**3GPP TSG-RAN WG1 Meeting #112 R1-2300117**

**Athens, Greece, February 27 – March 03, 2023**

**Agenda Item: 9.11.1**

**Source: Huawei, HiSilicon**

**Title:** **Discussion on coverage enhancement for NR NTN**

**Document for: Discussion and Decision**

# Introduction

In RAN#111 [1], the following were made for discussion on coverage enhancement for NR NTN.

|  |
| --- |
| **Conclusion**RAN1 concluded that PUSCH DMRS bundling with sufficient TDW size should be applicable in NTN to meet the performance requirement for VoIP* FFS: How to determine TDW size, including UE capability.
* Note: The above does not mean the performance requirements will be satisfied with DMRS bundling
 |

In this contribution, we will continue discuss on the coverage enhancement of PUSCH for VoIP and PUCCH for Msg4 under set-1 LEO-1200 LOS evaluation scenario.

# PUCCH for Msg4 HARQ-ACK

In RAN1#111, a working assumption was made to consider both the cell-specific and dynamic indication of repetition number for PUCCH of Msg4 HARQ-ACK. Besides, several proposals were proposed concerning the details of the dynamic repetition indication procedure, the necessity of UE’s repetition request, and other enhancement such as frequency hopping and DMRS bundling. In the following, we provide further discussion based on the remaining issues.

## Frequency hopping and DMRS bundling for Msg4 HARQ-ACK



Figure 1 Frequency hopping performance.

During the last meeting, one proposal 1-5\_v1 listed three frequency hopping options to be considered during the repetition transmission of PUCCH for Msg4 HARQ-ACK, namely, the intra-slot frequency hopping as currently specified in NR, the inter-slot frequency hopping, and no frequency hopping among repetitions.

|  |
| --- |
| **Proposal 1-5\_v1 in RAN1#111**For PUCCH repetition for Msg4 HARQ-ACK,* Further study the following options.
	+ Option X: Apply intra-slot frequency hopping as currently specified by extending applicability to repetitions
	+ Option Y: Apply inter-slot frequency hopping
	+ Option Z: no frequency hopping in case of repetitions
 |

Based on the discussion, Figure 1 illustrates the performance of different options of frequency hopping scheme during PUCCH repetition transmissions. From Figure 1, it is observed that inter-slot frequency hopping only provide marginal gain (e.g., less than 0.5dB), for all repetition cases. Besides, a negative performance of up to 0.8 dB is observed with intra-slot frequency hopping enabled, due to the degraded channel estimation [2].

Apart from the link level simulation performance, the inter-slot frequency hopping for PUCCH during initial access is not supported by the current spec, therefore additional standard effort is expected in order to support option Y. Nevertheless, the observed gain of inter-slot frequency is too little to proceed such effort.

***Proposal 1: For PUCCH repetition for Msg4 HARQ-ACK, do not introduce inter-slot frequency hopping in case of repetition transmission.***



Figure 2 DMRS bundling performance of PUCCH for Msg4-ACK

Figure 2 demonstrates the performance of DMRS bundling based on PUCCH repetition number of 2, 4, and 8, respectively, with various TDW configurations. And the constraint on maximum allowable phase difference for DMRS bundling in clause 6.4.2.5 in TS38.101-1[3] is kept for all the simulations in Figure 2. It is observed the ACK miss-detection performance is exactly the same within each case of repetition numbers, among various TDW length configurations. Specifically, the SNR at 1% miss-detection rate for repetition number of 2, 4, and 8 are -7.2dB, -9.3dB, and -11.5dB, respectively, no matter what the TDW length is. Thus, DMRS bundling offers no performance gain on top of repetition transmission for PUCCH of Msg4 HARQ-ACK.

Besides, DMRS bundling is a technique which depends on UE capability of maintaining phase continuity and power consistency during repetition transmissions, which requires additional early capability report regarding the unfinished RRC setup during initial access. On the other hand, further specification change regarding the PUCCH TDW configurations in SIB messages before dedicated RRC configuration is also expected. Therefore, we suggest that DMRS bundling should not to be introduced for PUCCH of Msg4 HARQ-ACK in NTN.

