**3GPP TSG RAN WG1 #113 R1-2304943**

**Incheon, Korea, May 22nd – May 26th, 2023**

**Agenda Item: 9.16.5**

**Source: Moderator (AT&T)**

**Title: Summary of UE features for NR NTN enhancements**

**Document for:** **Discussion/Decision**

# Introduction

This document presents the summary of email discussion [113-R18-UE\_features-02] during RAN1 #113. According to the Chairman’s Notes:

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| [113-R18-UE\_features-02] Email discussion on UE features for MIMO, positioning, NCR, NR-NTN, IoT-NTN, BWP without restriction – Ralf (AT&T)* To be used for sharing updates on online/offline schedule, details on what is to be discussed in online/offline sessions, tdoc number of the moderator summary for online session, etc
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The following was discussed and/or agreed during RAN1 #113 within the scope of [113-R18-UE\_features-02]. All proposals are based on the latest RAN1 UE features list for Rel-18 in [1].

# Summary of Contributions Submitted to RAN1 #113

The following is the moderator’s summary of contributions submitted to RAN1 #113 in this agenda item.

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| Company | Summary |
| Vivo [2] | **UE features of coverage enhancements in NTN**PUCCH repetition for Msg4 HARQ-ACK

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| **Conclusion**For PUCCH repetition for Msg4 HARQ-ACK,* The existing mechanism on repetition slot counting (as in section 9.2.6 of TS 38.213) can be applied.
	+ FFS: whether specification update to apply the existing mechanism to PUCCH repetition for Msg4 HARQ-ACK is needed.

**Agreement**For PUCCH transmission for Msg4 HARQ-ACK, supported number of transmissions are 1, 2, 4, 8.* Note: single PUCCH transmission is performed as in the existing specification, and/or (if supported for single PUCCH transmission) according to configuration/indication e.g., in signaling with respect to number of transmissions.
* FFS: whether larger number of transmissions is supported
* FFS: whether/how single PUCCH transmission can be configured and/or indicated

Working assumptionFor 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

**Working assumption**For PUCCH repetition for Msg4 HARQ-ACK,* A RSRP threshold can be configured via SIB at least when the number of repetitions is configured by SIB.
	+ If the RSRP threshold is configured and the configured RSRP threshold is smaller than X,
		- UE capable of PUCCH repetition for Msg4 HARQ-ACK transmits repetition request if measured RSRP is lower than a RSRP threshold.
	+ If the RSRP threshold is not configured, or if the configured RSRP threshold is X,
		- UE capable of PUCCH repetition for Msg4 HARQ-ACK reports the capability of PUCCH repetition for Msg4 HARQ-ACK
	+ FFS: value of X (the maximum configurable value of the RSRP threshold)

Down-select one from the following alternatives for the RSRP threshold.* + - Alt A: The same RSRP threshold as R17 Msg3 repetition (i.e., *rsrp-ThresholdMsg3-r17*) is used.
		- Alt B: New RSRP threshold is introduced.
* Note: UE incapable of PUCCH repetition for Msg4 HARQ-ACK transmits neither repetition request nor capability report

**Working assumption**For PUCCH repetition for Msg4 HARQ-ACK, support Option B as container of the repetition request or capability report indicated by UE.* Option B: Higher layer signaling in Msg3 PUSCH

**Agreement**For PUCCH repetition for Msg4 HARQ-ACK, support Alt 1-1 for dynamic indication of repetition factor from gNB. Further discuss which field(s) to be used.* Alt 1: Field in DCI scheduling the Msg4 PDSCH
	+ Alt 1-1: One or two bits of the existing field(s)
		- Alt 1-1a: MCS field
		- Alt 1-1b: PUCCH resource indicator field (e.g., with repetition factor configuration per PUCCH resource)
		- Alt 1-1c: HARQ process number filed
		- Alt 1-1d: DAI field
		- Alt 1-1e: PDSCH-to-HARQ\_feedback timing indicator field

**Agreement**For PUCCH repetition for Msg4 HARQ-ACK, apply frequency hopping mechanism in R15/16/17 defined for PUCCH transmission for Msg4 HARQ-ACK, in every slot.**Agreement**For PUCCH repetition for Msg4 HARQ-ACK, candidate values of only one repetition factor configuration via SIB are {2, 4, 8}.* i.e., configuration of only ‘1’ is not supported.
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In previous meetings, the necessary agreements and conclusions above for supporting PUCCH repetition for Msg4 HARQ-ACK have been reached. Some further discussions of detailed solutions are still ongoing. Note that there’s no conclusion yet on whether the PUCCH repetition to be supported is applicable to all PUCCH transmissions on common PUCCH resource when dedicated PUCCH resource is not provided, therefore this should be further discussed.According to above, we propose to discuss at least following UE feature group described in Table 1 for supporting common PUCCH repetition in Rel-18 NTN. ***Proposal 1:**** ***RAN1 to discuss UE feature group provided in Table 1 as a start point to support common PUCCH repetition in NTN.***

*Table 1. Potential UE features of supporting common PUCCH repetition in Rel-18 NTN.*

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| common PUCCH repetition in NTN | Support PUCCH repetition for Msg4 HARQ-ACK. FFS: the applicability when dedicated PUCCH resource configuration is not provided. | N/A | Yes | UE does not support PUCCH repetition based on common PUCCH resource configuration.  | [Per UE or Per Band] | [No] | [No] | FFS | Optional with capability signaling |

PUSCH DMRS bundling in NTN

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| **Agreement**For NTN-specific PUSCH DMRS bundling,* Discuss further the need of enhancement in consideration of at least the following:
	+ Phase difference due to timing drift and/or doppler shift.
		- e.g., whether/how long a UE can meet phase continuity requirement specified as Table 6.4.2.5-1 in 38.101-1 in consideration of frequency error within ± 0.1 PPM specified in section 6.4.1 of 38.101-5 and timing error specified in Table 7.1C.2-1 of 38.133, whether RAN1 should introduce enhancement to meet the requirement and/or recommend RAN4 to update the requirement or UE should pre-compensate phase difference by UE implementation, etc.
	+ An event which causes power consistency and phase continuity not to be maintained.
		- e.g., whether the new event is necessary to determine actual TDW(s) from each nominal TDW or the existing specification can work without any specification change or whether such event may not occur depending on implementations, etc.
	+ Note: baseline performance for legacy UEs can include antenna switching

**Conclusion**For the study of NTN-specific PUSCH DMRS bundling, RAN1’s understanding is that Phase variation due to constant frequency error within ± 0.1 PPM specified in section 6.4.1 of 38.101-1 does not have impact on the phase continuity requirement for two adjacent slots specified as Table 6.4.2.5-1 in 38.101-1, according to annex F.9 and F.4 of 38.101-1.**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

**Working assumption**For NTN-specific PUSCH DMRS bundling, to satisfy the phase difference limit without causing phase discontinuity, it is assumed that pre-compensation to keep phase rotation due to timing drift within the phase difference limit can be performed at UE side.* UE shall not perform TA pre-compensation update within an actual TDW if it causes phase discontinuity that may violate the phase difference limit.
	+ FFS: how to determine the actual TDW
* FFS: specification impact
* Send an LS to RAN4

**Agreement**For NTN-specific PUSCH DMRS bundling, support Alt 2 for TDW determination.* Alt 2: gNB-centric TDW determination
	+ Nominal TDW is determined based on gNB configuration.
	+ Actual TDW is determined based on gNB configuration/indication.
	+ Note: Alt 2 does not imply that spec impact of actual TDW determination is assumed for NTN.
	+ FFS: details, including UE capability and assistance information reporting
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According to the agreements and conclusions above, support of PUSCH DMRS bundling in NTN would be potential coverage enhancement for NTN although further discussions of detailed solutions are still ongoing. According to above, we propose to discuss at least following UE feature group as described in Table 2 for supporting PUSCH DMRS bundling in Rel-18 NTN. Based on the UE features agreed in NR Rel-17 for coverage enhancement[2], 30-4a/b are basic UE feature groups required for DMRS bundling. Therefore, they can be prerequisite FGs for PUSCH DMRS bundling in NTN.***Proposal 2:**** ***RAN1 to discuss UE feature group provided in Table 2 as a start point to support PUSCH DMRS bundling in NTN.***

