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

**e-Meeting, 10th – 27th May, 2021**

**Agenda item: 8.8.1.1**

**Source: Moderator (Sharp)**

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

**Document for: Discussion and Decision**

# Introduction

For PUSCH enahancements the following objectives are described in the Coverage Enhancement WID.

* *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.*

This document is intended to facilitate view exchange and discussions on the enhancements on PUSCH repetition type A, for the following assigned email discussion.

[105-e-NR-R17-CovEnh-01] Email discussion regarding enhancements for PUSCH repetition type A – Toshi (Sharp)

* 1st check point: 5/21
* 2nd check point: 5/25
* Final check: 5/27

# Open Issues summary

## Increasing 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}. TDRA 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}. For CG-PUSCH, RRC parameter *repK* configures the number of repetitions, where the candidate value set of *repK* = {2, 4, 8}. For Type 2 configured PUSCH repetition, TDRA based dynamic repetition number indication with *numberOfRepetitions-r16* using activation DCI is also applicable.

In RAN1#104-e, we discussed several aspects including the maximum number itself, other candidate values, repetitions for configure grant, RRC parameters to be extended, and TDRA list.

### Issue#1-1: Value of the maximum number of repetitions

In RAN1#104-e, although the majority supported the maximum number of 32, some companies wanted to first see companies’ views on assumptions for designing of the maximum value, e.g. whether the number of repetitions is counted based on contiguous slots or available slots, whether to consider both FDD and TDD or either of them and whether to consider both VoIP and eMBB or either of them.

When discussing how much the maximum repetition factor should be increased, the following three cases were raised by companies.

* Case 1: FDD or SUL
* Case 2: TDD with contiguous-slot-based counting
* Case 3: TDD with available-slot-based counting

Although most of the companies believed that, once the increased maximum repetition factor is decided, it should be applicable to all the three cases, there were different views on which cases should assumed when evaluating if proposed values achieve sufficient PUSCH coverage. Some company said the value should be decided based on Case 1 while other companies argued it should be Case 2 or Case 3. This divergence came from different views on the “bundle” of two enhancements, (a) increasing the maximum number of repetitions and (b) the number of repetitions counted on the basis of available slots. The majority thought that the two enhancements are not bundled (i.e. can be configured separately/independently) while a few companies said that the two enhancements are always bundled. The most of the majority companies were also thinking that the maximum value should be extended to 32 by the enhancement (a) so that sufficient coverage can be achieved without the enhancement (b). Furthermore, the some of the companies who preferred “always-bundle” were also saying that the maximum value should be extended to 32 even with the enhancement (a).

According to the contributions for RAN1#105-e, companies’ preferences on the maximum repetition number are:

* 32
  + Supported by: ZTE [3], vivo [4], CATT [5], Qualcomm [7], OPPO [8], China Telecom [9], Intel [11], Apple [12], Panasonic [13], Samsung (if a need is identified) [15], Xiaomi [18], Sharp [19], NTT DOCOMO [21], Lenovo/Motorola Mobility [22]
* 16 (i.e. the same as in Rel-16)
  + Supported by: Huawei/HiSilicon (based on available slots) [1], CMCC (based on available slots) [6], Samsung [15], Ericsson (based on available slots) [20]
* 20
  + Supported by: Ericsson (for FDD with 15kHz SCS) [20]
* 24
  + Supported by: Samsung (if a need is identified) [15]
* 40
  + Supported by: Huawei/HiSilicon (based on contiguous slots, and for 30kHz SCS) [1]

Some of the observations from contributions are also listed below.

* Reasons to propose 32 for the maximum repetition number
  + Coverage enhancements specified in this WI should be also applicable for NTN scenarios. Since FDD is assumed for core specification work for NTN scenarios, there are enough consecutive UL slots to transmit the maximum 32 repetitions transmission to obtain the performance gain.
  + This WI is not aiming at LPWA scenario, in which the minimum number of the maximum repetition number among the typical LPWA systems is 32.
  + Excessive repetition number will reduce the performance such as UL UPT.
  + HARQ retransmission mechanism can cooperate with repetition transmission. There is no need to pursue hard one-shot BLER (iBLER) in all scenarios.
  + Considering VoIP as a motivating example, a voice packets gets generated once every 20ms, with voice packet aggregation, an aggregated packet may get generated once every 40ms. With 15 kHz subcarrier spacing, 40 uplink slots are available to transmit an aggregated packet in a FDD system.
  + 2-3dB performance gain can be observed compared with repetition factor of 16.
* Reasons to propose 16 for the maximum repetition number
  + Counting on the basis of available slots for repetition should be as mandate feature of CE UE capability. Based on the available slot counting method, repetition factor of 16 can compensate the coverage gaps. (CMCC)
* Reasons to propose 20 for the maximum repetition number
  + For FDD with 15kHz SCS, the number of actual repetitions of 20 result in 16 kbps (the lowest VoIP data rate).
* Reasons to propose 40 for the maximum repetition number
  + Considering the 20ms data arrival period and typical TDD configuration with 30KHz subcarrier spacing (i.e. has 40 slots), a maximum repetition number of being 40 can be supported for full occupation of all 40 slots within 20ms.

Based on the above, the large majority is still thinking that 32 is a reasonable value for the maximum number of repetitions. Moreover, even if 32 is adopted, the network may still have a choice to configure a smaller value, such as 20 or 24, depending on the outcomes from Issue#1-3. Considering these observations, companies are asked again if it is acceptable to take 32 as the maximum number of repetitions.

**Initial FL proposal #1-1**

* The maximum number of repetitions supported by Rel-17 PUSCH repetition Type A is 32.

### Issue#1-2: RRC parameters to be extended for supporting the increased maximum number

In Rel-16, there are three RRC parameters which are used to configure repetition factors, *pusch-AggregationFactor*, *numberOfRepetitions*, and *repK*. In RAN1#104-e, we discussed which parameter(s) should be extended to support the increased maximum repetition factor. Although the large majority supported extension of all the three parameters, several companies expressed that extension of *numberOfRepetitions* (i.e. the one associated with TDRA list) is sufficient. In RAN1#104-e, it was agreed that Rel-17 PUSCH repetition Type A supports the increase of maximum number of repetitions with repetition factors configured in a TDRA list with a row index indicated either by the configured grant configuration or by TDRA field in a DCI. There was still the sub-bullet saying that “FFS: increasing the maximum number of repetitions with repetition factor configured in *PUSCH-Config* and/or *ConfiguredGrantConfig*”. In other words, the repetition factors semi-statically configured without using the TDRA list can be set to 2, 4 or 8 in Rel-15/16, but it should be decided whether those semi-static repetition factors also support the increase of maximum number of repetitions or not.

According to the contributions for RAN1#105-e, companies’ preferences on extensions on the repetition factor configured in *PUSCH-Config* and/or *ConfiguredGrantConfig*.

* Repetition factor configured in *PUSCH-Config* and/or *ConfiguredGrantConfig* supports increase of the maximum number of repetitions.
  + Supported by: Intel [10], Samsung [15], LG [16], Lenovo/Motorola Mobility [22], Nokia/Nokia Shanghai Bell [24]
  + Not supported by: ZTE [3], vivo [4], CATT [5], CMCC (studied further) [6], NTT DOCOMO [21]
  + Up to RAN2: Xiaomi [18]

Based on the above analysis, companies have different views on this issue. Therefore, it is suggested having more discussions on whether to support this function.

**Initial FL proposal #1-2**

* Discuss if repetition factor configured in *PUSCH-Config* and/or *ConfiguredGrantConfig* supports the increased maximum number of repetitions.

### Issue#1-3: Other candidate value set for configuration of the number of repetitions

In Rel-16, 8 candidates for repetition factors are supported. The exact value set is {1, 2, 3, 4, 7, 8, 12, 16}.

In RAN1#104-e, several companies proposed adding {20, 24, 28, 32}, as finer granularity among the value set improves resource efficiency. At the same time, it was commonly understood that the exact values should be discussed after concluding the discussion on Issue#1-1.

According to the contributions for RAN1#105-e, companies’ preferences on other candidate values are summarized as the following.

* The number of candidate repetition factors to be increased from 8 to 16.
  + Supported by ZTE [3]
* {20, 24, 28} are also supported.
  + Supported by: vivo [4], CATT [5], Lenovo/Motorola Mobility [22]

In addition, in RAN1#104-e there was a discussion about the number of rows of TDRA list. Although several companies expressed that it should remain unchanged from Rel-16, the large majority wanted to postpone this discussion as this issue should be affected by the number of candidate repetition factors. According to the contributions for RAN1#105-e, Samsung [15], LG [16], Xiaomi [18] are suggesting that the number of rows of the TDRA table should remain unchanged from Rel-16, though Xiaomi [18] is proposing having multiple TDRA tables which correspond to different CE targets.

As discussed in the previous meeting, it is suggested discussing Issue#1-3 after concluding Issue#1-1 discussion.

**Initial FL proposal #1-3**

* Discuss Issue#1-3 after concluding Issue#1-1 discussion.