***Observation 1: DMRS bundling offers no performance gain on top of repetition transmission for PUCCH of Msg4 HARQ-ACK.***

***Proposal 2: Do not support DMRS bundling during repetition transmission of PUCCH for HARQ-ACK.***

## Repetition request

|  |
| --- |
| **Working assumption**For PUCCH repetition for Msg4 HARQ-ACK,* One or more repetition factors may be configured via SIB
	+ If only one repetition factor is configured via SIB and if the value is one of {[1], 2, 4, 8}, UE capable of PUCCH repetition for Msg4 HARQ-ACK can perform repetition with the repetition factor
		- FFS: whether UE requests repetition or indicates repetition capability
	+ If multiple factors from {1, 2, 4, 8} are configured via SIB, PUCCH repetition for Msg4 HARQ-ACK may be dynamically determined and indicated by gNB
		- FFS: whether UE requests repetition or indicates repetition capability
		- FFS: whether repetition factor is indicated by UE
	+ FFS: UE behavior when repetition factor is not configured via SIB
	+ FFS: whether one or more UE capabilities are needed for the above is for further discussion
 |

Based on the working assumption made in RAN1#111, when multiple repetition factors are configured via SIB, PUCCH repetition for Msg4 HARQ-ACK may be dynamically determined and indicated by gNB. In our understanding, UE should send repetition request to the gNB first, if necessary. And for those UEs who does not request, it is not necessary to schedule PUCCH repetition transmission for Msg4 HARQ-ACK.

***Proposal 3: For PUCCH of Msg4 HARQ-ACK, only UEs that send repetition request need to perform the repetition transmission.***

|  |
| --- |
| **Proposal 1-2\_v2**[Repetition request or Repetition capability report] of PUCCH for Msg4 HARQ-ACK is transmitted by:* Option A: PRACH preamble and/or occasion
	+ FFS: relationship with Msg3 repetition request
	+ FFS: whether/how to avoid further fragmentation of **PRACH resources**
* Option B: Msg3 PUSCH
	+ FFS: how to transmit the information (e.g., higher layer signaling, scrambling, DMRS port, etc.)
* ~~Option C: PUCCH for Msg4 HARQ-ACK~~
	+ ~~FFS: how to transmit the information~~
 |

One proposal 1-2\_v2 made in the last RAN1 meeting proposed following two options regarding the request procedure. For option A, similar mechanism as NR Msg3 PUSCH repetition request is proposed, where PRACH preambles and/or occasions are partitioned in order for UE to perform the request. For option B, the signal processing of Msg3 PUSCH, such as the scrambling, DMRS port, etc., is utilized to inform the gNB of UE repetition request. In this case, the complexity increases at gNB receiver, which should be avoided for the sake of less processing complexity and processing delay on gNB. Besides, since the feature request/report mechanism through PRACH resources is already supported by the current specification, i.e., through the configuration of higher layer parameter *FeatureCombinationPreambles* in SIB messages, we suggest that a similar mechanism can be applied for the repetition request for PUCCH of Msg4.

As the details of option A, the configuration shall include a set of PRACH preambles/occasions for UEs who needs PUCCH repetitions, the UE can use the configured PRACH resources to initiate Msg1 transmission to inform gNB the request for PUCCH repetition.

***Proposal 4: Support option A with the following details of cell-specific configurations:***

* ***A PRACH resource is configured, in which a PRACH preamble or RO is selected to indicate the repetition request for PUCCH of Msg4 HARQ-ACK.***
* ***Other PRACH preambles/ROs can be selected when the Msg4 PUCCH repetition is not requested or the UE does not support it.***

Additionally, the request for Msg4 HARQ-ACK automatically means the UE also requests Msg3 PUSCH repetition considering the link budget of PUCCH for Msg4 HARQ-ACK is better than Msg3. This can avoid the further partitioning of PRACH resources for Rel-18 UE supporting Msg3 repetition only and for Rel-18 UE supporting both Msg3 repetition and PUCCH repetition. For Rel-17 UE supporting Msg3 repetition, another dedicated PRACH resource needs to be allocated, i.e. the M preambles in Figure 3.

If a UE selects a PRACH resource other than the cell-specific configured PRACH resource for PUCCH repetition request, PUCCH repetition will not be applied by the UE. Furthermore, a measurement threshold different from the Msg3 repetition request should be defined due to the better link budget for PUCCH. As illustrated in Figure 3, two thresholds are configured for UE to decide whether to request Msg3 repetition or both Msg3 and PUCCH repetition. When the measured SSB RSRP is lower than Threshold 2, UE use one of the configured N preambles to request both the repetition of Msg3 and PUCCH simultaneously.





