3GPP TSG RAN WG1 Meeting #104bis-e R1-2103962

April 12th – April 20th, 2021

Agenda Item: 8.15.1

Source: Moderator (MediaTek)

Title: Summary #3 of AI 8.15.1 Scenarios applicable to NB-IoT/eMTC

Document for: Discussion and Decision

# Introduction

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

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

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

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

# Link Budget Calibration

The following agreements were made in RAN1#104e.

Agreement:

The following assumptions are agreed for a common set of link budget parameters:

* UE power class (PC5=20 dBm)
* UE Noise Figure (NF=9 dB)
* Channel Bandwidth for NB-IoT and eMTC as was included in IoT NTN reference scenario parameters agreed in RAN1#103e
  + 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)
* Other losses

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

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

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

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

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

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

Agreement:

Link budget analysis assumes 3 dB polarization loss for DL and 3 dB polarization loss on UL for satellite parameters Set 1, Set 2, Set 3, and Set 4

Agreement:

Include in TR 36.763, the 3 dB beam width (HPBW), central beam center elevation and central beam edge elevation in the satellite parameter set(s) to be used in link budget calculations – (Corresponding satellite parameter Set 3 and Set 4 are given in Section 9.4)

|  |  |  |  |
| --- | --- | --- | --- |
| SET 3 | GEO 35786 km | LEO-600 km | LEO-1200 km |
| 3 dB Beam width (HPBW) | 0.735 degree | 22.0631 degree | 22.0631 degree |
| Central beam center elevation | 20.88 degree | 43.78 degree | 46.05 degree |
| Central beam edge elevation | 12.5 degree | 30 degree | 30 degree |
| Central beam edge satellite-UE distance | 40316 km | 1074 km | 1998 km |

|  |  |
| --- | --- |
| SET 4 | LEO-600 km |
| 3 dB Beam width (HPBW) | 104.7 degree |
| Central beam center  elevation | 90 degree |
| Central beam edge elevation | 30 degree |
| Central beam edge satellite-UE distance | 1076 km |

NOTE 1: The 3 dB beam width (HPBW)  is already included in satellite parameter set 1 and Set 2 in TR 38.821 Table 6.1.1.1-1 and Table 6.1.1.1-2  respectively. The central beam center elevation  for Set-1 and Set-2 is defined as the target elevation angle that is included in in TR 38.821 Table 6.1.3.2-1.   The central beam edge satellite-UE distance can be derived from the central beam edge elevation and does not need to be included.

NOTE 2: Central beam center elevation is the beam center elevation of the central beam in the beam layout.

NOTE 3: Central beam edge elevation is the minimum beam edge elevation of the central beam in the beam layout.

NOTE 4 In SLS evaluation with a multiple beam layout, the central beam is the serving beam for UEs. The outer beams have beam center elevation that is different from the central beam center elevation.  For the interference modelling, the interference due to the outer beams is determined by using their respective beam center elevations.

NOTE 5: For the multiple-beam satellite cell, the longest beam edge distance will correspond to the minimum beam edge elevation of the most outer beam as illustrated in figure below.



Agreement:

Include the following tables in TR 36.763:

* Set 1 satellite parameters (based on TR 38.821, Table 6.1.1.1-1)
* Set 2 satellite parameters (based on TR 38.821, Table 6.1.1.1-2)
* Set 3 satellite parameters (Eutelsat R1-2101146 with central beam edge elevation 12.5 degree for GEO, and 30 degree for LEO-600 km and 1200 km)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Satellite orbit | | GEO | LEO-1200 | LEO-600 |
| Satellite altitude | | 35786 km | 1200 km | 600 km |
| Central beam edge elevation | | 12.5 degree | 30 degree | 30 degree |
| Central beam center elevation | | 20.9 degree | 46.05 degree | 43.8 degree |
| 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 (HPBW) | 0.7353 degree | 22.1 degree | 22.1 degree |
| Satellite beam diameter (NOTE 2) | 459km | 470 km | 234 km |
| Payload characteristics for UL transmissions | | | | |
| Equivalent satellite antenna aperture (NOTE 1) | S-band  (i.e. 2 GHz) | 12 m | 0.4 m | 0.4 m |
| G/T | 16.7dB K-1 | -12.8 dB K-1 | -12.8 dB K-1 |
| Satellite Rx max Gain | 45.7 dBi | 16.2 dBi | 16.2 dBi |

NOTE 1: This value is equivalent to the antenna diameter in Sec. 6.4.1 of TR 38.811

NOTE 2: Satellite beam diameter is at Nadir point

NOTE 3: Central beam center elevation is referred to as central beam elevation in TR 38.821

NOTE 4: Central beam edge elevation is the minimum beam edge elevation of the central beam in the beam layout.

