the postpone mechanism. The number of counted repetitions is configured/indicated by gNB. * *Actual repetitions for a PUSCH repetition*: Transmission occasions with actual transmissions the UE performs for the PUSCH repetition.   + If there are transmission occasions without actual transmissions, the number of actual repetitions is smaller than the number of the transmission occasions.   **Question 2-2:**  Any views on the above proposal 2-2? | |
| **Company** | **Comment** |
| Samsung | The proposed definitions seem not to be needed. “Counted” or “Actual” is independent on how a slot is determined to be available.  We only need to decide whether a slot is considered available for UL transmission based on the tdd\_ul\_dl configuration or can be also adapted by SFI.  We support adaptation by SFI. It is a Rel-15 feature. Rel-16 already supports a similar functionality through the UL CI and even Rel-17 URLLC considers operation in conjunction with SFI despite the much higher reliability requirements. |
| Qualcomm | It may further help to identify at what point a slot is deemed to be available and when a repetition counter is incremented. |
| Apple | Try to understand the proposal, *counted repetitions for a PUSCH repe*tition just precludes the DL slots for unpaired spectrum case, and *actual repetitions* precludes some of UL slots which could not be used for transmission. |

With the above terminology, companies’ preferences can be classified as follows:

Alt 1: Counted repetitions for a PUSCH repetition are determined by semi-static configuration (e.g. TDD configuration). Actual repetitions for a PUSCH repetition are determined as remaining counted repetitions after dropping according to dynamic signaling (e.g. SFI, CI, etc).

Alt 2: Counted repetitions for a PUSCH repetition are determined by semi-static configuration (e.g. TDD configuration) and dynamic signaling (e.g. SFI, CI, etc). Actual repetitions are the same as the counted repetitions.

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| **FL proposal 2-2a:**  Adopt one of the following:   * Alt1: Whether or not a slot is considered as available for UL transmissions depends on tdd\_ul\_dl configuration and does not depend on SFI. * Alt2: Whether or not a slot is considered as available for UL transmissions depends on tdd\_ul\_dl configuration and also depends on SFI.   **Question 2-2a:**  Any views on the above proposal 2-2a? | |
| **Company** | **Comment** |
| Samsung | We support adaptation by SFI. It is a Rel-15 feature. Rel-16 already supports a similar functionality through the UL CI and even Rel-17 URLLC considers operation in conjunction with SFI despite the much higher reliability requirements. |
| Qualcomm | Support Alt 1. Please see response to Question 2-1 for justification. This is for eMBB/Voice traffic, and the latency considerations for URLLC are not required here. Its best to keep this specification straightforward. |
| Apple | Some cases are not considered by the proposal, such as UE specific UL/DL configuration, CI, PUSCH priority for URLLC.  From our side, the available slot simply means the slot with actual transmission. This is compliant what we agreed up to Rel.16. |

# Special slot handling

4 companies (OPPO, Huawei, HiSilicon, Samsung) discussed that a slot can be identified as an available UL slot if it consists of sufficient number of consecutive uplink symbols, e.g. number of consecutive uplink symbols is larger than a predefined or configurable threshold. 1 company (China Telecom) discussed symbol allocation in a special slot can be different from the one for UL slots.

2 companies (OPPO, China Telecom) discussed that utilizing of special slot(s) improves performance especially in low SNR case.

2 companies (Huawei, HiSilicon) discussed that new rate matching is performed if the number of UL symbols in a special slot is smaller than the scheduled number of symbols for the PUSCH.