Figure 3 UE choose different preambles to request PUCCH repetition based on SSB RSRP

***Proposal 5: A measurement threshold different from the Msg3 repetition request can be configured due to the better link budget of PUCCH than Msg3.***

***Proposal 6: PUCCH repetition request for Msg4 HARQ-ACK is based on preamble or RO resource selection.***

* ***The selected ROs/resources can be used to request both the repetition of Msg3 and PUCCH of Msg4 simultaneously.***

Regarding the last FFS bullet in working assumption, UE that has the capability to perform PUCCH repetition for Msg4 HARQ-ACK shall perform the repetition request via Msg1. While UE that does not have such capability shall perform single PUCCH transmission. Besides, the discussion of PUCCH repetition procedure is based on UE repetition request. For those UEs that have better link budget, they will not send request to gNB and the single PUCCH repetition transmission is performed. Therefore, the capability report by RRC signaling is not necessary.

***Proposal 7: For PUCCH repetition transmission of Msg4 HARQ-ACK, no need to introduce UE capability report in RRC signalling.***

## Dynamic indication

When multiple repetition factors are broadcast in SIB messages, gNB should indicate one of the repetition factors to UE for PUCCH repetition of Msg4 HARQ-ACK. Regarding this issue, some of the existing fields in DCI 1\_0 for msg4 PDSCH scheduling can be reused/reinterpreted for this purpose.

|  |
| --- |
| **Proposal 1-4\_v2**For dynamic indication of PUCCH repetition for Msg4 HARQ-ACK,* Maximum N value(s) of repetition factor can be candidates of dynamic indication.
	+ ~~Alt 1: N = 1~~
	+ ~~Alt 2: N = 2~~
	+ Alt 3: N = 4
	+ ~~FFS: configuration per cell or per beam or per PUCCH resource included in a PUCCH resource set provided by~~ *~~pucch-ResourceCommon~~*
* PUCCH repetition factor or whether repetition is performed is indicated by:
	+ Alt A: some of the existing fields in DCI scheduling the Msg4 PDSCH
		- FFS: which field (e.g., MCS information field)
	+ ~~Alt B: MCS information field of DCI scheduling Msg3 PUSCH jointly with indication of Msg3 repetition factor~~
		- ~~FFS: details on the joint indication~~
* A configured PUCCH resource set is included in:
	+ Alt X: Table 9.2.1-1 of TS 38.213
		- Note: no spec change is assumed
	+ ~~Alt Y: A newly defined table for PUCCH repetition for Msg4 HARQ-ACK~~
		- ~~FFS: details~~
 |

Firstly, it is not preferred to change the length of the DCI format 1\_0 to avoid impact on the legacy UEs. It is proposed to consider the reinterpretation of MCS field to support the indication of Msg4 PUCCH-ACK repetition. This is considering modulation order and the coding rate for transmission of Msg4 in NTN does not need to be large, due to the link budget in NTN. Therefore 3LSB of MCS information field, i.e., MCS0~7 are enough for the scheduling of Msg4 PDSCH. As a result, the 2MSB of MCS information field in DCI format 1\_0 with CRC scrambled by TC-RNTI for scheduling Msg4 PDSCH can be redefined for Msg4 PUCCH repetition indication of 4 repetition factors, e.g., 1,2,4, and 8. Besides, a similar approach has been already used in NR specifications to redefine the 2MSB of MCS information field in DCI 0\_0 with CRC scrambled by TC-RNTI in NR coverage enhancement for Msg3 PUSCH repetition indication.

For other alternatives, e.g. the PRI field in DCI format 1\_0, the value of PRI field in DCI 1\_0 with CRC scrambled by TC-RNTI is intended for the determination of PUCCH frequency domain resource location, if a UE is provided a PUCCH resource by *pucch-ResourceCommon*, according to clause 9.2.1 in TS38.213. Therefore, for dynamic indication of the repetition number via redefining PRI, the change of value in PRI filed is inevitable, which as a result changes the calculation of PUCCH frequency domain resource location. To conclude, the bits in PRI field is not appropriate to be redefined as dynamic indication of PUCCH repetition number for Msg4 HARQ-ACK.

