3GPP TSG RAN WG1 #104-e R1-210xxxx

e-Meeting, January 25th – February 5th, 2021

**Agenda item: 8.8.3**

**Title: Feature lead summary on support of Type A PUSCH repetitions for Msg3**

**Source: Moderator (ZTE Corporation)**

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

# Introduction

In RAN#90-e, a new WID on NR coverage enhancements was approved [1]. One objective of the WID is to specify mechanism(s) to support Type A PUSCH repetitions for Msg3.

This contribution provides a summary of proposed Msg3 enhancements in contributions submitted under AI 8.8.3 and AI 8.8.4.

# Summary of Tdocs

## Indication of the number of repetitions for Msg3

### **[H] Issue#1: Indication of the number of repetitions for Msg3 initial transmission**

For Msg3 initial transmission, it can be scheduled by RAR UL grant or fallbackRAR UL grant. Based on companies’ input, the following options are proposed for indication of the number of repetitions for Msg3 initial transmission.

* Option 1: MAC RAR or fallbackRAR
  + Support (17): [2, ZTE], [4, Huawei, HiSilicon], [5, CATT], [6, vivo], [8, Intel], [9, LG], [10, InterDigital], [11, China Telecom], [13, Panasonic], [14, CMCC], [15, ETRI], [16, Xiaomi], [17, Samsung], [18, Apple], [19, Qualcomm], [20, Ericsson], [22, NTT DOCOMO]
  + Note, Option 1 includes using the one reserved bit in MAC RAR/fallbackRAR and/or using RAR UL grant for indication.
  + [4, Huawei, HiSilicon], [15, ETRI], [16, Xiaomi] and [20, Ericsson] propose that the size of RAR UL grant used for Msg3 repetition indication shall be unchanged.
  + [6, vivo]: Mechanisms should be defined for UE to determine which RAR UL grant format to parse, if new UL grant format is introduced.
  + [2, ZTE], [10, InterDigital], [15, ETRI], [16, Xiaomi]: The TDRA field of the RAR UL grant indicates the number of repetitions for the initial transmission of msg3.
  + [16, Xiaomi]: Reuse the TPC field in UL grant of RAR to indicate the repetition number of Msg.3 initial transmission.
  + [2, ZTE], [22, NTT DOCOMO]: MAC RAR payload has one reserved bit, it may be possible to reuse the bit for the indication without changing the MAC structure.
* Option 2: DCI format 1\_0 with CRC scrambled by RA-RNTI
  + Support (3): [3, OPPO], [6, vivo], [11, China Telecom]
* Option 3: Implicit method, e.g, implicitly determined by PRACH configuration or information carried by RAR.
  + Support (2): [5, CATT], [ 12, NEC]?
* Option 4: SIB1 only
  + Support (4): [11, China Telecom], [14, CMCC], [17, Samsung], [20, Ericsson]

Regarding fallbackRAR, it is used for scheduling Msg3 in case of switching from 2-step RACH to 4-step RACH, which most possibly happens for cell-edge UEs. The Msg3 scheduled by fallbackRAR is also part of 4-step RACH, and it’s better to include here per FL understanding.

There is a clear majority on Option 1 and most companies supporting other options are also fine with Option 1. In addition, most companies prefer to use RAR UL grant instead of the one reserved bit in MAC RAR/fallbackRAR. Thus, FL suggest to focus on the following proposal.

**Proposal 1: The number of repetitions for Msg3 initial transmission is indicated by RAR UL grant or fallbackRAR UL grant.**

* **The size of RAR UL grant or fallbackRAR UL grant is unchanged.**
* **FFS the bit field for repetition indication.**

### **[H] Issue#2: Indication of the number of repetitions for Msg3 re-transmission**

For Msg3 re-transmission, it is scheduled by DCI format 0\_0 scrambled by TC-RNTI. Based on companies’ input, the following options are raised for indication of the number of repetitions for Msg3 re-transmission.

* Option 1: DCI format 0\_0 with CRC scrambled by TC-RNTI.
  + Support(11): [2, ZTE], [3, OPPO], [8, Intel], [9, LG], [10, InterDigital], [11, China Telecom], [16, Xiaomi], [18, Apple], [19, Qualcomm], [20, Ericsson], [22, NTT DOCOMO]
  + [4, Huawei, HiSilicon]: The size of DCI 0\_0 is strived to be unchanged when the repetition number of Msg3 PUSCH re-transmission is indicated by DCI*.*
  + [2, ZTE], [10, InterDigital][15, ETRI]: The TDRA field of DCI format 0\_0 with CRC scrambled by TC-RNTI indicates the number of repetitions for HARQ retransmission of msg3.
* Option 2: Implicit method. E.g., the repetition factor is implicitly determined by Msg3 initial transmission.
  + [5, CATT]

Based on above summary, FL suggests to discuss the following proposal.

**Proposal 2: The number of repetitions for Msg3 re-transmission is indicated by DCI format 0\_0 with CRC scrambled by TC-RNTI.**

* **The size of DCI format 0\_0 with CRC scrambled by TC-RNTI is unchanged.**
* **FFS the bit field for repetition indication.**

### **[M] Issue#3: Candidate values for Msg3 initial/re-transmission repetitions**

In Rel-16, the candidate values for the number of repetitions of PUSCH repetition Type A/B are copied as follows.

|  |
| --- |
| *numberOfRepetitions-r16 ENUMERATED {n1, n2, n3, n4, n7, n8, n12, n16}* |

The maximum number of repetitions would be further increased in Rel-17 as to be discussed in AI 8.8.1.1. For Msg3 repetition, the candidate values including the maximum number of repetitions should be discussed.