### Issue#1-4: Other issues

According to contributions for RAN1#105-e, no other issue related to the increased maximum number of repetitions is provided.

## The number of repetitions counted on the basis of available UL slots

In Rel-16, transmission occasions for a PUSCH with repetition type A are derived based on K consecutive slots, and then transmissions at some occasions may be omitted according to TDD configuration, dynamic SFI, PUSCH priority, and Cancelation Indication. Rel-15/16 also support PUCCH with N-time repetition in which only slots having sufficient UL/flexible symbols for the allocated PUCCH resource are counted as part of N slots, where UL/flexible symbols are determined by only semi-static configurations (i.e. TDD configuration and SSB configuration).

In RAN1#104-e, there were two different directions proposed for the determination of ”available slots for PUSCH repetition”, one was to follow Rel-16 PUSCH omission rule, and the other was to follow Rel-15/16 PUCCH repetition rule. Both of the rules refer to TDD configuration and SSB configuration. Therefore, it is straightforward that TDD configuration and SSB configuration are also used for the dermination of available slots in Rel-17. On the other hand, there are two aspects which identify the difference between those rules.

The first aspect is whether or not dynamic signal (dynamic SFI, PUSCH priority, and cancelation indication) is used for the determination of available slots. This aspect was described the following agreement in RAN1#104-e. For Alt 1, we discussed which semi-static configurations should be considerd for the available slot determination. Many companies preferred to reuse Rel-15/16 PUCCH repetition rules, i.e. using TDD configuration and SSB configuration, while a few companies wanted to use more configuration, e.g. invalid UL symbol configuration or Type0-CSS / CORESET#0 configuration. For Alt 2, we discussed which dynamic signaling should be considerd for the available slot determination. Although not many companies provided views on it, all the companies proving their views preferred to reuse Rel-16 PUSCH omission rule, i.e. to use all of SFI, PUSCH priority and Cancelation Indication.

|  |
| --- |
| Agreements:  Select one of the following alternatives, considering the aspect whether or not the determination of all the available slots should be done prior to the first actual transmission of the repetitions (other alternatives are not precluded)  -        Alt1: Whether or not a slot is determined as available for UL transmissions depends on RRC configurations (at least tdd\_ul\_dl configuration, FFS: other RRC configurations) and does not depend on dynamic signaling (at least SFI, FFS: other dynamic signaling e.g. CI, PUSCH priority for URLLC).  -        Alt2: Whether or not a slot is determined as available for UL transmissions depends on RRC configurations (at least tdd\_ul\_dl configuration, FFS: other RRC configurations) and also depends on dynamic signaling (at least SFI, FFS: other dynamic signaling e.g. CI, PUSCH priority for URLLC). |

Relating to this aspect, in RAN1#104bis-e it was taken as a working assumption that the number of repetitions is counted on the basis of available slots for Type A PUSCH repetitions for Msg3. It is obvious that neither dynamic SFI, PUSCH priority nor cancelation indication is applicable for the determination of available slots for Msg3. In this sense, it can be said that Alt1 needs to be supported al least for Msg3.

The second aspect is whether or not the determination of available slots is done o prior to the first transmission of the repetition. This aspect was mentioned the following conclusion made in RAN1#104-e.

|  |
| --- |
| **Conclusion:**  Discuss further to select one of the following alternatives:   * Alt-a: The determination of all the available slots has to be done prior to the first actual transmission of the repetitions. * Alt-b: The determination of all the available slots does not have to be done prior to the first actual transmission of the repetitions. The timeline requirement is per repetition basis. |

In Rel-16 PUSCH repetition Type A, the indicated TDRA is applied to K consecutive slots, and then the UE determines to omit the PUSCH transmission in each slot depending on whether the TDRA causes any collision/overlapping or not. RAN1#104bis-e, we discussed whether or not the same principle applies, and it was agreed that, for defining available slots, a slot is determined as unavailable if at least one of the symbols indicated by TDRA for a PUSCH in the slot overlaps with the symbol not intended for UL transmissions. On the other hand, whether this is applied to special slots or not is still for further study. In RAN1#104-e, 5 companies expressed their views that PUSCH symbol allocation in special slots can be different from UL slots so that UL portion of the special slots can be fully utilized by Rel-17 PUSCH repetition Type A transmissions. At the same time, there were also some companies which see no need of special handling of special slots.

### Issue#2-1: Use of dynamic signaling for the determination of available slots

As in the agreement from RAN1#104-e, it should be discussed whether or not the determination of all the available slots depends on dynamic signaling.

* Alt 1: Whether or not a slot is determined as available for UL transmissions depends on RRC configurations and does not depend on dynamic signaling.
* Alt 2: Whether or not a slot is determined as available for UL transmissions depends on RRC configurations and also depends on dynamic signaling.

During the email discussions in RAN1#104-e, 19 companies preferred Alt 1, i.e. dynamic signaling is not used for the determination of availble slots, while 5 companies preferred Alt 2, i.e. dynamic signaling is not used for the determination of availble slots, to Alt 1. The proponents of Alt 1 expressed several reasons to support it, which includs (1) Alt 1 simplifies UE implementation in terms of processing timeline, and (2) Alt 1 resolves different understanding of available slots between gNB and UE due to detection failure of the dynamic signaling at the UE side. Meanwhile, the proponents of Alt 1 argued that (a) the available slots imply mean the slots with actual transmissions in order to ensure the sufficient number of repetitions, and (b) there is no increase of difficulty over Rel-16 PUSCH repetition omission.

According to the contributions for RAN1#105-e, one more alternative solution is raised, which takes into account issue#2-3’s aspect as well. More specifically, Alt 3 determines available slots by referring to dynamic signaling in the DCI which schedules the concerned PUSCH, so that the determination can be done prior to the 1st actual transmission of the PUSCH repetitions. Companies’ preferences can be summarized as the following. The concern on Alt 2 raised by the Alt 1 proponents is that detection failures of dynamic signaling lead to different understanding of available slots between UE and gNB.

For PUSCH repetition Type A counted on the basis of available slots,

* Alt 1: The determination of available slots does not depend on any dynamic signaling.
  + Note: Further omission of PUSCH repetition in the available slot is subject to dynamic signaling.
  + Supported by : Huawei/HiSilicon (if the determination is done prior to the 1st transmission.) [1], vivo [4], CATT [5], CMCC [6], Qualcomm [7], OPPO [8], China Telecom [9], InterDigital [10], Intel [11], NEC [14], LG [16], Sierra Wireless [17], Xiaomi [18], Sharp [19], Ericsson [20], NTT DOCOMO [21], WILUS [23]
* Alt 2: The determination of available slots depends on dynamic signaling including e.g., dynamic SFI.
  + Supported by : Huawei/HiSilicon (if the determination is done per slot.) [1], ZTE [3], Samsung [15], Lenovo/Motorola Mobility [22], Nokia/Nokia Shanghai Bell [24]
* Alt 3: The determination of available slots depends on dynamic signaling in the scheduling DCI only.
  + OPPO [8], Panasonic [13]

Some of the observations from contributions are also listed below.

* Reasons to propose Alt 1
  + With Alt 2, reception failures of dynamic signaling at the UE side lead to different understanding of available slots between the UE and gNB.
  + Alt 1 makes UE implementation easier, as it does not require re-counting when receiving dynamic signaling.
* Reasons to propose Alt 2
  + Alt 2 can ensure enough number of actual repetitions and meet the requirement of PUSCH coverage performance, while Alt 1 may cause insufficient coverage performance due to PUSCH dropping in a determined available slot.
  + It is not apparent why for coverage enhancement a UE cannot determine whether or not to transmit in a slot based on DCI indication when that is already supported or why a network should be practically prohibited from benefiting from coverage enhancements when it dynamically adapts the UL-DL TDD configuration.
* Reasons to propose Alt 3
  + Well-balanced design in terms of scheduling flexibility and UE complexity.

In addition, more detailed determination rules are also proposed, which are listed below.

* The slot where a PUSCH repetition is dropped due to overlapping with PUCCH should be determined as unavailable.
  + ZTE [3]
* The flexible symbols configured with SSB based measurement by SMTC should be determined as unavailable.
  + Vivo [4]
* The slot with PUSCH dropping due to power reduction should be counted as an available slot.
  + OPPO [8]
* Support opportunistic UL transmission on “non-available” UL slots dynamically indicated by SFI
  + InterDigital [10]
* Overlapping with SR with larger priority should not have any impact on the determination of available slots.
  + Sharp [19]
* Flexible symbol should be determined as available for UL transmissions
  + Nokia/Nokia Shanghai Bell [24]

Alt 1 now has more supports than in the previous meeting. Also, many companies pointed that Alt 2 has the problem that UE and gNB may have different understanding on available slots, which leads the issues described in Issue#2-2 and Issue#2-3.