There are also some field, DAI field, reserved in DCI format 1\_0 scrambled by TC-RNTI. However, these two bits are preferred to be kept for future purpose if MCS field can already support the indication of PUCCH repetition number.

***Proposal 8: For dynamic indication for PUCCH repetition of Msg4 HARQ-ACK, the existing MCS field in DCI 1\_0 with CRC scrambled by TC-RNTI are reinterpreted as following:***

* ***the 3LSB of MCS information field to indicate MCS0~7.***
* ***the 2MSB of MCS information field to indicate 4 repetition factors of Msg4 PUCCH repetition configured in SIB.***

When repetition factor is not configured via SIB, UE who sends repetition request have two options for the PUCCH transmission. Option 1 is to perform repetition transmission and gNB shall perform blind detection with reserved time resources. In this way, the processing delay and complexity at gNB is increased and resource is wasted if UE only transmit small number of PUCCH repetitions.

Option 2 is to follow the same mechanism as Msg3 PUSCH repetition indication. Specifically, as specified in TS38.331, *BWP-UplinkCommon* contains the higher layer parameter *numberOfMsg3-RepetitionsList-r17*, which is an optional configuration. This means that the repetition number can either be broadcast in SIB or not. According to clause 6.1.2.1 in TS38.214, if the repetition number is configured in SIB by gNB, the 2MSB of MCS field in DCI is interpreted by UE as the configured value location in the higher layer parameter *NumberOfMsg3-Repetitions-r17*. While if the repetition number is not configured in SIB by gNB, the 2MSB of MCS field directly indicates the exact value of repetition as in {1,2,3,4}. Therefore, the option 2 for UE that sends the request is to follow the two different DCI interpretation as Msg3 repetition indication, where if the repetition number is not configured in SIB by gNB, the 2MSB in MCS field in DCI 1\_0 shall be interpreted as the exact value of Msg4 HARQ-ACK repetition number. To summarize, we think option 2 is more supportable.

***Proposal 9: When repetition factor is not configured via SIB, UE should interpret the corresponding 2bits in DCI 1\_0 that used for repetition indication as the exact repetition number in*** ***{1,2,3,4}.***

## Cell specific indication

Regarding the first bullet in the working assumption in [1], if only one repetition factor is configured via SIB and if the value is one of {[1], 2, 4, 8}, UE capable of PUCCH repetition for Msg4 HARQ-ACK can perform repetition with the given repetition factor. In such case, all UEs that request repetition in the satellite cell should perform PUCCH repetition with a same repetition factor indicated by SIB messages. And no further grant or indication by DCI 1\_0 is required, which has simpler procedure and induces less spec. change compared to the dynamic repetition indication amongst multiple repetition factors.

To conclude, cell-specific repetition indication with only one repetition factor should be supported for PUCCH of Msg4 HARQ-ACK. Note that, UE repetition request is also necessary to avoid radio resource waste if only one repetition factor is cell specifically indicated. The request can be performed through similar manner as discussed in the last section.

***Proposal 10: confirm the working assumption to support both cell-specific repetition indication with only one repetition factor and the dynamic indication of Msg4 PUCCH-ACK repetition.***

***Proposal 11: Support UE repetition request when only one repetition factor is configured in the SIB.***

In addition, concerning the specified repetition numbers in the first bullet of the working assumption, we think the number 1 should be agreed. Since the higher layer parameter *NumberOfMsg3-Repetitions-r17* contains the slot value {n1}, it seems reasonable to include value 1 for Msg4 HARQ-ACK repetition for spec consistency.

***Proposal 12: The repetition number 1 in the working assumption should be supported.***

# PUSCH for VoIP

## The necessity of further enhancement to enable DMRS bundling for NTN

Following the agreed simulation parameters in Table 2 in Appendix A, the PUSCH BLER performance for VoIP is illustrated in Figure 4, considering the existing coverage enhancement supported by Rel-17, which includes TBoMS. For the low SNR range, the channel estimation performance is the bottleneck of the BLER performance. To investigate the performance bound of the DMRS bundling, the ideal channel estimation (ICE) results are illustrated along with the realistic channel estimation (RCE) results without DMRS bundling. Here, the ICE with the perfect channel estimation represents the best achievable DMRS bundling performance.