This issue is discussed in [3, OPPO], [4, Huawei, HiSilicon], [6, vivo], [7, SoftBank Corp], [ 12, NEC], [18, Apple], [21, Sharp].

* [4, Huawei, HiSilicon], [18, Apple]: The maximal repetition number up to 16 can be considered for Msg3 PUSCH repetition.
* [6, vivo]: The repetition numbers used for PUSCH repetition type A should be adopted as the baseline for the Msg3 repetition design, and the down selection of the repetition numbers should be studied further for the efficient indication.
* [7, SoftBank Corp]: Support at least 2 and 4 repetitions for Type A PUSCH repetitoins for Msg.3
* [12, NEC]: The number of repetition of Msg3 is suggested to be 2, 4, and 8.
* [21, Sharp]: Additional repetition factor on top of ones in Rel-16 should be considered (e.g., 5).

Based on above, FL suggest to discuss the following proposal.

**Proposal 3: The repetition factors used for PUSCH repetition type A in Rel-16 is adopted as the baseline for Msg3 repetition design.**

* **FFS potential down selection of the repetition factors or adding new repetition factor(s).**

## Frequency hopping related issues.

### **[H] Issue#4: Support of inter-slot frequency hopping**

In Rel-15/16, only intra-slot FH is supported for Msg3 transmission. Similar to regular PUSCH repetition, support of inter-slot FH for Msg3 repetition should be discussed.

There are totally 9 companies propose to support inter-slot FH for Msg3 repetition, including [2, ZTE], [4, Huawei, HiSilicon], [5, CATT], [13, Panasonic], [16, Xiaomi], [18, Apple] [19, Qualcomm], [20, Ericsson] and [22, NTT DOCOMO]. Some observations are summarized as follows.

* [2, ZTE]: Inter-slot FH for Msg3 could achieve frequency diversity gain without increasing the overall DMRS overhead and fragmenting the frequency resource allocation in each slot.
* [4, Huawei, HiSilicon]: The inter-slot frequency schemes discussed for PUSCH enhancements can be reused for Msg3 PUSCH, including inter-slot frequency hopping with inter-slot bundling
* [13, Panasonic]: It was observed that inter-slot frequency hopping can achieve an improvement of 0.5~0.8 dB gain compared to intra-slot frequency hopping.
* [20, Ericsson]: Inter-slot frequency hopping allows channel filtering (averaging) in time domain over a larger duration compared to intra-slot frequency hopping. Initial link level results show 1–2 dB gain from inter-slot hopping over two frequencies compared to repetition without FH.

Based on above, FL suggest to discuss the following proposal.

**Proposal 4: Support inter-slot frequency hopping for repetition of Msg3 initial and re-transmission.**

* **FFS details, e.g., signaling indication and support of inter-slot frequency hopping with inter-slot bundling etc.**

### **[M] Issue#5: Intra-slot frequency hopping for Msg3 repetition**

In Rel-15/16, intra-slot FH is supported for Msg3 transmission without repetition. If repetition is introduced, it needs to discuss whether intra-FH could be still supported, and the FH pattern if supported.

[16, Xiaomi] proposes that only inter-slot frequency hopping is supported for Msg.3 transmission with repetitions. On the other hand, [19, Qualcomm] believe intra-slot FH should be supported, and when intra-slot frequency hopping is configured, the UE assumes the same starting RB and the same frequency offset for Msg3 PUSCH repetitions within a transmission.

FL’s understanding is intra-slot FH is already supported in legacy. It would be natural to also support in Rel-17. In addition, if Msg3 repetition could be dynamically changed, it would be weird to enable or disable intra-slot FH dynamically depending on the number of repetitions. Note, for regular PUSCH, both intra-slot and inter-slot FH are supported. It could be applied to Msg3 as well. Based on above, FL suggests to discuss the following proposal.

**Proposal 5: Support intra-slot frequency hopping for repetition of Msg3 initial and re-transmission.**

* **When intra-slot frequency hopping is configured, the UE assumes the same starting RB and the same frequency offset for Msg3 PUSCH repetitions within a transmission.**

## RV pattern

### **[M] Issue#6: RV pattern for Msg3 repetition**

In NR Rel-15/16, a UE shall use RV0 for Msg3 initial transmission, and use the 2-bit RV bit field in DCI format 0\_0 scrambled by TC-RNTI for RV indication. If Msg3 repetition is enabled, it needs to further determine the RV pattern for repetitions.

In [2, ZTE], [3, OPPO], [5, CATT], [9, LG] and [19, Qualcomm], 5 companies provide views on this issue, where [2, ZTE] and [19, Qualcomm] raise more detailed proposals as follows.

* For RV pattern for repetition of Msg3 initial transmission,
  + [2, ZTE]: FFS whether to use a fixed or dynamically indicated RV for the first repetition of Msg3 initial transmission.
  + [19, Qualcomm]: An RV pattern is fixed in the specification (e.g., 0 2 3 1) for initial Msg3 repetition, the RV associated with the first repetition of the initial Msg3 transmission is the first RV of the RV pattern.
* For RV pattern for repetition of Msg3 re-transmission,
  + [2, ZTE], [19, Qualcomm]: The RV for each repetition of Msg3 re-transmission is based on a fixed RV cycling pattern (e.g., 0 2 3 1) with the RV index for the first repetition indicated by DCI format 0\_0 scrambled by TC-RNTI.

Given there are limited input for detailed solutions for this issue, FL suggests to first discuss the following proposal.

