3GPP TSG RAN WG1 Meeting #105-e R1-2104571

e-Meeting, May 10th – 27th, 2021

Agenda Item: 8.15.1

Source: Moderator (MediaTek)

Title: Summary #1 of AI 8.15.1 Scenarios applicable to NB-IoT/eMTC

Document for: Discussion and Decision

# Introduction

At the RAN#86 meeting, a new Study Item was approved for IoT Non Terrestrial Network (NTN) and revised in RAN#91 [1]. There was an email discussion on [91E][42][NTN\_IoT\_Roadmap] In RAN#91 with moderator summary and final proposal for GTW input in [2].

In RAN#91-e GTW session, the Chairman endorsed a Way Forward Proposal in [3] on email discussion on [50][New\_proposals\_approval]. This included guidance from RAN Chairman for NTN NR and NTN IoT as follows

* *RAN#92E (June) to finalize the scope and project plan to deliver the essential minimum functionality of both NTN NR and NTN IoT (both NB-IoT and eMTC) within the existing TU allocations*
* *Detailed scoping exercise (NTN NR WID revision, NTN IoT WID approval) to be undertaken at RAN#92E (June)*

In this meeting, company views on scenarios applicable to NB-IoT/eMTC are summarized and observations/proposals on identified issues are made. Observations and proposals in Company’s TDoc contributions are listed in the Appendix.

# Link Budget Aspects

## Atmospheric Path Loss for Case 1 – GEO

ZTE proposed the value of atmosphere loss used in Case-1 GEO of link budget should be updated as 0.88 dB (instead of 0.2 dB) as central beam edge elevation is 2.3 degree. This is to align all results based on NOTE 5 Atmospheric losses are a function of elevation angle.

***Moderator view****: The results provide good alignment assuming additional losses of 0 dB on DL and 3 dB on UL, NF=7 dB and PC3. Other losses for MEO can be added into table 6.2-1 in TR 36.763. After checking TS 38.811, this seems correct understanding. Case link budget results can be updated with atmosphere loss of 0.88 dB instead of 0.2 dB.*

***Initial proposal - Section 2.1***

* ***Update Case link budget results can be updated with atmosphere loss of 0.88 dB instead of 0.2 dB in Section 6.2.2.1.1 Set-1 in TR 36.763***

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| PC3 (23 dBm), NF=7 dB |
| Cases |  EIRP Density  | EIRP per spot | DL C/N  |  G/T |  UL C/N1080 kHz / 360 kHz /180 kHz / 90 kHz / 45 kHz / 30 kHz / 15 kHz / 3.75 kHz |
| 1 | 59 dBW/MHz | 81.6 dBm | -4.0 dB | 19 dB/K | -22.7 dB / -17.9 dB / -14.9 dB / -11.9 dB / -8.9 dB / -7.2 dB / -4.2 dB / 1.9 dB |
| 2 | 40 dBW/MHz | 62.6 dBm | 2.9 dB | 1.1 dB/K | -14.7 dB / -10.0 dB / -7.0 dB / -4.0 dB / -1.0 dB / 0.8 dB / 3.8 dB / 9.8 dB |
| 3 | 34 dBW/MHz | 56.6 dBm | 2.3 dB | 1.1 dB/K | -9.3 dB / -4.6 dB / -1.6 dB / 1.5 dB / 4.5 dB / 6.2 dB / 9.2 dB / 15.3 dB |

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| PC5 (20 dBm), NF=9 dB |
| Cases |  EIRP Density  | EIRP per spot | DL C/N  |  G/T |  UL C/N1080 kHz / 360 kHz /180 kHz / 90 kHz / 45 kHz / 30 kHz / 15 kHz / 3.75 kHz |
| 1 | 59 dBW/MHz | 81.6 dBm | -6.0 dB | 19 dB/K | -25.0 dB / -20.3 dB / -17.2 dB / -14.2 dB / -11.2 dB / -9.5 dB / -6.5 dB / -0.4 dB |
| 2 | 40 dBW/MHz | 62.6 dBm | 0.9 dB | 1.1 dB/K | -17.0 dB / -12.3 dB / -9.3 dB / -6.3 dB / -3.3 dB / -1.4 dB / 1.5 dB / 7.5 dB |
| 3 | 34 dBW/MHz | 56.6 dBm | 0.3 dB | 1.1 dB/K | -12.3 dB / -7.6 dB / -4.5 dB / -1.5 dB / 1.5 dB / 3.2 dB / 6.2 dB / 12.3 dB |

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### FIRST ROUND: Atmospheric Path Loss for Case 1 - GEO

## Additional Path Losses

CMCC observed carriage and container penetration loss (9~20 dB) for logistics application and vegetation loss (e.g., 9 dB) for outdoor application and proposed additional path loss should be considered for evaluating the basic coverage performance of IoT NTN in real deployment conditions.

Nokia observed including outdoor-to-indoor loss, vegetation loss or non-LOS loss results in at least 10 dB additional loss, which may therefore require link budget improvements. Use of repetitions is needed for NPUSCH Format 1 and level of repetitions gain should be evaluated in normative phase.

***Moderator view****: Cellular NB-IoT / eMTC can support high level of repetitions consistent with extreme coverage conditions at MCL = 164 dB with SNR as low as -20 dB. In NB-IoT, this is in addition to selecting up to 10 RUs to transmit a given TBS which result in a very low effective code rate. Single tone operations may also apply to further improve coverage. Taken all these into account, the maximum PUSCH duration to transmit a single TBS can be in the order of 40 seconds.*

***Initial proposal - Section 2.2***

***Companies are encouraged to comment on their understanding of the specifications and of the issues associated with additional losses:***

* ***Q1: Is it understanding that for example for NB-IoT the specified maximum level of repetitions is 128 and number of Resource Units is 10, which result in duration of transmission of a single TBS with single tone in extreme coverage at MCL=164 dB that can be as long as 40 seconds?***
* ***Q2: Is it understanding that the SNR levels consistent with extreme coverage in extreme coverage with MCL = 164 dB can be in the order of -20 dB?***
* ***Q3: What are realistic SNR and duration of a single TBS transmission with additional losses in NTN?***

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### FIRST ROUND - Additional Path Losses

# IoT NTN Scenario D - MEO

RAN1#104bis- made agreement to include MEO Set-5 parameters for link budget analysis in a new Table 6.2-8 in TR 36.763, as a representative characterization of NTN-IoT scenarios with MEO altitude and characteristics.