Figure 4 PUSCH performance for VoIP under rural NTN-TDL-C (Rel-17 NR NTN without antenna switching)

Figure 4 shows the upper bound (best achievable performance) of DMRS bundling only, i.e. the ideal channel estimation performance, requires an SNR of -8.81 dB for rBLER 2%, which is still 2.24 dB higher than the achievable CNR (-11.05 dB) from the link budget analysis. Thus, it does not make sense to consider DMRS bundling only considering the ideal performance gain is 2.13 dB and the minimum coverage GAP of set-1 LEO 1200 PUSCH for VOIP is still 2.24 dB.

***Observation 2:* The upper bound performance of utilizing DMRS bundling only, i.e. the SNR @2%rBLER with the ideal channel estimation performance, is still 2.24dB worse than the achievable CNR for** **the Set-1 LEO 1200 PUSCH and elevation of 30 degree for VoIP.**

Furthermore, based on the simulation results in Figure 4, if only antenna switching is applied, the SNR working point @2%rBLER is -9.88 dB, which is even about 1 dB better than the upper bound performance of DMRS bundling only (-8.81 dB).

***Observation 3: U*tilizing antenna switching can achieve 1 dB better performance than that of the upper bound performance of utilizing DMRS bundling only, i.e. the ideal channel estimation performance.**

Therefore, there is no need to discuss the solutions to enable the use of DMRS bundling, if antenna switching is not jointly considered.

***Proposal 13: There is no need to discuss any solution to enable the use of DMRS bundling for NTN, if antenna switching is not jointly considered based on the upper bound performance of utilizing DMRS bundling.***

Based on the above observations and the PUSCH simulation results in [4], antenna switching is an efficient way for coverage enhancement of NTN. Therefore, we investigate the best performance that can be provided when DMRS bundling is performed for the case when antenna switching is disabled and enabled, respectively. The simulation results are plotted in Figure 5.



Figure 5 PUSCH performance for VoIP under rural NTN-TDL-C with DMRS bundling

**DMRS bundling performance when antenna switching is not enabled**

For the case when the NTDW size is 12, there cannot be two 12ms-TDW transmissions considering the total budget of a single VoIP packet is 20ms. Therefore, in our simulation for the curve with NTDW = 12, the two actually used TDW sizes of the JCE are 12 and 8, respectively for the first and second DMRS bundles. Thus, the NTDW = 12 performance is no better than that of NTDW = 10 in Figure 5.

***Observation 4: For PUSCH VoIP, setting nominal TDW larger than 10 could not achieve additional DMRS bundling gain considering the time budget of 20ms for a single PUSCH VoIP packet.***

***Observation 5: For PUSCH VoIP, DMRS bundling could provide a maximum 1.58 dB gain for the case when antenna switching is disabled.***

***Observation 6: For PUSCH VoIP, DMRS bundling performance* is still 2.79 dB worse than the achievable CNR for** **the Set-1 LEO 1200 PUSCH and elevation of 30 degree for VoIP *when antenna switching is disabled.***

**DMRS bundling performance when antenna switching is enabled**

When DMRS bundling is used, the phase continuity or power consistency during the TDW of DMRS bundling will restrict the possibility of antenna switching. The antenna switching could be only performed at the boundary of DMRS bundles. Therefore, the performance of DMRS bundling with antenna switching should be jointly investigated.

***Observation 7: Antenna switching cannot be* executed *within a DMRS bundle; otherwise the phase continuity and power consistency cannot be guaranteed within the DMRS bundle.***

In the simulation, for the DMRS bundling with antenna switching enabled, the nominal TDW is set as 1, 2, 4, 8, 10 and 12 and for each antenna switching interval, the phase continuity complies with clause 6.4.2.5 in TS 38.101‑1. Therefore, the antenna switching is executed at the boundary of DMRS bundles, i.e. the antenna switching and DMRS bundling restarting are performed jointly. The BLER vs. SNR performances in Figure 5 are summarized in Table 1.

In the following table, the case of “NTDW=1” can represent the performance when there is no DMRS bundling and the case of “ICE” represents the best performance of jointly using DMRS bundling, antenna switching, repetitions and TBoMS.