* Set 4 satellite parameters (Thales, Sateliot, Gatehouse R1-2101019)

|  |  |  |
| --- | --- | --- |
| Satellite orbit | | LEO-600 |
| Satellite altitude | | 600 km |
| Central beam edge elevation | | 30 degree |
| Central beam center elevation | | 90 degree |
| Payload characteristics for DL transmissions | | |
| Equivalent satellite antenna aperture (NOTE 1) | S-band  (i.e. 2 GHz) | 0.097 m |
| Satellite EIRP density | 21.45 dBW/MHz |
| Satellite Tx max Gain | 11 dBi |
| 3dB beam width (HPBW) | 104.7 degree |
| Satellite beam diameter (Note 2) | 1700 km |
| Payload characteristics for UL transmissions | | |
| Equivalent satellite antenna aperture (Note1) | S-band  (i.e. 2 GHz) | 0.097 m |
| G/T | - 18.6 dB·K-1 |
| Satellite Rx max Gain | 11 dBi |

NOTE 1: This value is equivalent to the antenna diameter in Sec. 6.4.1 of TR 38.811

NOTE 2: Satellite beam diameter is at Nadir point

NOTE 3: Central beam center elevation is referred to as central beam elevation in TR 38.821

NOTE 4: Central beam edge elevation is the minimum beam edge elevation of the central beam in the beam layout.

Agreement:

Include in TR 36.763, the 3 dB beam width (HPBW), central beam center elevation and central beam edge elevation in the satellite parameter set(s) to be used in link budget calculations – (Corresponding satellite parameter Set 3 and Set 4 are given in Section 9.4)

|  |  |  |  |
| --- | --- | --- | --- |
| SET 3 | GEO 35786 km | LEO-600 km | LEO-1200 km |
| 3 dB Beam width (HPBW) | 0.735 degree | 22.0631 degree | 22.0631 degree |
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|  |  |
| --- | --- |
| SET 4 | LEO-600 km |
| 3 dB Beam width (HPBW) | 104.7 degree |
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NOTE 1: The 3 dB beam width (HPBW)  is already included in satellite parameter set 1 and Set 2 in TR 38.821 Table 6.1.1.1-1 and Table 6.1.1.1-2  respectively. The central beam center elevation  for Set-1 and Set-2 is defined as the target elevation angle that is included in in TR 38.821 Table 6.1.3.2-1.   The central beam edge satellite-UE distance can be derived from the central beam edge elevation and does not need to be included.

NOTE 2: Central beam center elevation is the beam center elevation of the central beam in the beam layout.

NOTE 3: Central beam edge elevation is the minimum beam edge elevation of the central beam in the beam layout.

NOTE 4 In SLS evaluation with a multiple beam layout, the central beam is the serving beam for UEs. The outer beams have beam center elevation that is different from the central beam center elevation.  For the interference modelling, the interference due to the outer beams is determined by using their respective beam center elevations.

NOTE 5: For the multiple-beam satellite cell, the longest beam edge distance will correspond to the minimum beam edge elevation of the most outer beam as illustrated in figure below.



## Link budget results summary

Link budget - CNR results:

Link budget results were provided by Huawei, OPPO, Vivo, CATT, MediaTek, Nokia, CMCC, ZTE, Xiaomi, Ericsson, Qualcomm, Apple, Samsung, Sony, Sateliot

The following observations from individual company contributions were made:

* Huawei observed the worst CNR for the four sets of satellites are around -12 dB, -16 dB, -13dB and -17dB, respectively.
* Vivo observed device antenna with 0 dBi gain assumption is optimistic for link budget calculations, lower antenna gain can be considered for the worst case, e.g. -5dBi.
* CATT recommended smaller uplink transmission bandwidth for larger UL CNR when channel condition is poor. CNR in some cases reached below -20dB. Further consider whether we need to support the case with -20 dB CNR.
* MediaTek commented that NB-IoT can support the observed SNR UL and DL with moderate level of repetitions consistent with MCL=154 dB. MediaTek, Samsung results show lowest SNR observed are for Set 4 with -12 dB on DL and -2.4 dB or -8.5 dB (ST with SCS=3.75 kHz or 15 kHz) on UL.
* Nokia observed CNR is reduced as the channel bandwidth increases. CNR is reduced about 15.5 dB if the channel bandwidth increases from 30 kHz to 1080 kHz in uplink of eMTC. CNR of NB-IoT decreases about 16.8 dB when the channel bandwidth increases from 3.75 kHz to 180 kHz. Sets 1 and 2 results in positive maximum CNR (for NB-IoT), while set 3 and especially set 4 have challenging link budgets with low CNR.
* CMCC observed that: For GEO with Set 2 satellite parameter, the UL CNR will reach -18.8dB level for NB-IoT with 180kHz BW, and reach -26.5dB level for eMTC with 1080kHz BW. For LEO at 1200km with Set 3 satellite parameter, the UL CNR will reach -17.4dB level for NB-IoT with 180kHz BW, and reach -25.2dB level for eMTC with 1080kHz BW. For LEO at 600km with Set 4 satellite parameter, the UL CNR will reach -14.9dB level for NB-IoT with 180kHz BW, and reach -22.7dB level for eMTC with 1080kHz BW. Additional path loss can be observed in some deployment scenarios – i.e Carriage and container penetration loss (9~20 dB) for logistics application; Vegetation loss (e.g., 9 dB) for outdoor application.
* ZTE observed in all the cases, the coupling loss would be less than 164 dB, but in some cases of Set-3 LEO-1200 and Set-4 LEO-600, the coupling loss would be larger than 159 dB.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | GEO | LEO-600 | LEO-1200 |
| Set-1 | Coupling loss (dB) | 151.04 | 140.99 | 146.39 |
| Set-2 | Coupling loss (dB) | 156.50 | 147.71 | 153.15 |
| Set-3 | Coupling loss (dB) | 156.24 | 154.16 | 159.55 |
| Set-4 | Coupling loss (dB) |  | 159.38 |  |