*Table 2. Potential UE features of supporting PUSCH DMRS bundling in Rel-18 NTN.*

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| NTN DMRS bundling enhencement for PUSCH | Support DM-RS bundling for PUSCH in NTN over consecutive slots.FFS: new events rules for NTN are introduced.  | 30-4a/b (DM-RS bundling for PUSCH repetition Type A/B) | Yes | UE does not support DM-RS bundling enhancement for PUSCH in NTN.  | [Per UE] | [No] | [No] | FFS | Optional with capability signaling |

**UE features of UE location verification in NTN**According to the discussions so far in NR NTN UE location verification topic, Multi-RTT positioning method with single satellite in view by UE would be specified although the detailed solution discussions are still on going. In addition, some additional information may be reported to satellite to mitigate the timing error which is more serious in NTN. Therefore, at least 2 UE feature groups, UE Rx-Tx Measurement and Report for Multi-RTT with single satellite in NTN and assistant information report in Multi-RTT positioning in NTN, should be discussed for supporting UE location verification in Rel-18 NTN.Based on the agreed UE features summarized in NR Rel-16 for TN [3], 13-4 and 13-8 are basic UE feature groups required for supporting the PRS and SRS transmission in Multi-RTT methods. The PRS and SRS design in Rel-16 for Multi-RTT positioning in NTN should be reused according to the agreement below and we do not think any enhancements of PRS/SRS are needed at this stage for UE location verification in NTN. Therefore, 13-4 and 13-8 can be prerequisite FGs for Multi-RTT positioning in NTN.

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| **Agreement**Existing DL/UL reference signals for positioning are used for supporting Network verified UE location in NTN. FFS: Whether some enhancements on these reference signals are needed for NTN |

Assistant information report can be further discussed in RAN1 when the UE/gNB Rx-Tx time difference is determined. UE Rx-Tx Measurement and Report for Multi-RTT with single satellite in NTN can be the prerequisite FG of assistant information report for Multi-RTT positioning in NTN. According to above, details of the 2 FGs are provided in Table 3, and we have following proposal.***Proposal 3:**** ***RAN1 to discuss UE feature groups provided in Table 3 as a start point to support UE location verification in NTN.***

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| UE Rx-Tx Measurement and Report for Multi-RTT with single satellite in NTN | Support UE Rx-Tx Measurement and Report for Multi-RTT positioning with single satellite in NTN | 13-4 (DL PRS Resources for Multi-RTT),13-8 (SRS Resources for Positioning) | No | UE does not support Multi-RTT positioning with single satellite in NTN | [Per UE] | N/A | [No] | Need for location server to know if the feature is supported.FFS other notes | Optional with capability signaling |
| Assistant information report in Multi-RTT positioning in NTN | Support assistance information report to mitigate the timing error in Multi-RTT positioning in NTN. FFS: the detailed assistance information, e.g. Common TA offset, UE autonomous TA offset. | Multi-RTT positioning with single satellite in NTN | No | UE does not support assistance information report to mitigate the timing error | [Per UE] | N/A | [No] | Need for location server to know if the feature is supported.FFS other notes | Optional with capability signaling |

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| Huawei/HiSilicon [3] | **UE feature for NR NTN coverage enhancement**UE feature for PUCCH repetitionIn RAN1#112 [3] and 112bis-e [2], following agreements and working assumptions are made with respect to PUCCH repetition for Msg4 HARQ-ACK in NR NTN.

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| **Working assumption**For PUCCH repetition for Msg4 HARQ-ACK,A RSRP threshold can be configured via SIB at least when the number of repetitions is configured by SIB.If the RSRP threshold is configured and the configured RSRP threshold is smaller than X,UE capable of PUCCH repetition for Msg4 HARQ-ACK transmits repetition request if measured RSRP is lower than a RSRP threshold.If the RSRP threshold is not configured, or if the configured RSRP threshold is X,UE capable of PUCCH repetition for Msg4 HARQ-ACK reports the capability of PUCCH repetition for Msg4 HARQ-ACKFFS: value of X (the maximum configurable value of the RSRP threshold)Down-select one from the following alternatives for the RSRP threshold.Alt A: The same RSRP threshold as R17 Msg3 repetition (i.e., *rsrp-ThresholdMsg3-r17*) is used.Alt B: New RSRP threshold is introduced.Note: UE incapable of PUCCH repetition for Msg4 HARQ-ACK transmits neither repetition request nor capability report**Working assumption**For PUCCH repetition for Msg4 HARQ-ACK, support Option B as container of the repetition request or capability report indicated by UE.Option B: Higher layer signaling in Msg3 PUSCHSend an LS to RAN2 at RAN1#113 to provide details of “repetition request or capability report”, to ask the feasibility of Option B, and if feasible, to specify the details of Option B.**Agreement**For PUCCH repetition for Msg4 HARQ-ACK, support Alt 1-1 for dynamic indication of repetition factor from gNB. Further discuss which field(s) to be used.Alt 1: Field in DCI scheduling the Msg4 PDSCHAlt 1-1: One or two bits of the existing field(s)Alt 1-1a: MCS fieldAlt 1-1b: PUCCH resource indicator field (e.g., with repetition factor configuration per PUCCH resource)Alt 1-1c: HARQ process number filedAlt 1-1d: DAI fieldAlt 1-1e: PDSCH-to-HARQ\_feedback timing indicator field**Agreement**For PUCCH repetition for Msg4 HARQ-ACK, apply frequency hopping mechanism in R15/16/17 defined for PUCCH transmission for Msg4 HARQ-ACK, in every slot.**Agreement**For PUCCH repetition for Msg4 HARQ-ACK, candidate values of only one repetition factor configuration via SIB are {2, 4, 8}.i.e., configuration of only ‘1’ is not supported. |

Based on RAN1 agreements, PUCCH repetition request or capability reporting is based on early reporting during the RACH procedure. Currently, RAN1’s working assumption is based on higher layer signalling in Msg3. In this sense, there is no need to define a dedicated capability signalling in RRC signalling considering the gNB can get the UE’s capability with respect to the repetition of PUCCH of Msg4 through the Msg3.***Proposal 1: No need to define UE capability signalling in RRC layer for repetition of PUCCH for Msg4 HARQ-ACK, considering the capability is reported in Msg3 during the RACH procedure.*** UE feature for PUSCH DMRS bundlingFollowing agreements and working assumptions are made with respect to DMRS bundling for PUSCH repetitions in NR NTN.

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| **Observation**For NTN-specific PUSCH DMRS bundling, * In LEO 1200 with elevation angle 30 deg. and SCS = 15 kHz, RAN1’s understanding is the following:
	+ Phase difference limit (Table 6.4.2.5-1 in 38.101-1) cannot be satisfied over multiple slots (for carrier bandwidth 5 MHz or larger), if the PRB allocation is not within 6 PRBs from the DC carrier, pre-compensation by UE and post-compensation by gNB are not assumed, and 70.5 (us/s) timing drift rate is assumed.
	+ Note: this does not imply that UE shall be scheduled within 6 PRBs from the DC carrier.

**Working assumption**For NTN-specific PUSCH DMRS bundling, to satisfy the phase difference limit without causing phase discontinuity, it is assumed that pre-compensation to keep phase rotation due to timing drift within the phase difference limit can be performed at UE side.* UE shall not perform TA pre-compensation update within an actual TDW if it causes phase discontinuity that may violate the phase difference limit.
	+ FFS: how to determine the actual TDW
* FFS: specification impact
* Send an LS to RAN4

**Agreement**Final LS is endorsed in R1-2304094 with the following revision to the action:**ACTION**: RAN1 respectfully asks RAN4 to take the above RAN1 observations and ~~agreement~~ working assumption into account.**Agreement**For NTN-specific PUSCH DMRS bundling, support Alt 2 for TDW determination.* Alt 2: gNB-centric TDW determination
	+ Nominal TDW is determined based on gNB configuration.
	+ Actual TDW is determined based on gNB configuration/indication.
	+ Note: Alt 2 does not imply that spec impact of actual TDW determination is assumed for NTN.

