3GPP TSG RAN WG1 Meeting #104e R1-210XXXX

January 25th – February 5th, 2021

Agenda Item: 8.15.1

Source: Moderator (MediaTek)

Title: Summary #2 of AI 8.15.1 Scenarios applicable to NB-IoT/eMTC

Document for: Discussion and Decision

# Introduction

In RAN#86 meeting, a new Study Item was approved for IoT Non Terrestrial Network (NTN) [1]. 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 Calibration

The link budget parameters were discussed in RAN1#103e. FL recommendation on link budget:

*The IOT NTN (reference scenario) parameters in Proposal#2.6.2-1 (2nd round outcome) assume 10 degree minimum elevation angle as was the case in TR 38.821. The link budget can assume higher elevation angle as was also the case in TR 38.821. The link budget should consider challenging scenarios for worst case assumptions for IoT NTN EIRP and G/T figure. Companies are encourage to use Set 3 based on Eutelsat [1] and Set 4 based on Sateliot/Gatehouse [2] as shown in the ANNEX. It is of course also fine to use TR 38.821 with Set 1 and Set 2, but these sets are likely to show much more favourable link budget on DL and UL compare to Set 3 and Set 4. Alignment on the link budget figures based on company contributions can be discussed in RAN1#104e.*

In Rel-16 NR NTN SI, TR 38.821, Table 4.2-2 Reference scenario parameters provides maximum beam foot print size (edge to edge) for a minimum elevation angle of 10 degrees. The intention was to determine the maximum max distance between satellite and user equipment at min elevation angle and a corresponding maximum round trip delay. This also provides corresponding maximum differential delay within a cell and maximum Doppler shift /and Doppler shift variation. The intention was to fix the maximum values of key parameters for satellite delay and Doppler shift on the service link to ensure the solutions needed for enhancements for timing and synchronization will work regardless of the actual elevation angle configured in the satellite constellation. In Rel-17 IoT NTN SI, the minimum Elevation angle for both sat-gateway and C-IoT device was chosen to be 10 degrees to be consistent with TR 38.821 to set a similar floor for the maximum values of key parameters for satellite delay and Doppler shift on the service link.

In Rel-16 NR NTN SI, TR 38.821 included Table 6.1.1.1-9 with list of calibration study cases. The central beam elevations for the cases considered were 10 deg for GEO and 45 deg for LEO. The elevations are practical values typically configured in legacy satellite constellations. Typical EIRP figures and G/T figures for GEO and LEO cases were also chosen assuming S band and Ka bands. The intention was to use common assumptions for the key Tx and Rx power parameters for the list of cases included in Table 6.1.1.1-9: List of calibration study cases

Hence, the feature lead recommendation was to encourage companies to have a similar approach as use in rel-16 NR NTN SI and use for Rel-17 IoT NTN SI the link budget parameters in Set 3 satellite parameters based on Eutelsat and in Set 4 satellite parameters based on Sateliot / Gatehouse. The tables for satellite parameters set 3 and set 4 are shown in Section 2.2 and 2.3 below.

Link budget analysis were provided OPPO, ZTE, CATT, Zheijiang, Sateliot, Gatehouse, Kepler, MediaTek, Sony, Ericsson, Thales, Nokia, CMCC, Eutelsat, Apple, Qualcomm. In the following sections, the assumptions used by the companies in the link budget analysis will be discussed for the following:

* UE Power Class and Noise Factor
* UL channel bandwidth
* Other losses including polarisation
* Central beam elevation
* NB-IoT and eMTC parameter sets

## Baseline for required SNR for NB-IoT/eMTC NTN

ZTE proposed central beam elevation angle should be updated as 20 degrees for Set-3 GEO and 35 degrees for Set-3 LEO-1200 for beam layout for CIR calculation. ZTE observed that the central beam is not present since part of them is already beyond of earth. The moderator view is that set 3 with 12.5 degrees minimum elevation for GEO and 30 degree elevation for LEO and set 4 with 30 degree minimum elevation are for practical deployments of satellite constellations proposed by Eutelsat and Sateliot, Gatehouse, and Thales.

ZTE provided a Maximum Coupling loss analysis for Set 1 and Set 2 satellite parameters

* Case-1: Refers to the cases in which the central beam elevation angle is assumed in TR 38.821 for Set-1 and Set-2, and values in Tables in Section 2.2 and 2.3 for Set-3 and Set-4, respectively.
* Case-2: Refers to the cases in which the beam edge elevation angle is 10 degree for all parameter sets.

The moderator understanding is that based on reading of Rel-12 TR 36.888 Table 5.2.1.2-2 “MCL calculation for normal LTE FDD”, a MCL of 144 dB for cellular IoT correspond to a required SNR of -3 dB for PDSCH and -7.6 dB for PUSCH. The MCL=164 dB correspond to a required SNR of -23 dB for PDSCH and -27.6 dB for PUSCH for cellular IoT.

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|  | Coupling loss (dB) | GEO | LEO-600 | LEO-1200 |
| Set-1 | Case-1 | 148.04  | 137.99 | 143.39  |
| Case-2 | 148.04 | 142.59 | 147.79 |
| Set-2 | Case-1 | 153.5 | 144.71 | 150.15 |
| Case-2 | 153.54 | 148.59  | 152.79 |
| Set-3 | Case-1 | 153.3 | 155.74 | 159.58 |
| Case-2 | 153.34 | 156.39 | 160.59 |
| Set-4 | Case-1 |  | 156.37 |  |
| Case-2 |  | 161.59 |  |

MediaTek mentioned cellular NB-IoT can support minimum performance requirement based on Rel-13 TS 36.101 User Equipment (UE) radio transmission and reception as follows:

* NPDSCH and NPDCCH with SNR = -10.2 dB and SNR=-11.4 dB with 256 and 1024 repetitions respectively on non-anchor carrier (TS 36.101 Table 8.12.1.1.2-2 and Table 8.12.2.1.1-1).
* NPBCH can be supported with minimum performance requirement with SNR=-11.5 dB (TS 36.101 Table 8.12.3.1.2.1-1).
* NPUSCH Format 1 and NPUSCH Format 2 with SNR = -12.2 dB and SNR=-10.9 dB with 64 repetitions respectively on non-anchor carrier (TS 36.104 Table 8.5.1.1.1-1 and Table 8.5.2.2.1-1).
* NPRACH can be supported with minimum performance requirement with SNR=-6.8 dB (TS 36.104 Table 8.5.3.2.1-1).

A UE can be expected to work at lower SNR than that shown above as the number of repetitions that can be scheduled for the NB-IoT Physical channels can be higher:

* NPDSCH supports to 2048 repetitions
* NPDCCH supports to 1024
* NPUSH supports to 128
* NPRACH supports to 1024

On the UL, the eNB may schedule UL transmission with an UL channel bandwidth of 3.75 kHz, or with 15 kHz or 3\*15 kHz, with a smaller number of repetitions needed compare to full-PRB scheduling.

ZTE proposed that NB-IoT/eMTC NTN used as baseline the required SINR for standalone NB-IoT/eMTC in terrestrial network. Based on the moderator understanding of TR 36.888 [4], we have for cellular IoT

* DL with minimum required SNR -19.3 dB assuming 6 PRBS with average 100-200 repetitions (refer to TS 36.888 Table 9.5.6.1-2 in [4])
* UL with Repetitions/TBS/achieved SNR 250/56/-27 dB assuming 2 PRBs (refer to TS 36.888 Table 9.5.7.1-3 in [4])

For NB-IoT and eMTC, the effective code rate achieved with a given level of repetitions and TBS to achieve 10% BLER target at the required SNR. On the UL, the SNR can be improved by selecting a smaller UL channel bandwidth. For example,

* for NB-IoT selecting singe tone transmission with 3.75 kHz improves the SNR by about 10\*log(360 kHz/3.75 kHz)=19.8 dB
* for eMTC, selecting transmission with 3 \* 15 kHz improves the SNR by about 10\*log(360 kHz/(3\*15 kHz)=9 dB

IoT applications are not delay-sensitive: M2M devices may in general support relaxed delay characteristics. M2M applications (e.g. alarms) may require a delay profile with a delay requirement of 10 seconds for the uplink when measured from the application ‘trigger event’ to the packet being ready for transmission from the base station towards the core network (Rel-13 TR 45.820 Cellular system support for Cellular IoT ).

This analysis of Cellular IoT show that the required SNR for DL and UL can be very low in cellular IoT with maximum coupling loss. This would suggest that IoT NTN could potentially operate at very low required SNR if long reception and repetition times are acceptable. This may not be practical for IoT NTN scenarios if the UE is only in coverage of the satellite beam for several seconds.