* Xiaomi observed that low CNR is observed on the UL with maximum channel bandwidth is used, e.g, 180 kHz for NB-IoT and 1080 kHz for eMTC.
* Ericsson observed that Set 1 typically has the most favourable link budget results whereas Set 4 has the most challenging link budgets
* Qualcomm observed the uplink SNRs reduce significantly, which could make providing coverage at certain (especially low) elevation angles—e.g., those corresponding to the beam-edge, challenging. For Set 3, the uplink SNRs that are achievable will be lower than that in Set 2. At the edge of the beam approach -20 dB in Set 4, which could make providing coverage at these (low) elevation angles—e.g., those corresponding to the beam-edge—significantly challenging. A 15 kHz numerology and a full (one) PRB transmission (in the uplink) was used in the link budget results. Apple has similar obervations with full RB used on UL.

|  |  |  |
| --- | --- | --- |
| **Elevation Angle = 30 Degrees** | **Set 2** | **Set 3** |
| Uplink SNR (dB) @1200 km | -11.5 | **-19.4** |
| Uplink SNR (dB) @600 km | -6.2 | **-14** |

|  |  |  |  |
| --- | --- | --- | --- |
| **Elevation Angle**  **= 30 Degrees** | **Set 2** | **Set 3** | **Set 4** |
| Uplink SNR (dB) @600 km | -6.2 | -14 | **-19.9** |

|  |  |  |  |
| --- | --- | --- | --- |
| **Elevation Angle**  **= 30 Degrees** | **Set 2** | **Set 3** | **Set 4** |
| Downlink SNR (dB) @600 km | -4.3 | -4.3 | **-10.9** |

* Sony proposed to prioritize link budget study for PC3 devices (23dBm) with 7dB noise figure. An AWGN channel model is assumed for IoT-NTN link level simulations.
* Sateliot showed lowest SNR DL -13.98 dB and SNR UL -6.16 dB and best SNR DL 1.09 dB and SNR UL 6.19 dB for Set 4.

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | **Configuration A**  (Based on common assumptions in TR 36.763 v0.1.0 section 6.2.1) | **Configuration B**  (common assumptions + some enhancements) |
| **Downlink SNR** | Elevation angle=90º | -5.91 dB | 1.09 dB |
| Elevation angle=30º | -13.98 dB | -6.98 dB |
| **Uplink SNR**  **(ST 3.75 kHz)** | Elevation angle=90º | 1.90 dB | 6.90 dB |
| Elevation angle=30º | -6.16 dB | -1.16 dB |

Calibration of link budget results:

Contributing companies:

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Huawei | OPPO | Vivo | CATT | | MediaTek | | Nokia | | CMCC | | ZTE | |
| Xiaomi | Ericsson | Qualcomm | | Apple | | Samsung | | SONY | | Sateliot | |

OPPO, CATT, Huawei, Vivo, Nokia, CMCC, ZTE, Xiaomi, Ericsson, Apple, Sateliot (Configuration A) used agreed link budget assumptions for PC5 (20 dBm) and NF=9 dB in TR 36.763 for their simulations. MediaTek, Qualcomm, Samsung, Sony used link budget assumptions for PC3 (23 dBm) and NF=7 dB in the simulations.

All contributing companies used agreed losses as shown in Table below

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

To align assumptions for unified results, in the moderator summary we adjust figures of all companies with common assumptions for Noise Figure and PC5. When needed SNR DL figure is adjusted by 2 dB and SNR UL figure by 3 dB. With PC3 (23 dBm) there is a 3dB gain compared to the PC5 (20 dBm) assumption on UL. With NF=7 dB, there is a 2 dB gain compare to NF=9 dB. We used central beam edge elevations agreed in TR 36.763 for Set 1, Set 2, Set 3, and Set 4 for the determination of the FSPL. With these adjustments, we found reasonable consistency between the results from contributing companies

Set 1

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Cases | EIRP Density | EIRP per spot | DL C/N | G/T | UL C/N  180 kHz / 90 kHz / 45 kHz / 15 kHz / 3.75 kHz |
| 1 | 59 dBW/MHz | 81.6 dBm | -3.0 dB | 19 dB/K | -13.9 dB / -10.9 dB / -7.9 dB / -3.1 dB / 2.9 dB |
| 2 | 59 dBW/MHz | 81.6 dBm | -3.0 dB | 19 dB/K | -13.9 dB / -10.9 dB / -7.9 dB / -3.1 dB / 2.9 dB |
| 3 | 40 dBW/MHz | 62.6 dBm | 4.2 dB | 1.1 dB/K | -5.6 dB / -2.6 dB / 0.4 dB / 5.2 dB / 11.2 dB |
| 4 | 40 dBW/MHz | 62.6 dBm | 4.2 dB | 1.1 dB/K | -5.6 dB / -2.6 dB / 0.4 dB / 5.2 dB / 11.2 dB |
| 5 | 34 dBW/MHz | 56.6 dBm | 3.6 dB | 1.1 dB/K | -0.2 dB / 2.8 dB / 5.8 dB / 10.5 dB / 16.6 dB |
| 6 | 34 dBW/MHz | 56.6 dBm | 3.6 dB | 1.1 dB/K | -0.2 dB / 2.8 dB / 5.8 dB / 10.5 dB / 16.6 dB |