FFS: details, including UE capability and assistance information reporting |

Besides original Rel-17 UE feature for DMRS bundling, new UE feature should be introduced to support the DMRS bundling in NTN considering more requirement may be needed on UE in NTN, e.g. as agreed in the working assumption, to pre-compensate the phase rotation due to the time drift. UE should report to gNB the capability of performing pre-compensation to keep phase rotation due to timing drift within the phase difference limit as agreed by RAN1. Besides, for the agreed gNB-centric TDW determination, UE should report to gNB the information impacting the TDW size, such as the antenna switching interval for the determination of actual TDW at gNB side. However, it is FFS on whether this information is part of capability signalling or defined as assistance information. To conclude, we have the following proposal.***Proposal 2: New UE capability is introduced for PUSCH DMRS bundling in NTN, considering at least the following components:**** ***The capability of pre-compensation of phase difference to keep phase rotation due to timing drift within the phase difference limit;***
* ***The information impacting on UE’s supported TDW size in NTN e.g. considering antenna switching interval etc.***
	+ ***FFS: whether this information is reported as UE capability or UE assistance information***

**UE feature for NTN network verified location**In RAN#99[1], the objectives on network verified UE location for NR NTN was made in the WID:

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| Based on RAN1 conclusions of the study phase, RAN to prioritize the specification of necessary enhancements to multi-RTT to support the network verified UE location in NTN assuming a single satellite in view [RAN1, 2, 3, 4]. DL-TDoA methods for verification may be considered as lower priority and if time permits and condition in Note is satisfied.Note 1: Enhancements assume reuse of the RAT dependent positioning frameworkNote 2: The specification of DL-TDOA enhancements will be subject to the study of the impact of realistic UE clock drift onto DL-TDOA performanceNote 3: The target accuracy for position verification purposes is as documented in clause « recommendations » of the 3GPP TR 38.882 (i.e. 10 km granularity)Note 4 : Multiple satellite in view by the UE may be considered if time allowsNote 5 : The enhancements may be subject to relevant SA WGs (e.g. SA3/SA3-LI) feedbacks on the reliability of UE reports involvedNote 6 : The enhancements should take into account the mirror-image ambiguityNote 7 : Network verified UE location is an optional UE feature |

According to the revised WID, Multi-RTT positioning is considered with higher priority to support network verified UE location in NTN. Therefore, the feature of network verified UE location should at least support Multi-RTT positioning in NTN. ***Proposal 3: The UE feature of network verified UE location should at least include the component of Multi-RTT positioning.*** |
| CMCC [4] | **UE feature for NTN coverage enhancement**The work item “NR NTN enhancements” has been studied during previous RAN1 meetings, for the NR NTN coverage enhancements schemes, RAN1 mainly focus on the PUCCH enhancements for Msg4 HARQ-ACK and DMRS bundling in NTN, and progress are reached on supporting PUCCH repetition for Msg4 HARQ-ACK and PUSCH DMRS bundling in NTN scenarios.For PUCCH repetition for HARQ-ACK in NTN, UE may transmit the information of repetition request or capability report to inform gNB UE capable of PUCCH repetition for Msg4 HARQ-ACK, the corresponding WA achieved in previous meetings are listed below.

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| **Working assumption**For PUCCH repetition for Msg4 HARQ-ACK,* A RSRP threshold can be configured via SIB at least when the number of repetitions is configured by SIB.
	+ If the RSRP threshold is configured and the configured RSRP threshold is smaller than X,
		- UE capable of PUCCH repetition for Msg4 HARQ-ACK transmits repetition request if measured RSRP is lower than a RSRP threshold.
	+ If the RSRP threshold is not configured, or if the configured RSRP threshold is X,
		- UE capable of PUCCH repetition for Msg4 HARQ-ACK reports the capability of PUCCH repetition for Msg4 HARQ-ACK
	+ FFS: value of X (the maximum configurable value of the RSRP threshold)
	+ Down-select one from the following alternatives for the RSRP threshold.
		- Alt A: The same RSRP threshold as R17 Msg3 repetition (i.e., rsrp-ThresholdMsg3-r17) is used.
		- Alt B: New RSRP threshold is introduced.
* Note: UE incapable of PUCCH repetition for Msg4 HARQ-ACK transmits neither repetition request nor capability report

**Working assumption**For PUCCH repetition for Msg4 HARQ-ACK, support Option B as container of the repetition request or capability report indicated by UE.* Option B: Higher layer signaling in Msg3 PUSCH

Send an LS to RAN2 at RAN1#113 to provide details of “repetition request or capability report”, to ask the feasibility of Option B, and if feasible, to specify the details of Option B. |

Therefore, one UE feature group for the support of PUCCH repetition for HARQ-ACK in NTN can be introduced, and the terminology for “PUCCH repetition for Msg4 HARQ-ACK” in NTN added in the components of FG can be further discussed.**Proposal 1. The support of PUCCH repetition for Msg4 HARQ-ACK can be introduced as a new UE feature group for NR NTN enhancement.** For NTN-specific PUSCH DMRS bundling, it was agreed the TDW for DMRS bundling is determined based on gNB configuration, and UE capability reporting needs to be further discussed. Besides, it is assumed that UE shall not perform TA pre-compensation update within an actual TDW if it causes phase discontinuity that may violate the phase difference limit. From our perspective, the determination of TDW size should take the maximum time duration during which UE is able to maintain power consistency and phase continuity into consideration.

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| **Working assumption**For NTN-specific PUSCH DMRS bundling, to satisfy the phase difference limit without causing phase discontinuity, it is assumed that pre-compensation to keep phase rotation due to timing drift within the phase difference limit can be performed at UE side.* UE shall not perform TA pre-compensation update within an actual TDW if it causes phase discontinuity that may violate the phase difference limit.
	+ FFS: how to determine the actual TDW
* FFS: specification impact
* Send an LS to RAN4

**Agreement**For NTN-specific PUSCH DMRS bundling, support Alt 2 for TDW determination.* Alt 2: gNB-centric TDW determination
	+ Nominal TDW is determined based on gNB configuration.
	+ Actual TDW is determined based on gNB configuration/indication.
	+ Note: Alt 2 does not imply that spec impact of actual TDW determination is assumed for NTN.
	+ FFS: details, including UE capability and assistance information reporting
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Therefore, one UE feature group for the support of UE reporting maximum duration during which UE can maintain the power consistency and phase continuity in NTN can be introduced.**Proposal 2. The maximum duration for DMRS bundling reported by UE in NTN can be introduced as a new UE feature group for NR NTN enhancement.*** **The maximum duration during which UE is able to maintain power consistency and phase continuity to support DMRS bundling for PUSCH in NTN**

**UE feature for ATG scenarios**The work item of enhancements for NR NTN with implicit compatibility to support HAPS (High Altitude Platform Station) and ATG (Air To Ground) scenarios is included in both Rel-17 and Rel-18 scope, thus the feature groups introduced for NTN solutions can also be applicable to HAPS and ATG scenarios. However, when specifying the feature groups for Rel-17 NR NTN solutions, the note “This UE feature group is applicable only for bands in Table 5.2.2-1 in TS 38.101-5 and HAPS operation bands in Clause 5.2 of TS 38.104” added in the Feature 26 only mentioned satellite bands and HAPS bands, considering that ATG bands was not specified in the Rel-17 WI phase. ATG network deployment has been discussed in Rel-18 led by RAN4, and ATG operating bands in ATG network deployment scenarios specified by RAN4 are listed as below. From our perspective, as NR NTN solutions and enhancements are compatible with the ATG scenarios, with ATG operating bands already being specified, separate feature groups can be discussed and introduced in Rel-18.