**Proposal 6: Further discuss the determination of RV pattern for Msg3 repetition, including the following aspects.**

* **FFS whether to use a fixed RV pattern, e.g., [0 2 3 1], for the repetition of Msg3 initial and re-transmission.**
* **FFS whether to use a fixed or dynamically indicated RV for the first repetition of Msg3 initial transmission**
* **The RV index for the first repetition of Msg3 re-transmission is indicated by the 2-bit RV bit field in DCI format 0\_0 scrambled by TC-RNTI.**

## Support of enhancements studied for PUSCH in RRC\_CONNECTED state for Msg3 PUSCH initial and re-transmission

According to the WI scope, the following enhancements are included for regular PUSCH enhancements. It needs to discuss whether these enhancements could be applied for Msg3 repetition or not.

|  |
| --- |
| * 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.   + Specify mechanism(s) to support TB processing over multi-slot PUSCH [RAN1]     - TBS determined based on multiple slots and transmitted over multiple slots.   + Specify mechanism(s) to enable joint channel estimation [RAN1, RAN4]     - Mechanism(s) to enable joint channel estimation over multiple PUSCH transmissions, based on the conditions to keep power consistency and phase continuity to be investigated and specified if necessary by RAN4 [RAN1, RAN4]       * Potential optimization of DMRS location/granularity in time domain is not precluded     - Inter-slot frequency hopping with inter-slot bundling to enable joint channel estimation [RAN1] |

Note that, regarding the maximum number of repetitions supported for Msg3 repetition, e.g., whether support increased number of repetitions compared to PUSCH repetition type A in Rel-16, it will be discussed under Issue#3.

### **[M] Issue#7: Support of the number of repetitions counted on the basis of available slots for Msg3 repetition.**

Based on companies’ input, the support of enhanced PUSCH repetition type A regarding the number of repetitions counted on the basis of available slots for Msg3 initial/re-transmission is summarized as follows.

* The number of repetitions is counted on the basis of available UL slots for Msg3 repetition.
  + Support: [2, ZTE], [3, OPPO], [8, Intel], [ 12, NEC], [14, CMCC], [25, CATT]

In addition, it needs to discuss whether the number of repetitions counted on the basis of consecutive UL slots should be also supported.

Based on above, FL suggests to discuss the following proposal.

**Proposal 7: The number of repetitions is counted on the basis of available UL slots for repetition of Msg3 initial and re-transmission.**

* **FFS on support of the number of repetitions counted on the basis of consecutive UL slots.**

### **[M] Issue#8: Support of TB processing over multi-slot PUSCH for Msg3**

Based on companies’ input, the support of TB processing over multi-slot PUSCH for Msg3 initial/re-transmission is summarized as follows.

* Support TB processing over multi-slot PUSCH for Msg3 repetition
  + Support: [3, OPPO],
  + Not support: [2, ZTE]
  + FFS: [25, CATT]

Considering the limited input, FL suggests to first discuss the following proposal.

**Proposal 8: FFS support of TB processing over multi-slot PUSCH for Msg3.**

### **[M] Issue#9: Support of joint channel estimation for Msg3 repetition**

Based on companies’ input, the support of joint channel estimation for Msg3 initial/re-transmission is summarized as follows.

* Support joint channel estimation for Msg3 repetition
  + Support: [2, ZTE], [3, OPPO], [8, Intel] , [9, LG]?, [14, CMCC], [25, CATT]
  + Note that, whether support inter-slot frequency hopping with inter-slot bundling could be further discussed after making decision on Proposal 4 and Proposal 9.

Some companies also provide evaluation results for joint channel estimation for Msg3 with the following observations.

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| [8, Intel]: For Msg3 PUSCH with 8 repetitions, ~1.6dB performance gain can be achieved by joint channel estimation and inter-slot frequency hopping with inter-slot bundling, compared to Rel-15 inter-slot frequency hopping without joint channel estimation.  [14, CMCC]: The joint channel estimation could bring additional 1.75dB coverage gain when 2 slot repetitions are considered.  [2, ZTE]: Cross-slot channel estimation among 4 Msg3 repetitions can provide about 1 dB gain. Inter-slot frequency hopping with inter-slot bundling to enable joint channel estimation per bundle can provide additional performance gain for Msg3 repetition. |

In addition, [17, Samsung] and [19, Qualcomm] also raise above issue and propose to further discuss.

Based on above, FL suggests to discuss the following proposal.

**Proposal 9: Support joint channel estimation for repetition of Msg3 initial and re-transmission.**

## Differentiation between CE UEs and legacy UEs

### **[H] Issue#10: Differentiation between CE UEs and legacy UEs**

In NR Rel-15/16, PUSCH repetition is not supported for Msg3. In Rel-17, for coverage enhancement (CE) UEs supporting Msg3 repetition, mechanism is needed to differentiate these Rel-17 CE UEs from legacy UEs during initial access. Then, gNB could identify CE UEs for corresponding signaling indication and link adaptation.

Based on companies’ input, two options are proposed and summarized as follows.

* For differentiation between legacy UEs and Rel-17 CE UEs supporting Msg3 enhancements,
  + Option 1: via PRACH transmission (e.g., via separate initial UL BWP, separate PRACH resource, or PRACH preamble)
    - Support: [2, ZTE], [4, Huawei, HiSilicon], [6, vivo], [8, Intel], [9, LG], [10, InterDigital], [11, China Telecom], [ 12, NEC], [13, Panasonic], [16, Xiaomi], [17, Samsung], [19, Qualcomm], [20, Ericsson], [21, Sharp], [22, NTT DOCOMO]
    - Not support: [5, CATT]
  + Option 2: via Msg3 transmission (e.g., via separate DMRS configuration or UCI multiplexing with Msg3 PUSCH)
    - [6, vivo], [17, Samsung], [19, Qualcomm], [20, Ericsson]
    - [26, vivo]: NW may decode MSG.3 PUSCH from multiple UEs, which have transmitted the same preamble on the same RO. It is beneficial to support contention resolution for multiple UEs simultaneously to reduce the access delay of CBRA procedure, if MSG.3 PUSCH repetition is supported.
    - [19, Qualcomm]: The UE indicates the recommended number of repetitions in UCI multiplexing with Msg3 PUSCH.