***FL recommendations - Section 2.1:***

**Companies are encouraged to check understanding on whether the baseline for required SNR for NB-IoT/eMTC NTN can be the required SINR for NB-IoT/eMTC in terrestrial network as follows:**

* ***DL with minimum required SNR -19.3 dB***
* ***UL with minimum required SNR -27 dB***

***NOTE1: For NB-IoT and eMTC, the minimum required SNR can be met with adequate selection of repetitions and TBS to achieve 10% BLER target. On the UL, the SNR can be improved by selecting a smaller UL channel bandwidth.***

***NOTE 2: IoT NTN could potentially operate at very low required SNR if long reception and repetition times are acceptable. This may not be practical for IoT NTN scenarios if the UE is only in coverage of the satellite beam for several seconds.***

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| **Company** | **Comments and Views** |
| Eutelsat | We agree with ‘Note 2’ above. We suggest to use UL and DL SNR values which are compatible with LEO limited coverage time (i.e. avoid being too optimistic by using terrestrial results “as is”). |
| ZTE | W.r.t the baseline SINR value, fine to take the TN setting as baseline for evaluation. It should be noticed that potential revision is also possible since the timing/Doppler variation will be much larger for NTN, and the benefits of larger repetition may be degraded. W.r.t the Note 1, except for the link budget issue, whether the required data rate can be satisfied or not should also be justified. For the Note 2, different observation is expected for each satellite configuration, e.g., fixed beam vs moving beam.  |
| Qualcomm | No need of these numbers; it is okay to just report link budget SNRs achieved, in the TR. Those numbers will help guide the reader/deployer accordingly. |
| Ericsson | These SNR values are exceptionally low, which might be possible only under extreme settings and certain assumptions (e.g. AWGN channel). Without clearly spelling out the underlying assumptions, it’s difficult to assess if this can be baseline. We also do not think IoT NTN needs to work with such low SNRs that come from ill-dimensioned systems. |
| Huawei | We are not sure whether the required SINR for NB-IoT/eMTC in terrestrial network can actually be used for NTN deployment. The high mobility and different channel conditions could lead to a very different SNR requirement for NB-IoT/eMTC assuming the same target. It should be noted that the UL timing synchronization due to the long transmission duration has already been identified in the other agenda items. Link-level evaluations are required. |
| CATT | These SINR values are not suitable for NTN case. Due to short service time and foreseeable synchronization error, NTN working condition should be better than TN scenario. Need simulation result to justify it. |
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## Set-3 Satellite parameters

For set 3 satellite parameters, the worst case central beam elevation is highlighted in yellow in the table below and shown below.

For Set 3 satellite parameters:

* Worst case central beam elevation is 12.5 deg for GEO and 30 deg for LEO
* EIRP is 59.8 / 33.7 / 28.3 dBW/MHz for GEO, LEO-1200 km, LEO-600 km respectively
* G/T is 16.7 / -12.8 / -12.8 dB/K for GEO, LEO-1200 km, LEO-600 km respectively

Set-3 satellite parameters

|  |  |  |  |
| --- | --- | --- | --- |
| Satellite orbit | GEO | LEO-1200 | LEO-600 |
| Satellite altitude | 35786 km | 1200 km | 600 km |
| Central beam elevation  | 12.5 deg | 30 deg | 30 deg |
| Payload characteristics for DL transmissions |
| Equivalent satellite antenna aperture (Note 1) | S-band(i.e. 2 GHz) | 12 m | 0.4m | 0.4 m |
| Satellite EIRP density | 59.8 dBW/MHz | 33.7 dBW/MHz | 28.3 dBW/MHz |
| Satellite Tx max Gain | 45.7 dBi | 16.2 dBi | 16.2 dBi |
| 3dB beam width | 0.7353 deg | 22.1 deg | 22.1 deg |
| Satellite beam diameter (Note 2) | 459km | 470 km | 234 km |
| Payload characteristics for UL transmissions |
| Equivalent satellite antenna aperture (Note1) | S-band (i.e. 2 GHz) | 12 m | 0.4 m | 0.4 m |
| G/T | 16.7dB/K | -12.8 dB/K | -12.8 dB/K |
| Satellite Rx max Gain | 45.7 dBi | 16.2 dBi | 16.2 dBi |

***Initial Proposal Section 2.2:***

***Include in TR 36.763 the Table with Set-3 satellite parameters***

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| --- | --- |
| **Company** | **Comments and Views** |
| Eutelsat | Agree. |
| ZTE | This proposal is overlapped with ***Initial Proposal - Section 5,*** it’s preferred to the latter one firstly.Firstly, clarification on the definition of parameter, i.e., “Central beam elevation” should be done. In general, there are following two understanding w.r.t the “central beam elevation” and the 1st one is used in NR NTN SI. If following the same way, updates on the parameter for set-3 is needed. Otherwise, partial coverage of central beam will be out of earth’s surface. Meanwhile, if the 2nd option-2 is preferred to companies, it seems that even larger serving elevation angle is preferred for IoT case than NR-NTN, further checking on the feasibility with consideration on the commercial usage including cost for constellation is needed. |
| Qualcomm | Agree with including this set. Proponents should double check that everything listed matches their scenarios accurately. |
| Ericsson | Fine with considering Set-3 parameters. Note 1 and Note 2 are missing. |
| Huawei | We are fine to include Set 3 parameter set as long as the satellite operators/manufactures think this will a typical setup and will be used in practice for NB-IoT/eMTC service in NTN. In addition, we would like to understand better whether Set 1 and Set 2 are still relevant for this study. Moreover, central beam elevation can be left out and discussed in section 5.  |
| CATT | In RAN1 #103e meeting, it was agreed that Max beam foot print size (edge to edge) regardless of the elevation angle is 3500km for GEO and 1000km for LEO. Now the set 3 only supports 459km, 470km and 234km. Hence, we are not sure what is the relationship between the new set 3 and agreed beam size. Does it mean we are not intended to evaluate the case of 3500km beam size or 3500km size is not practical?Another issue is what is target SINR for the set 3? Actually before having the common sense for SINR target, the feasibility of EIRP and G/T value are questionable. |
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## Set 4 Satellite parameters

For set 4 satellite parameters, the worst case central beam elevation is highlighted in yellow in the table below and shown below:

For Set 4 satellite parameters

* Worst case central beam elevation is 30 deg for LEO
* EIRP is 21.45 dBW/MHz
* G/T is -20.9 dB/K

Set-4 satellite parameters

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| --- | --- |
| Satellite orbit | LEO-600 |
| Satellite altitude | 600 km |
| Central beam elevation  | (Beam Edge)30 deg | (Beam center)65.5 deg |
| Payload characteristics for DL transmissions |
| Satellite EIRP density |  | 21.45 dBW/MHz |
| Satellite Tx max Gain | 8 dBi | 11 dBi |
| Satellite beam diameter  | 1702 km | 654 km |
| Payload characteristics for UL transmissions |  |
| Equivalent satellite antenna aperture (Note1) | S-band (i.e. 2 GHz) | 0.154 m |  |
| G/T | - 20.9 dB/K | -17.9 dB/K |
| Satellite Rx max Gain | 8 dBi | 11 dBi |

***Initial Proposal Section 2.3:***

***Include in TR 36.763 the Table with Set-4 satellite parameters***

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| **Company** | **Comments and Views** |
| Eutelsat | Agree. |
| ZTE | According to the definition of cube satellite, there is upper bound limitation on the transmission power. Then, in addition to the fixed EIRP density listed in the table, it’s preferred to also provide the max transmission power. The value, e.g., 33dBm provided in R1-2100521 can be considered as baseline.Meanwhile, additional note should be added to highlight that maybe there is only single beam deployment for such satellite since the coverage of 2nd tier of beam will be out of earth’s surface. And in this way, discontinuous coverage is expected and typical interruption time is preferred to have better understanding of service continuity. |
| Qualcomm | Agree with including this set. Proponents should double check that everything listed matches their scenarios accurately. |
| Ericsson | The feasibility of Set-4 for supporting IoT is unclear. Some study is needed first before including it in the TR. |
| Huawei | Similar to above, we are fine to include Set 4 parameter set as long as the satellite operators/manufactures think this will a typical setup and will be used in practice for NB-IoT/eMTC service in NTN. Again, we would like to understand better whether Set 1 and Set 2 are still relevant for this study. We think the issue mentioned by ZTE is valid but maybe more relevant for discussions to align assumptions for link budget or system-level evaluations if needed. |
| CATT | Same comments with section 2.2. We need to firstly ensure what is the effective beam size and what is effective SINR target. Then determine what kind of parameters are valid. |
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# UE Power Class and Noise Figure

Contributing companies used different assumptions for UE power class and UE noise figure as shown in table below. There are 4 possible sets of assumptions for UE power class and UE noise figure. As it is shown for ZTE link budget results for Set 3 satellite parameters in Section 7.1, With PC5 assumption of 20 dBm transmission power there is a 3 dB degradation difference compare to PC3 assumption of 23 dBm transmission power on UL. Similarly, with noise figure assumption of 7 dB, there is a 2 dB improvement compare to noise figure of 9 dB on DL. To simplify calibration and documenting of link budget results, it is sufficient to only consider one set for assumptions for power class and UE noise figure. The moderator view is to adopt assumption of PC3 (23 dBm), NF (9 dB) and add a note to clarify how link budget figures can be updated with the different assumptions for UE power class 3 and noise figure 7 dB..