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| **Clause 5 in TR 38.876 v0.3.0**ATG will operate within existing NR operating bands and does not need new bands and band properties to be identified. Depending on the operator’s request, the following NR bands are intended for ATG deployment:Table 5-1: ATG operating bands

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| --- | --- | --- | --- |
| **NR operating band** | **Uplink (UL) *operating band*BS receive / UE transmit****FUL\_low  – FUL\_high** | **Downlink (DL) *operating band*BS transmit / UE receive****FDL\_low – FDL\_high** | **Duplex Mode** |
| n1 | 1920 MHz – 1980 MHz | 2110 MHz – 2170 MHz | FDD |
| n3 | 1710 MHz – 1785 MHz | 1805 MHz – 1880 MHz | FDD |
| n34 | 2010 MHz – 2025 MHz | 2010 MHz – 2025 MHz | TDD |
| n39 | 1880 MHz – 1920 MHz | 1880 MHz – 1920 MHz | TDD |
| n41 | 2496 MHz – 2690 MHz | 2496 MHz – 2690 MHz | TDD |
| n78 | 3300 MHz – 3800 MHz | 3300 MHz – 3800 MHz | TDD |
| n79 | 4400 MHz – 5000 MHz | 4400 MHz – 5000 MHz | TDD |

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From our perspective, at least increasing the number of HARQ processes for HARQ enhancements and K1 range extension for timing relationship enhancement are supported in ATG scenarios, extending K1 value range is beneficial to guarantee all 32 HARQ processes’ feedback can be multiplexed in a HARQ-ACK codebook, at least for TDD or half-duplex FDD, which is important for ATG and HAPS, corresponding agreements reached in RAN1 are listed as following.

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| **Agreement:**For unpaired spectrum, extend the value range of K1 from (0..15) to (0..31) * FFS: Whether there is an impact on the size of the PDSCH-to-HARQ\_feedback timing indicator field in DCI.

**Agreement:**The extension of maximal HARQ process number can be considered with following assumptions:* The maximal supported HARQ process number is up to 32.
* FFS: Support on the maximal HARQ process number is up to UE capability
* Minimizing the impacts on specification and scheduling
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Therefore, it is proposed to introduce new feature groups for NR ATG network, and support of maximal supported HARQ process number reported by UE and extended K1 value range of (0..31) for unpaired spectrum can be introduced as the new UE feature groups for ATG scenarios.**Proposal 3. Enhancement on the HARQ process number is introduced as a new UE feature group for ATG scenarios, and add the note “This UE feature group is applicable only for bands in Table 5-1 in TR 38.876”.****Proposal 4. Enhancement on the K1 range extension is introduced as a new UE feature group for ATG scenarios, and add the note “This UE feature group is applicable only for bands in Table 5-1 in TR 38.876”.**

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| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| xx-x | Increasing the number of HARQ processes | The maximal supported HARQ process number is X for UL and Y for DL | Yes | No | Increased number of HARQ processes is not supported for NR communication via satellite | Per band | Candidate component values for (X,Y): {(16,32),(32,16),(32,32)}Note: This UE feature group is applicable only for bands in Table 5-1 in TR 38.876 | Optional with capability signalling |
| xx-x | K1 range extension | Support of extended K1 value range of (0..31) for unpaired spectrum | Yes | No | K1 range extension is not supported  | Per band | Note: This UE feature group is applicable only for bands in Table 5-1 in TR 38.876 | Optional with capability signalling  |

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| Apple [5] | For NR NTN coverage enhancement objective, there are two tasks: PUCCH enhancements for Msg 4 HARQ-ACK and enhancements for DMRS bundling for PUSCH taking into account NTN-specifics. For PUCCH enhancements for Msg4 HARQ-ACK, the main scheme designed in RAN1 is PUCCH repetition. This includes UE sending repetition request or capability report to gNB to indicate either it has PUCCH repetition capability for Msg4 HARQ-ACK or it additionally requests PUCCH repetition for Msg4 HARQ-ACK based on its own downlink RSRP measurements. This repetition request or capability report is via Msg3 PUSCH higher layer signaling based on working assumption. If more than one repetition factor is configured by network, network will dynamically indicate the number of repetitions for Msg4 HARQ-ACK to a UE. Overall, we propose to define a new UE feature group of PUCCH repetition for Msg4 HARQ-ACK. The components of this FG include UE sending repetition request or capability report to gNB; UE receiving repetition factor from gNB and applying it to PUCCH repetition for Msg4 HARQ-ACK. ***Proposal 1:*** *Define a UE FG of PUCCH repetition for Msg4 HARQ-ACK, including the following components** *Send repetition request or capability report to gNB.*
* *Receive repetition factor from gNB and apply it to PUCCH repetition for Msg4 HARQ-ACK.*

For enhancements for DMRS bundling for PUSCH taking into account NTN-specifics, it was agreed [3] that for NTN-specific PUSCH DMRS bundling, gNB-centric TDW determination is supported where nominal TDW is determined based on gNB configuration and actual TDW is determined based on gNB configuration/indication. To facilitate gNB configuration of nominal TDW and actual TDW, UE needs to report its capability on pre-compensation to keep phase rotation within the phase difference limit, as well as its capability on TA pre-compensation update within an actual TDW. Both capabilities may be reflected in the form of the maximum number of slots, in which UE couldpre-compensate to keep phase rotation within the phase difference limit and keep timing error within the timing error limit. Hence, we propose to define a new UE feature group of enhanced DMRS bundling for PUSCH taking into account NTN-specifics. ***Proposal 2:*** *Define a UE FG of enhanced DMRS bundling for PUSCH taking into account NTN-specifics, including the following component** *Report its capability of pre-compensation to keep phase rotation within the phase difference limit and its capability of TA pre-compensation update within an actual TDW.*

For the objective of network verified UE location, the existing RAN1 discussions focus on multi-RTT positioning method. There are no discussions on DL-TDoA positioning method. Hence, we propose to define a new UE feature group of supporting network verified UE location based on multi-RTT. According to the existing RAN1 agreements, the legacy definition of UE Rx-Tx time difference does not fit for NTN case. A new definition of UE Rx-Tx time difference is being actively discussed. Here, UE needs to measure UE Rx-Tx time difference based on the new definition for NTN. This measurement needs to be reported to LMF for its verification of UE location. Hence, the new UE feature should include a component of “measure UE Rx-Tx time difference based on the definition for NTN and report the measured UE Rx-Tx time difference to LMF. ***Proposal 3:*** *Define a UE FG of supporting network verified UE location based on multi-RTT, including the following component** *Measure UE Rx-Tx time difference based on the definition for NTN and report it to LMF.*
 |
| OPPO [6] |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| X. NR\_NTN\_enh-Core | X-1 | MSG4 PUCCH repetition | 1. read repetition factor in SIB1
2. read threshold in SIB1
3. Send repetition request in MSG3 if RSRP<threshold
4. Send capability report in MSG3 if threshold is not configured or threshold value = X
 | [per UE/per band] | Optional with capability signalling |
| X. NR\_NTN\_enh-Core | X-1a | MSG4 PUCCH repetition | 1. Indicate repetition request in MSG3
2. Indicate capable of MSG3 PUCCH repetition
3. Reinterpret XXX field in DCI format 1-0 with TC-RNTI, where the field is to indicate repetition factor
4. Perform MSG4 PUCCH repetition according to indicated repetition factor
 | [per UE/per band] | Optional with capability signalling |
| X. NR\_NTN\_enh-Core | X-2 | PUSCH DMRS bundling | 1. Determine actual TDW
2. Not perform TA adjustment within actual TDW
 | [per UE/per band] | Optional with capability signalling |
| X. NR\_NTN\_enh-Core | X-2a | PUSCH DMRS bundling | Indicate capable of performing TA adjustment within actual TDW while keeping phase continuity | [per UE/per band] | Optional with capability signalling |
| X. NR\_NTN\_enh-Core | X-3 | [multi-RTT for single serving satellite] | [indicate support multi-RTT for single serving satellite] | [per UE/per band] | Optional with capability signalling |

 |
| ZTE [7] | In normative phase, the coverage enhancement and network verified UE location for NR-NTN have been discussed. For coverage enhancement, agreement has been achieved to support PUCCH repetition for Msg4 HARQ-ACK. Accordingly, repetition capability for PUCCH for Msg4 HARQ-ACK need to be defined. Moreover, the procedure of PUCCH repetition configuration has also been discussed. It is basically consensus that network can configure repetition factor using SIB, UE can report repetition capability, and network can dynamically indicate a repetition factor when multiple repetition factors are indicated in SIB. Hence, they can also be considered in UE feature.