Table 1 Coverage analysis for PUSCH VoIP with DMRS bundling

|  |  |  |
| --- | --- | --- |
| **PUSCH VoIP** | **DMRS bundling Setting** | **Rural NTN-TDL-C** |
| **Satellite orbit** | **Satellite parameter set** | **Elevation angle (deg)** | **CNR (dB)** | **Antenna switching on/off** | **Nominal TDW** | **Required SNR@rBLER2% (dB)** | **Coverage Gap (dB)** |
|
| **LEO-1200** | 1 | 30 | -11.05 | off | 1(JCE Disable) | -6.68 | 4.37 |
| On (AS interval=1) | 1 (JCE Disable) | -9.64 | 1.41 |
| off | 2 | -7.55 | 3.5 |
| On (AS interval=2) | 2 | -10.31 | 0.74 |
| On (AS interval=2) | 1 (JCE Disable) | -9.88 | 1.17 |
| off | 4 | -7.93 | 3.12 |
| **On (AS interval=4)** | **4** | **-10.79** | **0.26** |
| off | 8 | -8.14 | 2.91 |
| On (AS interval=8) | 8 | -10.55 | 0.5 |
| off | 10 | -8.26 | 2.79 |
| On (AS interval=10) | 10 | -10 | 1.05 |
| off | 12 | -8.25 | 2.8 |
| On (AS interval=12) | 12 | -9.96 | 1.09 |

***Observation 8: To meet the set-1 LEO-1200 PUSCH for VoIP, antenna switching should be jointly considered with DMRS bundling.***

Smaller antenna switching interval could exploit more spatial diversity within the 20ms VoIP transmission time budget, while larger TDW could provide more channel estimation gain. Therefore, when jointly using DMRS bundling with antenna switching, the required SNR is not monotone decreasing with the increase of TDW size, which is the same as the interval for antenna switching. When NTDW and ASInter are equal to 4 (i.e. the actual TDW is 4), the coverage performance could achieve the best trade-off between spatial diversity gain, channel coding gain and joint channel estimation gain. Thus, the actual TDW should be jointly decided by the nominal TDW and antenna switching interval, which achieves the best trade-off between phase continuity requirement for better channel estimation and larger spatial diversity gain by antenna switching.

***Observation 9: For PUSCH VoIP, jointly using DMRS bundling with antenna switching can reduce the coverage gap to 0.26 dB compared to 2.79 dB minimum coverage gap that can be provided by only using DMRS bundling.***

***Observation 10: For PUSCH VoIP, jointly using DMRS bundling with antenna switching can reduce the coverage gap to 0.26 dB compared to the 1.17 dB minimum coverage gap that can be provided by only using antenna switching.***

For the coverage gap when JCE and antenna switching is jointly used, we could observe a marginal gap of 0.26 dB in our simulations, which can be negligible and should be resolved by implementation.

***Proposal 14: Support Antenna switching as the PUSCH for VoIP baseline and consider antenna switching into the TDW size determination procedure.***

## TDW determination

Based on the simulations mentioned in Section 3.1, the DMRS TDW restarted after each antenna switching. It is equivalent to that antenna switching performance as an event that cause power consistency and phase continuity not to be maintained across PUSCH transmission within the nominal TDW.

*Proposal 15: Support antenna switching as an event that triggers the end of an actual TDW for DMRS bundling within the nominal TDW to eliminate the coverage gaps of PUSCH VoIP by joint utilization of antenna switching and DMRS bundling.*

Based on the simulations mentioned in Section 3.1, using all the available transmission antenna sets in a PUSCH for VoIP could maximize spatial diversity gain. Thus, the network could schedule the PUSCH for VoIP transmission with optimal coverage performance if the antenna switching capability of a UE is available.

*Proposal 16: Support UE PUSCH antenna switching capability requiring/reporting to determine the TDW size.*

# Conclusions

In summary, we discuss on the coverage enhancement for NR NTN. The following observations and proposals are made:

***Observation 1: DMRS bundling offers no performance gain on top of repetition transmission for PUCCH of Msg4 HARQ-ACK .***

***Observation 2:* The upper bound performance of utilizing DMRS bundling only, i.e. the SNR @2%rBLER with the ideal channel estimation performance, is still 2.24dB worse than the achievable CNR for** **the Set-1 LEO 1200 PUSCH and elevation of 30 degree for VoIP.**

***Observation 3: U*tilizing antenna switching can achieve 1 dB better performance than that of the upper bound performance of utilizing DMRS bundling only, i.e. the ideal channel estimation performance.**

***Observation 4: For PUSCH VoIP, setting nominal TDW larger than 10 could not achieve additional DMRS bundling gain considering the time budget of 20ms for a single PUSCH VoIP packet.***