**Initial FL proposal #2-1**

* The determination of available slots does not depend on any dynamic signaling. (i.e. Taking Alt 1 of the previous agreement)

### Issue#2-2: RV Cycle

In Rel-16 PUSCH repetition Type A, RV to be applied on a given slot is derived from when this slot comes from the start of the K consecutive slots as in the following TS38.214 descriptions.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| For PUSCH repetition Type A, in case *K>1,* the same symbol allocation is applied across the *K* consecutive slots and the PUSCH is limited to a single transmission layer. The UE shall repeat the TB across the *K* consecutive slots applying the same symbol allocation in each slot. The redundancy version to be applied on the *n*th transmission occasion of the TB, where n = 0, 1, … *K*-1, is determined according to table 6.1.2.1-2.  Table 6.1.2.1-2: Redundancy version for PUSCH transmission   |  |  |  |  |  | | --- | --- | --- | --- | --- | | *rvid* indicated by the DCI scheduling the PUSCH | *rvid* to be applied to *n*th transmission occasion (repetition Type A) or *n*th actual repetition (repetition Type B) | | | | | *n* mod 4 = 0 | *n* mod 4 = 1 | *n* mod 4 = 2 | *n* mod 4 = 3 | | 0 | 0 | 2 | 3 | 1 | | 2 | 2 | 3 | 1 | 0 | | 3 | 3 | 1 | 0 | 2 | | 1 | 1 | 0 | 2 | 3 | |

For PUSCH repetition based on the K available slots, it should be discussed how RV in each slot of the K available slots is determined.

According to the contributions for RAN1#105-e, only two companies are providing their views, which are listed below.

* RV in a slot is derived by the index of the slot, where the indexing is based on available slots according to semi-static configurations, and the index=0 at the slot *K*s derived from the slot offset *K*2.
  + Sharp [19]
* RV cycling should be based on available slots which are determined by RRC configurations only.
  + Ericsson [20]

Both of them are suggesting that RV cycling should be affected only by RRC configurations. Otherwise, reception failures of dynamic signaling lead to different understanding of RV. Therefore, it is suggested discussing the following proposal as a starting point.

**Initial FL proposal #2-2**

* RV cycling is based on *rvid* indicated by the DCI scheduling the PUSCH and the indexing of *n* within *K* transmission occasions (may be in *K* non-contiguous slots) which are determined by only RRC configurations, where *K* is the indicated/configured repetition factor.

### Issue#2-3: Inter-Slot Frequency Hopping Cycle

According to contributions for RAN1#105-e, Qualcomm [7] raises the issue related to inter-slot frequency hopping. Similar to RV cycling, in Rel-15/16, inter-slot frequency hopping cycle is determined on the basis of consecutive physical slots. More specifically, hop index in a slot is determined based on whether the slot index is odd or even. However, it causes an uneven distribution of hops in TDD system. InterDigital [10] also mentions the same issue.

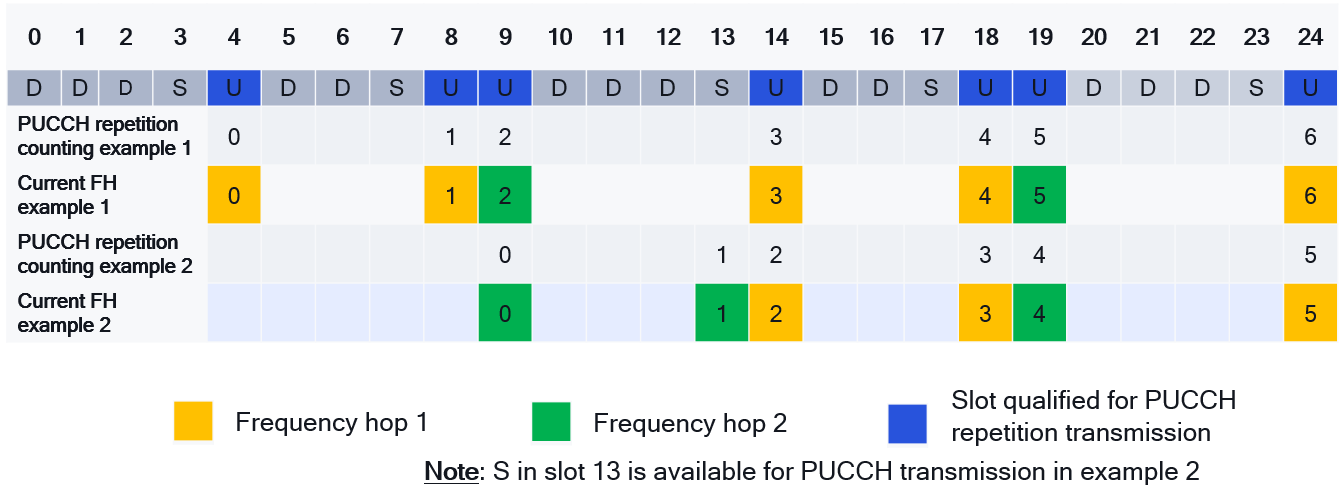


Figure: Uneven distribution of hops in TDD [7]

A possible solution proposed in [7] is that, for inter-slot frequency hopping, hop index is determined based on indexing within the determined available slots.

* For inter-slot frequency hopping, hop index is derived based on indexing within the determined *K* transmission occasions.

The proposal seems a good starting point.

**Initial FL proposal #2-3**

* For inter-slot frequency hopping, hop index is derived based on the indexing of *n* within *K* transmission occasions (may be in *K* non-contiguous slots) which are determined by only RRC configurations, where *K* is the indicated/configured repetition factor.

### Issue#2-4: Timeline aspect for the determination of available slots

As in the conslusion from RAN1#104-e, it should be discussed whether or not the determination of all the available slots has to be done prior to the first actual transmission of the repetitions.

* Alt-a: The determination of all the available slots has to be done prior to the first actual transmission of the repetitions.
* Alt-b: The determination of all the available slots does not have to be done prior to the first actual transmission of the repetitions. The timeline requirement is per repetition basis.

As this aspect was raised in the email discusion in RAN1#104-e, companies did not have enough time to deeply look into this aspect during RAN1#104-e. FL asked companies to provide their analyses in RAN1#105 on what is a possible bar/bottleneck in terms of timeline requirements in the available-slot-based PUSCH repetition, if any, compared to the omission rules of Rel-16 PUSCH repetitin Type A.

According to the contributions for RAN1#105-e, companies’ views on this aspect are summarized as the following.

* Alt-a: The determination of all the available slots has to be done prior to the first actual transmission of the repetitions.
  + Supported by: vivo [4], Qualcomm [7], OPPO [8], China Telecom [9], InterDigital [10], Intel [11], LG [16], Sierra Wireless [17], Xiaomi [18], Ericsson [20], Lenovo/Motorola Mobility (if not adopting the limitation of overall duration (i.e. Issue#2-6)) [22]
* Alt-b: The determination of all the available slots does not have to be done prior to the first actual transmission of the repetitions. The timeline requirement is per repetition basis.
  + Supported by: ZTE [3], Lenovo/Motorola Mobility (if adopting the limitation of overall duration (i.e. Issue#2-6)) [22], Nokia/Nokia Shanghai Bell [24]

Some of the observations from contributions are also listed below.

* Reasons to propose Alt-a
  + It enables cross-slot channel estimation/DMRS bundling.
  + It simplifies UE implementation as it does not require recounting.
  + Alt-a also simplifies hopping determination.
* Reasons to propose Alt-b
  + Alt-b reuses Rel-15/16 PUSCH omission mechanism (i.e. per-slot based timeline requirements).

**Initial FL proposal #2-4**

* The determination of all the available slots has to be done prior to the first actual transmission of the repetitions. (i.e. Take Alt-a of the previous conclusion)

### Issue#2-5: Semi-static configurations to be used for the determination of available slots

Regarding semi-static configurations to be used for the determination of available slots, there was some email discussions in RAN1#104-e. Many companies preferred to use TDD configuration and SSB configuration as in Rel 15/16 PUCCH repetition, while a few companies wanted to use more configuration, e.g. invalid UL symbol configuration or Type0-CSS / CORESET#0 configuration as in Rel 16 PUSCH repetition Type B. The agreement in RAN1#104-e states that at lease TDD configuration is used and FFS for other semi-stataic configurations, and there was no company which disagree with using of SSB configuration.

Since the previous meeting, no one has objected to refer to *ssb-PositionsInBurst* (i.e. SSB configuration) for determination of available slots. Therefore, the following should be agreeable.

* *ssb-PositionsInBurst* (i.e. SSB configuration) is used for determination of available slots.
  + Flexible symbol(s) for the reception of SSB is determined as unavailable.

For other semi-static configurations, according to the contributions for RAN1#105-e, several companies are proposing using the following RRC configurations for the determination of available slots.

* SSB based measurement by SMTC
  + Vivo [4]
* CORESET0 with Type0-PDCCH CSS set
  + Intel [11], Samsung [15], WILUS [23]
* Invalid UL symbols for DL-to-UL switching purpose
  + Intel [11], Samsung [15], WILUS [23]
* Other CG-PUSCH with larger priority index
  + Sharp (for CG-PUSCH) [19]
* PUCCH with larger priority index carrying HARQ-ACK for SPS
  + Sharp (for CG-PUSCH) [19]
* Semi-static PUCCH with repetition
  + WILUS [23]

Base on the above, the following proposals were made.