It seems majority companies understanding is Msg3 repetition scheduling is decided by gNB, and what UE needs to do is report whether it supports Msg3 repetition or not. However, [6, vivo], [9, LG], [ 12, NEC], [13, Panasonic], [19, Qualcomm] and [21, Sharp] also propose that UE decided/triggered Msg3 repetition can also be considered. Below is a summary of options proposed.

Option 1-1: gNB scheduled Msg3 repetition without UE request.

* + A UE reports support of Msg3 repetition via separate PRACH transmission.
  + For a UE supporting Msg3 repetition, gNB decides whether to schedule Msg3 repetition or not. If scheduled, gNB decides the number of repetitions.
    - It’s up to gNB implementation for decision, e.g., based on the detection of PRACH transmission.
  + *Pros: Simple solution since what needs UE do is to report the corresponding capability, and the scheduling of Msg3 is all up to gNB, and there is no need bind detection of Msg3 at gNB side.*
  + *Cons: Potential more RACH congestion*

Option 1-2: gNB scheduled Msg3 repetition without UE request.

* + gNB decides whether to schedule Msg3 repetition or not. If scheduled, gNB decides the number of repetitions.
    - It’s up to gNB implementation for decision, e.g., based on the detection of PRACH transmission.
  + If Msg3 repetition is scheduled, UE transmits Msg3 with or without repetition based on its capability, which will be indicated to gNB by Msg3 transmission (e.g., via separate DMRS configuration or UCI multiplexing with Msg3 PUSCH).
  + *Pros: Potential less RACH congestion.*
  + *Cons: It may cause gNB blind detection of Msg3 and may cause resource waste.*

Option 2: UE triggered Msg3 repetition with gNB indicating the number of repetitions

* + A UE can trigger RACH procedure with Msg3 repetition via separate PRACH transmission.
    - Whether a UE would trigger is based on some conditions, e.g., measured SS-RSRP threshold, which may or may not have spec impact.
  + If Msg3 repetition is triggered by UE, gNB decides the number of repetitions X (X>1) for Msg3 (re)-transmission.
  + *Pros: There is no need bind detection of Msg3 at gNB side.*
  + *Cons: Potential more RACH congestion.*

Option 3: UE decided Msg3 repetition.

* + A UE can trigger RACH procedure with Msg3 repetition and decide the number of Msg3 repetitions via separate PRACH transmission.
    - Whether a UE would trigger or how many repetitions to trigger is based on some conditions, e.g., measured SS-RSRP, which may or may not have spec impact.
  + *Pros: There is no need bind detection of Msg3 at gNB side.*
  + *Cons: More RACH congestion. Potential more spec efforts to define the conditions if any.*

For both Option 2 and Option 3, the UE may not trigger RACH procedure with Msg3 PUSCH repetition even the UE have the capability of supporting Msg3 repetition.

Based on the summary of Issue#1, implicitly determination of the number of repetitions for Msg3 initial transmission is not preferred by most of companies since it needs a large portion of PRACH sub-grouping. Therefore, FL suggests to focus on Option 1-1/1-2 and Option 2 above.

**Proposal 10: For triggering and scheduling of Msg3 repetition, down-select one option from the following options.**

**Option 1-1: gNB scheduled Msg3 repetition without UE request.**

* + **A UE reports support of Msg3 repetition via separate PRACH transmission.**
  + **For a UE supporting Msg3 repetition, gNB decides whether to schedule Msg3 repetition or not. If scheduled, gNB decides the number of repetitions.**
    - **It’s up to gNB implementation for decision, e.g., based on the detection of PRACH transmission.**

**Option 1-2: gNB scheduled Msg3 repetition without UE request.**

* + **gNB decides whether to schedule Msg3 repetition or not. If scheduled, gNB decides the number of repetitions.**
    - **It’s up to gNB implementation for decision, e.g., based on the detection of PRACH transmission.**
  + **If Msg3 repetition is scheduled, UE transmits Msg3 with or without repetition based on its capability, which will be indicated to gNB by Msg3 transmission (e.g., via separate DMRS configuration or UCI multiplexing with Msg3 PUSCH).** 
    - **Note: Bind detection of Msg3 repetition at gNB side is needed.**

**Option 2: UE triggered Msg3 repetition with gNB indicating the number of repetitions**

* + **A UE can trigger RACH procedure with Msg3 repetition via separate PRACH transmission.**
    - **Whether a UE would trigger is based on some conditions, e.g., measured SS-RSRP threshold, which may or may not have spec impact.**
  + **If Msg3 repetition is triggered by UE, gNB decides the number of repetitions X (X>1) for Msg3 (re)-transmission.**

## Start of Contention Resolution timer and PDCCH monitoring for Msg3 repetition

### **[M] Issue#11: Start of Contention Resolution timer and PDCCH monitoring for Msg3 repetition**

In Rel-15/16 RACH procedure, a UE starts the *ra-ContentionResolutionTimer* and restart the *ra-ContentionResolutionTimer* at each HARQ retransmission in the first symbol after the end of the Msg3 transmission. The UE shall monitor PDCCH for Contention Resolution while the *ra-ContentionResolutionTimer* is running. If Msg3 repetition is enabled, then it needs to discuss whether the *ra-ContentionResolutionTimer* can start or re-start after one repetition instead of after all repetitions.