***Observation 5: For PUSCH VoIP, DMRS bundling could provide a maximum 1.58 dB gain for the case when antenna switching is disabled.***

***Observation 6: For PUSCH VoIP, DMRS bundling performance* is still 2.79 dB worse than the achievable CNR for** **the Set-1 LEO 1200 PUSCH and elevation of 30 degree for VoIP *when antenna switching is disabled.***

***Observation 7: Antenna switching cannot be* executed *within a DMRS bundle; otherwise the phase continuity and power consistency cannot be guaranteed within the DMRS bundle.***

***Observation 8: To meet the set-1 LEO-1200 PUSCH for VoIP, antenna switching should be jointly considered with DMRS bundling.***

***Observation 9: For PUSCH VoIP, jointly using DMRS bundling with antenna switching can reduce the coverage gap to 0.26 dB compared to 2.79 dB minimum coverage gap that can be provided by only using DMRS bundling.***

***Observation 10: For PUSCH VoIP, jointly using DMRS bundling with antenna switching can reduce the coverage gap to 0.26 dB compared to the 1.17 dB minimum coverage gap that can be provided by only using antenna switching.***

***Proposal 1: For PUCCH repetition for Msg4 HARQ-ACK, do not introduce inter-slot frequency hopping in case of repetition transmission.***

***Proposal 2: Do not support DMRS bundling during repetition transmission of PUCCH for HARQ-ACK.***

***Proposal 3: For PUCCH of Msg4 HARQ-ACK, only UEs that send repetition request need to perform the repetition transmission.***

***Proposal 4: Support option A with the following details of cell-specific configurations:***

* ***A PRACH resource is configured, in which a PRACH preamble or RO is selected to indicate the repetition request for PUCCH of Msg4 HARQ-ACK.***
* ***Other PRACH preambles/ROs can be selected when the Msg4 PUCCH repetition is not requested or the UE does not support it.***

***Proposal 5: A measurement threshold different from the Msg3 repetition request can be configured due to the better link budget of PUCCH.***

***Proposal 6: Support PUCCH repetition request for Msg4 HARQ-ACK is based on preamble or RO resource selection.***

* ***The selected ROs/resources can be used to request both the repetition of Msg3 and PUCCH of Msg4 simultaneously.***

***Proposal 7: For PUCCH repetition transmission of Msg4 HARQ-ACK, no need to introduce UE capability report in RRC signalling.***

***Proposal 8: For dynamic indication for PUCCH repetition of Msg4 HARQ-ACK, the existing MCS field in DCI 1\_0 with CRC scrambled by TC-RNTI are reinterpreted as following:***

* ***the 3LSB of MCS information field to indicate MCS0~7.***
* ***the 2MSB of MCS information field to indicate 4 repetition factors of Msg4 PUCCH repetition configured in SIB.***

***Proposal 9: When repetition factor is not configured via SIB, UE should interpret the corresponding 2bits in DCI 1\_0 that used for repetition indication as the exact repetition number in*** ***{1,2,3,4}.***

***Proposal 10: confirm the working assumption to support both cell-specific repetition indication with only one repetition factor and the dynamic indication of Msg4 PUCCH-ACK repetition.***

***Proposal 11: Support UE repetition request when only one repetition factor is configured in the SIB.***

***Proposal 12: The repetition number 1 in the working assumption should be supported.***

***Proposal 13: There is no need to discuss any solution to enable the use of DMRS bundling for NTN, if antenna switching is not jointly considered based on the upper bound performance of utilizing DMRS bundling.***

***Proposal 14: Support Antenna switching as the PUSCH for VoIP baseline and consider antenna switching into the TDW size determination procedure.***

*Proposal 15: Support antenna switching as an event that triggers the end of an actual TDW for DMRS bundling within the nominal TDW to eliminate the coverage gaps of PUSCH VoIP by joint utilization of antenna switching and DMRS bundling.*

*Proposal 16: Support UE PUSCH antenna switching capability requiring/reporting to determine the TDW size.*

# References

1. R1-2212865, Summary #5 for 9.11.1 Coverage enhancement for NR NTN.
2. R1-2210872, Discussion on coverage enhancement for NR NTN, Huawei, HiSilicon.
3. TS 38.101-1, User Equipment (UE) radio transmission and reception.