Set 2

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Cases | EIRP Density | EIRP per spot | DL C/N | G/T | UL C/N  180 kHz / 90 kHz / 45 kHz / 15 kHz / 3.75 kHz |
| 7 | 53.5 dBW/MHz | 76.1 dBm | -8.5 dB | 14 dB/K | -18.9 dB / -15.9 dB / -12.9 dB / -8.1 dB / -2.1 dB |
| 8 | 53.5 dBW/MHz | 76.1 dBm | -8.5 dB | 14 dB/K | -18.9 dB / -15.9 dB / -12.9 dB / -8.1 dB / -2.1 dB |
| 9 | 34 dBW/MHz | 56.6 dBm | -1.8 dB | -4.9 dB/K | -11.6 dB / -8.6 dB / -5.6 dB / -0.8 dB / -5.2 dB |
| 10 | 34 dBW/MHz | 56.6 dBm | -1.8 dB | -4.9 dB/K | -11.6 dB / -8.6 dB / -5.6 dB / -0.8 dB / -5.2 dB |
| 11 | 28 dBW/MHz | 50.6 dBm | -2.4 dB | -4.9 dB/K | -6.2 dB / -3.2dB / -0.2 dB / 4.5 dB / 10.6 dB |
| 12 | 28 dBW/MHz | 50.6 dBm | -2.4 dB | -4.9 dB/K | -6.2 dB / -3.2dB / -0.2 dB / 4.5 dB / 10.6 dB |

Set 3

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Cases | EIRP Density | EIRP per spot | DL C/N | G/T | UL C/N  180 kHz / 90 kHz / 45 kHz / 15 kHz / 3.75 kHz |
| 13 | 59.8 dBW/MHz | 84.4 dBm | -2.2 dB | 16.7 dB/K | -16.2 dB / -13.2 dB / -10.2 dB / -5.4 dB / 0.6 dB |
| 14 | 59.8 dBW/MHz | 84.4 dBm | -2.2 dB | 16.7 dB/K | -16.2 dB / -13.2 dB / -10.2 dB / -5.4 dB / 0.6 dB |
| 15 | 33.7 dBW/MHz | 56.3 dBm | -2.1 dB | -12.8 dB/K | -19.5 dB / -16.5 dB / -13.5 dB / -8.7 dB / -2.7 dB |
| 16 | 33.7 dBW/MHz | 56.3 dBm | -2.1 dB | -12.8 dB/K | -19.5 dB / -16.5 dB / -13.5 dB / -8.7 dB / -2.7 dB |
| 17 | 28.3 dBW/MHz | 50.9 dBm | -2.1 dB | -12.8 dB/K | -14.1 dB / -11.1 dB / -8.1 dB / -3.4 dB / 2.7 dB |
| 18 | 28.3 dBW/MHz | 50.9 dBm | -2.1 dB | -12.8 dB/K | -14.1 dB / -11.1 dB / -8.1 dB / -3.4 dB / 2.7 dB |

Set 4

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Cases | EIRP Density | EIRP per spot | DL C/N | G/T | UL C/N  180 kHz / 90 kHz / 45 kHz / 15 kHz / 3.75 kHz |
| 19 | 21.4 dBW/MHz | 44 dBm | -12.0 dB | -20.9 dB/K | -19.2 dB / -16.2 dB / -13.2 dB / -8.5 dB / -2.4 dB |

Link budget – Distribution of CIR results:

OPPO showed cdf of CIR for Set 1, Set 2, set 3. The set 3 has lowest CIR, with 5% percentile at -5 dB.

**Table 4. CIR results for both DL and UL in Satellite set 3**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | | Ave. | 5% | 50% | 95% |
| DL | Scenario A  (GEO) | 2.0 | -2.1 | 1.9 | 6.1 |
| Scenario B&C-600km  (LEO-600) | -0.8 | -3.7 | -0.9 | 2.2 |
| Scenario B&C-1200km  (LEO-1200) | -1.0 | -3.9 | -1.0 | 1.7 |
| UL | Scenario A  (GEO) | 2.4 | -1.9 | 1.9 | 8.1 |
| Scenario B&C-600km  (LEO-600) | -2.7 | -4.8 | -2.8 | -0.5 |
| Scenario B&C-1200km  (LEO-1200) | -2.7 | -5.0 | -2.7 | -0.2 |

|  |  |
| --- | --- |
|  |  |
| 1. **GEO** | 1. **LEO-600** |
|  | |
| 1. **LEO-1200** | |

**Figure 3. CIR results for both DL and UL in Satellite set 3**

Link budget – Distribution of CL results:

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

Rural scenarios: The cdf of CL for DL for set 1, set 2, set 3, and set 4 in rural scenarios was provided in [ZTE, R1-2102916]. In rural scenarios, the Coupling Loss of about

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

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

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

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

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

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

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

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

Moderator conclusion for link budget results:

Moderator view is that there is reasonable consistency in link budget results and observations from contributing companies. The above summary of company contributions on link budget can be captured in a TP to TR 36.763.