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| --- |
| 5.1.5 Contention Resolution Once Msg3 is transmitted, the MAC entity shall:  1> start the *ra-ContentionResolutionTimer* and restart the *ra-ContentionResolutionTimer* at each HARQ retransmission in the first symbol after the end of the Msg3 transmission;  1> monitor the PDCCH while the *ra-ContentionResolutionTimer* is running regardless of the possible occurrence of a measurement gap;  1> if notification of a reception of a PDCCH transmission of the SpCell is received from lower layers:  ..... |
| *ra-ContentionResolutionTimer ENUMERATED { sf8, sf16, sf24, sf32, sf40, sf48, sf56, sf64}*  ***ra-ContentionResolutionTimer***  The initial value for the contention resolution timer (see TS 38.321 [3], clause 5.1.5). Value *sf8* corresponds to 8 subframes, value *sf16* corresponds to 16 subframes, and so on. |

[6, vivo], [ 12, NEC] and [17, Samsung] propose that the *ra-ContentionResolutionTimer*/PDCCH monitoring can start **before** the end of all repetition of Msg3, e.g., start after the first repetition of Msg3 transmission. The main benefits are summarized as follows:

* It is possible that gNB receives and decodes Msg3 PUSCH successfully and send PDSCH with UE contention resolution before the end of Msg3 repetition. Then, a quicker contention resolution response can be sent, i.e., a lower RACH procedure latency can be achieved.
* A UE could stop Msg3 repetition transmission if an early Contention Resolution is successful. Then, it could save the PUSCH resources by avoiding the unnecessary Msg3 repetition transmission.

An example from [6, vivo] is shown below.



Figure 1. Two candidate mechanism for Contention Resolution

FL understanding is that above advantages are valid and the potential spec impact seems minor. Therefore, FL suggests to discuss the following proposal.

**Proposal 11: Further discuss the following options for the start of Contention Resolution timer and PDCCH monitoring for Msg3 repetition**

* **Option 1: (Re-)start *ra-ContentionResolutionTimer* and PDCCH monitoring in the first symbol after the end of the all repetitions of Msg3 (re-)transmission**
* **Option 2: (Re-)start *ra-ContentionResolutionTimer* and PDCCH monitoring before the end of Msg3 (re-)transmission.**
* **FFS details**

## Other issues

### **[L] Issue#12: Spatial Domain Transmission Relation**

[17, Samsung]: The repetitions for the msg3 PUSCH transmission that is scheduled by RAR use the same beam (spatial setting) as the one for the corresponding PRACH transmission. On the other hand, the UE can select the beam for msg3 re-transmissions.

[27, Samsung]: Support UE to transmit multiple PRACH preambles over a RO bundle, with same or different spatial settings, prior to a RAR reception. Support use of CSI-RS measurements for a UE to select one or more spatial settings for PRACH transmissions. FL’s understanding is these proposals are out of WI scope.

[19, Qualcomm]: Consider one of the following options on spatial domain transmission relation for Msg3 PUSCH transmission:

* Option 1: The UE transmits the Msg3 PUSCH repetitions within a transmission (initial transmission or re-transmission) using the same spatial domain transmission relation.
* Option 2: The UE may transmit the Msg3 PUSCH repetitions within a transmission (initial transmission or re-transmission) using the different spatial domain transmission relations.

Based on the limited input, FL suggests to discuss the following questions first.

**Q-1 for Issue 12: Do you think the repetitions for Msg3 initial transmission should use the same beam (spatial setting) as the one for the corresponding PRACH transmission?**

**Q-2 for Issue 12: Do you think the beam for repetitions for Msg3 re-transmission can be up to UE implementation?**

**Q-3 for Issue 12: Do you think the UE could use different beams for different repetitions for Msg3 initial and re-transmission?**

### **[L] Issue#13: Support of qam64-LowSE MCS**

In [18, Apple]. it raises that qam64-LowSE MCS table provides more lower coding rate entries, it’s beneficial for small data transmission, such as the Msg3 56bit payload size. Therefore, it proposes that qam64-LowSE MCS table is considered for Msg3 PUSCH coverage enhancement.

Based on the limited input, FL suggests to discuss the following questions first.

**Q-1 for Issue 13: Do you think the qam64-LowSE MCS table can be supported for Msg3 repetition?**

### **[L] Issue#14: RedCap related issues**

In [2, ZTE] and [23, ZTE], it observes that Msg3 repetition based enhancements studied for CE UEs can all be applied for RedCap UEs, and no additional RedCap-specific enhancement is needed. In addition, no differentiation between Rel-17 CE UEs and Redcap UEs before Msg3 transmission can be considered.

* If differentiation between Rel-17 CE UEs and Redcap UEs before Msg3 transmission is needed. More separate PRACH configurations are required. This would need more specification efforts and may cause PRACH congestion. Since gNB may not know how many CE UEs and RedCap UEs are in the cell, using separate PRACH configurations may also potentially cause lower resource efficiency.
* In addition, the maximum initial BWP configured for CE UEs should not be larger than 20 MHz during initial access. Because the maximum supported UE bandwidth during initial access for RedCap UEs is 20 MHz, and gNB has to meet this requirement if it doesn’t know whether the accessing UE is a CE UE or RedCap UE. In our view, the physical channels during initial access basically requires very a few number of RBs and would not exceed 20MHz BW. In addition, the frequency selective fading within 20MHz is diverse enough to achieve sufficient diversity gain.

In [16, Xiaomi], it proposes that PRACH resource partition can be considered to indicate the coverage status for both normal UEs and reduced capability UEs. How to avoid too much PRACH resource fragment needs further study.

Though coverage recovery for RedCap UE will be further discussed in the next RAN meeting, it is also good to collect companies initial views on related aspects. Thus, FL suggests to discuss the following questions.