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| **Agreement**For PUCCH for Msg4 HARQ-ACK,* Support PUCCH repetition
	+ Further discuss the specification impact for at least the following
		- Procedure and signaling (e.g., cell-specific configuration, request to gNB and dynamic indication from gNB, UE capability indication before Msg4, etc.)
		- Repetition factor
		- Repetition slot counting for FDD
	+ Further study whether to enhance or support the following
		- Frequency hopping
		- DMRS bundling
 |

For network verified UE location, the basic conclusion is that existing multi-RTT framework may be reused for location verification with potential enhancements to adapt it to NTN context. However, till now, no agreement has been achieved on how to enhance the multi-RTT framework and what new UE feature is needed. Hence, the corresponding feature discussion can be postponed.***Proposal 1:*** *Adopt the feature groups in Table 1 for Rel-18 NR-NTN.*

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 44. NR\_NTN\_enh-Core | 44-1 | PUCCH repetition for Msg4 HARQ-ACK | 1. Support repetition transmission of PUCCH for Msg4 HARQ-ACK and common PUCCH resource
 |  | n/a | Yes | Coverage performance of PUCCH of MSg4 HARQ-ACK and common PUCCH will be reduced | Per Band | Yes | No | No |  | Optional with capability signaling |
| 44. NR\_NTN\_enh-Core | 44-2 | PUCCH repetition based on SIB indication | 1. Support UE receiving repetition factor in system information
 | 44-1 | n/a | Yes | Coverage performance of PUCCH of MSg4 HARQ-ACK and common PUCCH will be reduced | Per Band | Yes | No |  |  | Optional with capability signaling |
| 44. NR\_NTN\_enh-Core | 44-3 | PUCCH repetition based on dynamic indication | 1. Support UE receiving repetition factor in DCI scheduling Msg4 PDSCH
 | 44-1, 44-2 | n/a | Yes | Coverage performance of PUCCH of MSg4 HARQ-ACK and common PUCCH will be reduced | Per Band | Yes | No |  |  | Optional with capability signaling |

 |
| NTT DOCOMO, INC. [8] | **Coverage enhancement**PUCCH repetition for Msg4 HARQ-ACKWith respect to PUCCH for Msg4 HARQ-ACK, it was agreed that repetition is introduced to improve the bottleneck channel. For the repetition feature, we believe that all related behaviors should be included in a single FG; otherwise, it is quite difficult for gNB to accommodate various capability-types of UEs in a single NTN cell. We can reuse decision of R17 Msg3 repetition as a kind of baseline, where only a single FG, i.e., FG 30-6, is defined.It is noted that the following aspects were agreed so far, including working assumptions.* Repetition factor is configured via SIB.
* When only a single factor is configured, the repetition factor is applied without dynamic indication.
* When multiple factors are configured, a repetition factor from the list is indicated by Msg4 PDSCH scheduling DCI.
* UE transmits repetition request (with RSRP comparison) or capability report (without RSRP comparison) via Msg3 PUSCH. Details of repetition request or capability report are FFS
* Legacy frequency hopping for non-repetition case is reused per slot

Besides, the enhancement target is under discussion. Repetition may be applicable to any transmission by using common PUCCH, or may be limited to PUCCH transmission only for Msg4 HARQ-ACK. After further WI discussion or plenary discussion, some relevant part may need to be updated later.**Proposal 1: Define only a single FG for PUCCH repetition for Msg4 HARQ-ACK as follows.**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| NR\_NTN\_enh |  | PUCCH repetition for [Msg4 HARQ-ACK] | 1. Support of repetition of PUCCH transmission [scheduled by DCI format 1\_0 with CRC scrambled by TC-RNTI] when a single repetition factor is configured via SIB2. Support of repetition of PUCCH transmission [scheduled by DCI format 1\_0 with CRC scrambled by TC-RNTI] when multiple repetition factors are configured via SIB and a repetition factor is indicated by the DCI |  | Yes | N/A |  | Per band | N/A | N/A | N/A |  | Optional with capability signalling |

PUSCH DMRS bundling in NTNFor PUSCH DMRS bundling in NTN, we believe that basically Rel-17 FGs (FGs 30-4/30-4a/30-4b/30-4c) can be used for NTN as well as TN since these FGs are per band or per band/BC and thus separate report between TN and NTN is already possible. There would be no need to define FGs for the same purpose. On the other hand, it was agreed in WI discussion that UE can perform pre-compensation to keep phase rotation due to timing drift within the phase difference limit. This is an NTN-specific UE behavior and thus corresponding capability would be necessary.

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| **Working assumption**For NTN-specific PUSCH DMRS bundling, to satisfy the phase difference limit without causing phase discontinuity, it is assumed that pre-compensation to keep phase rotation due to timing drift within the phase difference limit can be performed at UE side.* UE shall not perform TA pre-compensation update within an actual TDW if it causes phase discontinuity that may violate the phase difference limit.
	+ FFS: how to determine the actual TDW
* FFS: specification impact
* Send an LS to RAN4
 |

**Proposal 2: Reuse FGs 30-4/30-4a/30-4b/30-4c to report PUSCH DMRS bundling-related capability for NR NTN.****Proposal 3: Define a new FG to report whether to support pre-compensation to keep phase rotation due to timing drift within the phase difference limit, as follows.**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| NR\_NTN\_enh |  | Pre-compensation for PUSCH DMRS bundling in NTN | Support of pre-compensation to keep phase rotation due to timing drift within the phase difference limit |  | Yes | N/A |  | [Per band] | N/A | N/A | N/A |  | Optional with capability signalling |

**NW verified UE location**It was agreed that multi-RTT positioning framework with necessary enhancement is adopted to support the network verified UE location in NTN assuming a single satellite in in view. Regarding the multi-RTT positioning method in NTN, for the UE Rx-Tx time difference which is measured and reported by UE, following options are under discussion.

|  |
| --- |
| **Agreement**For RTT determination in NTN, discuss further the accuracy, and reporting details of combinations of the following UE and gNB receive-transmit time difference measurements:* Alt-1: UE Rx-Tx time difference based on Option 3 and gNB Rx-Tx time difference as defined in TS 38.215.
	+ Note 1: The signaling method of UE Rx-Tx time difference definition option 1 is not precluded if Alt1 is adopted
* Alt-2: UE Rx-Tx time difference based on Option 2 and gNB Rx-Tx time difference as defined in TS 38.215.
	+ Note 2: The LMF will use the time stamp of the PRS and the time stamp of SRS to calculate the time difference between the transmission of PRS and the reception of SRS
* Alt-3: UE Rx-Tx time difference based on Option 2 and gNB Rx-Tx time difference based on Option 4

      FFS: One or multiple SRS can be used in determining the arrival time      FFS: Additional enhancement including additional information to be reported, if justifiedNote 3: The impact of UE autonomous adjustment of TA (when applied) should be taken into accountNote 4: The gNB Rx-Tx time difference option in the above alternatives may need updates accordingly based on the outcome of discussion on reference point for the gNB Rx – Tx time difference**Agreement**Select one (or more) of the following options for enhancing UE Rx-Tx time difference in NTN* Option 1: The UE Rx – Tx time difference is defined as TUE-RX –TUE-TX

Where:* + UE Rx-Tx time difference is defined with respect to the Rx and Tx subframe timing associated with the TRP.

For a Transmission Point * + TUE-RX is the UE received timing of downlink subframe #*i* from this Transmission Point (TP), defined by the first detected path in time.
	+ TUE-TX is the UE transmit timing of the uplink subframe corresponding to subframe #*i* received from the TP
	+ One or multiple DL RS for positioning, as instructed by higher layers, can be used to determine the start of one subframe of the first arrival path of the TP.

FFS: For a Transmission Point different from the serving cell (e.g. a DL-PRS-only TP)* Option 2*:*
	+ For RTT measurement in NTN, support UE report that indicates the time difference between the arrival time of a DL RS for positioning and the transmit time of an SRS.
	+ FFS: details of report and the definition of UE Rx-Tx time difference
* Option 3: The legacy R17 definition of UE Rx-Tx time difference is adopted for NTN with an offset that is determined based on one of the following options:
	+ Option 3-1: This offset is reported as the nearest integer value in the unit of milliseconds by rounding the time difference of transmit timing of uplink subframe #i and receive timing of downlink subframe#i
	+ Option 3-2: UE report the index of the subframe j that is closest in time to the subframe #i received from the TP and LMF can derive the offset
	+ Option 3-3: TA report which corresponds to the time difference of received timing of downlink subframe #i and transmit timing of uplink subframe#i rounding up to slot granularity.
* Option 4:
	+ UE Rx – Tx time difference TUE-RX – TUE-TX can be directly derived from timing advance TTA
		- FFS: the granularity and the reporting range of TA.
		- Note: This implies that the existing framework for Multi-RTT positioning report can be used without need to specify a new TA report.