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| **FL observation 2-3:**  There seems to be several views on how to handle special slots. In general, some companies discussed some special handling on the special slots while some other companies discussed it together with definition of available slots for PUSCH repetitions.  **FL proposal 2-3:**  Discuss further how to handle special slots:  Alt 1: Discuss special slots together with section 3.2. Definition of available slots for PUSCH repetitions.  Alt 2: Discuss special slots separately from section 3.2. Definition of available slots for PUSCH repetitions.  **Question 2-3:**  Any views on the above proposal 2-3? | |
| **Company** | **Comment** |
| Samsung | Alt. 1 |
| Qualcomm | Alt. 1 |
| Apple | We are fine with both alternatives. |

# PUSCH repetition mode configuration/indication

2 companies (China Telecom, Ericsson) discussed that Network should be able to configure one of two modes: Mode 1) the number of repetitions is counted on the basis of contiguous slots; and Mode 2) the number of repetitions is counted on the basis of available UL slots; by RRC. 3 companies (Panasonic, Lenovo, Motorola Mobility)) mentioned either RRC configuration or use of TDRA table can be considered for the mode indication.

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| **FL observation 2-4:**  So far, only a few companies provided their views on configuration/indication of PUSCH repetition mode between:   * the number of repetitions counted on the basis of contiguous slots (i.e. legacy PUSCH repetition) * the number of repetitions counted on the basis of available slots for the PUSCH transmissions (i.e. enhanced PUSCH repetition)   There seems to be two options:   * Alt 1: Whether the counting is based on contiguous slots or available slots is configured by higher-layer configuration. * Alt 2: Whether the counting is based on contiguous slots or available slots is indicated by dynamic signaling.   **Question 2-4:**  Companies are invited to provide their views on PUSCH repetition mode configuration/indication. | |
| **Company** | **Comment** |
| Samsung | No need to discuss. In case of no postponing, the counting is based on contiguous slots. In case of postponing, the counting is based on available slots. |
| Qualcomm | Motivation to maintain two modes of counting is not clear. Needs sufficient justification. Else, prefer to go with the new mode that is being discussed currently.  @Samsung, a case of no postponing but based on available slots (using semi-static tdd ul-dl configurations) is also a possibility. |
| Apple | According to the WID, the counting is only based on available slot. So the proposal seems beyond the objective of this WI. |

# Appendix

# References

1. R1-2100095 Discussion on enhanced PUSCH repetition type A ZTE
2. R1-2100172 Enhancements on PUSCH repetition type A OPPO
3. R1-2100196 Coverage enhancements for PUSCH repetition typeA Huawei, HiSilicon
4. R1-2100397 Discussion on enhancements on PUSCH repetition type A CATT
5. R1-2100457 Discussion on enhancement for PUSCH repetition type A vivo
6. R1-2100665 Enhancements on PUSCH repetition type A Intel Corporation
7. R1-2100712 Discussions on PUSCH repetition type A enhancements LG Electronics
8. R1-2100731 PUSCH repetition for coverage enhancements InterDigital, Inc.
9. R1-2100915 Enhancements on PUSCH repetition type A China Telecom
10. R1-2100942 Discussion on enhancements on PUSCH repetition type A NEC
11. R1-2101001 Enhancements on PUSCH repetition type A Lenovo, Motorola Mobility
12. R1-2101017 Discussion on enhancements on PUSCH repetition Type A Panasonic Corporation
13. R1-2101055 Discussion on enhancements on PUSCH repetition type A CMCC
14. R1-2101127 Enhancements on PUSCH repetiton type A Xiaomi
15. R1-2101221 Enhancements on PUSCH repetition type A Samsung
16. R1-2101327 Design Considerations for Enhancements on PUSCH repetition Sierra Wireless, S.A.
17. R1-2101395 Discussion on PUSCH repetition type A enhancement Apple
18. R1-2101407 PUSCH Repetitions for Coverage Enhancement Indian Institute of Tech (H)
19. R1-2101477 Enhancements on PUSCH repetition type A Qualcomm Incorporated
20. R1-2101520 PUSCH Repetition Type A Enhancement Ericsson
21. R1-2101545 Enhancements on PUSCH repetition type A Sharp
22. R1-2101641 Enhancements on PUSCH repetition type A NTT DOCOMO, INC.
23. R1-2101656 Enhancements on PUSCH repetiton type A Xiaomi
24. R1-2101679 Discussion on enhancements on PUSCH repetition type A WILUS Inc.
25. R1-2101710 Enhancements on PUSCH repetition type A Nokia, Nokia Shanghai Bell