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|  | **Proposed MEO Scenarios (Set 5)** |
| Satellite orbit | MEO |
| Satellite altitude | 10,000 km |
| Payload characteristics for DL transmission |
| Frequency band | S-band (i.e. 2 GHz) |
| Equivalent satellite antenna aperture (NOTE1) | 1.5 m |
| Satellite EIRP density | 45.4 dBW/MHz |
| Satellite Tx max Gain | 28.1 dBi |
| 3dB beamwidth | 6.5 degrees |
| Satellite beam diameter (at nadir pointing) | 1140 km |
| Payload characteristics for UL reception |
| Frequency band | S-band (i.e. 2 GHz) |
| Equivalent satellite antenna aperture (NOTE1) | 1.5 m |
| G/T | 3.8 dB/K |
| Satellite Rx max Gain | 28.1 dBi |
| NOTE 1: This value is equivalent to the antenna diameter for the parabolic reflector modelled in Sec. 6.4.1 of TR 38.811.NOTE 2: Antenna models different from the parabolic reflector described in TR 38.811 should be used. |

**Table 6.2-8: Sets of satellite parameters for link budget and system level evaluations**

Huawei, Nokia, CATT, CMCC, CMCC, ZTE, Apple, EchoStar (R1-2102750) provided Link budget using “Set 5” NTN-IoT scenarios with MEO altitude and characteristics.

CATT and OPPO proposed to add other losses for MEO into table 6.2-1 in TR 36.763

ZTE Clarification on the definition of EIRP for MEO w.r.t to whether including a 3 dB additional loss due to beamwidth is needed.

***Moderator view****: The results provide good alignment assuming additional losses of 0 dB on DL and 3 dB on UL, NF=7 dB and PC3. Other losses for MEO can be added into table 6.2-1 in TR 36.763.*

***Initial proposal - Section 3-1***

* ***Include the following Table for Set 5 – MEO in TR 36.763***

***Set 5***

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| ***Cases*** |  ***EIRP Density***  | ***EIRP per spot*** | ***DL C/N***  |  ***G/T*** |  ***UL C/N******1080 kHz / 360 kHz / 180 kHz / 90 kHz / 45 kHz / 30 kHz / 15 kHz / 3.75 kHz*** |
| ***10*** | ***45.4 dBW/MHz***  | ***68 dBm*** | ***-4.5 dB*** | ***3.8 dB/K*** | ***-24.8 dB / -20.0 dB / -17.0 dB / -14.0 dB / -11.0 dB / -9.2 dB / -6.2 dB / -0.2 dB***  |

***Initial proposal - Section 3-2***

* ***Add other losses for MEO in Table 6.2-1: Other losses in TR 36.763***

***Table 6.2-1: Satellite losses***

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| ***Other Losses*** | ***GEO (35786 km)*** | ***LEO (1200 km)*** | ***LEO (600 km)*** | ***MEO (10000 km)*** |
| ***Scintillation losses*** | ***2.2 dB*** | ***2.2 dB*** | ***2.2 dB*** | ***2.2 dB*** |
| ***Atmospheric losses*** | ***0.2 dB*** | ***0.1 dB*** | ***0.1 dB*** | ***0.2 dB*** |
| Polarization loss | 3 dB | 3 dB | 3 dB | 3 dB |
| Shadow margin  | 3 dB | 3 dB | 3 dB | 3 dB |

*NOTE 1: With PC3 (23 dBm) there is a 3dB gain compared to the PC5 (20 dBm) assumption on UL.*

*NOTE 2: With NF=7 dB, there is a 2 dB improvement compare to NF=9 dB on DL.*

*NOTE 3: Link budgets with other link budget parameters are not excluded from being captured in the TR.*

*NOTE 4: These parameters are only for the purpose of link budget calculations.*

*NOTE 5: Atmospheric losses are a function of elevation angle.*

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## FIRST ROUND – Scenario D – MEO

TBA

# Deployment Modes

MediaTek summarized Rel-16 NB-IoT WI coexistence with NR feature as copied below:

In Rel-16 NB-IoT WI, Coexistence of NB-IoT with NR feature allows the configuration of the DL/UL resource reservation in subframe/slot/symbol-levels on non-anchor carriers for unicast transmission to avoid resource overlapping with NR channels/signals. The configuration can be for 10ms or 40ms duration, with a periodicity from {10ms, 20ms, 40ms, 80ms, 160ms} and a start position in a granularity of 10ms, which is independent from legacy configurations. It also allows dynamic indication whether the resource reservation is applied or not [RP-201229].

Moderator copies the Rel-16 NB-IoT agreements related to NR co-existence:

* Specify NB-IoT resource reservation only for FDD/TDD NB-IoT non-anchor carriers.
* UL resource reservation for NB-IoT is supported.
* FDD UL resource reservation is supported with subframe-level granularity
	+ FFS: Slot-level, symbol-level
* DL resource reservation is supported with slot-level and symbol(s)-level granularity.
* The reserved resource in NB-IoT non-anchor carrier is semi-statically configured by higher layer signalling.
	+ FFS whether the resource in an invalid and/or valid subframe indicated by legacy downlink bitmap can be configured as the reserved resource
	+ FFS signalling
* NB-IoT transmission can be postponed or dropped depending on the granularity of the reserved resources.
* NB-IoT transmission is dropped for symbol-level reserved resources.
* NB-IoT transmission is dropped for slot-level reserved resources.
* NB-IoT transmission is postponed for subframe-level reserved resources.