***Initial proposal – Section 2.1***

* ***Capture in TR 36.763 the summary of link budget results from contributing companies in Section 2.1***

|  |  |
| --- | --- |
| Company | Comments |
| Ericsson | The underlying assumptions used by companies need to be checked first. Then it would be preferred to capture a unified set of link budget results, based on inputs from companies. |
| ESA | Generally speaking, there is a good match among the link budget results (e.g., thanks to the alignment effort in 38.821). However, there are mainly two sets of results with a difference of 3dB, due to “*additional losses*” considered by some companies.  We suggest to further clarify this point, and most likely in the next meeting all companies results will be aligned and agreeable to be captured in the TR. |
| vivo | Agree with the comments from Ericsson. |
| CATT | If no significant difference exists, we can agree the FL proposal. In general, aligning the result is not big issue, as long as evaluation conditions are clarified. If only additional 3dB loss is not aligned, these results can be fixed with less effort. |
| Samsung | It is suggested to further check the assumptions companies used to generate link budget results. Easy understanding of the performance from reading the TR should be prioritized when summarizing the results. |
| Apple | Agree with the comments from some companies on checking the assumptions used for link budget. |
| Eutelsat | Agree with the point made by ESA. Clarifying ‘additional losses’ and the scenarios/ use-cases where they have been applied would clarify wider understanding. |
| Sateliot | Agree with ESA and Eutelsat points. |
| Novamint | Agree with ESA |
| Huawei, HiSilicon | The parameters for the link budget calculation should be aligned first. It is difficult to categorize the results when different cases have been addressed by proponents. |
| ZTE | Fine to capture it and cross check is needed. |
| Nokia, NSB | For comparison of link budgets, same assumption should be considered. Suggest to have aligned assumption as the agreement in RAN1 104-e meeting and capture all related link budget results from companies in TR. |
| MODERATOR (Mediatek) | A moderator summary to align assumptions for unified results as commented by several companies was added in Section 2.1. |
| CMCC | Agree with the comments from ESA.  For the purpose of calibration, “*additional losses*” can be set to zero to align all inputs.  Nevertheless, the potential source and impact of additional losses can be separately discussed. E.g., in our view, compare with link budget results for calibration, additional path loss should be considered for evaluating the basic coverage performance of IoT NTN in real deployment conditions.   * Carriage and container penetration loss (9~20 dB) for logistics application. * Vegetation loss (e.g., 9 dB) for outdoor application. * Additional FSPL (0~10 dB) for lower elevation angle. |
| SONY | It seems like the set of link budget results in the tables (cases 1->19) are only for NB-IoT. We need to add tables for eMTC, based on company inputs.  It is unclear how “additional losses” are considered in the tables. Our understanding is that additional losses are losses that are additional to {scintillation loss, atmospheric loss, polarization loss, shadow margin}. We applied an additional loss of 3dB that accounted for 3dB beam width of the satellite for downlink or uplink.  We would also prefer that the link budgets are calculated assuming PC3 (23dBm) and NF = 7dB. While we agreed on the use of PC5 (20dBm) and NF = 9dB in RAN1#104e, at the subsequent RANP#91, there was significant agreement on considering essential functionality only in Rel-17. We should hence use realistic parameters (PC3, 7dB NF) that do not lead us to the conclusion that coverage enhancement is necessary. We can consider PC5, 9dB NF in Rel-18 enhancements. |
| MediaTek | Alignment of company link budget results with comparable assumption will be helpful. Summary needs to be included in a way that helps easy understanding of the performance from reading the TR |

### SECOND ROUND: Link budget results summary

In the first round, Ericsson, ESA, Vivo, Apple, Eutelsat, Sateliot, Novamint, Huawei, Nokia, CMCC commented link budget results need alignment. ESA commented there are mainly two sets of results with a difference of 3dB, due to “additional losses” considered by some companies. CATT commented aligning the result is not big issue, as long as evaluation conditions are clarified. If only additional 3dB loss is not aligned, these results can be fixed with less effort. ZTE commented results can be captured and cross-checked.

Moderator view is that the 3 dB difference between the two sets of results is due to different assumption of PC3 (23 dBm) and PC5 (20 dBm) for UL; there is also a difference of 2 dB due to a different assumption of Noise Figure (7 dB and 9 dB). To align assumptions for unified results, in the moderator summary we included link budget results with PC3 (23 dBm) and NF=7 dB, and also included link budget results for PC5 (20 dBm) and NF=9 dB. With PC3 (23 dBm) there is a 3dB gain compared to the PC5 (20 dBm) assumption on UL. With NF=7 dB, there is a 2 dB gain compare to NF=9 dB. We used central beam edge elevations agreed in TR 36.763 for Set 1, Set 2, Set 3, and Set 4 for the determination of the FSPL. With these adjustments, we found reasonable consistency between the results from contributing companies

There is consensus to capture summary of link budget results with alignment between contributing companies. The moderator view is that this can be done when drafting the TP to TR 36.763. The summary in Appendix 1, Section 6.1 can be further checked and revised during the drafting of Text Proposal as necessary.

The first round proposal is unchanged for second round.