**Initial FL proposal #2-5**

* *ssb-PositionsInBurst* (i.e. SSB configuration) is used for determination of available slots. Flexible symbol(s) for the reception of SSB is determined as unavailable.
* Discuss further use of the following RRC configurations for determination of available slots:
  + SSB based measurement by SMTC
  + CORESET0 with Type0-PDCCH CSS set
  + Invalid UL symbols for DL-to-UL switching purpose
  + Other CG-PUSCH with larger priority index
  + PUCCH with larger priority index carrying HARQ-ACK for SPS
  + Semi-static PUCCH with repetition

### Issue#2-6: Special slot handling

In RAN1#104-e, 5 companies expressed their views that PUSCH symbol allocation in special slots can be different from UL slots so that UL portion of the special slots can be fully utilized by Rel-17 PUSCH repetition Type A transmissions. At the same time, there were also some companies which see no need of special handling of special slots. RAN1#104bis-e, it was agreed that, for defining available slots, a slot is determined as unavailable if at least one of the symbols indicated by TDRA for a PUSCH in the slot overlaps with the symbol not intended for UL transmissions. On the other hand, there was a sub-bullet saying ”FFS:details”. With this sub-bullet, the current situation is that whether this agreement is applied to special slots or not is still for further study.

|  |
| --- |
| Agreements:  For defining available slots: a slot is determined as unavailable if at least one of the symbols indicated by TDRA for a PUSCH in the slot overlaps with the symbol not intended for UL transmissions.   * FFS details |

According to the contributions for RAN1#105-e, only one company is discussing the special slot handling.

* For the number of repetitions for PUSCH repetition type A counted on the basis of available UL slots, the special slot is determined as an available UL slot. For the special slots, the available UL symbols can be used for PUSCH transmission.
  + China Telecom [9]

**Initial FL proposal #2-6**

* For defining available slots: a special slot is determined as unavailable if at least one of the symbols indicated by TDRA for a PUSCH in the special slot overlaps with the symbol not intended for UL transmissions.

### Issue#2-7: Limitation of overall duration of PUSCH repetitions

In RAN1#104-e, several companies proposed having a time window/limitation of overall time duration for a signle set of PUSCH repetitions so that an excessive delay can be avoided. Meanwhile, more companies thought that the network can control the overall time duration by setting an appropreate repetition factor.

* Alt 1: Count of available slots continues until reaching the indicated/configured repetition factor.
* Alt 2: Count of available slots continues until reaching the indicated/configured repetition factor or reaching the limitation of overall duration for a set of PUSCH repetitions, whichever comes first.

At the same time, it was widely understood that whether this issue needs to be discussed depends on the outcome of Issue#2-1, because the overall duration is certainly deterministic and controlable if the available slots are determined by semi-static configurations only while the postponement of PUSCH repetition due to dynamic scheduling may lead to difficulty to predict when the repetitions finish.

According to the contributions for RAN1#105-e, the following companies are proposing introducing the limitation of the overall duration.

* Alt 2: Count of available slots continues until reaching the indicated/configured repetition factor or reaching the limitation of overall duration for a set of PUSCH repetitions, whichever comes first.
  + Supported by: OPPO [8], Intel [11], Samsung [15], Lenovo/Motrola Mobility [22]

**Initial FL proposal #2-7**

* Discuss Issue#2-7 after concluding the discussion on Issue#2-1.

### Issue#2-8: Enhancements on PUSCH dropping

Similar to special slot handling, in the previous meeting it was also proposed introducing the mechanizm to fully utilize UL slots. More specifically, it was proposed that, even if some of the UL symbols allocated for a PUSCH are determined as unavailable for the PUSCH transmission due to e.g., overlapping with higher priority channels or cancellation indication, the PUSCH transmission using only remaining UL symbols should be possible.

According to contributions for RAN1#105-e, three companies are providing their views on this issue, as shown below.

* Huawei/HiSilicon is proposing that, if available UL slot is determined prior to 1st actual PUSCH repetition while other burst signals overlap with PUSCH repetition on determined available UL slot, then non-overlapped symbols of PUSCH repetition within this overlapped available UL slot can be used for PUSCH repetition to make a full use of UL resource.
* CMCC mentions that confliction between PUSCH repetitions and other uplink transmissions (e.g. SRS) should be further studied.
* Ericsson is also discussing the issue of overlapping of PUSCH and other UL channels (e.g. SPS HARQ-ACK discussed in Rel-17 IIoT/URLLC WI) and signal (A-SRS discussed in Rel-17 FeMIMO WI) within a slot.

**Initial FL proposal #2-8**

* Discuss further:
  + Necessity of collision handling between PUSCH repetition Type A and the other UL transmissions, e.g. SPS HARQ-ACK, SRS
  + How to handle the collision, if any, e.g.
    - Dropping whole part of either PUSCH repetition or the colliding UL transmission
    - Partially dropping either PUSCH repetition or the colliding UL transmission

### Issue#2-9: Enhancement on UCI multiplexing on PUSCH repetitions

This issue was raised in TEI-17 agenda item (TEI proposal #6) in RAN1#104-e meeting, and the conclusion was to continue discussion in RAN1#105-e.

In Rel-15/16, 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. For Rel-17 Coverage Enhancement, two enhancements are considered, both enhancements result in increase of overall time duration for a single set of PUSCH repetitions. Therefore, the restriction to PDSCH scheduling may have more impact to the gNB scheduler.



Figure: Rel-15/16 PDSCH scheduling restriction when PUSCH repetitions is scheduled [4]

According to contributions for RAN1#105-e, vivo [4] is proposing enhancement on UCI multiplexing on PUSCH repetitions such that HARQ-ACK multiplexing on PUSCH repetitions can be allowed even if HARQ-ACK for the scheduling DCI comes after the UL grant of the PUSCH repetition transmission. Panasonic [13] also mentions the same issue and suggests discussing it.

* HARQ-ACK multiplexing on PUSCH repetitions can be allowed even if HARQ-ACK for the scheduling DCI comes after the UL grant of the PUSCH repetition transmission

It should be noted that R1-2105536 sourced by Huawei/HiSilicon and China Unicom under AI 8.16 (TEI-17) is also addressing exactly the same issue.

A fundamental problem is that total UCI bit size to be reported is not known when the gNB schedules the PUSCH. This uncertainty leads to two sub-issues to be resolved. One is how to perform rate-matching of UCI around the PUSCH. The other is which DAI to be used to determine the UCI bit size. The solutions proposed in [4], [13] and R1-2105536 are listed below:

* Option 1: HARQ-ACK bits for later DL assignments puncture the PUSCH repetition.
* Option 2: When HARQ-ACK bits for the DL assignments later than UL grant is received, PUCCH with HARQ-ACK is transmitted and the PUSCH repetition is dropped or postponed.
* Option 3: The time restriction on scheduling HARQ after UL grant is only applied to initial PUSCH repetition, and HARQ information bits corresponding to the PDSCH(s) scheduled after UL grant which triggers the PUSCH transmission are allowed to be multiplexed on the non-initial repetitions, where DAI in the last DCI applies.

**Initial FL proposal #2-9**

* Discuss further whether/how HARQ-ACK multiplexing on PUSCH repetitions can be allowed if HARQ-ACK for the scheduling DCI comes after the UL grant of the PUSCH repetition transmission, taking the following options into account.
  + Option 1: HARQ-ACK bits for later DL assignments puncture the PUSCH repetition.
  + Option 2: When HARQ-ACK bits for the DL assignments later than UL grant is received, PUCCH with HARQ-ACK is transmitted and the PUSCH repetition is dropped or postponed.
  + Option 3: The time restriction on scheduling HARQ after UL grant is only applied to initial PUSCH repetition, and HARQ information bits corresponding to the PDSCH(s) scheduled after UL grant which triggers the PUSCH transmission are allowed to be multiplexed on the non-initial repetitions, where DAI in the last DCI applies.

### Issue#2-10: Configuration/indication of CovEnh functions

In RAN1#104-e, we had discussions on configurability of CovEnh functions and relationship of two enhancements, i.e., increase of the maximum number of repetitions and the repetitions counted on the basis of available slots. Although this issue is higher related to the UE features that should be discussed under a dedicated agenda item later, it is good to exchange companies’ views on it in order to have better understanding among companies on their proposed designs.

According to contributions for RAN1#105-e, the following views have been provided.