**Q-1 for Issue 14: Do you think Msg3 repetition based enhancements studied for Rel-17 CE UEs can all be applied for RedCap UEs, and no additional RedCap-specific enhancement is needed?**

**Q-2 for Issue 14: Do you think is there a need to differentiate between Rel-17 CE UEs and Redcap UEs before Msg3 transmission?**

# Discussion (1st round)

Regarding the Issue#01~11, the detailed summary is provided in Section 2. Companies are encouraged to first check the summary above, and then provide your input for these issues below.

### **[H] Issue#1: Indication of the number of repetitions for Msg3 initial transmission**

Proposal 1: The number of repetitions for Msg3 initial transmission is indicated by RAR UL grant or fallbackRAR UL grant.

* The size of RAR UL grant or fallbackRAR UL grant is unchanged.
* FFS the bit field for repetition indication.

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| **Company** | **Comments** |
| China Telecom | Generally support this proposal. Considering that the size of RAR UL grant should not be expanded, some of the current bit filed in RAR grant should then be reused to indicate Msg3 repetition factor. In our view, “PUSCH time resource allocation” field may be reused. |
| CATT | Although we are one of the proponents for explicit indication, there are some drawbacks, e.g. reuse the reserved bits defined in RAN2, re-parse some bit fields which may impact the performance of legacy UE, etc. The pros and cons are not fully discussed yet.  Considering this is the first meeting of the WI, we don’t need to preclude the potential solutions without necessary assessment. We propose to add a FFS point as ‘FFS the implicit mechanism’  Furthermore, the fallback RAR UL grant, it is only used for the two-step RACH, which is already precluded in the SI. It should be removed in the main bullet.  Based on the above comments, we proposed the following modified proposal:  Proposal 1: The number of repetitions for Msg3 initial transmission is indicated by RAR UL grant or fallbackRAR UL grant.   * The size of RAR UL grant or fallbackRAR UL grant is unchanged. * FFS the bit field for repetition indication. * FFS the implicit mechanism |
| NTT DOCOMO | We support unchanging the size of RAR UL grant. However, it is unclear how to indicate the number of repetitions with reserved 1 bit. We should specify how to indicate by RAR UL grant, before deciding that RAR UL grant is the number of repetition. |
| OPPO | Generally we are fine with this proposal, although option2 is our preference. The size of RAR UL grant should not be changed. Some of the current bit field in RAR UL grant can be used to indicate Msg3 repetition number. “Frequency resource allocation” filed can also be considered for the purpose. |
| Xiaomi | The number of repetitions for Msg3 initial transmission indicated by RAR UL grant is a good choice, which can provide an appropriate repetition number for a single UE.  The bit filed can reuse some existing fields, such as TPC, which will neither affect the scheduling, nor change the size of RAR UL grant to enable backward compatibility.  In addition, repetition number can also be merged into TDRA table and indicated by TDRA index in the RAR UL grant, just like the PUSCH repetition number indication mechanism in release 16. |

### **[H] Issue#2: Indication of the number of repetitions for Msg3 re-transmission**

Proposal 2: The number of repetitions for Msg3 re-transmission is indicated by DCI format 0\_0 with CRC scrambled by TC-RNTI.

* The size of DCI format 0\_0 with CRC scrambled by TC-RNTI is unchanged.
* FFS the bit field for repetition indication.

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| **Company** | **Comments** |
| China Telecom | Support this proposal. Bit field “Time domain resource assignment” can be used for repetition indication. |
| CATT | We don’t support the proposal.  The fundamental question is why we need to change the repetition number of a re-transmission. For a CE UE, the network should try to guarantee the performance of initial transmission, i.e. the repetition number of initial transmission should be suitable or even conservative. Even the initial transmission fails, gNB can achieve the link adaptation by FH, FDRA, TDRA, MCS and so on. Furthermore, the combination of initial transmission and re-transmission can further improve the coverage performance. From this perspective, transmit the Msg3 PUSCH re-transmission with the same repetition number as initial transmission is sufficient.  If the repetition number for Msg3 re-transmission is indicated by DCI format 0\_0, additional standard efforts are needed but the necessity is not justified. |
| NTT DOCOMO | We are fine with the FL’s proposal |
| OPPO | Support this proposal. How to indicate via DCI format 0\_0 can be further studied. |
| Xiaomi | Agree, since DCI format 0\_0 could provide more flexibility so that the network could adjust the number of repetitions for the retransmission based on the reception situation of the initial transmission. While for the detailed indication design, similar to the consideration in the indication in the initial transmission case, the TPC field can be reused as well. |

### **[M] Issue#3: Candidate values for Msg3 initial/re-transmission repetitions**

Proposal 3: The repetition factors used for PUSCH repetition type A in Rel-16 is adopted as the baseline for Msg3 repetition design.

* FFS potential down selection of the repetition factors or adding new repetition factor(s).

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| **Company** | **Comments** |
| China Telecom | Support this proposal. We think that the total number of repetition factors should be no larger than 4 (no larger than 4 kinds of repetition factors). |
| CATT | We are fine with the proposal. Maybe ‘baseline’ should be replaced by ‘starting point’? |
| OPPO | We are fine with the proposal. |
| Xiaomi | Redcap UE with 3 dB loss need more repetition numbers than normal UE, which should be taken into consideration for repetition factor determination if redcap UEs and normal UEs have the same coverage target. |

### **[H] Issue#4: Support of inter-slot frequency hopping**

Proposal 4: Support inter-slot frequency hopping for repetition of Msg3 initial and re-transmission.

* FFS details, e.g., signaling indication and support of inter-slot frequency hopping with inter-slot bundling etc.