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| --- | --- | --- | --- |
| PC3 (23 dBm), NF (9 dB) | PC3 (23 dBm), NF (7 dB) | PC5 (20 dBm), NF (9 dB) | PC5 (23 dBm), NF (7 dB) |
| OPPO, MediaTek, Eutelsat | OPPO, Zhejiang, Apple | OPPO, ZTE | OPPO, CATT |

***Initial Proposal Section 3:***

**Do companies agree to use UE PC3 (23 dBm) and UE Noise Figure 9 dB for the link budget analysis?**

**NOTE 1: With PC5 (20 dBm) assumption, there is a 3 dB degradation compare to PC3 (23 dBm) on UL.**

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

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| **Company** | **Comments and Views** |
| Eutelsat | Agree |
| ZTE | Fine to take the assumption above as baseline. And corresponding clarification should be needed in TR and potential updates on the SI is also expected since only PC3 is supported for the SI. |
| Qualcomm | We would prefer NF = 7 dB as a baseline. We are a bit sceptical of providing a reader (who is skimming through the numbers) with unreasonably low numbers in a table.We agree with the principle that at the beginning of the final SNR tables, notes like what is written in the proposal above would enable us to not copy the same results multiple times for different power classes, etc. No setting (PC5, PC3, etc.) should be deemed to be of higher/lower priority to a reader. |
| Ericsson | Fine, as long as the same assumptions are used by all companies. |
| Huawei | We are fine to include them into the study. |
| CATT | We are ok for this configuration. |
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# UL Channel bandwidth

Contributing companies used different assumptions for UL channel bandwidth. It is not necessary to use the same UL channel bandwidth, though this would be welcomed by the moderator. However, in some cases UL Channel bandwidth for eMTC that are not specified were considered. This should be avoided.

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| NB-IoT UL channel bandwidth | 3.75 kHz | 15 kHz | 45 kHz | 180 kHz |
| OPPO, ZTE, MediaTek , Sateliot, Gatehouse, Thales, Nokia, CMCC | OPPO, ZTE, MediaTek , Sateliot, Gatehouse, Thales, Sony, CMCC, Apple, Qualcomm | OPPO, ZTE, MediaTek, CMCC | CATT, Zhejiang, Sony, Nokia, ZTE, CMCC |

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| --- | --- | --- | --- | --- |
| eMTC UL channel bandwidth | 15 kHz | 30 kHz | 45 kHz | 90 kHz |
| Sony, Qualcomm | OPPO, ZTE , Nokia, CMCC | OPPO, ZTE, CMCC | OPPO, ZTE, CMCC |
| 180 kHz | 360 kHz | 1080 kHz |  |
| OPPO, ZTE, CATT, Sony, Nokia, CMCC, Apple | OPPO, ZTE | CMCC |  |

***Feature Lead Recommendation - Section 4:***

***Companies should preferably use specified UL Channel bandwidth for NB-IoT and eMTC, as was included in IoT NTN reference scenario parameters agreed in RAN1#103e. These are as shown in table below***

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| Device channel Bandwidth (service link)  | * NB-IoT 180 kHz (DL), Up to 180 kHz with all permissible smaller resource allocations 12\*15 kHz, 6\*15 kHz, 3\*15 kHz, 1\*15 kHz, 1\*3.75 kHz
* eMTC: 1080 kHz (DL), Up to 1080 kHz with all permissible smaller resource allocations , including 2\*180 kHz, 180 kHz, 2\*15 kHz or 3\*15 kHz or 6\*15 kHz  (UL)
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| **Company** | **Comments and Views** |
| Eutelsat | UL Channel bandwidth for NB-IOT (in line with Eutelsat R1.2101146) and eMTC agreed |
| ZTE | Fine with the proposal. |
| Qualcomm | Accept recommendation. |
| Ericsson | It is not necessary to do link budget for all bandwidths. Select the smallest bandwidths would be sufficient. |
| Huawei | Fine with the proposal but it would good to have one or more common set of parameters which can be used to collect link budget analysis. |
| CATT | When UL bandwidth is large, the SINR is quite low. So we prefer smaller bandwidth set is configured as reference parameters. For example, for NB-IoT, at most support 3\*15 khz, and for eMTC, at most 180khz can be considered. |
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# Central beam elevation

Contributing companies used central beam elevations for NB-IoT and eMTC as given in the following:

* TR 38.821 Set 1 and Set 2 satellite parameters in Table Table 6.1.1.1-9 List of calibration study cases with GEO @45 degrees, LEO@90 degrees.
* IoT NTN Set 3 and Set 4 in Tables in Section 2.2 with (Set-3) 12.5 deg for GEO and 30 deg for LEO and (Set-4) 30 deg for LEO

We summarised the company central elevation assumptions for set 1, 2, 3, and 4. The central elevation as agreed in TR 38.821 for set 1 and 2, or as proposed in Section 2.2 and 2.3 are highlighted in yellow.

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| **NB-IoT NTN** |
| Set 1 | Set 2 | Set 3 | Set 4 |
| OPPO, ZTE, Zhejiang, CMCC (GEO @45 deg, LEO@90 deg)Nokia (GEO@12.5 deg, GEO@30 deg) ZTE, CATT (GEO@10 deg, LEO@10 deg) | OPPO, ZTE, Zhejiang, CMCC (GEO @45 deg, LEO@90 deg)ZTE, Apple CATT (GEO@10 degree, LEO@10 degrees)Qualcomm (LEO @ 10, 20, 30, 40, 50, 60, 70, 80, 90 degrees) | ZTE, MediaTek, Sony, CMCC, Eutelsat (GEO@12.5 deg, LEO@30 deg)ZTE (GEO@10 degree, LEO@10 degrees) | ZTE, Sateliot, Gatehouse, Thales, Kepler, MediaTek, Eutelsat (LEO@30 deg)ZTE (GEO@10 degree, LEO@10 degrees) |

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| **eMTC NTN** |
| Set 1 | Set 2 | Set 3 | Set 4 |
| OPPO, Zhejiang , CMCC (GEO @45 deg, LEO@90 deg)ZTE, CATT (GEO@10 deg, LEO@10 deg) | OPPO, ZTE, Zhejiang, CMCC (GEO @45 deg, LEO@90 deg)OPPO, Zhejiang, CMCC, AppleQualcomm (LEO @ 10, 20, 30, 40, 50, 60, 70, 80, 90 degrees) | ZTE, MediaTek, Sony, CMCC, Eutelsat (GEO@12.5 deg, LEO@30 deg) | ZTE, Sateliot, Gatehouse, Thales, Kepler, MediaTek, Eutelsat (LEO@30 deg) |

***Initial Proposal - Section 5***

***Use central beam elevations for NB-IoT and eMTC in the link budget analysis for the following:***

* ***TR 38.821 Set 1 and Set 2 satellite parameters in Table 6.1.1.1-9 List of calibration study cases with GEO @45 degrees, LEO@90 degrees.***
* ***IoT NTN Set 3 with central elevation 12.5 deg for GEO and 30 deg for LEO and Set-4 with central elevation 30 deg for LEO***

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| **Company** | **Comments and Views** |
| Eutelsat | Agree*o IoT NTN Set 3 with central elevation 12.5 deg for GEO and 30 deg for LEO and Set-4 with central elevation 30 deg for LEO*We selected the above or NB-IoT. |
| ZTE | This proposal is overlapped with ***Initial Proposal Section 2.2.*** ***Same comments as before are copied below***Firstly, clarification on the definition of parameter, i.e., “Central beam elevation” should be done. In general, there are following two understanding w.r.t the “central beam elevation” and the 1st one is used in NR NTN SI. If following the same way, updates on the parameter for set-3 is needed. Otherwise, partial coverage of central beam will be out of earth’s surface. Meanwhile, if the 2nd option-2 is preferred to companies, it seems that even larger serving elevation angle is preferred for IoT case than NR-NTN, further checking on the feasibility with consideration on the commercial usage including cost for constellation is needed. |
| Qualcomm | We are OK to go with consensus of proponents here. Generating SNR values for different elevation angles is simple anyway. |
| Ericsson | It’s unclear why set 1 and set 2 use values different from set 3 and set 4. We suggest using the same values across all the sets of parameters. |
| Huawei | For the link budget analysis, the central beam elevations should consider the worst case defined in 38.821, i.e. GEO@12.5 deg, GEO@30 deg. We would like to study the assumption for set 3 and set 4 further before agreeing on detailed values.  |
| CATT | Central beam elevation will impact the beam number used for interference statistics, for example in some cases the beam may be out of earth surface. However, we don’t know what is underlying reason for proposed elevation angle? Need more clarifications. |
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# Losses in link budget

## Polarisation loss

The path loss modelling from TR 38.821 in Table 6.1.3.3-1 have been used in the link budget analsysis provided by the contributing companies. In Table 6.1.3.3-1, the polarization loss is set to zero. A 3 dB polarisation was assumed by several companies. Satellites for IoT NTN may have simpler design and cost compare to satellite design for NR NTN. It seem reasonable to include a 3 dB polarisation loss as worst case assumption. In case polarisation is used in a satellite for IoT NTN, the polarisation loss can be assumed to be 0 dB which would improve by 3 dB the link budget.