Moderator copies the Rel-16 NB-IoT agreements related to NR co-existence:

* DL subcarrier puncturing is supported on both sides of [transmission bandwidth]
* The maximum number of LTE-MTC DL subcarriers that can be punctured is 2
* The [maximum] number of punctured subcarriers and their locations are configured by higher layers via [SIB or UE-specific RRC signaling]. It is FFS whether DCI can override or modify the higher-layer configuration.
* The same higher-layer configuration of [maximum] number of punctured subcarriers and their locations apply to both MPDCCH and PDSCH.
* FFS: till the next meeting whether DMRS, CSI-RS and SFBC RE pairs are punctured or not.
* LTE-MTC DL time-domain resource reservation is supported with a finer granularity than slot level. Transmissions in these reserved resources are dropped.
	+ FFS: How to handle DMRS
* Support LTE-MTC DL time-domain resources reservation with slot-level granularity. Transmissions in these reserved resources are dropped.
* The LTE-MTC resource reservation is configured by higher layers via [SIB or UE-specific RRC signaling]. It is FFS whether DCI can override or modify the higher-layer configuration.
* For LTE-MTC resource reservation, for unicast, symbols of MPDCCH/PDSCH scrambled by C-RNTI or SPS-C-RNTI that would fall into the reserved resource are dropped for symbol-level and slot-level reserved resources.
	+ Dropped means punctured
* For LTE-MTC resource reservation, UL resource reservation for LTE eMTC with slot-level and symbol(s)-level granularity in addition to subframe-level granularity is supported.
* For LTE-MTC resource reservation, for unicast transmission, dynamic DCI signalling can be used to [indicate or override] which reserved resources are used for the scheduled LTE eMTC transmission
* For LTE-MTC resource reservation, the higher-layer configuration is cell-specific
* LTE-MTC DL frequency-domain resource reservation is supported
	+ FFS: granularity of resource reservation
* Subcarrier puncturing
	+ The puncturing feature is configured by higher layers via SIB (details FFS)
	+ From UE point of view, if one RE of the SFBC RE pair is configured as the punctured subcarrier, the SFBC pair is assumed to be punctured.
	+ LTE MTC DL subcarrier puncturing applies to CSI-RS

MediaTek CATT provided a summary on NB-IoT deployments with NR feature based on TR 37.824: [6, 7]. We copy the CATT summary below:

In TN system, NB-IoT supports three deployment modes, which are standalone, guard-band (assumed an LTE guard band) and in-band (with LTE). Similarly, eMTC supports in-band (with LTE) and stand-alone deployment.

According to TR 37.824, for NB-IoT operating in LTE, system scenarios have involved 3 following operations,

* **Category NB1/NB2 stand-alone operation**: category NB1/NB2 is operating standalone when it utilizes its own spectrum, for example the spectrum used by GERAN systems as a replacement of one or more GSM carriers, as well as scattered spectrum for potential IoT deployment.
* **Category NB1/NB2 guard band operation:** category NB1/NB2 is operating in guard band when it utilizes the unused resource block(s) within an E-UTRA carrier’s guard-band.
* **Category NB1/NB2** **in-band operation:** category NB1/NB2 is operating in-band when it utilizes the resource block(s) within a normal E-UTRA carrier.

For IoT NTN system, we need to reconsider the deployment modes of NB-IoT with NR band. Based on the summary of TR 37.824, for NB-IoT operation in NR in-band, RB alignment, power boosting and numerologies have been addressed. NB-IoT and NR operating with 15 kHz SCS could coexist in NR band while optimizing resource utilization by aligning respective RBs. For NB-IoT operation in NR guard band, it is concluded that even if one NB-IoT system with 15 kHz sub-carrier would operate in NR guard band, still need to consider this case as NB-IoT operation in NR in-band. For NB-IoT standalone operation, based on coexistence study, it is concluded that there is no issue for NB-IoT standalone coexistence with NR.

It seems that both stand-alone operation and in-band operation can be used. However, in-band operation may need to be further studied. Potential issues for NB-IoT and NR NTN in-band coexistence:

* Channel raster, PRB and subcarrier grid alignment

Refer to TR 37.824, MSR BS supporting NR and LTE+NB-IoT (LTE in-band/guard band) could also meet current RF requirements when operating NR+(LTE)+NB-IoT (NR in-band) with following limitations:

* Same NR channel bandwidth as LTE
* NR uses 15 kHz SCS
* NB-IoT carrier frequency kept when operating with LTE and NR, or shifted closer to NR carrier.

For NB-IoT and NR NTN in-band coexistence, there may have similar limitations.

* Power boosting

For Rel-13 power bosting for E-UTRA guard band operation and in-band operation is introduced in both TS 36.104 and TS 37.104. The minimum requirement is +6 dB power bosting for one NB-IoT RB located within E-UTRA transmission bandwidth configuration for in-band operation or adjacent to the E-UTRA transmission bandwidth configuration edge as close as possible for guard band operation. Legacy deployment should be taken into account and similar hardware capability should be maintained. Hence +6 dB power boosting should be kept for the NR NTN scenario. Meanwhile +6 dB power boosting will be challenging for NR NTN.

* Numerologies

As NR NTN could support several numerologies, which might be different from NB-IoT numerologies, there might exist mixed numerology configuration which would result in interference between NR subcarrier and NB-IoT subcarrier when NB-IoT carrier is deployed within NR NTN carrier. Hence, requirement needs to be defined for mixed numerology between NR NTN and NB-IoT.

* Synchronization between NR NTN and NB-IoT

Considering the large delay and Doppler shift of NTN system，timing and frequency misalignment between NB-IoT and NR NTN might exceed maximum tolerance.

CATT observed that in order to avoid potential interference and complicated coordination, the stand-alone operation is more suitable for IoT NTN. Similarly, for eMTC, supports stand-alone deployment.

MediaTek observed co-existence between NTN RN and NTN IoT is beyond the scope of Rel-17 IoT NTN study and whether a normative phase would include such study would require discussions at RAN and RAN4 levels.