* Counting on the basis of available slots for repetition should be as mandate feature of CE UE capability.
  + CMCC
* Flexible configurability of two enhancemets is suitable. Two enhancements can be configured independently (either one or both of them can be configured).
  + CATT, OPPO, China Telecom, Apple
* One between three repetition options, i.e. legacy repetition, increased max repetition factor and repetitions based on available slots, is configured.
  + Ericsson
* One of the two counting methods (i.e., contiguous slot basis / available slot basis) is RRC configured or dynamically indicated by gNB
  + OPPO (implicitly indicated), Panasonic (dynamically indicated via TDRA table), Lenovo/Motorola Mobility (implicitly indicated)
* Separate capabilities for the two enhancements
  + Apple
* Single feature which support the two enhancements
  + Nokia/Nokia Shanghai Bell
* The (Increase of max repetition factor feature or the TBoMS feature) and the “Counting based on available UL slots” feature should be allowed to be enabled at the same time.
  + Sierra Wireless

**Initial FL proposal #2-10**

* Discuss further the following options, in terms of configurations/indications of two enhancements, i.e., (a) increase of the maximum number of repetitions and (b) the repetitions counted on the basis of available slots:
  + Option 1: The enhancement (a) is RRC-configurable. The enhancement (b) is a basic feature of CovEnh capability.
  + Option 2: A set of the enhancements (a) and (b) is RRC-configurable (i.e., configured together).
  + Option 3: Either enhancements (a) or (b) is RRC-configurable (i.e., not configured together).
  + Option 4: Either enhancements (a) or (b) or both is RRC-configurable.
  + Option 5: Either enhancements (a) or (b) is dynamically-indicated.

### Issue#2-11: Modification on

This issue raised by Samsung [15] is not strongly related to the CovEnh WI scope but is a kind of a correction proposal on the existing UCI on PUSCH repetition procedures.

In RAN1#91 and RAN1#92bis the following agreements were made.

|  |
| --- |
| **Agreement: (RAN1#91)**   * For UCI on PUSCH with UL-SCH, the amount of resources used for HARQ-ACK is calculated based on the following equation.     where is the number of ACK/NACK bits, is the scheduled bandwidth for PUSCH transmission in the current PUSCH transmission period for the transport block, expressed as a number of subcarriers. , and are obtained from the PDCCH scheduling the PUSCH transmission. is the number of OFDM symbols in the PUSCH transmission duration excluding DMRS. REs occupied by PTRS are also excluded.   * FFS: if an upper bound on the number of symbols for HARQ-ACK resource is needed   **Agreement: (RAN1#92bis)**  For HARQ-ACK, CSI part 1, and CSI part 2 (if exists) transmission on PUSCH without UL-SCH, the number of coded modulation symbols per layer for HARQ-ACK, CSI part 1, and CSI part 2 (exists), are determined as follows:  SE is the spectrum efficiency which is code rate \* modulation order |

On the other hand, TS 38.212 v16.5.0 computes the number of coded modulation symbols as follows, where the value range of is from 1 to 126.

|  |
| --- |
| 6.3.2.4.1.1 HARQ-ACK For HARQ-ACK transmission on PUSCH not using repetition type B with UL-SCH, the number of coded modulation symbols per layer for HARQ-ACK transmission, denoted as , is determined as follows:    …  For HARQ-ACK transmission on an actual repetition of a PUSCH with repetition Type B with UL-SCH, the number of coded modulation symbols per layer for HARQ-ACK transmission, denoted as , is determined as follows:  … 6.3.2.4.1.2 CSI part 1 For CSI part 1 transmission on PUSCH not using repetition type B with UL-SCH, the number of coded modulation symbols per layer for CSI part 1 transmission, denoted as , is determined as follows:    …  For CSI part 1 transmission on an actual repetition of a PUSCH with repetition Type B with UL-SCH, the number of coded modulation symbols per layer for CSI part 1 transmission, denoted as , is determined as follows: |

The current TS38.213 is not according to RAN1 agreements as UCI is multiplexed in only one repetition while is over repetitions. Scaling by may make it more aligned to the intended behaviour. Samsung [15] is suggesting the correction as part of the Rel-17 coverage enhancements.

One discussion point would be whether or not the maximum value of 126 in current specification provide sufficient reliability of UCI on a PUSCH repetition.

**Initial FL proposal #2-11**

* Discuss first if Issue#2-11 is discussed in this AI.

### Issue#2-12: Other issues

According to contributions for RAN1#105-e, NICT/TOYOTA are proposing that additional methods may be necessary, because applications require low latency. However, any specific methods have not been provided. Therefore, the proponents are asked to provide more details on what methods they have in mind.

# First round discussion

## Issues for the 1st round discussion

### [Open] Issue#1-1: The maximum number of repeitions

According to the contributions for RAN1#105-e, there is almost nothing newly added to the discussions, compared to what we had in RAN1#104-e. The large majority is still thinking that 32 is a reasonable value for the maximum number of repetitions. Moreover, even if 32 is adopted, the network may still have a choice to configure a smaller value, such as 20 or 24, depending on the outcomes from Issue#1-3. Considering these observations, it is suggested taking 32 as the maximum number of repetitions for Rel-17 PUSCH repetition Type A.

**Initial FL proposal #1-1**

* The maximum number of repetitions supported by Rel-17 PUSCH repetition Type A is 32.

Companies are asked if the above proposal #1-1 is acceptable.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Qualcomm | Support. |
| Intel | We are fine with the proposal. |
| China Telecom | We support this proposal. |
| ZTE | Support |
| vivo | Support |
| Samsung | OK with proposal |
| Apple | Support |
| Ericsson | Although 20 is enough in our view, we’re fine to support up to 32 repetitions counted based on physical slots which should also be reflected in the proposal.  Given above, we propose following updates to the FL proposal to reflect the fact that we’re talking about Type A PUSCH repetition enhancement with increasing the number of repetitions counted based on physical slots:  **Initial FL proposal #1-1**   * The maximum number of repetitions counted based on physical slots and supported by Rel-17 PUSCH repetition Type A is 32. |

### [Open] Issue#1-2: RRC parameters to be extended for supporting the increased maximam number

As described in section 2.1.2, companies have different views on whether or not repetition factor configured in *PUSCH-Config* and/or *ConfiguredGrantConfig* supports the increased maximum number of repetitions. Therefore, it is suggested having more discussions on whether to support this function.

**Initial FL proposal #1-2**

* Discuss if repetition factor configured in *PUSCH-Config* and/or *ConfiguredGrantConfig* supports the increased maximum number of repetitions.

Companies are invited to provide their views/justifications on whether or not repetition factor configured in *PUSCH-Config* and/or *ConfiguredGrantConfig* supports the increased maximum number of repetitions.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Qualcomm | Support. We are okay to not update these parameters. Updating the TDRA tables seems sufficient. |
| Intel | We think repetition factor configured in PUSCH-Config and/or ConfiguredGrantConfig should support the increased maximum number of repetitions.  When UE is not configured with number of repetitions in the TDRA table, UE needs to follow the pusch-AggregationFactor configured in PUSCH-Config. In this case, sufficient number of repetitions for PUSCH can still be possible, which can help meet the coverage enhancement target. This also applies for repK in ConfiguredGrantConfig |
| China Telecom | Agree with Intel. Repetition factor configured in PUSCH-Config and/or ConfiguredGrantConfig should support the increased maximum number of repetitions. |
| ZTE | Similar as Rel-16 URLLC enhancement, increasing the repetition factor in TDRA table is sufficient. |
| vivo | Extension on *numberOfRepetitions* is sufficient, which can be applied to both dynamic grant and configured grant. |
| Samsung | Coverage issues can exist also with configured transmissions. It is fine to increase the number of repetitions for the above parameters. |
| Apple | Repetition indication in the TDRAT table provide full flexibility and is enough. |
| Ericsson | Supporting the further increased number of repetitions in TDRA list is enough in Rel-17, following the same logic as we enhanced type A PUSCH repetition in Rel-16.  Dedicated TDRA list is already flexible enough, there’s no need to increase the repetitions indicated in semi-static signalling. |

### [Pending] Issue#1-3: Other candidate value set for configuration of the number of repetitions

Issue#1-3 will be discussed after concluding the discussion on Issue#1-1.

### [Open] Issue#1-4: Other issues

Companies are invited to provide other issues to be discussed in this meeting, if any, for the increase of the maximum number of repetitions.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| XXX |  |
|  |  |

### [Open] Issue#2-1: Use of dynamic signaling for the detemination of available slots

For the determination of available slots, the following three alternatives have been proposed. Alt 1 and Alt 2 was captured in the agreement in RAN1#104, and Alt 3 is a sub-option of Alt-2 considering Issue#2-4.

* Alt 1: The determination of available slots does not depend on any dynamic signaling.
* Alt 2: The determination of available slots depends on dynamic signaling including e.g., dynamic SFI.
* Alt 3: The determination of available slots depends on dynamic signaling in the scheduling DCI only.

According to the contributions for RAN1#105-e, Alt 1 now has more supports than in the previous meeting. Also, many companies pointed that Alt 2 has the problem that UE and gNB may have different understanding on available slots.