***Initial Proposal Section 6.1:***

**Do companies agree that the polarisation loss is 3 dB for link budget analysis of IoT NTN.**

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| **Company** | **Comments and Views** |
| Eutelsat  | Agreed to include a 3 dB polarization loss as worst case assumption. |
| Lockheed Martin | A 3 dB loss is a theoretical figure. Recommend increasing to 3.5 dB polarization loss for practical antennas, as the 3 dB loss does not consider additional losses due to cant angle of the antenna. |
| ZTE | Fine to take the polarization loss into account since the mismatch of polarization between terminal and BS is typical case for IoT over NTN.  |
| Qualcomm | Agree. |
| Ericsson | Agree. |
| Huawei | Fine to take this into the link budget analysis. |
| CATT | Agree |
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## Other losses

It seems reasonable to re-use the same losses for FSPL, scintillation losses, atmospheric losses, shadow margin for IoT NTN in S band. Whether NR or NB-IoT/eMTC is used for the RAT technology should not change the fundamental of physics on the service link.

Two companies discussed the impact of other losses due to vegetation, or UEs that are indoors or in a container. These were aspects not included in the link budget analysis in NR NTN. The moderator view is that these additional path losses depend on the type of IoT application and the deployment of the IoT NTN devices. In case there is such additional losses, the link budget would correspondingly degrade by the assumption for the loss due to vegetation impact or UE indoor/container.

Vegetation impact on link budget:

* Nokia (10 dB), CMCC (9 dB)

Indoor impact on link budget:

* Nokia (25 dB), CMCC (9 dB indoor/container)

***Initial Proposal Section 6.2:***

***Include in TR 36.763 the Table with losses for link budget analysis of IoT NTN***

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | GEO 35786 km | LEO 1200 km | LEO 600 km |  |
| FSPL  | 190.6 | 164.5 | 159.1 | dB |
| Scintillation losses | 2.2 | 2.2 | 2.2 | dB |
| atmospheric losses | 0.1 | 0.1 | 0.1 | dB |
| polarization loss | 3 | 3 | 3 | dB |
| shadow margin  | 3 | 3 | 3 | dB |
| sum of all losses  | 198.9 | 172.8 | 167.4 | dB |

|  |  |
| --- | --- |
| **Company** | **Comments and Views** |
| Eutelsat  | Agreed  |
| ZTE | This proposal can be postponed once the discussion on all relevant discussion is stable, e.g., polarization loss, beam layout (3dB antenna gain loss for edge UE). |
| Qualcomm | Agree. |
| Ericsson | This would depend on the discussion on Issue #5, as elevation angle affects the losses. Including this table is not proper. Need to align assumptions first. |
| Huawei | The FSPL is based on the assumption of the central beam hence can be discussed later once the basic beam layout is agreed. |
| CATT | FSPL can be decided later. |
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# NB-IoT and eMTC parameter sets

## Link budget for Set 3 satellite parameters for NB-IoT

Based on Set 3parameters (this corresponds to the worst case Set 2 in Eutelsat, Inmarsat, Mediatek, Ligado, Hughes/EchoStar, ESA, Intelsat R1-2008815 TDoc in RAN1#103e), we include the link budget results from MediaTek, Sony, Eutelsat, ZTE. The path loss modelling from TR 38.821 in Table 6.1.3.3-1 were agreed to be included in TR36.763 as discussed in Section 7. The results show reasonable alignment for UL; there seems to be significant difference on DL with ZTE.

List of calibration study cases for Link Budget for Set 3

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Case | Satellite orbit | Parameter Set | Central beam elevation | Terminal | Frequency band | RAT |
| 1 | GEO-35786 km | Set 3 | 12.5 deg | CIoT | S-band | NB-IoT |
| 2 | LEO-600 km | Set 3 | 30 deg | CIoT | S-band | NB-IoT |
| 3 | LEO-1200 km | Set 3 | 30 deg | CIoT | S-band | NB-IoT |

NOTE: In the tables below showing the link budget results from MediaTek, Sony, Eutelsat, ZTE, to harmonise the results we show C/N on edge of the beam for DL and UL and assume PC3 with 23 dBm. This means an additional loss of 3 dB for DL C/N values shown in MediaTek and Eutelsat contributions. For ZTE results with PC5 assumption of 20 dBm, 3 dB were added. We only included ZTE results with noise figure assumption of 9 dB. In case noise figure assumption is 7 dB, there would be a 2 dB improvement. The moderator observed that ZTE UL results seemed to have used the GEO G/T of -16.7 dB/K for LEO. If G/T of -12.8 dB/K is used according to Table with set 3 satellite parameters and PC3 is assume, there is better alignment between ZTE MediaTek, Sony, and Eutelsat results on UL.

Link Budget results for Set 3 satellite parameters - Case 1 (GEO-35786 km, min elevation 12.5 deg)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  EIRP Density  | EIRP per spot | G/T  |  Companies | DL C/N (edge) |  UL C/N (edge) |
| 3.75 kHz | 15 kHz | 45 kHz | 90 kHz | 180 kHz |
| 59.8 dBW/MHz  | 82.3 dBm | 16.7 dB/K | MediaTek | -5.1 dB | 0.6 dB | -5.4 dB | -10.2 dB | -13.2 dB | -16.2 dB |
| Sony | -5.1 dB | - | -5.4 | - | - | - |
| Eutelsat | -5.1 dB | 0.6 dB | -5.4 dB | -10.2 dB | -13.2 dB | -16.2 dB |
| ZTE | -7.2 dB | -2.4 dB | -8.4 dB | -13.2 dB | -16.4 dB | -19.2 dB |

Link Budget results for Set 3 satellite parameters - Case 2 (LEO-600 km, min elevation 30 deg)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  EIRP Density  | EIRP per spot | G/T  |  Companies | DL C/N(edge) |  UL C/N |
| 3.75 kHz | 15 kHz | 45 kHz | 90 kHz | 180 kHz |
| 28.3 dBW/MHz  | 50.9 dBm | -12.8 dB/K | MediaTek | -5.1 dB | 2.7 dB | -3.4 dB | -8.1 dB | -11.1 dB | -14.1 dB |
| Sony | -5.1 dB | - | -3.4 dB | - | - | - |
| Eutelsat | -5.1 dB | 2.7 dB | -3.5 dB | -8.2 dB | -11.2 dB | -14.3 dB |
| ZTE | -11.7 dB | -4.9 dB | -10.9 dB | -15.7 dB | -18.7 dB | -21.7 dB |

Link Budget results for Set 3 satellite parameters - Case 3 (LEO-1200 km, min elevation 30 deg)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  EIRP Density  | EIRP per spot | G/T  |  Companies | DL C/N(edge) |  UL C/N |
| 3.75 kHz | 15 kHz | 45 kHz | 90 kHz | 180 kHz |
| 33.7 dBW/MHz | 56.3 dBm | -12.8 dB/K | MediaTek | -5.1 dB | -2.7 dB | -8.7 dB | -13.5 dB | -16.5 dB | -19.5 dB |
| Sony | -5.1 dB | - | -8.7 dB | - | - | - |
| Eutelsat | -5.1 dB | -2.8 dB | -8.8 dB | -13.6 dB | -16.6 dB | -19.6 dB |
| ZTE | -10.1 dB | -5.3 dB | -11.5 dB | -14.6 dB | -19.3 dB | -22.3 dB |

***Initial Proposal Section 7.1:***

***Include in TR 36.763 the following tables in Section 7.1:***

* ***Table for List of calibration study cases for link budget for Set 3 satellite parameters for NB-IoT***
* ***Table for link budget results for Set 3 satellite parameters for NB-IoT - Case 1 (GEO-35786 km, min elevation 12.5 deg)***
* ***Table for link budget results for Set 3 satellite parameters for NB-IoT - Case 2 (LEO-600 km, min elevation 30 deg )***
* ***Table for link budget results for Set 3 satellite parameters for NB-IoT - Case 3 (LEO-1200 km, min elevation 30 deg )***

|  |  |
| --- | --- |
| **Company** | **Comments and Views** |
| Eutelsat | Agreed |
| ZTE | Prefer to postpone this proposal since the assumption for the link budget is not aligned, e.g., in our contribution, the Option-1 (illustrated in the feedback for ***Initial Proposal - Section 5***) for “central beam elevation” is used as NR-NTN SI, but the 2nd is used for other sources.  |
| Qualcomm | OK with list of calibration study cases.We would like to run some numbers on our end too. If things match, we can agree on the numbers later. This may be confirmed in an email discussion even after meeting (to utilize meeting time for other discussion). |
| Ericsson | Need to algin assumptions first before including the tables for link budget. Also, Set-3 is applicable to eMTC as well. |
| Huawei | Similar view with ZTE and Ericsson. The basic assumptions for link budget analysis should be discussed first. |
| CATT | We need finalize the set 3 parameters firstly. Current set 3 parameters seem not convinced.  |
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## Link budget for Set 4 satellite parameters for NB-IoT

The Set 3 satellite parameters was proposed by Eutelsat, Inmarsat, Mediatek, Ligado, Hughes/EchoStar, ESA, Intelsat R1-2008815 TDoc in RAN1#103e) as a compromise between cost and complexity of satellite and NB-IoT NTN operations. As discussed in Section 7.1, the Set 3 is already requiring low minimum SNRs in the order of -5.1 dB on the DL and at least -2.7 dB on the UL.