CMCC observed that coexistence with terrestrial NR should be deprioritized, since with the large Doppler shift and propagation delay in NTN, it may be challenging for effective frequency sharing between eMTC over NTN and terrestrial NR. In-band of LTE should be precluded, since there is no LTE NTN. Guard-band of NR-NTN can be further studied. Furthermore, regarding the maximum channel bandwidth capability for NR-NTN is 30MHz for band <6GHz [3], study on NB-IoT deployed in guard-band of NR-NTN with 15kHz SCS can be prioritized, if needed, to ensure subcarrier orthogonality between NB-IoT over NTN and NR-NTN.

Qualcomm discussed that there is currently, terrestrial NB-IoT supports four deployment modes—standalone, guard-band (assumed an LTE guard band), in-band (with LTE) with same PCI (as underlying LTE cell), and in-band with different PCI. Qualcomm proposed for NB-IoT over NTN, support only Standalone, In-band with NR / guard band of NR.

Nokia proposed all guard band, inband/DSS and standalone mode (LTE NB-IoT/eMTC and NR in NTN) can be considered but whether they can be supported should depend on detailed analysis and solutions in the normative phase.

Samsung observed RAN1 considers that NTN NB-IoT / eMTC is developed for deployment in standalone mode, and further discussion on coexistence with NR NTN can happen during the WI phase with RAN4 involvement.

CMCC, CATT, ZTE, MediaTek proposed to support stand-alone deployment for NB-IoT and eMTC in IoT NTN

ZTE proposed the supports for in-band mode should be further studied with only assuming the NR SCS as 15 kHz.

CMCC, MediaTek proposed study of NTN IoT inband deployment and guard band deployment are de-prioritized in Rel-17 IoT NTN normative phase.

***Moderator view****: there is a general view to de-prioritize NB-IoT / eMTC deployment modes which are many:*

* *Current terrestrial standalone, guard-band (assumed an LTE guard band), in-band (with LTE) with same PCI (as underlying LTE cell)*
* *In-band and guard band with NR co-existence (Rel-16 NB-IoT/ eMTC WI and TR 37.824)*

*There is a general view that study of deployment of NB-IoT / eMTC in band and guard band with NR co-existence will be needed before considering detailed analysis and solutions in a normative phase, with several companies proposing to de-prioritise such study in Rel-17 normative phase.*

*There is general view that at least standalone deployment for NB-IoT / eMTC should be supported in Rel-17 normative phase, with several companies proposing to prioritize this deployment.*

*Rel-16 NB-IoT / eMTC Inband / guard band with NR co-existence specifications will need enhancements to support NTN? Is impact to specification likely to be significant and would require a study first before a normative phase can be considered.*

*Solutions in TR 37.824 further expand scope of solutions for NB-IoT / eMTC inband and guard band with NR co-existence with impact on RAN4 specifications* *TS 38.104, TS 38.141-1, TS 37.104 and TS 37.141*

***Initial proposal - Section 4.1***

***Companies are encouraged to comment on NB-IoT / eMTC deployment modes in NTN***

* ***Q1: Is it understanding that Rel-16 NB-IoT / eMTC Inband / guard band with NR co-existence specifications will need enhancements to support NTN? Is impact to specification likely to be significant and would require a study first before a normative phase can be considered?***
* ***Q2: Is it understanding that solutions in TR 37.824 further expand scope of solutions for NB-IoT / eMTC inband and guard band with NR co-existence with impact on RAN4 specifications TS 38.104, TS 38.141-1, TS 37.104 and TS 37.141? Is impact to specification likely to be significant and would require a study first before a normative phase can be considered?***
* ***Q3: Is a study of deployment of NB-IoT / eMTC in band and guard band with NR co-existence needed before considering detailed analysis and solutions in a normative phase, and would such study / detailed analysis and solutions in a normative phase be consistent with a Rel-17 normative phase.***
* ***Q4: Can standalone deployment for NB-IoT / eMTC at least be prioritized for support in Rel-17 normative phase?***

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## FIRST ROUND – Deployment nodes

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# Others

Ericsson made a number of observations:

* eMTC and NB-IoT can address different types of IoT use cases based on their unique capabilities and thus complement each other.
* NB-IoT supports ultra-low complexity devices with very narrow bandwidth, while eMTC can achieve higher data rates, more accurate device positioning, and supports voice calls and connected mode mobility.
* The approved Rel-17 IoT NTN SID is dedicated to LEO and GEO satellite communication, while HAPS/HIBS and A2G are not in the scope.
* Rel-17 IoT NTN study should equally treat eMTC and NB-IoT. The study item will be incomplete unless each of them is properly studied for its feasibility for NTN.
* It was agreed at RAN2#112e that support for EPC is assumed for IoT NTN.
* Identifying specific bands of interest in sub 6 GHz can be a topic for RAN4 to discuss when a potential normative phase begins.
* The approved Rel-17 IoT NTN SID is dedicated to transparent payload.

MediaTek made the following observations:

* A UE may only need a new GNSS position solely for UE pre-compensation for UL synchronization in corner case scenarios where (i) it is not fixed; (ii) reporting of the GNSS position is not needed by application layer.
* The satellite system design should fix key parameters such as EIRP and G/T in the satellite to ensure the link budget can be closed on DL and UL.

Omnispace observed the following:

* There is a significant market opportunity for the broad range of IoT opportunities to be supported by satellite operations that cover areas devoid of communication opportunities. It is important to the satellite industry that the first NTN Rel17 provides a solid foothold to assist the development of both high value IoT market segments, in addition to low data rate infrequent packet data applications.
* The eMTC NGSO satellites parameters for Set1 and Set2 link budget will be adequate for supporting eMTC CE-Mode A which will unlock the delivery of high-value IoT use cases.