**Initial FL proposal #2-1**

* The determination of available slots does not depend on any dynamic signaling. (i.e. Taking Alt 1 of the previous agreement)

Companies are invited to provide their views on the above proposal #2-1. If still prefer Alt 2, also provide the views on the mis-alignment issue.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Qualcomm | Support. Relying on dynamic signaling is likely to make the system less robust. |
| Intel | We are fine with the proposal.  The major concern for Alt. 2/3 is the potential misalignment between gNB and UE on the PUSCH repetition, which may create some interference in the network. |
| China Telecom | We support this proposal. |
| ZTE | Do not support. We think at least dynamic SFI should be considered for determining available slots.  In Rel-15/16, when dynamic SFI is configured, there is no ambiguity on the number of repetitions between gNB and UE, regardless of the SFI is detected or not. Because, for DG PUSCH, it can be transmitted on UL symbols or semi-static flexible symbols, and no conflict between dynamic grant and SFI is expected on the flexible symbols. For CG PUSCH, the UE will not transmit on flexible symbols, and therefore there is no conflicts with SFI. So, could any proponent of this proposal could clarify in which case there is ambiguity on the number of repetitions between gNB and UE if dynamic SFI is considered?  We have no strong view on other dynamic signaling. |
| vivo | Support.  The available slots should be determined based on semi-static configurations only, dynamic signaling should not be considered, otherwise, NW and UE would have ambiguity on the resources used for PUSCH repetitions. |
| Samsung | Do not support.  If dynamic signaling does not work, Rel-15 and Rel-16 do not work. The issues from a potential miss of dynamic signaling are identical. No support of dynamic signaling means that Rel-17 coverage enhancements cannot coexist with deployment of basic NR features. Legacy behavior is also modified which makes no sense for a network. Moreover, the reasons for proposing that restriction are unclear. |
| Apple | We support this proposal. |
| Ericsson | Fine with the proposal to only consider semi-static TDD configuration for available slot determination, and whether a Type A PUSCH can be actually transmitted on the available slot can be based on rules related to SFI/CI/priority handling etc. same as legacy.  Regarding the misalignment between gNB and UE on the SFI signaling, in our understanding,   * For CG PUSCH, when dynamic SFI is receive, it can be only transmitted on uplink symbols   + meaning that SFI needs to change flexible symbols to be uplink, if this SFI is mis-detected, then CG PUSCH may be not transmitted/counted, but gNB may assume it will be transmitted/counted, then the issue happens. * For DG PUSCH, when dynamic SFI is received, it can be transmitted on both flexible and uplink symbols   + There should be no mis-alignment issue since gNB will never transmit an SFI to change a set of flexible symbols to be downlink for DG PUSCH, and even if an SFI to change flexible symbols to be uplink symbols for DG PUSCH transmission is mis-detected, DG PUSCH can still be transmitted on the set of flexible symbols |

### [Open] Issue#2-2: RV Cycle

Based on the proposals in contributions for this meeting, it is suggested discussing the following proposal as a starting point.

**Initial FL proposal #2-2**

* RV cycling is based on *rvid* indicated by the DCI scheduling the PUSCH and the indexing of *n* within *K* transmission occasions (may be in *K* non-contiguous slots) which are determined by only RRC configurations, where *K* is the indicated/configured repetition factor.

Companies are invited to provide their views on the above proposal#2-2.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Qualcomm | Not too sure if any changes are necessary. The spec is already clear and says that the RV index is updated for each transmission occasion. Once available slots are determined, the transmission occasions are determined as well. |
| Intel | Our view is that we can simply follow the existing spec for RV cycling. The only difference may be determination of K. However, if we agree to use RRC configuration to determine available UL slots for repetition type A, it seems we do not need to change the spec. |
| ZTE | Similar understanding as Qualcomm. |
| vivo | Agree with Qualcomm. |
| Samsung | The RV is intended for an actual transmission. It should be same as legacy. |
| Apple | Agree with Qualcomm. |
| Ericsson | Considering available slot is introduced in Rel-17, it’s enough to have a proposal:   * RV cycling is based on available slot for the Type A PUSCH repetition enhancement with repetitions counted based on available slot in Rel-17   Note that in legacy, the RV is cycled on slots determined without any misunderstanding between UE and gNB so that the RV pattern is aligned between gNB and UE side. |

### [Open] Issue#2-3: Inter-Slot Frequency Hopping Cycle

Similar to Issue#2-2, it is suggested discussing the following proposal as a starting point.

**Initial FL proposal #2-3**

* For inter-slot frequency hopping, hop index is derived based on the indexing of *n* within *K* transmission occasions (may be in *K* non-contiguous slots) which are determined by only RRC configurations, where *K* is the indicated/configured repetition factor.

Companies are invited to provide their views on the above proposal#2-3.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Intel | Our view is that we can simply follow the existing spec for inter-slot frequency hopping. The only difference may be determination of K. However, if we agree to use RRC configuration to determine available UL slots for repetition type A, it seems we do not need to change the spec. |
| ZTE | It’s not clear why any change is needed. The issue (potential uneven distribution of hops in TDD system) exists in Rel-15/16, the proposed enhancement may not be able to provide clear performance gain. In addition, inter-slot FH with inter-slot bundling is discussing in AI 8.8.1.3. It’s better to wait for the design there. |
| Apple | We don’t see the necessity to change the spec. |
| Ericsson | For Type A PUSCH repetition, start PRB of a hop is determined based on slot index, which can be reused by enhanced Type A PUSCH repetition in Rel-17 in our view, no specification change is needed.  For joint channel estimation, we may need to determine different FH patterns, e.g. change startPRB every N slots. However, these should be discussed in 8.8.1.3 as is also pointed out by ZTE. |

### [Open] Issue#2-4: Timeline aspect for the detemination of available slots

The following two alternative were listed in the conclusion from RAN1#104-e.

* Alt-a: The determination of all the available slots has to be done prior to the first actual transmission of the repetitions.
* Alt-b: The determination of all the available slots does not have to be done prior to the first actual transmission of the repetitions. The timeline requirement is per repetition basis.

If Alt 1 in Issue#2-1 is agreed as suggested in FL proposal #2-1, there is no need to discuss this issue, since Alt 1 automatically leads to Alt-a.

**Initial FL proposal #2-4**

* The determination of all the available slots has to be done prior to the first actual transmission of the repetitions. (i.e. Take Alt-a of the previous conclusion)

At the same time, exchanging views on the following points may help the progress of Issue#2-1 discussion. Therefore, companies are invited to provide their views on the following points:

* Reasons to propose Alt-a
  + It enables cross-slot channel estimation/DMRS bundling.
  + It simplifies UE implementation as it does not require recounting.
  + Alt-a also simplifies hopping determination.
* Reasons to propose Alt-b
  + Alt-b reuses Rel-15/16 PUSCH omission mechanism (i.e. per-slot based timeline requirements).

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Qualcomm | Support. Adding to the two reasons the FL has already captured, here is one more reason: asking the UE to perform a check for every slot makes the system error prone --- one instance of misunderstanding between UE and gNB derails entire sequence of transmissions since RV indexing then goes out of sync.  Its good to keep in mind that we are designing for a cell-edge UE, so the issue of UE missing DCIs could occur more frequently. |
| Intel | We are fine with the proposal. |
| China Telecom | We support this proposal. |
| ZTE | It depends on the outcome of issue#2-1.  If the available slot is only determined by RRC configuration and SFI, we are fine with the proposal. Note that, as we commented above, dynamic SFI would not cause any ambiguity, and the collision between SFI and PUSCH transmission is not expected to happen based on current specification.  If the available slot can also be affected by other dynamic signalling, e.g., UL CI or high priority PUCCH, Alt-b is preferred as it can relieve gNB scheduling restriction. We want to highlight that this also depends on the outcome of Issue#2-9. |
| vivo | Support the FL proposal |
| Samsung | This proposal is not needed and is not agreeable.  Rel-15 and Rel-16 already implement Alt-b (e.g. for PUCCH repetitions or for cancellations of repetitions). There is obviously no issue with UE complexity. There is also no relevance to cross-slot channel estimation (it is either possible if a repetition is not dropped, or not possible otherwise) and hopping determination can be based on the number of physical slots for either Alt-a or Alt-b (no difference). |
| Apple | Support this proposal. The Alt-a could avoid the misalignment on repetitions between gNB and UE. |
| Ericsson | Fine with the proposal.  As we comment on issue 2-3, for hopping determination, we can reuse what we have in Rel-16 for startPRB determination for Type A PUSCH repetition, no specification change is needed. |

### [Open] Issue#2-5: Semi-static configurations to be used for the detemination of available slots

Base on the analysis in section 2.2.5, the following proposals were made.

**Initial FL proposal #2-5**

* *ssb-PositionsInBurst* (i.e. SSB configuration) is used for determination of available slots. Flexible symbol(s) for the reception of SSB is determined as unavailable.