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| **Company** | **Comments** |
| China Telecom | Support this proposal. |
| CATT | Support. |
| NTT DOCOMO | We are fine with the FL’s proposal |
| OPPO | Support |
| Xiaomi | Comparing with intra-slot frequency hopping, Inter-slot frequency hopping could achieve better channel estimation performance due to more RS can be utilized. Furthermore, in poor channel conditions, the overall performance is more susceptible to the channel estimation performance. Thus, in our opinion, only support inter-slot is sufficient for Msg.3 transmission with repetitions. |

### **[M] Issue#5: Intra-slot frequency hopping for Msg3 repetition**

Proposal 5: Support intra-slot frequency hopping for repetition of Msg3 initial and re-transmission.

* When intra-slot frequency hopping is configured, the UE assumes the same starting RB and the same frequency offset for Msg3 PUSCH repetitions within a transmission.

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| **Company** | **Comments** |
| China Telecom | Support this proposal. |
| CATT | Support |
| OPPO | Support |
| Xiaomi | Disagree. As our analysis in issue#4, only support inter-slot frequency hopping is sufficient for Msg.3 repetition. |

### **[M] Issue#6: RV pattern for Msg3 repetition**

Proposal 6: Further discuss the determination of RV pattern for Msg3 repetition, including the following aspects.

* FFS whether to use a fixed RV pattern, e.g., [0 2 3 1], for the repetition of Msg3 initial and re-transmission.
* FFS whether to use a fixed or dynamically indicated RV for the first repetition of Msg3 initial transmission
* The RV index for the first repetition of Msg3 re-transmission is indicated by the 2-bit RV bit field in DCI format 0\_0 scrambled by TC-RNTI.

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| **Company** | **Comments** |
| China Telecom | For initial transmission of Msg3, we think a fixed RV pattern is enough. Otherwise, additional signalling may be needed.  For re-transmission of Msg3, the RV bit field in DCI can be used to indicate the RV pattern. |
| CATT | Fine with the proposal. |
| OPPO | Fine with the proposal. For the repetition of Msg3 initial transmission, dynamically indicated RV for the first repetition of Msg3 initial transmission is proposed. It is consistent with the RV indication mechanism for the repetition of Msg3 re-transmission. |
| Xiaomi | For the repetition of Msg3 initial transmission, the fixed RV pattern [0 2 3 1] with the fixed RV “0” for the first repetition should be supported, and we can’t see any benefits in dynamically indicating RV for the first repetition.  For the repetition of Msg3 re-transmission, the fixed RV pattern [0 2 3 1] with a dynamically indicated RV for the first repetition should be supported, just as the RV determination mechanism for type A PUSCH repetition in release 16. |

### **[M] Issue#7: Support of the number of repetitions counted on the basis of available slots for Msg3 repetition.**

Proposal 7: The number of repetitions is counted on the basis of available UL slots for repetition of Msg3 initial and re-transmission.

* FFS on support of the number of repetitions counted on the basis of consecutive UL slots.

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| **Company** | **Comments** |
| China Telecom | Support this proposal. |
| CATT | Although we are supportive to apply the type A repetition enhancement for normal PUSCH to Msg3 PUSCH, it may be better to defer this discussion waiting for outcome of PUSCH discussion. Additional standard efforts for Msg3 PUSCH are not expected. |
| OPPO | Fine with the proposal. The definition of available UL slots can follow the discussion on PUSCH repetition agenda item. |

### **[M] Issue#8: Support of TB processing over multi-slot PUSCH for Msg3**

Proposal 8: FFS support of TB processing over multi-slot PUSCH for Msg3.

Companies are encouraged to indicate whether do you support TB processing over multi-slot PUSCH for Msg3.

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| **Company** | **Comments** |
| China Telecom | We don’t support this proposal. On one hand, it is out of the scope of current Msg3 enhancement discussion. On the other hand, it is really complex for Msg3 transmission considering TB processing. |
| CATT | OK |
| OPPO | Fine with the proposal. |
| Xiaomi | To achieve better coverage, TB processing over multi-slot combining with type A PSUCH repetition for msg3 could be considered. |

### **[M] Issue#9: Support of joint channel estimation for Msg3 repetition**

Proposal 9: Support joint channel estimation for repetition of Msg3 initial and re-transmission.

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| **Company** | **Comments** |
| China Telecom | Support this proposal. |
| CATT | Support. |
| OPPO | Support |
| Xiaomi | Agree. |

### **[H] Issue#10: Differentiation between CE UEs and legacy UEs**

Proposal 10: For triggering and scheduling of Msg3 repetition, down-select one option from the following options.

Option 1-1: gNB scheduled Msg3 repetition without UE request.

* + A UE reports support of Msg3 repetition via separate PRACH transmission.
  + For a UE supporting Msg3 repetition, gNB decides whether to schedule Msg3 repetition or not. If scheduled, gNB decides the number of repetitions.
    - It’s up to gNB implementation for decision, e.g., based on the detection of PRACH transmission.

Option 1-2: gNB scheduled Msg3 repetition without UE request.

* + gNB decides whether to schedule Msg3 repetition or not. If scheduled, gNB decides the number of repetitions.
    - It’s up to gNB implementation for decision, e.g., based on the detection of PRACH transmission.
  + If Msg3 repetition is scheduled, UE transmits Msg3 with or without repetition based on its capability, which will be indicated to gNB by Msg3 transmission (e.g., via separate DMRS configuration or UCI multiplexing with Msg3 PUSCH).
    - Note: Bind detection of Msg3 repetition at gNB side is needed.

Option 2: UE triggered Msg3 repetition with gNB indicating the number of repetitions

* + A UE can trigger RACH procedure with Msg3 repetition via separate PRACH transmission.
    - Whether a UE would trigger is based on some conditions, e.g., measured SS-RSRP threshold, which may or may not have spec impact.
  + If Msg3 repetition is triggered by UE, gNB decides the number of repetitions X (X>1) for Msg3 (re)-transmission.