Qualcomm proposed for LEO satellites with non-steerable satellite beams, define techniques to configure a cell (Ncell for NB-IoT) that spans resources across multiple satellite beams of a satellite. This solution was described in AI 8.15.4 in R1-2104826 with proposals and observations to be captured additionally (to the essential proposals) in the TR as guiding principles and observations for future work.

## Maximum Coupling Loss

ZTE provided the distribution of Coupling Loss (CL) simulation results.

Rural scenarios: The cdf of CL for DL for set 1, set 2, set 3, and set 4 in rural scenarios was provided in [ZTE, R1-2105193]. In rural scenarios, the Coupling Loss of about

* 5%~10% GEO UEs are larger than 164 dB for Set-1, Set-2, and Set-3
* 5% LEO-600 are larger than 154 dB for Set-1, Set-2, Set-3, and Set-4
* 5% LEO-1200 UEs are larger than 160 dB for Set-1, Set-2, and Set-3

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| Figure 1 Illustration of DL CL for GEO in rural | Figure 2 Illustration of DL CL for LEO-600 in rural |
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| Figure 3 Illustration of DL CL for LEO-1200 in rural |  |

Urban scenarios: The cdf of Coupling Loss for DL for set 1, set 2, set 3, and set 4 in urban scenarios and dense urban scenarios was provided in [ZTE, R1-2102916].

* In urban scenario, the CLs of about 50% GEO UEs are larger than 164 dB, about 30% LEO-600 and LEO-1200 UEs are larger than 164 dB;

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| Figure 4 Illustration of DL CL for GEO in ubran | Figure 5 Illustration of DL CL for LEO-600 in urban |
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| Figure 6 Illustration of DL CL for LEO-1200 in urban |  |

Dense Urban scenarios: The cdf of Coupling Loss for DL for set 1, set 2, set 3, and set 4 in dense urban scenarios was provided in [ZTE, R1-2102916].

* In dense urban scenario, the CLs of about 50% GEO UEs are larger than 164 dB, the CLs of about 30%~40% LEO-600 and LEO-1200 UEs are larger than 164 dB.

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| Figure 7 Illustration of DL CL for GEO in Dense urban | Figure 8 Illustration of DL CL for LEO-600 in Dense urban |
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| Figure 9 Illustration of DL CL for LEO-1200 in Dense urban |  |

***Moderator view****: The tail in the the CDF of MCL DL for rural scenarios suggest MCL as high as 180 dB can be experienced for Set-1, Set-2, Set-3. This would suggest SNR in the order of -35 dB or lower. This seems to be much lower than SNR values in link budget analysis. For example for Case 1 even adjusting with higher atmospheric loss of 0.88 dB as discussed in Section 2, the lowest SNR DL is -4 dB. This means a difference in the order of 30 dB. The MCL values for urban and dense urban are significantly worse due to the NLOS. The relevance of urban and dense urban scenarios for NTN could be further discussed.*

***Initial proposal – Section 5.1***

***Companies are encouraged to comment on their understanding of the MCL results***

* ***Q1: The tail of cdf MCL for Case 1, Case 2, Case 3 in rural***
* ***Q2: Relevance of urban scenario for cdf MCL analysis for NTN?***
* ***Q3: Relevance of urban scenario for cdf MCL analysis for NTN?***

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## Achievable data rates

SONY observed eMTC can support communication in CE Mode A in all of the scenarios studied in IoT-NTN. DL data rates of up to 900kbps can be supported by eMTC in CE Mode A for the LEO-1200 set-1 scenario. UL data rates of up to 43kbps can be supported by eMTC in CE Mode A for the LEO-1200 set-1 scenario.

Available DL SNRs and UL SNRs for different IoT-NTN cases based on RAN1#104bis-e agreements

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| Case | Satellite orbit | Satellite parameter set | DL SNR (dB) | UL SNR (dB) for full PRB 180kHz allocation | UL SNR (dB) for 30kHz allocation |
| 1 | GEO | Set 1 | -3.22 | -14.15 | -6.4 |
| 2 | LEO-1200 | Set 1 | 3.49 | -6.34 | 1.4 |
| 3 | LEO-600 | Set 1 | 2.89 | -0.94 | 6.84 |
| 4 | GEO | Set 2 | -8.51 | -18.94 | -11.16 |
| 5 | LEO-1200 | Set 2 | -3.25 | -13.08 | -5.30 |
| 6 | LEO-600 | Set 2 | -3.82 | -7.65 | 0.13 |
| 7 | GEO | Set 3 | -2.18 | -16.21 | -8.43 |
| 8 | LEO-1200 | Set 3 | -2.19 | -19.62 | -11.84 |
| 9 | LEO-600 | Set 3 | -2.20 | -14.23 | -6.45 |
| 10 | LEO-600 | Set 4 | -12.05 | -20.03 | -12.25 |

TR38.811 section 6.1.2 proposes that an AWGN channel model is assumed in open environments. The UE and satellite are assumed to both operate with 1 TX antenna and 1 RX antenna.

The performance of the eMTC CE Mode A DL was simulated in [R1-1802058], leading to the following BLER-SNR performance of eMTC in AWGN for 1TX1RX communications in Figure below.



Based on the available SNRs available from the link budgets from Table above and the SNR-BLER performance from Figure above, the Table below summarises the data rates that can be supported in eMTC CE Mode A. These data rates are calculated based on the supported spectral efficiencies (from the Figure) and do not account for signaling overhead. For the symmetrical link, these BLER-SNR curves are also applicable to the UL. For the UL UE data rate, either full PRB transmission (blue) or 3-subcarrier sub-PRB transmissions (red) are applied. The UL cell data rate is the UL data rate aggregated over multiple UEs.