Companies are asked if the above proposal #2-5 is agreeable, and also encouraged to provide their views on use of the following RRC configurations for determination of available slots:

* + SSB based measurement by SMTC
  + CORESET0 with Type0-PDCCH CSS set
  + Invalid UL symbols for DL-to-UL switching purpose
  + Other CG-PUSCH with larger priority index
  + PUCCH with larger priority index carrying HARQ-ACK for SPS
  + Semi-static PUCCH with repetition

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Qualcomm | Support. We can also add CORESET0 to the list. Others don’t seem critical. |
| Intel | We think on top of SSB transmission, we also need to consider CORESET0 with Type0-PDCCH CSS set and invalid UL symbols for DL-to-UL switching purpose to ensure that UE has sufficient number of symbols for each repetition. |
| ZTE | Support the proposal.  We think the last two bullets in the list can be considered also. |
| vivo | For RRM measurement based on SSB, SMTC can be configured for UE to determine the measurement resource. The SMTC configuration is provided per frequency layer, which may cover SSB occasions from multiple serving cells in the frequency layer. Hence, the SSB occasions configured by SMTC configuration is not necessary the same as the SSBs indicated by *ssb-PositionsInBurst* for the serving cell*.* As shown in the following figure, the serving cell only transmit SSB#0, and symbols for SSB#1 is not configured with SSB for serving cell. While SSB#1 is transmitted on the neighbouring cell in the same frequency layer, UE can not transmit PUSCH on these occasions.    As specified in 38.133, on the SSB symbols configured by SMTC in TDD bands, UE is not expected to transmit PUSCH.   |  | | --- | | 9.2.5.3.1 Scheduling availability of UE performing measurements in TDD bands on FR1  When the UE performs intra-frequency measurements in a TDD band, the following restrictions apply due to SS-RSRP or SS-SINR measurement  - The UE is not expected to transmit PUCCH/PUSCH/SRS on SSB symbols to be measured, and on 1 data symbol before each consecutive SSB symbols to be measured and 1 data symbol after each consecutive SSB symbols to be measured within SMTC window duration. If the high layer in TS 38.331 [2] signalling of *smtc2*is configured, the SMTC periodicityfollows *smtc2*; Otherwise SMTC periodicity follows *smtc1.*  When the UE performs intra-frequency measurements in a TDD band, the following restrictions apply due to SS-RSRQ measurement  - The UE is not expected to transmit PUCCH/PUSCH/SRS on SSB symbols to be measured, RSSI measurement symbols, and on 1 data symbol before each consecutive SSB to be measured/RSSI symbols and 1 data symbol after each consecutive SSB to be measured/RSSI symbols within SMTC window duration. If the high layer signalling of *smtc2*is configured in TS 38.331 [2], the SMTC periodicityfollows *smtc2*; Otherwise the SMTC periodicity follows *smtc1.* |   Both NW and UE are aware of the SMTC configurations, there is no ambiguity if these symbols are counted as not available.  Hence, the flexible symbols configured with the SSB measurement by SMTC is not considered as available for type-A PUSCH repetition. |
| Samsung | Support. Also OK with CORESET#0. |
| Ericsson | Not necessary.  Available slot determination based on the semi-static TDD-UL-DL configuration is simply enough in our view. We do not have to associate the availability of a slot with all legacy omission rules used to determine whether a PUSCH should be transmitted since the omission rules can be further applied on the determined available slots anyway.  For example, following rules with respect to the collision between SSB and other uplink channels in current spec. is enough and there’s no need to use these rules to determine available slots:   |  | | --- | | For operation on a single carrier in unpaired spectrum, for a set of symbols of a slot indicated to a UE by *ssb-PositionsInBurst* in *SIB1* or *ssb-PositionsInBurst* in *ServingCellConfigCommon*, for reception of SS/PBCH blocks, the UE does not transmit PUSCH, PUCCH, PRACH in the slot if a transmission would overlap with any symbol from the set of symbols and the UE does not transmit SRS in the set of symbols of the slot. The UE does not expect the set of symbols of the slot to be indicated as uplink by *tdd-UL-DL-ConfigurationCommon*, or *tdd-UL-DL-ConfigurationDedicated*, when provided to the UE.  If a UE  - is configured with multiple serving cells and is provided *half-duplex-behavior* = 'enable', and  - is not capable of simultaneous transmission and reception on any of the multiple serving cells, and  - indicates support of capability for half-duplex operation in CA with unpaired spectrum, and  - is not configured to monitor PDCCH for detection of DCI format 2\_0 on any of the multiple serving cells,  for a set of symbols of a slot that are indicated to the UE for reception of SS/PBCH blocks in any of multiple serving cells by *ssb-PositionsInBurst* in *SystemInformationBlockType1* or by *ssb-PositionsInBurst* in *ServingCellConfigCommon*, when provided to the UE, the UE does not transmit PUSCH, PUCCH, or PRACH in the slot if a transmission would overlap with any symbol from the set of symbols, and the UE does not transmit SRS in the set of symbols of the slot in any of multiple serving cells. | |

### [Open] Issue#2-6: Special slot handling

According to the contributions for RAN1#105-e, only one company prefer having an exception that use of special slots does not require all the symbols indicated by TDRA to be valid for UL transmissions, although in RAN1#104-e more companies were in favor of it. Considering the situation, it is suggested checking if the following proposal is acceptable.

**Initial FL proposal #2-6**

* For defining available slots: a special slot is determined as unavailable if at least one of the symbols indicated by TDRA for a PUSCH in the special slot overlaps with the symbol not intended for UL transmissions.

Companies are asked if the above proposal #2-6 is acceptable.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Qualcomm | This discussion seems unnecessary. We already have an agreement that says in each available slot, all symbols needed for one repetition must be available. |
| Intel | It is not clear to why we need to discuss this proposal. In the RAN1#104-e meeting, it was agreed   * For defining available slots: a slot is determined as unavailable if at least one of the symbols indicated by TDRA for a PUSCH in the slot overlaps with the symbol not intended for UL transmissions   This agreement also covered all the slots, including special slots. We do not think we need to discuss this proposal. |
| China Telecom | As pointed out by FL in section 2.2.6, the use of special slots should be clarified based on the FFS in the following agreements.  Agreements:  For defining available slots: a slot is determined as unavailable if at least one of the symbols indicated by TDRA for a PUSCH in the slot overlaps with the symbol not intended for UL transmissions.   * FFS details   In our understanding, FL proposal #2-6 cannot make full use of special slots. TDRA should be separately indicated for special slots. |
| ZTE | Agree with Qualcomm and Intel. |
| vivo | Agree with Qualcomm and Intel. |
| Samsung | We assume that the existing agreement applies to any slot. |
| Apple | Agree with Qualcomm and Intel. |
| Ericsson | No need to discuss this, the agreement is clear as pointed out by Intel. |

### [Pending] Issue#2-7: Limitation of overall duration of PUSCH repetitions

Issue#2-7 will be discussed after concluding the discussion on Issue#2-1.

### [Open] Issue#2-8: Enhancements on PUSCH dropping

Since not many views have been provided in terms of enhancements on PUSCH dropping, it is suggested collecting companies’ views on the necessity of any new collision handling with other UL transmissions.

**Initial FL proposal #2-8**

* Discuss further:
  + Necessity of collision handling between PUSCH repetition Type A and the other UL transmissions, e.g. SPS HARQ-ACK, SRS
  + How to handle the collision, if any, e.g.
    - Dropping whole part of either PUSCH repetition or the colliding UL transmission
    - Partially dropping either PUSCH repetition or the colliding UL transmission

Companies are invited to provide their views on the above proposal #2-9.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Qualcomm | Don’t see any need to revise the existing rules. |
| Intel | Our view is that for repetition type A, we can simply follow existing collision handling rule after determination of available UL slots. We do not need additional rules to handle this. |
| ZTE | Share with Qualcomm and Intel, the motivation to revise the existing rules is unclear to us. |
| vivo | Agree with Qualcomm and intel. |
| Samsung | Changes of Rel-15/16 collision rules with other UL transmissions may depend on other proposals. We can revisit this proposal later. Overall we prefer to maintain the same Rel-15/16 overlapping rules. |
| Apple | Agree with Qualcomm and intel. |
| Ericsson | Collision handling may be needed between the enhanced Type A PUSCH repetitions and other UL channels introduced in Rel-17, e.g. enhancements of SPS HARQ-ACK, A-SRS are discussed in NR IIoT and URLLC WI and FeMIMO WI respectively.  Priorities should be defined among these channels though we agree that the existing priority handling mechanisms in Rel-16 should be used for the collision handling in Rel-17. |

### [Open] Issue#2-9: Enhancement on UCI multiplexing on PUSCH repetition

Based on the analysis described in section 2.2.9, the following proposal is made.

**Initial FL proposal #2-9**

* Discuss further whether/how HARQ-ACK multiplexing on PUSCH repetitions can be allowed if HARQ-ACK for the scheduling DCI comes after the UL grant of the PUSCH repetition transmission, taking the following options into account.
  + Option 1: HARQ-ACK bits for later DL assignments puncture the PUSCH repetition.
  + Option 2: When HARQ-ACK bits for the DL assignments later than UL grant is received, PUCCH with HARQ-ACK is transmitted and the PUSCH repetition is dropped or postponed.
  + Option 3: The time restriction on scheduling HARQ after UL grant is only applied to initial PUSCH repetition, and HARQ information bits corresponding to the PDSCH(s) scheduled after UL grant which triggers the PUSCH transmission are allowed to be multiplexed on the non-initial repetitions, where DAI in the last DCI applies.