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| **Company** | Comments |
| China Telecom | We think it is better to divided this proposal into several part, and discuss them separately.  For example:  **Praposal a**: For differentiation between legacy UEs and Rel-17 CE UEs supporting Msg3 enhancements,  Option 1: via PRACH transmission (e.g., via separate initial UL BWP, separate PRACH resource, or PRACH preamble)  Option 2: via Msg3 transmission (e.g., via separate DMRS configuration or UCI multiplexing with Msg3 PUSCH)  **Proposal b**: Considering Msg.3 repetition, it is up to:  Option 1: gNB scheduling without UE request.  Option 2: UE triggering.  We think it will be clearer in this way. In our view, we prefer to differentiate between legacy UEs and Rel-17 CE UEs via PRACH transmission. If the differentiation work is done via Msg3 transmission, it means initial Msg3 cannot be transmitted with repetition, or else gNB should configure repetition resource for each initial Msg3 transmission, resulting in resource waste.  About the triggering of Msg3 repetition, we think it should be up to gNB scheduling, including: gNB decide whether to trigger Msg3 repetitoin and gNB decide the number of repetition factor. |
| CATT | For option 1-2, I am confused why gNB need to blind detect the Msg3 PUSCH? In the first sub-bullet, gNB already decide whether schedule Msg3 repetition or not via some mechanisms, e.g. based on the detection of PRACH transmission. If gNB already make a decision, why blind detection is still needed?  Actually, I am confused for the other options as well. No matter we call the solutions listed above, UE always need to let gNB know whether Msg3 PUSCH repetition is possible or not. Correspondingly, gNB needs to identify whether the UE supports Msg3 PUSCH repetition.  The same procedure is applied for achieving the same understanding between gNB and UE across option 1-1, option 1-2 and option 2. Furthermore, what is the difference between ‘A UE reports support of Msg3 repetition via separate PRACH transmission’ and ‘A UE can trigger RACH procedure with Msg3 repetition via separate PRACH transmission’? |
| NTT DOCOMO | We are fine with the FL’s proposal |
| OPPO | In our view, for the initial access of UE, the coverage can be evaluated by UE through measurement. It is difficult for gNB to determine whether Msg3 transmission of a UE should be repeated, and the repletion number. Option 1-1 and 1-2 require gNB to have the knowledge of UE coverage, then gNB can determine the repetition of Msg3 transmission. Option 2 seems more reasonable, but more spec impacts can be foreseen. |
| Xiaomi | Option 1-1, option 1-2 and option 3 all work well. |

### **[M] Issue#11: Start of Contention Resolution timer and PDCCH monitoring for Msg3 repetition**

Proposal 11: Further discuss the following options for the start of Contention Resolution timer and PDCCH monitoring for Msg3 repetition

* Option 1: (Re-)start *ra-ContentionResolutionTimer* and PDCCH monitoring in the first symbol after the end of the all repetitions of Msg3 (re-)transmission
* Option 2: (Re-)start *ra-ContentionResolutionTimer* and PDCCH monitoring before the end of Msg3 (re-)transmission.
* FFS details

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| **Company** | **Comments** |
| China Telecom | We support Option 2. It may be beneficial for improving the UL resource utilization. |
| CATT | Support. |
| OPPO | Support. We are fine with both option 1 and 2. |
| Xiaomi | Option 2 should be supported. Following the method given by option 2, the early termination of msg3 repetition could be achieved, which will reduce the power consumption and save the PUSCH resources by avoiding the unnecessary Msg3 repetition transmission. Besides, it can also minimize the delay of RACH procedure. |

### **Other issues**

Regarding Issue#12~13, there are limited input, and it seems no urgent to discuss for now. Thus, FL would like to down-prioritize these issues. However, interested companies are also encouraged to provide your view below, if any, based on the listed questions. If the proposals above could somehow progress fast, FL proposals would be made correspondingly.

* Q-1 for Issue 12: Do you think the repetitions for Msg3 initial transmission should use the same beam (spatial setting) as the one for the corresponding PRACH transmission?
* Q-2 for Issue 12: Do you think the beam for repetitions for Msg3 re-transmission can be up to UE implementation?
* Q-3 for Issue 12: Do you think the UE could use different beams for different repetitions for Msg3 initial and re-transmission?
* Q-1 for Issue 13: Do you think the qam64-LowSE MCS table can be supported for Msg3 repetition?
* Q-1 for Issue 14: Do you think Msg3 repetition based enhancements studied for Rel-17 CE UEs can all be applied for RedCap UEs, and no additional RedCap-specific enhancement is needed?
* Q-2 for Issue 14: Do you think is there a need to differentiate between Rel-17 CE UEs and Redcap UEs before Msg3 transmission?

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| **Company** | **Comments** |
| Xiaomi | Q-3 for Issue 12, Q-1 for Issue 13: Yes.  Q-1 for Issue 14: Msg3 repetition based enhancements studied for Rel-17 CE UEs can be applied for Redcap UE with adjustment in the several aspects:   * Repetition number. Comparing with normal UEs, Redcap UEs in the same channel condition have 3 dB loss due to form factor limitation, so the redcap UE needs more repetition numbers if it has the same coverage target with normal UE. * Frequency hopping for msg3 repetition. If redcap UEs and normal UEs share the same initial UL BWP, redcap UE may hop over its system bandwidth if it use the same RB offset or start RB determination with normal UE.   Q-2 for Issue 14: Since redcap UEs have a limited bandwidth and may require more repetition numbers, gNB needs to differentiate between normal UEs and redcap UEs before resource allocation of msg3. |

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