# Appendix A: link level evaluation assumption

## A.1 PUSCH

For the agreed simulation scenario, channel model/delay spread, and NTN system bandwidth, the frequency hopping could not provide attractive performance gain for PUSCH. Thus, the frequency hopping is disabled in the simulation.

As 2 transmit chains will require more power consumption, which will challenge the power supply and the cost of the UEs, only 1 transmit chain is adopted in our simulation.

To maximize the Link Budget, we consider 2 PRBs for both VoIP and Msg.3 simulation.

As AMR 4.75 kbps (TBS of 184 bits without CRC in physical layer) is agreed for VoIP simulation, adopting the MCS 11 in MCS Table 6.1.4.1-2 in [7] or MCS 5 in MCS Table 6.1.4.1-1 [7] could provide a TBS equalling to 208, which is just above 184.

For Msg.3, the agreed TBS is 56, which could adopt MCS 6 in MCS Table 6.1.4.1-2 in [7] or MCS 0 in MCS Table 6.1.4.1-1 [7] with Modulation Order Qm=2 to meet the requirements.

For low data rate 100kbps, adopting MCS 8 in MCS Table 6.1.4.1-1 in [7].

**PUSCH for VoIP**

 Table 2 PUSCH VoIP simulation assumption

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| Frequency hopping  | w/o frequency hopping |
| TBoMS | N= {4} |
| BLER | For VoIP, 2% rBLER. |
| Number of UE transmit chains  | 1 |
| DMRS configuration  | For 3km/h: Type I, 2 DMRS symbol, no multiplexing with data.PUSCH mapping Type A, DMRS positions defined in Table 6.4.1.1.3 with *ld*=14, *l0*=2 and *pos1* in [38.211]. |
| Waveform | DFT-s-OFDM |
| PUSCH duration | 14 OS |
| Repetitions  | w/ type A repetition, M = {4,5} |
| MCS for VoIP | MCS 5 in MCS Table 6.1.4.1-2 in [TS 38.214]  |
| Number of PRBs | 2 |

## A.2 PUCCH

The simulation of PUCCH is restrict to PUCCH format-1 (1bit) for Msg4 HARQ-ACK according to [4]. The resource allocation and other simulation assumptions are listed in Table 3.

Intra-slot and inter-slot frequency hopping are applied in the simulation based on the channel bandwidth listed in Table 5.3.5-1 in 38.101-5, where the two-hops of PUCCH occupies the first and the last PRB of the satellite bandwidth, respectively. User multiplexing and inter-cell interference are not considered, therefore group and sequence hopping and cyclic shift hopping are disable in the simulation, for PUCCH format-1.

Table 3 PUCCH simulation assumption

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| PUCCH format  | Format 1, 1bits UCI. |
| Repetition | Enabled/disabled |
| Frequency hopping | Inter/intra-slot frequency hopping enabled/disabled |
| DMRS bundling | Enabled/disabled |
| BLER | -     For PUCCH format 1: DTX to ACK probability: 1%;ACK missed detection probability: 1% |
| Number of UE transmit chains | 1  |
| DMRS configuration  | Number of DMRS symbols for PUCCH Format 1: 7 |
| PUCCH duration         | 14 OS |
| Number of PRBs | 1 PRB |
| Residual CFO | 200Hz (35Hz) for disabled (enabled) DMRS bundling |

# Appendix B: link budget analysis

Table 4 Link budget results

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| PHY Channel | SCS (KHz) | Bandwidth(Number of PRB) | Orbit\_ParaSet\_Elevation | CNR (dB) |
| PUCCH format 1/3 | 15 | 1 | GEO\_SET1\_12.5o | -16.23 |
| GEO\_SET2\_20o | -21.07 |
| LEO1200\_SET1\_30o | -8.04 |
| LEO1200\_SET2\_30o | -14.04 |
| LEO600\_SET1\_30o | -2.65 |
| LEO600\_SET2\_30o | -8.65 |
| PUSCH for VoIP | 15 | 2 | GEO\_SET1\_12.5o | -19.24 |
| GEO\_SET2\_20o | -24.08 |
| LEO1200\_SET1\_30o | -11.05 |
| LEO1200\_SET2\_30o | -17.05 |
| LEO600\_SET1\_30o | -5.66 |
| LEO600\_SET2\_30o | -11.66 |
| LEO600\_SET1\_30o | -1.82 |
| LEO600\_SET2\_30o | -7.82 |