Supported throughputs in IoT-NTN CE Mode A [R1-2105182]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Case | Satellite orbit | Satellite parameter set | DL data rate | UL UE data rate | UL cell data rate |
| 1 | GEO | Set 1 | 144 | 3.6 | 130 |
| 2 | LEO-1200 | Set 1 | 900 | 14.4 | 86.4 |
| 3 | LEO-600 | Set 1 | 720 | 43.2 | 259.2 |
| 4 | GEO | Set 2 | 45 | 0.45 | 16.2 |
| 5 | LEO-1200 | Set 2 | 144 | 4.5 | 162 |
| 6 | LEO-600 | Set 2 | 90 | 7.2 | 43.2 |
| 7 | GEO | Set 3 | 144 | 4.5 | 162 |
| 8 | LEO-1200 | Set 3 | 144 | 0.45 | 16.2 |
| 9 | LEO-600 | Set 3 | 144 | 3.6 | 130 |
| 10 | LEO-600 | Set 4 | 8 | 0.3 | 10.8 |

The Table above shows that all IoT-NTN scenarios are supported by eMTC CE Mode A. The LEO scenarios are particularly well suited for eMTC operation, where UE DL data rates of up to 900kbps and UE UL data rates of up to 43kbps can be supported. Note that other UL UE data rates and UL UE cell data rates can be supported through other choices of UL transmission scheme, such as the use of 2-of-3 /2 BPSK modulation. Note also that higher data rates would be supported with less conservative satellite assumptions that are applicable to some deployments.

***Moderator view****: Sony evaluation would suggest all IoT-NTN scenarios are supported by eMTC CE Mode A with data rates consistent with MCL of 144 dB or 154 dB.*

***Initial proposal – Section 5.2***

***Companies are encouraged to comment on the achievable data rates evaluation***

* ***Q1: Is it understanding that the evaluation show that all IoT-NTN scenarios supported by eMTC CE Mode A***
* ***Q2: is it understanding that data rates are consistent with MCL of 144 dB or 154 dB.***

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## Connection Density

Huawei proposed RAN1 agrees on the performance requirements of typical use cases in IoT over NTN to ensure that the system design can fulfil such requirements. RAN1 agrees on the evaluation methodology and performance metrics, e.g. DL/UL peak data rate, latency, user density, power consumption, etc., for the candidate solutions targeting optimization of IoT over NTN.

Ericsson observed the achievable connection density for eMTC is 364 UEs/km2 in Case 9 and 78 UEs/km2 in Case 14 for a single narrowband. Ericsson evaluated the connection density given the traffic assumption that the UE shall be able to deliver a 32 bytes packet in the uplink under 10 s with an outage probably of less than 1%. Ericsson observed the achievable connection density for eMTC is 364 UEs/km2 in Case 9 and 78 UEs/km2 in Case 14 for a single narrowband and proposed to adopt a TP shown in the Appendix for the TR 36.763 in [R2-2106169] copied below

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**TP to 37.763**

**X.Y.Z Connection density evaluation**

To determine the achievable connection density for an IoT NTN, the evaluation investigates the connection density achievable under the traffic assumption that the UE shall be able to deliver a 32 byte packet in the uplink within 10s with an outage probably of less than 1%.

To evaluate the connection density for NTN, we have chosen 2 LEO scenarios: Case 9 and Case 14 [2, TR 38.821] which have similar characteristics with the difference that Case 9 is at 600 km altitude and Case 14 is at 1200 km altitude. These scenarios target handheld devices. The UE characteristics follow those of Section 6.2.1 in [6], which correspond to the IoT devices.

The number of cells simulated has been selected as 19 cells with the statistics counted only for the inner 7 cells, as shown in Figure 5. Furthermore, the UEs will only have 20 seconds to deliver each packet before the delivery attempt is cancelled, meaning that no further re-transmissions will be attempted after 20 seconds. This is not to be confused with the 10 seconds that determines the outage rate. In other words, a UE may deliver the uplink packet after 10 seconds, but this will be counted as an outage. Not being able to deliver the packet at all within 20s is also counted as an outage.



Figure 5. Simulating 19 cells but only accounting for the inner 7 cells.

In order to be able to observe how the uplink and downlink SINR get worse with increasing load, i.e., arrival rate, the PUSCH SINR percentiles are shown in Figure 6 and PDSCH SINR percentiles are shown in Figure 7.



Figure 6. PDSCH SINR percentiles as a function of the arrival rate.



Figure 7. PUSCH SINR percentiles as a function of the arrival rate.



Figure 8. Outage rate as a function of the arrival rate.

The outage rate as a function of the arrival rate in these scenarios can be observed in Figure 8. For computing the achievable connection density, we can see that the maximum arrival rate where the outage rate is below 1% is 60 and 70 UE/sec/cell for Case 9 and Case 14 respectively. For the area of a cell in a satellite scenario, we do not have a specific cell size, as we only define beam separation from the point of view of the satellite. However, from observing the satellite antenna pattern on the ground, we can estimate the area on the ground as ~1385 km2 and 5543 km2. The connection density per narrowband can thus be computed as:

Connection density = 1st percentile arrival rate (UE/s/cell) \* UE traffic pattern [s] / cell area [km2]

We present the results for eMTC in Table x-y. Comparing Case 9 and Case 14 we can see that the achievable number of devices supported for Case 14 is significantly less than Case 9, owing to the much larger cell size associated with having the satellites at 1200 km versus 600 km altitude.

Table x-y. Connection density of IoT NTN for different scenarios.

|  |  |  |
| --- | --- | --- |
| **Scenario** | **eMTC NTN, Case 9 [2, TR 38.821]** | **eMTC NTN, Case 14 [2, TR 38.821]** |
| **Cell size** | A = 1385 km2 | A = 5543 km2 |
| **# of devices supported per km2 with 6 PRBs** | 364 devices/km2 | 78 devices/km2 |

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***Moderator view****: RAN2 has agreed to capture in TR 36.763 in Appendix B.2 the Non-Terrestrial network target performances per usage scenario for IoT connectivity (low power wide area service capability) was recommended in TR 38.821. Ericson discussed and proposed a TP to TR 36.763 in their companion TDoc R2-2106169 for evaluation of connection density evaluation as shown above. To the moderator’s understanding the discussion on this topic was started in RAN2 in [Post113-e][055][IoT NTN] Performance Evaluation (Ericsson) and is on-going. We can wait for this discussion to complete and TP can be endorsed by RAN2.*