The Set 4 satellite parameters proposed by Gatehouse and Sateliot further push the compromise between cost and complexity of satellite and NB-IoT NTN operations at low required SNRs. Representative values of typical available payload power (average per orbit) for different CubeSat sizes are shown below. A 1U CubeSat is a 10 cm × 10 cm × 11.35 cm cube with a mass up to 2 kg.

|  |  |
| --- | --- |
| Platform size | Available payload power |
| 3U (10cm x 10 cm x 30 cm, up to 3-4 kg) | 5W |
| 6U  | 20W |
| 12U (20cm x 20 cm x 34.05 cm, up to 24 kg) | 40W |

Thales, Sateliot, Gatehouse, Kepler, MediaTek, ZTE contributed on Set 4 parameters.

List of calibration study cases for Link Budget for Set 3

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Case | Satellite orbit | Parameter Set | Central beam elevation | Terminal | Frequency band | RAT |
| 4 | LEO-600 km | Set 4 | 30 deg (Beam edge), 90 deg (Nadir) | CIoT | S-band | NB-IoT |

THALES, Sateliot, Gatehouse provided Link Budget results for Set 4 satellite parameters - Case 4 (LEO-600 km, min elevation beam edge 30 deg, Nadir 90 degrees) and achievable data rates.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Case | Transmission mode | Frequency [GHz] | TX: EIRP [dBm] | RX: G/T [dB/T] | Bandwidth [kHz] | Free space path loss [dB] | Atmospheric loss [dB] | Shadow fading margin [dB] | Scintillation Loss [dB] | Polarization loss [dB] | Pointing losses [dB] | SNR [dB] | RSRP [dBm] |
| Beam edge,30° elev | DL | 2,0 | 44,0 | -29,6 | 180 | 159,1 | 0,1 | 3,0 | 2,2 | 3,0 | 3,0 | -10,0 | -137,2 |
| UL | 2,0 | 23,0 | -17,9 | 3,75 | 159,1 | 0,1 | 3,0 | 2,2 | 3,0 | 3,0 | -2,5 | -136,4 |
| Nadir,90° elev | DL | 2,0 | 44,0 | -29,6 | 180 | 154,0 | 0,1 | 3,0 | 2,2 | 3,0 | 0,0 | -1,9 | -129,2 |
| UL | 2,0 | 23,0 | -17,9 | 3,75 | 154,0 | 0,1 | 3,0 | 2,2 | 3,0 | 0,0 | 5,6 | -128,4 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| SNR[dB] | Datarate[bps] | iTBS | nSF | Nrep |
| -10,2 | 2800 | 0 | 10 | 8 |
| -10,1 | 2800 | 2 | 6 | 16 |
| -10 | 3500 | 7 | 2 | 32 |
| -9,9 | 3500 | 1 | 8 | 8 |
| -9,8 | 3500 | 3 | 5 | 16 |

Sateliot, Gatehouse provided further Link Budget results for Set 4 satellite parameters - Case 4 (LEO-600 km, min elevation beam edge 30 deg, Nadir 90 degrees) with different assumptions for Satellite NF / UE NF.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Satellite Antenna Gain | Satellite NF / UE NF | **DL SNR** | **UL SNR****(ST 15 kHz)** | **UL SNR****(ST 3.75 kHz)** |
| Worst location (α=30, Lapm=3 dB}  | Best location (α=90, Lapm =0 dB} | Worst location (α=30, Lapm =3 dB} | Best location (α=90,Lapm =0 dB} | Worst location (α=30,Lapm =3 dB} | Best location (α=90,Lapm =0 dB} |
| 7 dB | 5 dB / 7 dB | -16.0 dB | -7.9 dB | -13.2 dB | -8.1 dB | -7.2 dB | -2.1 dB |
| 3 dB /4 dB | -13.0 dB | -4.9 dB | -11.2 dB | -6.1 dB | -5.2 dB | -0.1 dB |
| 11 dB | 5 dB / 7 dB | -12.0 dB | -3.9 dB | -9.2 dB | -1.1 dB | -3.2 dB | 4.9 dB |
| 3 dB /4 dB | -9.0 dB | -0.9 dB | -7.2 dB | 0.9 dB | -1.2 dB | 6.0 dB |
| 15 dB | 5 dB / 7 dB | -8.0 dB | 0.1 dB | -5.2 dB | 2.9 dB | 1.2 dB | 8.9 dB |
| 3 dB /4 dB | -5.0 dB | 3.1 dB | -3.2 dB | 4.9 dB | 2.8 dB | 10.9 dB |

***Initial Proposal Section 7.2:***

***Include in TR 36.763 the following tables in Section 7.2:***

* ***Table for List of calibration study cases for link budget for Set 4 satellite parameters for NB-IoT***
* ***Tables for link budget results for Set 4 satellite parameters for NB-IoT - Case 4 (GEO-35786 km, min elevation 12.5 deg)***
* ***Table for data rate for Set 4 satellite parameters for NB-IoT - Case 4***

|  |  |
| --- | --- |
| **Company** | **Comments and Views** |
| Eutelsat | ***Table for List of calibration study cases Agreed******Tables for link budget results for Set 4 satellite parameters for NB-IoT - Case 4 LEO Agreed except for G/T (DL) shall be preferably -31.6 dB/K (in line with Set 3 assumptions) and the associated consequences on SNR.******Table for data rate for Set 4 satellite parameters for NB-IoT - Case 4 Agreed*** |
| ZTE | Fine to agree that study cases for set 4 , w.r.t the 2nd and 3rd sub-bullet, more discussion is needed. |
| Qualcomm | Similar comment as in 7.1 |
| Ericsson | Need to algin assumptions first before including the tables for link budget. Also, Set-4 is applicable to eMTC as well. |
| Huawei | Fine to study set 4 further but would like to settle down the definition of central beam. |
| CATT | Same comment as in 7.1, need firstly agree the set 4 parameters. |
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## Link budget for Set 1 satellite parameters for eMTC

Set 1 satellite parameters are given in TR 38.821 Table 6.1.1.1-1: Set-1 satellite parameters. As mentioned in Section 5, Set-1 was used by OPPO, ZTE, Zhejiang, CMCC (GEO @45 deg, LEO@90 deg) for NB-IoT and OPPO, Zhejiang , CMCC (GEO @45 deg, LEO@90 deg) for eMTC. The main change was the UL channel bandwidth. The same EIRP and G/T values as in NR NTN were used.

The moderator view is that for NB-IoT, using Set-1 satellite parameters would show higher C/N achievable on DL and UL as EIRP and G/T figures are higher. It would be up to the satellite designer to decide on using Set 3 or Set 4 based on compromise between cost and complexity of satellite and NB-IoT operations, data rates, and capacity. The Set 1 seems more suited for eMTC assuming eMTC operations targeting higher data rates and capacity.

***Initial Proposal Section 7.3:***

***Do companies agree that Set 1 satellite parameters are given in TR 38.821 Table 6.1.1.1-1: Set-1 satellite parameters can be used for link budget for eMTC.***

|  |  |
| --- | --- |
| **Company** | Comments and Views |
| Eutelsat | Set 1 can be accepted for eMTC but is far from being optimized for NB-IOT. Set 2 satellite parameters given in TR 38.821 should be studied as well for eMTC |
| ZTE | Same parameter is preferred for all IoT candidate solution. Otherwise, it may lead to a signal that eMTC has more tight requirement on the satellite for deployment.  |
| Qualcomm | At this point, no “set” should be deemed as “excluded” for any use case (NB-IoT/eMTC). We can present results with all sets (1,2,3 and 4); or, for brevity, it may be discussed whether it is OK to present eMTC results with just Set 1 and Set 2. But the TR shouldn’t give the impression to a reader that Set X (1,2,3,4) is “excluded” as a viable use case for deployment type Y (eMTC/NB-IoT) |
| Ericsson | Yes. Also, Set-1 is applicable to NB-IoT as well. |
| Huawei | Not sure how many set of parameters are to be used. It would be good to have an overview discussion. |
| CATT | In general it is fine to us.  |
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## Link budget for Set 2 satellite parameters for eMTC

Set 2 satellite parameters are given in TR 38.821 Table 6.1.1.1-2: Set-2 satellite parameters. As mentioned in Section 5, Set-1 was used by OPPO, ZTE, Zhejiang, CMCC (GEO @45 deg, LEO@90 deg) for NB-IoT and OPPO, ZTE, Zhejiang, CMCC (GEO @45 deg, LEO@90 deg) for eMTC. The main change was the UL channel bandwidth. The same EIRP and G/T values as in NR NTN were used.