Note: The impact of UE autonomous adjustment of TA (when applied) should be taken into account |

It is obvious that legacy definition of UE Rx-Tx time difference cannot be directly reused considering the large propagation delay in NTN scenario. Thus, enhancement for UE Rx-Tx time difference in NTN is necessary, e.g., additional information report, or NTN specific new definition. With consideration of enhancement for UE Rx-Tx time difference in NTN, a new FG will be needed. Meanwhile, as the legacy multi-RTT framework is generally reused, Rel-16/17 UE features related to multi-RTT positioning (e.g., FGs 13-1/13-4/13-4a/13-4b/13-8/etc.) can also be reused, and there’s no need to define new FG for NTN with the same function as Rel-16/17 FGs. **Proposal 4: Define a new FG for UE Rx-Tx time difference report in NR NTN, as follows.**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| NR\_NTN\_enh |  | Enhanced UE Rx-Tx Measurement Report for Multi-RTT in NTN | Support of enhanced UE Rx-Tx time difference measurement and report for multi-RTT in NTN. |  | No | N/A |  | Per UE | N/A | Yes | N/A |  | Optional with capability signalling |

 |
| Nokia/Nokia Shanghai Bell [9] | The following new FGs can be identified for NR NTN* PUCCH repetitions for Msg4 HARQ-ACK
* DMRS bundling for PUSCH
	+ Inherit the Rel-17 DMRS bundling for PUSCH capbilities such that the functionality builds on top of the existing defined feature.
* Multi-RTT support for UE location verification
	+ Inherit Rel-16 multi-RTT capabilities such that the functionality builds on top of the existing defined feature.

Baseline FGs for DMRS bundling and multi-RTT can either be copied from Rel-17/16 (approach 1 below), or directly referred to (approach 2 below)**Proposal 1: adopt the following FG for PUCCH repetition for MSG4 HARQ-ACK**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Index** | **FG** | **Components**  | **Pre-requisites** | **Note** |
| 44-1 | PUCCH repetitions for Msg4 HARQ-ACK for NR NTN | 1. Aqcuiring the Msg4 PUCCH repetition configuration and RSRP threshold from System Information
2. Support for {2, 4, 8} times repetition for PUCCH for Msg4 HARQ-ACK
3. Msg3 [support Indication / repetition request] for PUCCH Msg4 HARQ-ACK repetition
4. Reading of indicated amount of indicated amont of repetitions for PUCCH for Msg4 HARQ-ACK vis reinterpretation of DCI scheduling Msg4
5. Performing indicated amount of repetitions of PUCCH for Msg4 HARQ-ACK
 |  |  |

**Approach 1: copying the DMRS-bunlding and multi-RTT capabilities for NTN**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Index** | **FG** | **Components**  | **Pre-requisites** | **Note** |
| 44-2(30-4) | The maximum duration for DM-RS bundling for PUSCH for NR-NTN | 1. The maximum duration during which UE is able to maintain power consistency and phase continuity to support DM-RS bundling for PUSCH
2. Support for pre-compensation for phase continuity maintenance during the configured TDW
3. Suspension of TA pre-compensation update within an actual TDW
 |  | 1. [For FDD {4, 8, 16, 32}, for TDD {2, 4, 8, 16}]
 |
| 44-3(30-4a) | DM-RS bundling for PUSCH repetition type A for NR-NTN | Support DM-RS bundling for PUSCH repetition type A over consecutive symbols | 44-2 and at least one of {5-14, 5-16, 5-17} |  |
| 44-4(30-4b) | DM-RS bundling for PUSCH repetition type B for NR-NTN | Support DM-RS bundling for PUSCH repetition type B over consecutive symbols | 44-2, 11-5 |  |
| 44-5(30-4c) | DM-RS bundling for TB processing over multi-slot PUSCH for NR-NTN | Support DM-RS bundling for TB processing over multi-slot PUSCH over consecutive symbols | 44-2, 30-3 |  |
| 44-6(30-4e) | Enhanced inter-slot frequency hopping with inter-slot bundling for PUSCH for NR-NTN | Support enhanced inter-slot frequency hopping with inter-slot bundling for PUSCH | At least one of {44-3 44-4, 44-5} |  |
| 44-7(30-4g) | Restart DM-RS bundling for NR-NTN | Support restarting DM-RS bundling after the events triggered by DCI or MAC CE that violate power consistency and phase continuityNote: Events which are triggered by DCI or MAC CE, but do not require UE capability to resume maintaining power consistency and/or phase continuity as specified in subclause 6.1.7 of 38.214 v17.3.0 are excluded from this feature | 44-2 |  |
| 44-8(13-1) | Common DL PRS Processing Capability for NR-NTN | 1. Maximum DL PRS bandwidth in MHz, which is supported and reported by UE.
2. DL PRS buffering capability: Type 1 or Type 2
3. Duration of DL PRS symbols N in units of ms a UE can process every T ms assuming maximum DL PRS bandwidth in MHz, which is supported and reported by UE.
4. Max number of DL PRS resources that UE can process in a slot under it

Note: The above parameters are reported assuming a configured measurement gap and a maximum ratio of measurement gap length (MGL) / measurement gap repetition period (MGRP) of no more than 30%. |  | 1a) FR1 bands: {5, 10, 20, 40, 50, 80, 100}1b) FR2 bands: {50, 100, 200, 400}2a) Type 1 – sub-slot/symbol level buffering2b) Type 2 – slot level buffering3a) T: {8, 16, 20, 30, 40, 80, 160, 320, 640, 1280} ms3b) N: {0.125, 0.25, 0.5, 1, 2, 4, 6, 8, 12, 16, 20, 25, 30, 32, 35, 40, 45, 50} ms4a) FR1 bands: {1, 2, 4, 6, 8, 12, 16, 24, 32, 48, 64} for each SCS: 15kHz, 30kHz, 60kHz4b) FR2 bands: {1, 2, 4, 6, 8, 12, 16, 24, 32, 48, 64} for each SCS: 60kHz, 120kHz |
| 44-9(13-4) | DL PRS Resources for Multi-RTT for NR-NTN | 1. Max number of DL PRS Resource Sets per TRP per frequency layer supported by UE.
2. Max number of TRPs across all positioning frequency layers per UE.
3. Max number of positioning frequency layers UE supports
 | 44-8 | 1. {1, 2}
2. {4, 6, 12, 16, 24, 32, 64, 128, 256}
3. {1, 2, 3, 4}
 |
| 44-10(13-4a) | DL PRS Resources for Multi-RTT on a band for NR-NTN | 1. Max number of DL PRS Resources per DL PRS Resource Set
2. Max number of DL PRS Resources per positioning frequency layer.
 | 44-8 | 1. {1, 2, 4, 8, 16, 32, 64}

Note: 16, 32, 64 are only applicable to FR2 bands1. {6, 24, 32, 64, 96, 128, 256, 512, 1024}

Note: 6 is only applicable to FR1 bands |
| 44-11(13-4b) | DL PRS Resources for Multi-RTT on a band combination for NR-NTN | 1. Max number of DL PRS Resources supported by UE across all frequency layers, TRPs and DL PRS Resource Sets for FR1-only.
2. Max number of DL PRS Resources supported by UE across all frequency layers, TRPs and DL PRS Resource Sets for FR2-only.
3. Max number of DL PRS Resources supported by UE across all frequency layers, TRPs and DL PRS Resource Sets for FR1 in FR1/FR2 mixed operation.
4. Max number of DL PRS Resources supported by UE across all frequency layers, TRPs and DL PRS Resource Sets for FR2 in FR1/FR2 mixed operation.
 | 44-8 | 1. {6, 24, 64, 128, 192, 256, 512, 1024, 2048}

Note this is reported for FR1 only BC.1. {24, 64, 96, 128, 192, 256, 512, 1024, 2048}