***First round proposal – Section 2.1.1***

***Capture in TR 36.763 the summary of link budget results from contributing companies in Appendix 1, Section 6.1***

***NOTE 1: The summary in Appendix 1, Section 6.1 can be further checked and revised during the drafting of Text Proposal as necessary.***

***NOTE 2: The summary of link budget results will be captured with alignment between contributing companies***

## Cases for link budget analysis

ZTE propose to capture cases for link budget analysis

***Initial proposal – Section 2.2***

* ***Capture in TR 36.763 the Table for cases for link budget analysis***

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| ***Case*** | ***Satellite orbit*** | ***Satellite parameter set*** | ***Central beam center elevation (deg)*** | ***Central beam edge elevation (deg)*** | ***Frequency Reuse Factor*** |
| **1** | ***GEO*** | ***Set 1*** | ***12.5*** | ***10*** | ***1*** |
| **2** | ***GEO*** | ***Set 1*** | ***12.5*** | ***10*** | ***3*** |
| **3** | ***LEO-1200*** | ***Set 1*** | ***30*** | ***26.27*** | ***1*** |
| **4** | ***LEO-1200*** | ***Set 1*** | ***30*** | ***26.27*** | ***3*** |
| **5** | ***LEO-600*** | ***Set 1*** | ***30*** | ***26.98*** | ***1*** |
| **6** | ***LEO-600*** | ***Set 1*** | ***30*** | ***26.98*** | ***3*** |
| **7** | ***GEO*** | ***Set 2*** | ***20*** | ***10.95*** | ***1*** |
| **8** | ***GEO*** | ***Set 2*** | ***20*** | ***10.95*** | ***3*** |
| **9** | ***LEO-1200*** | ***Set 2*** | ***30*** | ***22.16*** | ***1*** |
| **10** | ***LEO-1200*** | ***Set 2*** | ***30*** | ***22.16*** | ***3*** |
| **11** | ***LEO-600*** | ***Set 2*** | ***30*** | ***23.80*** | ***1*** |
| **12** | ***LEO-600*** | ***Set 2*** | ***30*** | ***23.80*** | ***3*** |
| **13** | ***GEO*** | ***Set 3*** | ***20.88*** | ***12.5*** | ***1*** |
| **14** | ***GEO*** | ***Set 3*** | ***20.88*** | ***12.5*** | ***3*** |
| **15** | ***LEO-1200*** | ***Set 3*** | ***46.05*** | ***30*** | ***1*** |
| **16** | ***LEO-1200*** | ***Set 3*** | ***46.05*** | ***30*** | ***3*** |
| **17** | ***LEO-600*** | ***Set 3*** | ***43.78*** | ***30*** | ***1*** |
| **18** | ***LEO-600*** | ***Set 3*** | ***43.78*** | ***30*** | ***3*** |
| **19** | ***LEO-600*** | ***Set 4*** | ***90*** | ***30*** | ***1*** |

|  |  |
| --- | --- |
| Company | Comments |
| Ericsson | We’re open to this. |
| vivo | Open to discuss. And the scenarios with frequency reuse factor and polarization reuse for IoT NTN need further discussion and clarification. |
| CATT | Not sure what is purpose to use different frequency reuse factor. If calculating the SINR distribution, different frequency reuse factor should be considered, but herein it refers to link budget result. |
| Samsung | OK |
| Apple | Open to discuss. We do not see why the frequency reuse factor is introduced here. |
| Eutelsat | OK. However, agree with CATT. It would be preferable to clarify if CNR or CNIR was the intended calculation. |
| Sateliot | Agree with the proposal. |
| Novamint | Agree |
| Huawei, HiSilicon | Agree, but do we need to address frequency reuse factor? This would reduce the number of cases and it is easier to link them to respective simulation results in the TR. |
| ZTE | Agree |
| Nokia, NSB | As we already have agreement on assumptions for link budget, the link budget with same assumption should be captured in TR. For results with other assumption(s), if only reason for necessity is provided and accepted, it should be evaluated and compared in next meeting.  We do not think FRF = 3 is needed for link budget calculation. |
| MODERATOR (MediaTek) | A moderator summary to align assumptions for unified results as commented by several companies was added in Section 2.1. Including FRF=1 and FRF=3 |
| CMCC | Same view with Apple. |
| SONY | We don’t see the need for considering the different frequency reuse factors. We should clarify whether we are considering a CNR-based link budget or a CINR-based link budget. |
| MediaTek | We’re open to proposal |

### SECOND ROUND: Cases for link budget analysis

In first round, Apple, Nokia, CMCC commented more discussions needed on FRF = 3 for link budget calculation. Moderator view is that FRF=3 link budget results provided by ZTE are useful study and worthy of inclusion in the TR 36.763.

The first round conclusion is unchanged for second round.

Conclusion:

The link budget summary with FRF=3 are included in Appendix 1, Section 6.1. A table for the cases for link budget analysis with FRF = 1 is included in Appendix 1, Section 6.1.

## Detailed link budget results

The detailed link budget results from contributing companies are included in Appendix 1

***Initial proposal – Section 2.3***

* ***Capture the detailed link budget results from contributing companies in Appendix 1 in TR 36.763***

|  |  |
| --- | --- |
| Company | Comments |
| Ericsson | A separate excel sheet would be better, to avoid resulting in an unnecessarily long/large TR. |
| vivo | Agree with Ericsson to add a separate excel, and the accompanied excel file in our contribution can be as the starting file. |
| CATT | Agree with Ericsson view. |
| Samsung | Agree with previous comments. |
| Apple | Agree with the comments above. |
| Eutelsat | - |
| Novamint | Agree with Ericsson’s comment |
| Huawei, HiSilicon | Agree with the proposal but we share Ericsson’s concern increasing the document size. |
| ZTE | Agree with capture all results in excel or separate contribution as NR and also with aligned assumption |
| Nokia, NSB | Agree. We also agree to Ericsson to have separate excel sheet. |
| Xiaomi | Agree. |
| CMCC | Agree with Ericsson’s comment. |
| SONY | Separate Excel sheet seems like a good idea. Would all companies use the same assumptions in the Excel file? |
| MediaTek | Agree to have separate table |

### SECOND ROUND – Detailed link budget results

In first round, based on comments from companies there was consensus to capture all results in a separate spreadsheet to avoid unnecessarily long/large TR.