The moderator view is that for NB-IoT, using Set-2 satellite parameters would show higher C/N achievable on DL and UL as EIRP and G/T figures are higher. It would be up to the satellite designer to decide on using Set 3 or Set 4 based on compromise between cost and complexity of satellite and NB-IoT operations, data rates, and capacity. The Set 2 seems more suited for eMTC assuming eMTC operations targeting higher data rates and capacity. Compare to Set 1, it may have some compromise for cost and complexity compare to Set 1.

***Initial Proposal Section 7.4:***

***Do companies agree that Set 2 satellite parameters are given in TR 38.821 Table 6.1.1.1-2: Set-1 satellite parameters can be used for link budget for eMTC.***

|  |  |
| --- | --- |
| **Company** | **Comments and Views** |
| Eutelsat | Agreed: Set 1 can be used for eMTC link budget but is far from being optimized for NB-IOT. Agreed: Set 2 satellite parameters given in TR 38.821 should be studied as well for eMTC |
| ZTE | Same comment as before. |
| Qualcomm | Similar comment as in 7.3. |
| Ericsson | Yes. Also, Set-2 is applicable to NB-IoT as well. |
| Huawei | Not sure how many set of parameters are to be used. It would be good to have an overview discussion. |
| CATT | Share same view with Huawei, not have a picture how many sets are defined. |
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# Other aspects of IoT NTN scenarios

## GNSS Capability

Several companies discussed the GNSS capability in IoT NTN scenarios. OPPO mentioned GNSS-incapable device should be considered. Ericson mentioned 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. Nokia mentioned poor performance of GNSS in indoor and vegetation-impacted scenarios and impact of GNSS-based pre-compensation on combining gain of repetitions. Samsung mentioned impact of supporting GNSS capability in NTN IoT devices. Qualcomm proposed RAN1 to study how accurately an eMTC/NB-IoT UE can track the location of a satellite—specifically for the case of LEO satellites. Qualcomm also proposed RAN1 to study the downlink frequency accuracy of initial cell acquisition for eMTC and NB-IoT over NTN including accuracy of crystal oscillator at the UE and maximum Doppler frequency offset during initial acquisition. Qualcomm proposed RAN1 to agree on the length of connections that are supported for eMTC/NB-IoT over NTN.

A note in the Rel-17 IoT NTN SID states clearly that assumption of GNSS capability is that UE can estimate and pre-compensate timing and frequency offset with sufficient accuracy for UL transmission.

*NOTE: GNSS capability in the UE is taken as a working assumption in this study for both NB-IoT and eMTC devices. With this assumption, UE can estimate and pre-compensate timing and frequency offset with sufficient accuracy for UL transmission. Simultaneous GNSS and NTN NB-IoT/eMTC operation is not assumed.*

The moderator view is that GNSS capability is taken as working assumption for IoT NTN scenarios as stated in the SID. GNSS accuracy and impact UE power consumption for enhancements of timing and frequency synchronization can be discussed in IoT NTN in Agenda Item 8.15.2. Aspects of DL synchronization and SIB reading can also be discussed in IoT NTN in Agenda Item 8.15.2. On the legth of connections that are supported for eMTC/NB-IoT over NTN, this can be determined once the sets of satellite parameters including the maximum bem diameter size are agreed.

***Feature Lead recommendation - Section 8.1:***

***RAN1 can discuss GNSS accuracy and impact on UE power consumption for enhancements of timing and frequency synchronization in IoT NTN in Agenda Item 8.15.2***

|  |  |
| --- | --- |
| **Company** | **Comments and Views** |
| Eutelsat  | Agreed. RAN1 shall discuss GNSS accuracy and impact on UE power consumption for enhancements of timing and frequency synchronization. Power consumption data shall be reported in the Study Item report. |
| ZTE | Agree. The GNSS related issue including power saving should be well studied. |
| Qualcomm | Agree.***ADDITIONAL COMMENT for Section 8***: There should be a section on “deployment modes” that are to be studied/prioritized for NB-IoT (e.g., standalone deployment, in-band deployment, etc.). |
| Ericsson | Support |
| Huawei  | Agree |
| CATT | Agree |
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## Beam edge with 3 dB beamwidth

CATT mentioned satellite coverage angle can be determined from the altitude of the satellite, the elevation angle and the radius of the earth. They provide analysis where$ $one beam is applied for one satellite, $α$ is elevation angle of satellite, $β\_{1}$ is the angle from left edge of the beam to beam center and $β\_{2}$ is the angle from right edge of the beam to beam center.



|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Use cases | Elevation:$α$ | the max angle of beam coverage:$β\_{1}$ | the max angle of beam coverage:$β\_{2}$ | the corresponding beam diameter assuming beamwidth angle equal to 2\*$β\_{1}$ |
| GEO | 90 degree | 8.6922 degree | 8.6922 degree | 5429\*2 km |
| GEO | 45 degree | 2.5577 degree | 14.8266 degree | 1670\*2 km |
| GEO | 30 degree | 1.1718 degree | 16.2125 degree | 789.62\*2 km |
| GEO | 10 degree | 0.1331 degree | 17.2513 degree | 94.271\*2 km |
| LEO-1200 | 90 degree | 57.2989 degree | 57.2989 degree | 1200\*2 km |
| LEO-1200 | 45 degree | 20.7841 degree | 98.8137 degree | 573.1\*2 km |
| LEO-1200 | 30 degree | 10.5163 degree | 104.0815 degree | 366.88\*2 km |
| LEO-1200 | 10 degree | 1.3318 degree | 113.2660 degree | 313.09\*2 km |
| LEO-600 | 90 degree | 66.0541 degree | 66.0541 degree | 691.72\*2 km |
| LEO-600 | 45 degree | 25.7950 degree | 106.3132 degree | 366.83\*2 km |
| LEO-600 | 30 degree | 13.7295 degree | 118.3787 degree | 257.62\*2 km |
| LEO-600 | 10 degree | 1.8902 degree | 130.2180 degree | 63.725\*2 km |

Thales proposed for Set 4 satellite parameters one single large beam (104,7 deg HPBW) with a beam diameter of 1400 km. This would corresponds to a min elevation angle of 30 degrees. Sateliot provided analysis on antennas with a high HPBW in one dimension and low HPBW in the other could offer a good trade-off to support large beam footprints (for instance, in the direction perpendicular to satellite’s movement) with antenna gains higher than those achievable with symmetrical radiation pattern antennas.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Dimensional constraints | Horizontal HPBW (degrees) | Vertical HPBW(degrees) | Gain(dBi) | Estimated number of patches (X x Y) |
| 10x20cm | 60 | 30 | 11 | 2 |
| 10x20cm | 100 | 30 | 7.5 | 4 |
| 10x30cm | 60 | 30 | 12.5 | 3 |
| 10x30cm | 100 | 20 | 10 | 6 |
| 15x30cm | 45 | 20 | 13 | 8 |
| 20x30cm | 30 | 20 | 14.5 | 6 |
| 20x30cm | 90 | 30 | 12 | 12 |

Eutelsat, ZTE provided the 3 dB beamdwidth of 0.7 degree for beam diameter 459 km for GEO with 10 degree central beam elevation, 22.1 degree beam diameter 470 km for LEO-1200 km with 10 degree central beam, and 22.1 degree beam diameter 234 km for LEO-600 km with 10 degree central beam. These values for the 3 dB beamwidth are consistent with CATT analysis as highlighted in yellow in the table.

Sateliot, ZTE provided 3 dB beamwidth of 60 degrees with a satellite beam diameter of 700 km at Nadir point for Set 4 satellite parameters.

The moderator view is that the 3 dB beamwidth for Set 1, Set 2, Set 3, and Set 4 parameters could be discussed further to check understanding in RAN1 and capture the appropriate values for 3 dB beamwidth in these tables mentioned 3 dB beamwidth of 60 degrees for Set 4 satellite parameters. .

***FL recommendation Section 8.2***

***RAN1 to further discuss 3 dB beamwidth assumptions and include 3 dB beamwidth values for Set 1, Set 2, Set 3, and Set 4 satellite parameters for IoT NTN***

|  |  |
| --- | --- |
| **Company** | **Comments and Views** |
| Eutelsat | Prefer to stick to values where already agreed or reasonable consensus exists; accept discussion if detailed comments / justification are provided during this RAN 1 meeting. |
| ZTE | Clarification on the beam layout definition along with parameters is needed. This proposal is overlapped with the discussion on section 2.2/2.3 and 5. If common understanding on the parameter can be reached, same methodology as NR NTN SI can be reused. |
| Qualcomm | Not sure if additional discussion on this is required. We can double check for the purposes of accuracy of the TR, but this shouldn’t be prioritized at this point. |
| Ericsson | Support |
| Huawei  | Agree |
| CATT | 3dB beamwidth is one fundamental parameter. We are not sure if without this parameter, how to evaluate SINR for set 1, set2, set 3 and set 4. As agreed in last meeting, the maximum beam size is very large, so 3dB beamwidth should be also large. The validity of 3dB beamwidth of any sets should be clarified firstly. |
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# References

1. RP-193235, “New Study WID on NB-IoT/eTMC support for NTN”, MediaTek, RAN#88-e, june 2020.
2. TR 38.821 “Study on solutions for NR to support non-terrestrial networks”
3. RAN1#103e, Eutelsat, FL summary #4 for UL synchronization in R1-2008868, , November 2020
4. TR36.888-c00, Study on provision of low-cost Machine-Type Communications (MTC) User Equipment (UEs) based on LTE (Release 12).

