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

January 25th – February 5th, 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

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 satelite 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
* 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, Set 2two cases

* 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 TR 36.888 Table 5.2.1.2-2 “MCL calculation for normal LTE FDD”, a MCL of 144 dB 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

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 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 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 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

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

***Initial Proposal Section 2.1:***

**Do companies agree that 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***

***NOTE: 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.***

## 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***

## 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

|  |  |
| --- | --- |
| 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***

# 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..

|  |  |  |  |
| --- | --- | --- | --- |
| 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 PC5 (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 d 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.**

# 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.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 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 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 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***

|  |  |
| --- | --- |
| 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)
 |

# 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.

|  |
| --- |
| **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) |

|  |
| --- |
| **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***

# 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.**

## 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 |

# 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 also revised ZTE results which seemed to have used the GEO G/T of -16.7 dB/K for LEO, but -12.8 dB/K should be used according to Table with set 3 satellite parameters.

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 | 0.6 dB | -5.4 dB | -10.2 dB | -13.2 dB | -16.2 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 | 2.0 dB | -4 dB | -8.8 dB | -11.8 dB | -14.8 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 | -1.8 dB | -7.8 dB | -12.6 dB | -15.6 dB | -18.6 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 )***

## 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***

## 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.***

## 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 7.3:***

***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.***

# 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

|  |  |
| --- | --- |
| 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 |