The first round proposal is unchanged for second round.

***First round proposal – Section 2.3.1***

* ***Capture the detailed link budget results from contributing companies in a separate spreadsheet***

# IoT NTN Scenarios

## Scenario C – LEO Set 4

Sateliot proposed to revise the “Max beam footprint size (edge to edge) regardless of the elevation angle” parameter for LEO scenarios indicated in 3GPP TR 36.763 V0.1.0 Table 6.1-1: “IoT NTN reference scenario parameters” to 1700 km (currently the parameter is set to 1000 km for LEO scenarios).

Moderator view is to revise the “Max beam footprint size (edge to edge) for LEO scenarios indicated in 3GPP TR 36.763 V0.1.0 Table 6.1-1: “IoT NTN reference scenario parameters” to 1700 km (currently the parameter is set to 1000 km for LEO scenarios). This is to align with Table 6.2-7: Set-4 satellite parameters for system level simulator calibration in TR 37.763 V0.1.0 which indicates Satellite beam diameter 1700 km.

***Initial proposal – Section 3.1***

* ***Revise the “Max beam footprint size (edge to edge) for LEO scenarios indicated in 3GPP TR 36.763 V0.1.0 Table 6.1-1: “IoT NTN reference scenario parameters” to 1700 km***

|  |  |
| --- | --- |
| Company | Comments |
| Ericsson | Note that this revision would trigger a series of other revisions as well, such as max differential delay, max differential Doppler, etc.  It’s better to keep the current values intact; instead, add another table to capture parameters associated with Set 4, if the group has consensus to have this value of 1700 km. |
| ESA | Our understanding, it is that this proposal is associated with Set-4 only (e.g., specific antenna parameters in this very small satellite platform). As suggested by Ericsson, this could be captured accordingly. |
| vivo | According the agreements in last e-meeting, the satellite beam diameter for Set-4 has been agree to equal 1700 km. Thus, these relevant parameters for LEO scenarios in TR 36.763 V0.1.0 Table 6.1-1 should be updated. |
| CATT | Support this proposal. |
| Samsung | Agree to revise. |
| Apple | Support this proposal. |
| GateHouse | We agree that the beam footprint size should be revised to 1700 km for table 6.1-1. |
| Eutelsat | Support the proposal. |
| Sateliot | Support the proposal. As pointed out by the Moderator, the revision is mainly requested to have consistency for this parameter between Table 6.1-1 and Table 6.2-7 in 3GPP TR 36.763 V0.1.0.  We think that the proposed modification in Table 6.1-1 does not have any impact on the rest of parameters included in Table 6.1-1. More in detail:   |  |  |  |  | | --- | --- | --- | --- | | **3GPP TR 36.763 V0.1.0 Table 6.1-1 parameters that could be impacted by the beam size revision:** | **Current values in TR 36.763 V0.1.0 for LEO 600 km** | **Computed values under the consideration of beam pointed at Nadir with a beam footprint size of 1700 km:** | **Comment** | | Max distance between satellite and C-IoT device at min elevation angle | 1,932 km | 1075.8 km  (Computed for a terminal located at the beam edge, corresponding to an elevation angle of 30 degrees) | Computed value is lower that current value. No revision needed. | | Max Round Trip Delay (propagation delay only) | 25.77 ms (service and feeder links) | 20.05 ms  (Computed for a terminal located at the beam edge, corresponding to an elevation angle of 30 degrees. Service link kept at 10º) | Computed value is lower that current value. No revision needed. | | Max differential delay within a cell | 3.12 ms | 1.58 ms  (Computed as the maximum differential delay between a device at beam edge and one at beam center) | Computed value is lower that current value. No revision needed. | | Max Doppler shift variation (earth fixed user equipment) (NOTE 6)” | 24 ppm | 19,95 ppm  (Computed for a terminal at beam edge, corresponding to an elevation angle of 30 degrees) | Computed value is lower that current value. No revision needed. | | Max Doppler shift variation (earth fixed user equipment) (NOTE 6) | 0.27 ppm/s | Maximum at Nadir. Does not depend on beam size. | No revision needed. |   In any case, no objections if it could be preferred to capture parameters associated with Set 4 in another table specific to Set 4. |
| Novamint | Agree with the revision as proposed |
| Huawei, HiSilicon | Fine with revision as long as it does leads to a lot other revisions in the table. |
| ZTE | Fine to revise it |
| Nokia, NSB | We agree with Ericsson that a separate assumption table should be discussed and agreed before evaluation, as parameter will be impacted, e.g. max differential delay. |
| Xiaomi | Fine to have the revision. |
| SONY | Agree with Ericsson. It is better to have a separate table for scenarios based on the Set-4 parameters. |
| MediaTek | Fine with revision |

### SECOND ROUND: Scenario C – LEO Set 4

In first round, companies commented that it will be fine to have revision for Set 4 for maximum beam diameter of 1700 km, with preference by several companies to have revision in a separate table capture parameters associated with Set 4. The moderator view is to capture revision in a separate table

A NOTE was added to the first round proposal for second round.