# Appendix 1

The IoT NTN reference scenario parameters agreed in RAN1#103e are listed in Table 5.1-1 below:

|  |  |  |
| --- | --- | --- |
| Scenarios | GEO based non-terrestrial access network - scenario A  | LEO based non-terrestrial access network -Scenario B & C |
| Orbit type | station keeping a nominally fixed position in terms of elevation/azimuth with respect to a given earth point  | circular orbiting at low altitude around the earth |
| Altitude | 35,786 km | 600 km 1,200 km  |
| Frequency Range  (service link) | < 6 GHz (e.g. 2 GHz in S band)  |
| Device channel Bandwidth  (service link) (NOTE 7) | * NB-IoT 180 kHz (DL), Up to 180 kHz with all permissible smaller resource allocations 12\*15 kHz, 6\*15 kHz, 3\*15 kHz, 1\*15 kHz, 1\*3.75 kHz
* eMTC: 1080 kHz (DL), Up to 1080 kHz with all permissible smaller resource allocations , including 2\*180 kHz, 180 kHz, 2\*15 kHz or 3\*15 kHz or 6\*15 kHz  (UL)
 |
| Payload | Transparent type | Transparent Type |
| Earth-fixed beams | Yes | Scenario B:  Yes (steerable beams), see NOTE 1Scenario C: No  (the beams move with the satellite) |
| Max beam foot print size (edge to edge) regardless of the elevation angle | 3500 km (NOTE 3) | 1000 km  (NOTE 2) |
| Min Elevation angle for both sat-gateway and C-IoT device | 10° for service link and 10° for feeder link | 10° for service link and 10° for feeder link |
| Max distance between satellite and C-IoT device at min elevation angle  |  40,581 km  |  1,932 km (600 km altitude)  3,131 km (1,200 km altitude)  |
| Max Round Trip Delay (propagation delay only)  |  541.46ms (service and feeder links) | 25.77 ms (600km) (service and feeder links)41.77 ms (1200km) (service and feeder links) |
| Max differential delay within a cell  | 10.3 ms | 3.12 ms and 3.18 ms for respectively 600km and 1200km |
| Max Doppler shift (earth fixed user equipment) (NOTE 6) | 0.93 ppm | 24 ppm (600km)  21ppm(1200km)   |
| Max Doppler shift variation (earth fixed user equipment)  (NOTE 6) | 0.000 045 ppm/s  |   0.27 ppm/s  (600km)   0.13 ppm/s  (1200km)  |
| C-IoT device motion on the earth | Min 0 km/s (stationary device), max 120 km/h  | Min 0 km/s (stationary device), max 120 km/h |
| C-IoT device antenna types | Omnidirectional antenna with 0 dBi TX antenna gain and 0 dBi RX antenna gain  (NOTE 4)  |
| C-IoT device max Tx power | UE power class 3 with up to 200 mW (23dBm), UE power class 5 with up to 100 mW (20 dBm)  |
| C-IoT device Noise Figure | Omnidirectional antenna: 7 dB or 9 dB  (NOTE 5) |
| Service link | 3GPP defined Narrow Band IoT and eMTC |

NOTE 1:    Each satellite has the capability to steer beams **towards fixed points on earth** using beamforming techniques. This is applicable for a period of time corresponding to the visibility time of the satellite.

NOTE 2:   This beam size refers to the Nadir pointing of the satellite.

NOTE 3: The Maximum beam foot print size for GEO is based on current state of the art GEO High Throughput systems, assuming either spot beams at the edge of coverage (low elevation) or a single wide-beam.

NOTE 4: The use of a Circular polarized antenna is optional.

NOTE 5: Same Noise Figure of 7 dB as in Release 16 TR 38.821 or 9 dB as in Release 12 TR 36.888  for device can be assumed for link budget. The noise figure is device vendor implementation specific.

NOTE 6: Max Doppler shift and Max Doppler shift variation in the absence of any device pre-compensation of satellite Doppler shift on the service link.

NOTE 7: System bandwidth is FFS

# Appendix 2

|  |  |
| --- | --- |
| Contribution | Observation/Proposals |
| OPPO (R1-2100160) | Proposal 1: GEO satellite may be prioritized.Proposal 2: Scenario of coexistence with TN system is not considered.Proposal 3: GNSS-incapable device should be considered. Observation: The evaluated link budget results for the scenarios of NB-IoT/eMTC over NTN with different assumptions are provided in Table 1~Table 12. |
| Huawei (R1-2100225) | *Proposal 1: The cube satellite based deployment should be discussed further considering at least aspects related to link budget, steerable beams and discontinuous coverage.**Proposal 2: The performance metrics for IoT over NR-NTN includes at least the following* * + *DL/UL peak data rate*
	+ *Latency*
	+ *User density*
	+ *Power consumption*

*Proposal 3: Capture the link budget results in the Appendix into the TR.* |
| ZTE (R1-2100248) | Proposal 1: At least the satellite parameter Set-2 defined in 38.821 can be considered for IoT-NTN.Proposal 2: One limitation for the cube satellite (set-4) transmission power should be defined instead of constant EIRP over all potential system bandwidth assumption.Proposal 3: More suitable assumption on beam layout for Set-3 and Set-4 evaluation should be considered if supported.* Central beam elevation angle of the two cases should be updated as 20°for Set-3 GEO and 35°for Set-3 LEO-1200

Observation 1: The coupling loss of more than 30% UE is larger than 164 dB for LEO-600 with satellite parameters Set-1~4 in urban case. Situation is even worse in GEO scenario.Observation 2: For Set-3 and Set-4, coupling loss of LOS UE in some cases exceeds the MCL requirement for NB-IoT and eMTC.Observation 3: In some cases for Set-2, Set-3, and Set-4, even the coupling loss is smaller than 164 dB for NB-IoT and 159 dB for eMTC, the CNR is worse than the minimum required SNR.Proposal 4: Further enhancement on the transmission may be needed to support cases with large coupling loss and/or low CNR. |
| CATT (R1-2100365) | Observation 1：In GEO system, the UL CNR at the beam center will reach about -14dB when large bandwidth is configured.Observation 2：The existing 3dB beamwidth for S band on satellite parameter configuration in TR 38.821 cannot guarantee beam coverage for IoT NTN.Observation 3: For IoT NTN evaulation, due to larger beam size, mutiple tiers of beam layout may not be suitable. Observation 4: For steering beam case, smaller beam size is to be defined to fit different elevation angles. Proposal 1：In view of worse SNR range in large UL bandwidth, 360khz / 180khz UL bandwidth should not be set as typical configuation for calibration and performance evaluation. Proposal 2: New 3dB beamwidth paremeter for IoT NTN needs to be defined.Proposal 3: For evaluation purpose, it is suggested to limited beam tier and adjust the maximum beam size to get reasonble results. |
| Zhejiang (R1-2100480) | Observation 1: Set-3 satellites and Set-4 satellites have quite lower achievable CNRs in UL.Proposal 1: Lower antenna gain of devices should be considered. |
| Gatehouse, Sateliot, Thales, Kepler (R1-2100521) | Proposal #1: To include a set of satellite parameters in line with those proposed under “Set 4” as part of the cases to be studied in the IoT NTN SI, as a representative characterization of NB-IoT NTN scenarios with small satellite platforms such as CubeSats. |
| MediaTek (R1-2100600) | Observation 1: NB-IoT can support minimum performance requirement for NPDSCH, NPDCCH, NPUSCH format 1 and 2, NPRACH for NB-IoT NTN Set 3 and Set 4 for cases 1, 2, 3, and 4 by using specified range of repetitions.Observation 2: NB-IoT can support minimum performance requirement for NPBCH.Observation 3: It is up to the eNB UL scheduler to select the sub-carrier spacing and UL channel bandwidth with the required number of repetitions to transmit a TBS on NPUSCH or to transmit HARQ feedback on NPUSCH format 2. Proposal 1: List of Cases for Link Budget in Table 1 in R1-2100600 is used as working assumption for NB-IoT NTNProposal 2: Link Budget results for case 1, 2, 3, and 4 in Table 2 and losses in Table 3 in R1-2100600 are included in TR 36.763 |
| Sony (R1-2100874) | Observation 1: The following parameters need to be agreed for the IoT-NTN UL link budget:* RX G/T
* Pathloss modelling parameters
* Additional loss accounting for satellite RX antenna pattern

Observation 2: The following parameters need to be agreed for the IoT-NTN DL link budget:* TX EIRP density
* Pathloss modelling parameters
* Additional loss accounting for satellite TX antenna pattern

Proposal 1. The peak RX G/T values assumed in the UL link budget are:* GEO: 16.7 dBK-1
* LEO-600 and LEO-1200: -12.8 dBK-1