Table B.2-1: Non-Terrestrial network target performances per usage scenarios [source: TR 38.821]

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Usage scenarios** | **Experience data rate (Note 1)** | **Overall UE density per km2****(Note 2)** | **Activity factor (Note 1)** | **Max UE speed** | **Environment** | **UE categories** | **Sources** |
| DL | UL |
| IoT connectivity (low power wide area service capability) | 2 kbps | 10 kbps | 400 | 1,00% | 0 km/h | Extreme coverage | IoT | **Device density**: from R2-1901404 |6]**Data rate and activity factor**: derived from Rel-13 TR 45.820 [4] Annex E.2 "Traffic models for Cellular IoT" |
| NOTE 1: As defined in TS 22.261 [5]NOTE 2: The Overall UE density per km2 represents a peak value over a 40 km cell diameter. The actual value that can be achieved with a satellite will depend on the beam diameter. |

***Initial proposal - Section 5.3***

* ***Wait for RAN2 to complete and endorse TP in R2-2106169 for evaluation of connection density evaluation in TR 36.763.***

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## FIRST ROUND - Others

TBA

# Conclusions

TBA

# References

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3. RP-210906, Way forward on new proposals, Nokia (RAN Chair), RAN#91-e, March 2021
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15. R1-2105345, Samsung, Initial link budget evaluation for NB-IoT/eMTC, RAN1#105-e, May 2021
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# Appendix 1

|  |  |
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| Contribution | Observation/Proposals |
| Huawei (R1-2104258) | ***Proposal 1:*** *RAN1 agrees on the performance requirements of typical use cases in IoT over NTN**to ensure that the system design can fulfil such requirements.****Proposal 2:*** *RAN1 agrees on the evaluation methodology and performance metrics, e.g. DL/UL peak data rate, latency, user density, power consumption, etc., for the candidate solutions targeting optimization of IoT over NTN.****Proposal 3:*** *Capture the link budget results of MEO set-5 in the Appendix into TR 36.763.* |
| Omnispace (R1-2104403) | ***Observation 1****: There is a significant market opportunity for the broad range of IoT opportunities to be supported by satellite operations that cover areas devoid of communication opportunities. It is important to the satellite industry that the first NTN Rel17 provides a solid foothold to assist the development of both high value IoT market segments, in addition to low data rate infrequent packet data applications.****Observation 2****: The eMTC NGSO satellites parameters for Set1 and Set2 link budget will be adequate for supporting eMTC CE-Mode A which will unlock the delivery of high-value IoT use cases.* |
| CATT (R1-2104503) | ***Proposal 1:*** *The following Satellite losses should be used as a common set of link budget parameters and captured into TR 36.763.*Table 1: Satellite losses

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Other Losses | GEO (35786 km) | LEO (1200 km) | LEO (600 km) | MEO (10000 km) |
| Scintillation losses | 2.2 dB | 2.2 dB | 2.2 dB | 2.2 dB |
| Atmospheric losses | 0.2 dB | 0.1 dB | 0.1 dB | 0.2 dB |
| Polarization loss | 3 dB | 3 dB | 3 dB | 3 dB |
| Shadow margin  | 3 dB | 3 dB | 3 dB | 3 dB |

***Proposal 2****：Capture the result of Table 2 into TR 36.763.* ***Proposal 3****：Support stand-alone deployment for NB-IoT and eMTC in IoT NTN.* |
| MediaTek (R1-2104567) | IoT NTN Scenarios:***Observation 1****: A UE may only need a new GNSS position solely for UE pre-compensation for UL synchronization in corner case scenarios where (i) it is not fixed; (ii) reporting of the GNSS position is not needed by application layer.****Observation 2****: The satellite system design should fix key parameters such as EIRP and G/T in the satellite to ensure the link budget can be closed on DL and UL.**IoT NTN Deployment modes****:******Observation 3****: Co-existence between NTN RN and NTN IoT is beyond the scope of Rel-17 IoT NTN study and whether a normative phase would include such study would require discussions at RAN and RAN4 levels.****Proposal 1****: NTN IoT inband deployment and guard band deployment are de-prioritized in Rel-17 IoT NTN normative phase.* |
| CMCC (R1-2104636) | ***Observation 1:*** *The updated link budget including MEO Set-5 satellite parameter is provided in Table 5.****Observation 2:*** *For MEO Set-5 satellite parameter, the DL CNR reaches -4.43dB.****Observation 3:*** *For MEO Set-5 satellite parameter, the UL CNR for NB-IoT/eMTC with bandwidth 3.75kHz/15kHz/30kHz/45kHz/90kHz/180kHz/360kHz/1080kHz reaches -0.15dB/-6.17dB/-9.18dB/-10.94dB/-13.95dB/-16.96dB/-19.97dB/-24.74dB, respectively.****Observation 4:*** *Additional path loss can be observed in some deployment scenarios.** *Carriage and container penetration loss (9~20 dB) for logistics application.*
* *Vegetation loss (e.g., 9 dB) for outdoor application.*

***Observation 5:*** *Additional 0~5.1 dB FSPL can be experienced by a UE in locations other than in the center of the central beam.****Proposal 1:*** *Compare with link budget results for calibration, additional path loss should be considered for evaluating the basic coverage performance of IoT NTN in real deployment conditions.** *Carriage and container penetration loss for logistics application.*
* *Vegetation loss for outdoor application.*
* *Additional FSPL for lower elevation angle.*