Note this is reported for FR2 only BC1. {6, 24, 64, 96, 128, 192, 256, 512, 1024, 2048}

Note this is reported for BC containing FR1 and FR2 bands1. {24, 64, 96, 128, 192, 256, 512, 1024, 2048}

Note this is reported for BC containing FR1 and FR2 bands |

With a general note that was used for Rel-17 NTN solutionsOr alternatively, in short, reference the existing capabilities, as nothing currently forbids supporting 30-4 family of FGs in NTN bands. However, for some deployments the enhancements in Rel-18 are needed, and hence there is a value in supporting a Rel-18 specific UE FG for those, as seen in the table below:**Approach 2: Referencing the the DMRS-bundling and multi-RTT capabilities of Rel-17 and Rel-16**

|  |  |  |  |
| --- | --- | --- | --- |
| **Index** | **FG** | **Components**  | **Pre-requisites** |
| 44-2 | DMRS-bundling enhancement for NR NTN | 1. Support for pre-compensation for phase continuity maintenance during the configured TDW
2. Suspension of TA pre-compensation update within an actual TDW
 | 30-4 |
| 44-3 | Multi-RTT for network verified UE location for NR NTN | Support for multi-RTT positioning for network verified location for NR NTN | 13-4, 13-4a, 14-4b |

**Proposal 2: Adopt the Approach 2 of referencing the Rel-17 DMRS bundling capabilities and Rel-16 multi-RTT capabilities for NTN**As the NR-NTN FGs only apply to bands that are applicable to NTN, the Rel-17 practice can be reused in Rel-18 by adding the following note to all the new NR-NTN FGs, and discuss if the HAPS part of the note should be applied as well:**Proposal 3: Add the following note on band applicability used in Rel-17 NTN FGs to all the new Rel-18 NR-NTN FGs:*** **Note: This UE feature group is applicable only for bands in Table 5.2.2-1 in TS 38.101-5 [and HAPS operation bands in Clause 5.2 of TS 38.104]**
 |
| Ericsson [10] | **NR NTN coverage enhancement**PUCCH repetitionA single UE capability should be defined for PUCCH repetition of Msg4 HARQ-ACK PUCCH (and other cell-specific PUCCH, if scope extension is agreed), covering both the cases of single and multiple repetition factors configured in SIB.1. A single UE capability should be defined for repetition of Msg4 HARQ-ACK PUCCH (and other cell-specific PUCCH) ), covering both the cases of single and multiple repetition factors configured in SIB.

Even though repetition for Msg4 HARQ-ACK PUCCH (and other cell-specific PUCCH) is specified within the NR NTN enhancements work item, the feature as such should not be limited to non-terrestrial networks. Indeed, coverage on cell-specific PUCCH can potentially be a problem also in terrestrial networks. The need for Msg4 HARQ-ACK PUCCH repetitions in terrestrial networks was evaluated during the Rel-17 coverage enhancement study. The results in TR 38.830 were inconclusive since only a few companies evaluated this channel, but the results indicate that the Msg4 HARQ-ACK PUCCH might be the bottleneck in some FDD scenarios (see e.g. Table 5.1.1.5-2 in TR 38.830).1. Repetition of Msg4 HARQ-ACK PUCCH (and other cell-specific PUCCH) can be useful also in terrestrial networks.
2. The UE capability of repetition of Msg4 HARQ-ACK PUCCH (and other cell-specific PUCCH) should be possible to indicate for NTN and TN.

To allow early configuration of dedicated PUCCH resources with the Rel-17 feature dynamic PUCCH repetition enabled, we propose that a UE that supports “PUCCH repetition when dedicated PUCCH is not configured” also supports the Rel-17 feature dynamic PUCCH repetition on dedicated PUCCH.1. A UE that supports the Rel-18 feature for Msg4 HARQ-ACK PUCCH (and other cell-specific PUCCH) repetition shall also support the Rel-17 feature dynamic PUCCH repetition (feature group 30-5*)*.

Based on this, we propose to add one FG as shown in Table 1.1. Define one FG for cell-specific PUCCH repetition as proposed in Table 1.

PUSCH DMRS bundlingFor PUSCH DMRS bundling enhancements, the following working assumption has been made:**Working assumption**For NTN-specific PUSCH DMRS bundling, to satisfy the phase difference limit without causing phase discontinuity, it is assumed that pre-compensation to keep phase rotation due to timing drift within the phase difference limit can be performed at UE side.* UE shall not perform TA pre-compensation update within an actual TDW if it causes phase discontinuity that may violate the phase difference limit.
	+ FFS: how to determine the actual TDW
* FFS: specification impact
* Send an LS to RAN4

Based on this, we propose to add one FG as shown in Table 1 (assuming the working assumption is confirmed).1. Proposal 1 Define one FG for DMRS bundling with phase pre-compensation for NTN as proposed in Table 1.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 44. NR\_NTN\_enh  | 44-1 | Slot based dynamic PUCCH repetition on cell-specific PUCCH resources | Support slot based dynamic PUCCH repetition on cell-specific PUCCH resources | 30-5 (Slot based dynamic PUCCH repetition indication) | Yes | NA | PUCCH repetition will not be used on cell-specific PUCCH resources | Per band | NA | NA | NA |  | Optional with capability signaling |
| 44. NR\_NTN\_enh  | 44-2 | DMRS bundling with phase rotation pre-compensation | Support DMRS bundling with pre-compensation of phase rotation per sub-carrier based on timing drift | 26-1 (Uplink Time and Frequency pre-compensation and timing relationship enhancements),30-4a (DM-RS bundling for PUSCH repetition type A) OR30-4b (DM-RS bundling for PUSCH repetition type B) OR30-4c (DM-RS bundling for TB processing over multi-slot PUSCH) | Yes | NA | DMRS bundling will not work in NTN with high timing drift (e.g. LEO) | Per band | NA | NA | NA | **Working assumption**For NTN-specific PUSCH DMRS bundling, to satisfy the phase difference limit without causing phase discontinuity, it is assumed that pre-compensation to keep phase rotation due to timing drift within the phase difference limit can be performed at UE side.* UE shall not perform TA pre-compensation update within an actual TDW if it causes phase discontinuity that may violate the phase difference limit.
	+ FFS: how to determine the actual TDW
* FFS: specification impact
* Send an LS to RAN4
 | Optional with capability signaling |

 |

# Discussion Items during RAN1 #113 — First Checkpoint

After review of contributions submitted to RAN1 #113 in this agenda item, the following topics were identified by the moderator for discussion during RAN1 #113.

**General comments**

|  |  |
| --- | --- |
| Company | Comments/Questions/Suggestions |
|  |  |

# Issue 1: Coverage Enhancement

After review of contributions submitted to RAN1 #113 in this agenda item, the following is proposed by the moderator. Companies submitted the following views on the moderator’s proposals.

**Proposal: Adopt the following changes highlighted in chromatic fonts, while keeping the yellow highlighting, if any, as shown**

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| 44. NR\_NTN\_enh-Core | 44-1 | PUCCH repetition for Msg4 HARQ-ACK | 1. Support repetition transmission of PUCCH for Msg4 HARQ-ACK and common PUCCH resource 2. Support receiving repetition factor in system information3. Support receiving repetition factor in DCI scheduling Msg4 PDSCH 4. Support of Msg3 [support indication/repetition request] for PUCCH Msg4 HARQ-ACK repetition |  | Yes | No | UE does not support PUCCH repetition for Msg4 HARQ-ACK | Per Band | N/A | N/A | N/A | Note: This UE feature group is applicable only for bands in Table 5.2.2-1 in TS 38.101-5 [and HAPS operation bands in Clause 5.2 of TS 38.104] | Optional with capability signaling |

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| Company | Comments/Questions/Suggestions |
| DCM | Basically fine, but three comments.* + - Proposal text (not FG but ‘adopt…’) may be not intended for NR NTN since this is the first time for discussion on R18 NR NTN UE feature.
		- Component 4 should be updated as ‘Support Msg3 to transmit information for PUCCH Msg4 HARQ-ACK repetition’. The current text seems to be a bit unclear/strange.
		- The note should be removed. This feature can be applied to TN as well as NTN.
 |
| OPPO | The first bullet should be separate from the rest of the bullets. There is a UE who can support 2,3,4, but cannot support 1. For instance, the UE transmits repetition capability in Msg3 indicating the repetition is not supported. Thus, support repetition transmission of PUCCH for Msg4 HARQ-ACK and common PUCCH resource can be under 44-1a. |
| Nokia, NSB | Support the basic structure |
| Ericsson | The note should be removed. This feature can be supported also in TN bands. |

# Issue 2: PUSCH DMRS Bundling

After review of contributions submitted to RAN1 #113 in this agenda item, the following is proposed by the moderator. Companies submitted the following views on the moderator’s proposals.