Companies are invited to provide their views on whether/how HARQ-ACK multiplexing on PUSCH repetitions can be allowed if HARQ-ACK for the scheduling DCI comes after the UL grant of the PUSCH repetition transmission, taking the following options into account.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Qualcomm | Prefer to let this be discussed under R17-TEI. This seems out of scope of this sub-agenda. |
| Intel | We do not think we need to discuss this issue here. It is out of scope for enhancement on repetition type A. |
| ZTE | Propose to postpone the discussion considering this is discussing in Rel-17 TEI. |
| vivo | Generally, support this proposal.  Suggest to discuss under this Coverage Enh AI, and this issue becomes more important because the DL scheduling would be even restrictive if the number of repetitions is extended or the repetition is counted based on available slots, which is also enhanced under this AI.  For the UCI multiplexing on initial PUSCH repetition, the legacy timeline restriction can be reused. While for the later repetitions, the UCI can be multiplexed to the PUSCH by puncturing some PUSCH symbols, thus UE does not need to re-generate the PUSCH due to the UCI multiplexing. |
| Samsung | Option 3 for PUCCH without repetitions.  Option 2 for PUCCH with repetitions (that is Rel-15 behavior – no agreement needed). |
| Apple | Agree with others, this enhancement is out of scope of WID. |
| Ericsson | This seems not related to the Type A PUSCH repetition. |

### [Open] Issue#2-10: Configuration/indication of CovEnh functions

Although this issue is higher related to the UE features that should be discussed under a dedicated agenda item later, it is good to exchange companies’ views on it in order to have better understanding among companies on their proposed designs.

**Initial FL proposal #2-10**

* Discuss further the following options, in terms of configurations/indications of two enhancements, i.e., (a) increase of the maximum number of repetitions and (b) the repetitions counted on the basis of available slots:
  + Option 1: The enhancement (a) is RRC-configurable. The enhancement (b) is a basic feature of CovEnh capability.
  + Option 2: A set of the enhancements (a) and (b) is RRC-configurable (i.e., configured together).
  + Option 3: Either enhancements (a) or (b) is RRC-configurable (i.e., not configured together).
  + Option 4: Either enhancements (a) or (b) or both is RRC-configurable.
  + Option 5: Either enhancements (a) or (b) is dynamically-indicated.

Companies are invited to provide their views on the above option2.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Qualcomm | Option (1) seems closest to our preference. Although its not clear what is meant by RRC configuration for enhancement (a).  Just to elaborate a bit, we think R17 should go with a single counting method. Hence (b) should be a basic feature of CovEnh capability and not need any further configuration.  Regarding (a) UE can indicate capability to support increase repetitions. Besides this nothing more seems necessary; DG/CG configs can take care of the rest. |
| Intel | We slightly prefer Option 3. We think these two features need to be configurable, but they can be independent feature.  For instance, if we increase the maximum number of repetition level, we do not see the need to transmit PUSCH repetition type A based on available UL slots. |
| China Telecom | Two enhancements in Rel-17 are independent to each other. UE can be configured both or one of them subject to UE capability. |
| ZTE | Option 4 is preferred, and we are also fine with Option 1. |
| vivo | Prefer option 3.  Enabling both features simultaneously seems not necessary. |
| Samsung | Option 1 or Option 3. |
| Apple | Option 3 is preferred. If the maximum repetition is the same for (a) and (b), configuring both doesn’t make sense, configuring (b) is enough. |
| Ericsson | Option 3. No need to have the increased number of repetitions counted based on available slots. |
|  |  |

### [Open] Issue#2-11: Modification on

Since this issues was newly raised for this meeting, it is suggested discussing first if this issue is to be discussed in this AI.

**Initial FL proposal #2-11**

* Discuss first if Issue#2-11 is discussed in this AI.

Companies are invited to provide their views on whether to discuss modification of. If yes, also provide views on the following proposal in [15]:

* Scaling by so as to make it more aligned to the originally intended behaviour, where N is the number of repetitions.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Qualcomm | Seems out of scope. |
| Intel | We do not think this is needed. |
| ZTE | This is out of scope, and it could be discussed as Rel-17 TEI if needed. |
| Samsung | The issue directly relates to aspects of PUSCH repetitions (UCI multiplexing). Open to suggestions for a more appropriate AI than this one. |
| Apple | This is out of scope of WID. |
| Ericsson | No need to discuss this in this aganda. |

### [Open] Issue#2-12: Other issues

Companies are invited to provide other issues to be discussed in this meeting, if any, for the repetitions counted on the basis of available slots for UL transmissions.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| XXX |  |
|  |  |

## Summary of the 1st round discussion

*To be updated*

# Second round discussion

## Issues for the 2nd round discussion

*To be updated*

## Summary of the 2nd round discussion

*To be updated*

# References

1. R1-2104240 Discussion on coverage enhancements for PUSCH repetition type A Huawei, HiSilicon
2. R1-2104291 Discussion on enhancements on PUSCH repetition Type A for low latency requirement NICT, TOYOTA MOTOR CORPORATION
3. R1-2104330 Discussion on enhanced PUSCH repetition type A ZTE
4. R1-2104376 Discussion on enhancement for PUSCH repetition type A vivo
5. R1-2104537 Discussion on enhancements on PUSCH repetition type A CATT
6. R1-2104625 Discussion on enhancements on PUSCH repetition type A CMCC
7. R1-2104685 Enhancements on PUSCH Repetition Type A Qualcomm Incorporated
8. R1-2104792 Enhancements on PUSCH repetition type A OPPO
9. R1-2104846 Enhancements on PUSCH repetition type A China Telecom
10. R1-2104859 Type-A PUSCH repetition for coverage enhancement InterDigital, Inc.
11. R1-2104919 Enhancements on PUSCH repetition type A Intel Corporation
12. R1-2105119 Discussion on PUSCH repetition type A enhancement Apple
13. R1-2105146 Discussion on enhancements on PUSCH repetition Type A Panasonic Corporation
14. R1-2105255 Discussion on PUSCH repetition type A NEC
15. R1-2105325 Enhancements on PUSCH repetition type A Samsung
16. R1-2105488 Discussions on PUSCH repetition type A enhancements LG Electronics
17. R1-2105511 Design considerations for PUSCH repetition Type A Enhancements Sierra Wireless, S.A.
18. R1-2105575 Enhancements on PUSCH repetition type A Xiaomi
19. R1-2105640 Enhancements on PUSCH repetition type A Sharp
20. R1-2105652 PUSCH Repetition Type A Enhancement Ericsson
21. R1-2105711 Enhancement on PUSCH repetition type A NTT DOCOMO, INC.
22. R1-2105773 Enhancements on PUSCH repetition type A Lenovo, Motorola Mobility
23. R1-2105877 Discussion on enhancements on PUSCH repetition type A WILUS Inc.
24. R1-2105901 Enhancements on PUSCH repetition type A Nokia, Nokia Shanghai Bell

# List of agreements

## Agreements in RAN1#104-e

Agreements:

Select one of the following alternatives, considering the aspect whether or not the determination of all the available slots should be done prior to the first actual transmission of the repetitions (other alternatives are not precluded)

-        Alt1: Whether or not a slot is determined as available for UL transmissions depends on RRC configurations (at least tdd\_ul\_dl configuration, FFS: other RRC configurations) and does not depend on dynamic signaling (at least SFI, FFS: other dynamic signaling e.g. CI, PUSCH priority for URLLC).

-        Alt2: Whether or not a slot is determined as available for UL transmissions depends on RRC configurations (at least tdd\_ul\_dl configuration, FFS: other RRC configurations) and also depends on dynamic signaling (at least SFI, FFS: other dynamic signaling e.g. CI, PUSCH priority for URLLC).

Agreements:

The maximum number of repetitions for DG-PUSCH is also applicable to CG-PUSCH.

Agreements:

For defining available slots: a slot is determined as unavailable if at least one of the symbols indicated by TDRA for a PUSCH in the slot overlaps with the symbol not intended for UL transmissions

* FFS details

Agreements:

Rel-17 PUSCH repetition Type A supports the increase of maximum number of repetitions with repetition factors configured in a TDRA list with a row index indicated either by the configured grant configuration or by TDRA field in a DCI.

* FFS: increasing the maximum number of repetitions with repetition factor configured in *PUSCH-Config* and/or *ConfiguredGrantConfig*.

**Conclusion:**

Discuss further to select one of the following alternatives:

* Alt-a: The determination of all the available slots has to be done prior to the first actual transmission of the repetitions.
* Alt-b: The determination of all the available slots does not have to be done prior to the first actual transmission of the repetitions. The timeline requirement is per repetition basis.

## Agreements in RAN1#105-e