Proposal 2. An additional loss of 3dB is assumed in the cell edge UL link budget to account for satellite RX antenna pattern.Proposal 3. The following pathloss parameters are assumed in the UL and DL link budgets:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| FSPL  | 190.6 | 164.5 | 159.1 | dB |
| Scintillation losses | 2.2 | 2.2 | 2.2 | dB |
| atmospheric losses | 0.1 | 0.1 | 0.1 | dB |
| polarization loss | 3 | 3 | 3 | dB |
| shadow margin  | 3 | 3 | 3 | dB |
| sum of all losses  | 198.9 | 172.8 | 167.4 | dB |

Proposal 4. The peak TX EIRP densities values assumed in the DL link budget are:* GEO: 59.8 dBW / MHz
* LEO-600: 33.7 dBW / MHz
* LEO-1200: 28.3 dBW / MHz

Proposal 5. An additional loss of 3dB is assumed in the cell edge DL link budget to account for satellite TX antenna pattern.Proposal 6: Link level assumptions for IoT-NTN eMTC include the following:* Transport channels: PUSCH, PUCCH, PDSCH and MPDCCH
* Frequency hopping: {on, off}
* Antenna configurations:
	+ UE = {1RX, 1TX}
	+ Satellite = {1RX, 1TX}
* OTA channel: ETU, EPA, AWGN

Proposal 7: The IoT-NTN link budget is considered suitable if the available SNR is greater than the SNR required to support the traffic models defined in TR45.820. |
| Ericsson (R1-2100930) | 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.Proposal 1 IoT NTN study should focus on essential adaptations for NTN, while generic enhancements motivated by non-NTN are outside the scope.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.Proposal 2 In Rel-17 IOT NTN SI, consider nominal S band (2 GHz) for evaluation purposes.Proposal 3 In Rel-17 IOT NTN SI, limit the focus to FDD only.Observation 7 The approved Rel-17 IoT NTN SID is dedicated to transparent payload.Proposal 4 In Rel-17 IOT NTN SI, prioritize earth fixed beams.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.Proposal 5 In Rel-17 IOT NTN SI, evaluate eMTC and NB-IoT in the context of NTN at least for the following targets: (1) coverage performance through link budget analysis; (2) supported device density; (3) complexity and cost of equipping eMTC/NB-IoT devices with NTN capability; (4) power consumption performance of eMTC/NB-IoT devices with NTN connectivity; and (5) latency performance of eMTC/NB-IoT devices in NTN systems. |
| Asia Pacific Telecom (R1-2100975) | Observation 1 Regarding discontinuous service due to the cube satellites scenario, existing discussions on hard feeder link switch in Rel-17 NTN WI may cover this issue.Proposal 1 Support of max UE speed of 120 km/h shall be further clarified.Proposal 2 Regarding link budget and system-level simulation, a new scenario for the cube satellites scenario shall be considered. |
| Thales, Sateliot, Gatehouse (R1-2100019) | Set 4 SLS simulations show that at -10 dB SNR for downlink, we can close the link budget with a number of repetition of 64 The study [2] (figure 13) also shows a setup with a MCL of 164 dB which can achieve 11 kbps in DL, and 2 kbps in UL.Independent work at GateHouse and in [2] show that at -12 dB SNR, a data rate of 3.500 kbps (resp. 2 kbps in [2]) can be achieved. These figures are given in a terrestrial configuration, but provided that:• the link budget is closed in [2] at -14 dB SNR (compared to our -10 dB),• at UE side, optimizations can be made to better track the phase of the eNodeB,• the link budget is given at beam edge (worst case), |
| Nokia (R1-2101027) | Observation 1: System-level parameters in Set 1 are reused for link budget study.Observation 2: Polarization and additional losses are assumed to 0 dB in TR38.821. Observation 3: Including the proposed outdoor-to-indoor penetration loss requires link budget improvements.Observation 4: Including the proposed vegetation loss requires link budget improvements.Observation 5: The uplink bottleneck channels are the channels with the largest bandwidth. Observation 6: The UE power class(es), which support indoor scenarios shall be identified. Proposal 1: RAN1 to agree FDD usage for NTN IoT as a working assumption.Proposal 2: The study item shall use S-band (2 GHz) for evaluation.Proposal 3: RAN1 to discuss which device power class(es) to study.Proposal 4: RAN1 to discuss which release of NB-IoT and eMTC is assumed as baseline and which features to include.Proposal 5: RAN1 to agree half-duplex mode for NTN IoT as a working assumption.Proposal 6: RAN1 to discuss which device categories to include in the study.Proposal 7: RAN1 to discuss data rate definitions, required SINR, and maximum coupling loss for LEO (600 km and 1200 km) and GEO scenarios.Proposal 8: RAN1 to discuss technology objectives in terms of number of supported devices, user equipment battery lifetime, and maximum user data uplink latency.Proposal 9: RAN1 to discuss whether indoor or vegetation-impacted UEs are in scope and how to handle poor GNSS performance in those scenarios.Proposal 10: RAN1 to discuss how to handle poor GNSS performance in indoor and vegetation-impacted scenarios.Proposal 11: The system-level satellite parameters in Set 1 are reused for link budget study.Proposal 12: The polarization and additional losses are assumed to be 0 dB for the basic link budget study.Proposal 13: RAN1 to define outdoor-to-indoor penetration loss of 25 dB for further link budget analysis.Proposal 14: RAN1 to define vegetation loss of 10 dB for further link budget analysis.Proposal 15: RAN1 to define the maximum number of repetitions to apply in the link budget analsysis.Proposal 16: RAN1 to discuss impact of GNSS-based precompensation on combining gain of repetitions. Proposal 17: The link budget evaluation in Table 3, Table 4, and Table 5 shall be included in the study item report. |
| CMCC (R1-2101069) | Proposal 1: For link budget, the following additional pathloss needs to be considered.- Carriage and container penetration loss (9~20dB) for logistics application.- Vegetation loss (e.g., 9dB) for outdoor application.Proposal 2: Regarding connection density for IoT NTN, revisit the target requirement is needed.Proposal 3: Regarding complexity of IoT device, investigate the impact of GNSS-assisted operation is needed. |
| Eutelsat (R1-2101146) | Proposal: Other 3GPP member companies should as well report their results to prove that there is a consensus within the technical community and provide inputs to the final study item report |
| Samsung (R1-2101242) | Proposal 1: Discuss simulation assumptions for link/system level evaluation and link budget analysis using Sec.6.1in TR 38.821 as starting point. Proposal 2: Study the impact of supporting GNSS capability in NTN IoT devices. Proposal 3: Support only the stand-alone operation mode for NB-IoT. |
| Apple (R1-2101368) | Proposal 1: RAN1 to align the link budget analysis for IoT NTN. |
| CAICT (R1-210141) | Proposal 1: UEs served by NB-IoT/eMTC over NTN should adapt to GNSS capacities. |
| Qualcomm (R1-2101512) | Proposal 1: RAN1 to study the downlink frequency accuracy of initial cell acquisition for eMTC and NB-IoT over NTN. This includes studying:- Accuracy of crystal oscillator at the UE (in ppm)- Maximum doppler frequency offset during initial acquisitionProposal 2: RAN1 to study how accurately an eMTC/NB-IoT UE can track the location of a satellite—specifically for the case of LEO satellites. - RAN1 to also study how frequently the UEs need to read system information from the satellite in order to maintain the above accuracy of satellite location.Proposal 3: RAN1 to agree on the length of connections that are supported for eMTC/NB-IoT over NTN. - RAN1 to also discuss UE impact of SIB reads during a connection, if such is required to maintain a given satellite location accuracy at the UE, as described in the above proposal. Proposal 4: For LEO satellites with fixed (non-steerable) satellite beams, study techniques to configure a cell (Ncell for NB-IoT) that spans resources across multiple satellite beams of a satellite.Proposal 5: For NB-IoT over NTN, support only the following deployment modes- Standalone- In-band with / guard band of NR |
| Lockheed Martin | **Observation**: In Section 2.1 there is no indication whether HARQ is enabled or not for the provided SNR values. NR NTN discussion so far permits a HARQ process to be enabled or disabled.**Observation**: Some SNR values cited in Section 2.1 assume high number (64 or higher) of repetitions. R1-2100264 requests study on whether high number of repetition is achievable in NGSO, especially LEO environment with large rate of change in propagation delay.**Proposal:** The required CNIR should account for HARQ configuration (enabled/disabled).**Proposal:** Conduct study on upper limit of number of repetitions in a LEO link environment and then determine link robustness improvement with repetition.  |
| Lockheed Martin | **Observation 1**: Appendix 1 states that 0 dBi Tx and Rx antenna directivity is assumed. We understand that that practical UE (e.g., smartphone and IoT device) antennas may perform several dBs worse than 0 dBi.**Proposal 1**: Include an additional loss term of [6] dB for practical UE antenna directivity.**Observation 2**: In Appendix 1 no implementation loss is explicitly accounted for.**Proposal 2**: Include an implementation loss term of [2] dB. |