**Proposal: Adopt the following changes highlighted in chromatic fonts, while keeping the yellow highlighting, if any, as shown**

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| 44. NR\_NTN\_enh-Core | 44-2 | NTN DMRS bundling enhancement for PUSCH | 1. Support of DM-RS bundling for PUSCH over consecutive slots2. Support of pre-compensation to keep phase rotation due to timing drift within the phase difference limit3. Support of TA pre-compensation update within an actual TDW | 30-4a/b | Yes | No | UE does not support DM-RS bundling enhancement for PUSCH in NTN | Per Band | N/A | N/A | N/A | Note: This UE feature group is applicable only for bands in Table 5.2.2-1 in TS 38.101-5 [and HAPS operation bands in Clause 5.2 of TS 38.104] | Optional with capability signaling |

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| Company | Comments/Questions/Suggestions |
| DCM | Two comments.* + - Proposal text (not FG but ‘adopt…’) may be not intended for NR NTN since this is the first time for discussion on R18 NR NTN UE feature.
		- Component 3 is not aligned with the previous working assumption. It should be like ‘Support not to perform TA pre-compensation update within an actual TDW if it causes phase discontinuity that may violate the phase difference limit.’
 |
| OPPO | Agree with DCM on bullet 3.  |
| Nokia, NSB | Support the proposal in principle. Agree with DCM on component 3, should read something like “support of the suspension of TA pre-compensation update within an actual TDW”? |
| Ericsson | Agree with DCM on bullet 3. |

# Issue 3: NTN Network Verified Location

After review of contributions submitted to RAN1 #113 in this agenda item, the following is proposed by the moderator. Companies submitted the following views on the moderator’s proposals.

**Proposal: Adopt the following changes highlighted in chromatic fonts, while keeping the yellow highlighting, if any, as shown**

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| 44. NR\_NTN\_enh-Core | 44-3 | UE Rx-Tx Measurement and Report for Multi-RTT with single satellite in NTN | Support UE Rx-Tx Measurement and Report for Multi-RTT positioning with single satellite in NTN | 13-4, 13-8 | Yes | No | UE does not support Multi-RTT positioning with single satellite in NTN | Per Band | N/A | N/A | N/A | Note: This UE feature group is applicable only for bands in Table 5.2.2-1 in TS 38.101-5 [and HAPS operation bands in Clause 5.2 of TS 38.104] | Optional with capability signaling |
| 44. NR\_NTN\_enh-Core | 44-4 | Assistant information report in Multi-RTT positioning in NTN | Support of assistance information report to mitigate the timing error in Multi-RTT positioning in NTN | 44-3 | Yes | No | UE does not support assistance information report to mitigate the timing error | Per Band | N/A | N/A | N/A | Note: This UE feature group is applicable only for bands in Table 5.2.2-1 in TS 38.101-5 [and HAPS operation bands in Clause 5.2 of TS 38.104] | Optional with capability signaling |

|  |  |
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| Company | Comments/Questions/Suggestions |
| DCM | Basically fine, but two comments.* + - Proposal text (not FG but ‘adopt…’) may be not intended for NR NTN since this is the first time for discussion on R18 NR NTN UE feature.
		- Discusion on FG44-4 can be postponed until the assistance information to mitigate timing error is identified/agreed.
 |
| OPPO | 3.3 can be further revisited after more progress is made on this topic. At the moment, the current 44-3, 44-4 are fine.  |

# Issue 4: ATG Scenarios

After review of contributions submitted to RAN1 #113 in this agenda item, the following is proposed by the moderator. Companies submitted the following views on the moderator’s proposals.

**Proposal: Adopt the following changes highlighted in chromatic fonts, while keeping the yellow highlighting, if any, as shown**

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| 44. NR\_NTN\_enh-Core | 44-5 | Increased number of HARQ processes | Maximal supported HARQ process number for UL and DL |  | Yes | No | Increased number of HARQ processes is not supported | Per Band | N/A | N/A | N/A | DL candidate values: FFSUL candidate values: FFSNote: This UE feature group is applicable only for bands in Table 5.2.2-1 in TS 38.101-5 [and HAPS operation bands in Clause 5.2 of TS 38.104] | Optional with capability signaling |
| 44. NR\_NTN\_enh-Core | 44-6 | K1 range extension | Support of extended K1 value range for unpaired spectrum |  | Yes | No | K1 range extension is not supported  | Per Band | N/A | N/A | N/A | Note: This UE feature group is applicable only for bands in Table 5.2.2-1 in TS 38.101-5 [and HAPS operation bands in Clause 5.2 of TS 38.104] | Optional with capability signaling |

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| Company | Comments/Questions/Suggestions |
| DCM | We are not sure whether RAN1 should make new FG for not TS but TR. Besides, at least these would be intended for ATG, thus the notes are not aligned with the intention. |

# Discussion Items during RAN1 #113 — Second Checkpoint

Based on the comments/questions/suggestions received by the first checkpoint, the following are the revised proposals and/or proposed agreements by the moderator. Companies submitted the following views on the moderator’s proposals.

***[Please submit all comments/questions/suggestions here, late comments/questions/suggestions submitted in Section 3 will not be considered]***

**General comments**

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| Company | Comments/Questions/Suggestions |
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# Issue 1: FG

**Proposal: Adopt the following changes highlighted in chromatic fonts, while keeping the yellow highlighting, if any, as shown**

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# Discussion Items during RAN1 #113 — Third Checkpoint

Based on the comments/questions/suggestions received by the second checkpoint, the following are the revised proposals and/or proposed agreements by the moderator. Companies submitted the following views on the moderator’s proposals.

***[Please submit all comments/questions/suggestions here, late comments/questions/suggestions submitted in Section 4 will not be considered]***

**General comments**

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| Company | Comments/Questions/Suggestions |
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# Issue 1: FG

**Proposal: Adopt the following changes highlighted in chromatic fonts, while keeping the yellow highlighting, if any, as shown**

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# Summary of Final Proposals for Agreements

This Section summarizes the final proposals for agreement in RAN1 #113 by email. There are no tables for comments.

***[All comments must be directly made on the RAN1 email reflector]***

Companies can continue to update their comments in the previous Sections, however, these are no longer monitored by the moderator. Any such comments will be for archival purposes only and will not influence the outcome of this email discussion. Any objection to any of the proposals in this Section must be voiced directly on the RAN1 email reflector.

**Possible Agreement: Adopt the following changes highlighted in chromatic fonts, while keeping the yellow highlighting, if any, as shown**

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# Conclusion

After further discussion on the RAN1 email reflector the following was agreed as part of this email discussion:

# References

1. R1-2304227, Initial RAN1 UE features list for Rel-18 NR after RAN1#112bis-e, Moderators (AT&T, NTT DOCOMO, INC.)
2. R1-2304510, Discussions on UE feature of NR NTN enhancements, vivo
3. R1-2304667, UE features for NR NTN enhancements, Huawei/HiSilicon
4. R1-2305119, Discussion on UE features for NR NTN enhancements, CMCC
5. R1-2305278, On UE Features for Rel-18 NR NTN Enhancements, Apple
6. R1-2305446, Discussion on UE features for NR NTN enhancements, OPPO
7. R1-2305561, Discussion on the UE feature for NR-NTN, ZTE
8. R1-2305621, Discussion on UE features for NR NTN enhancements, NTT DOCOMO, INC.
9. R1-2305721, Initial views on UE features for NR NTN enhancements, Nokia/Nokia Shanghai Bell
10. R1-2305806, On UE features for NR NTN enhancements, Ericsson