***Proposal 2:*** *Study on NB-IoT deployed in guard-band of terrestrial NR is to be deprioritized.****Proposal 3:*** *Study on NB-IoT deployed in guard-band of NR-NTN with 15kHz SCS can be prioritized, if needed, to ensure subcarrier orthogonality between NB-IoT over NTN and NR-NTN.****Proposal 4:*** *At least support standalone deployment mode for NB-IoT over NTN.****Proposal 5:*** *Study on coexistence with eMTC over NTN and terrestrial NR is to be deprioritized.****Proposal 6:*** *At least support standalone deployment mode for eMTC over NTN.* |
| OPPO (R1-2104777) | ***Proposal 1****: To add other losses for MEO into table 6.2-1 in TR 36.763.****Proposal 2****: capture the link budget results for MEO set-5 into TR 36.763.****Observation 1****: according to the link budget results for MEO set-5, NB IoT and eMTC can support the minimum SNR requirement.* |
| Ericsson (R1-2104814) | ***Observation 1****: eMTC and NB-IoT can address different types of IoT use cases based on their unique capabilities and thus complement each other.****Observation 2****: NB-IoT supports ultra-low complexity devices with very narrow bandwidth, while eMTC can achieve higher data rates, more accurate device positioning, and supports voice calls and connected mode mobility.****Observation 3****: The approved Rel-17 IoT NTN SID is dedicated to LEO and GEO satellite communication, while HAPS/HIBS and A2G are not in the scope.****Observation 4****: Rel-17 IoT NTN study should equally treat eMTC and NB-IoT. The study item will be incomplete unless each of them is properly studied for its feasibility for NTN.****Observation 5****: It was agreed at RAN2#112e that support for EPC is assumed for IoT NTN.****Observation 6****: Identifying specific bands of interest in sub 6 GHz can be a topic for RAN4 to discuss when a potential normative phase begins.****Observation 7****: The approved Rel-17 IoT NTN SID is dedicated to transparent payload.****Observation 8****: To study the feasibility of NTN for eMTC and NB-IoT, it is important to properly evaluate the various design targets originally envisioned for eMTC and NB-IoT in the new context of NTN, taking into account factors such as the additional complexity, cost, and power consumption associated with GNSS operation.****Observation 9****: The achievable connection density for eMTC is 364 UEs/km2 in Case 9 and 78 UEs/km2 in Case 14 for a single narrowband.* |
| Qualcomm (R1-2104822) | ***Proposal 1****: For NB-IoT over NTN, support only the following deployment modes**- Standalone**- In-band with NR / guard band of NR****Proposal 2****: For LEO satellites with non-steerable satellite beams, define techniques to configure a cell (Ncell for NB-IoT) that spans resources across multiple satellite beams of a satellite.**- Solutions described in R1-2104826 may be used as a starting point.* |
| Apple (R1-2105138) | ***Observation 1****: For set 5 satellite parameters, the CNR for DL NB-IoT/eMTC is -4.41 dB.****Observation 2****: For set 5 satellite parameters, the CNR for UL NB-IoT/eMTC with bandwidth 3.75/15 30/45/90/180/360/1080 kHz is -0.12/-6.14/-9.15/-10.92/-13.93/-16.94/-19.95/-24.72 dB, respectively.* |
| SONY (R1-2105182) | ***Observation A****: eMTC can support communication in CE Mode A in all of the scenarios studied in IoT-NTN.****Observation B****: DL data rates of up to 900kbps can be supported by eMTC in CE Mode A for the LEO-1200 set-1 scenario.****Observation C****: UL data rates of up to 43kbps can be supported by eMTC in CE Mode A for the LEO-1200 set-1 scenario.* |
| ZTE (R1-2105193) | ***Observation 1:*** *A large number of UEs would experience a worse coupling loss larger than 164 dB for urban and dense urban scenarios. And even for rural scenario, there are about 5% UEs which experience coupling loss larger than 164 dB.****Proposal 1:*** *Clarification on the definition of EIRP for MEO w.r.t to whether including a 3 dB additional loss due to beamwidth is needed.****Proposal 2:*** *The value of atmosphere loss used in Case-1 of link budget should be updated as 0.88 dB to align all results.****Proposal 3:*** *Capturing the distribution of DL CL based on the system simulation into TR 36.763.****Proposal 4:*** *Standalone mode should be prioritized for the deployment of IoT-NTN.****Proposal 5:*** *The supports for in-band mode should be further studied with only assuming the NR SCS as 15 kHz.* |
| Samsung (R1-2105345) | ***Observation 1:*** *RAN1 considers that NTN NB-IoT is developed for deployment in standalone mode, and further discussion on coexistence with NR NTN can happen during the WI phase with RAN4 involvement.****Observation 2:*** *RAN1 considers that NTN eMTC is developed for deployment in standalone mode, and further discussion on coexistence with NR NTN can happen during the WI phase with RAN4 involvement.* |
| Nokia (R1-2105404) | ***Observation 1****: The uplink bottleneck channels are the channels with the largest bandwidth.* ***Observation 2****: Outdoor-to-indoor penetration loss can be set to 25 dB for further link budget analysis.****Observation 3****: Vegetation loss can be set to 10 dB for further link budget analysis.**Observation 4: Including outdoor-to-indoor loss, vegetation loss or non-LOS loss results in at least 10 dB additional loss, which may therefore require link budget improvements.****Observation 5****: Comparing link budget evaluations with downlink performance targets of TS 36.101 indicates the requirements can be fulfilled by use of repetitions.****Observation 6****: Comparing link budget evaluations with uplink performance targets of TS 36.104 indicates the requirements cannot be fulfilled for NPUSCH format 1 without use of repetitions.****Observation 7****: High doppler shift, NTN channel condition and additional loss may lead to additional requirement on repetition for IoT UE.****Proposal 1****: The link budget evaluations in Table 1 and Table 2 shall be included in the study item report.****Proposal 2****: RAN1 to agree indoor and/or vegetation-impacted UEs are in scope of the NTN IoT study.****Proposal 3****: It should be added in TR36.763 that there could be additional loss in real environment, which may cause performance degradation and require link budget improvements.****Proposal 4****: RAN1 should evaluate the repetition gain for IoT UE in NTN in normative phase.****Proposal 5****: All guardband, inband/DSS and standalone mode should be considered and discussed in normative phase of IoT NTN.* |