***Second round proposal – Section 3.1.1***

***Capture parameters associated with Set 4 for maximum beam diameter of 1700 km in a separate table in TR 36.763:***

***NOTE: There is no impact on Table 6.1-1: IoT NTN reference scenario parameters in TR 36.763***

|  |  |  |  |
| --- | --- | --- | --- |
| ***3GPP TR 36.763 V0.1.0 Table 6.1-1 parameters that could be impacted by the beam size revision:*** | ***Current values in TR 36.763 V0.1.0 for LEO 600 km*** | ***Computed values under the consideration of beam pointed at Nadir with a beam footprint size of 1700 km:*** | ***Comment*** |
| ***Max distance between satellite and C-IoT device at min elevation angle*** | ***1,932 km*** | ***1075.8 km***  ***(Computed for a terminal located at the beam edge, corresponding to an elevation angle of 30 degrees)*** | ***Computed value is lower that current value in Table 6.1-1 in TR 36.763. No revision needed.*** |
| ***Max Round Trip Delay (propagation delay only)*** | ***25.77 ms (service and feeder links)*** | ***20.05 ms***  ***(Computed for a terminal located at the beam edge, corresponding to an elevation angle of 30 degrees. Service link kept at 10º)*** | ***Computed value is lower that current value in Table 6.1-1 in TR 36.763. No revision needed.*** |
| ***Max differential delay within a cell*** | ***3.12 ms*** | ***1.58 ms***  ***(Computed as the maximum differential delay between a device at beam edge and one at beam center)*** | ***Computed value is lower that current value in Table 6.1-1 in TR 36.763. No revision needed.*** |
| ***Max Doppler shift variation (earth fixed user equipment) (NOTE 6)”*** | ***24 ppm*** | ***19,95 ppm***  ***(Computed for a terminal at beam edge, corresponding to an elevation angle of 30 degrees)*** | ***Computed value is lower that current value in Table 6.1-1 in TR 36.763. No revision needed.*** |
| ***Max Doppler shift variation (earth fixed user equipment) (NOTE 6)*** | ***0.27 ppm/s*** | ***Maximum at Nadir. Does not depend on beam size.*** | ***No revision needed.*** |

## Scenario D – MEO

Echostar / HUGUES made the following proposals and observation for a new scenario D for MEO

***Proposal 1****: To add MEO scenario D in Table 4.2-1 in TR 36.763.*

|  |  |
| --- | --- |
| NTN Configurations | Transparent satellite |
| GEO based non-terrestrial access network | Scenario A |
| LEO based non-terrestrial access network generating steerable beams (altitude 1200 km and 600km) | Scenario B |
| LEO based non-terrestrial access network generating fixed beams whose footprints move with the satellite (altitude 1200 km and 600km) | Scenario C |
| MEO based non-terrestrial access network generating fixed beams whose footprints move with the satellite (altitude 10000 km) | Scenario D |

*Table 4.2-1: IoT NTN reference scenarios*

***Proposal 2****: To add MEO IoT NTN reference scenario parameters in Table 6.1-1 in TR 36.763.*

|  |  |  |  |
| --- | --- | --- | --- |
| Scenarios | **GEO based non-terrestrial access network - scenario A** | **LEO based non-terrestrial access network -Scenario B & C** | **MEO based non-terrestrial access network -Scenario D** |
| 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 | circular orbiting at low altitude around the earth |
| Altitude | 35,786 km | 600 km  1,200 km | 10,000 km |
| Frequency Range | < 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 (UL)  - 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 | Transparent type |
| Earth-fixed beams | Yes | Scenario B:  Yes (steerable beams), see NOTE 1  Scenario C: No (the beams move with the satellite) | Scenario D: The beams move with the satellite |
| Max beam footprint size (edge to edge) regardless of the elevation angle | 3500 km (NOTE 3) | 1000 km (NOTE 2) | 4018 km |
| 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 | 10° for service link and 5° 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) | 14018 km |
| 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) | 95.19 ms (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 | 13.4 ms |
| Max Doppler shift (earth fixed user equipment) (NOTE 6) | 0.93 ppm | 24 ppm (600km)   21ppm(1200km) | 7.5 ppm |
| 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) | 0.003 ppm/s |
| 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 | 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 footprint 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 | | | |

***Table 6.1-1: IoT NTN reference scenario parameters***

***Proposal 3****: To include MEO Set-5 parameters for link budget analysis in a new Table 6.2-8 in TR 36.763, as a representative characterization of NTN-IoT scenarios with MEO altitude and characteristics.*

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

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

***Proposal 4****: To add MEO Set-5 satellite parameters for system level simulator calibration in a new Table 6.2-9 in TR 36.763.*

|  |  |
| --- | --- |
| Set 5 | MEO |
| 3 dB Beam width (HPBW) | 6.5 degrees |
| Central beam center elevation | 90 degrees |
| Central beam edge elevation | 86.1 degrees |
| Central beam edge satellite-UE distance | 10042 km |

**Table 6.2-9: Set-5 parameters for link budget analysis**

***Observation****: The doppler shift/variation and the delay variation for MEO are smaller than for LEO. The maximum delay for MEO is smaller than for GEO. The IoT-NTN enhancements for LEO and GEO should be sufficient to support MEO.*

Link budget using “Set 5” NTN-IoT scenarios with MEO altitude and characteristics.



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

* ***Include the following in TR 36.763***
* ***Add MEO scenario D in Table 4.2-1 in TR 36.763.***
* ***Add MEO IoT NTN reference scenario parameters in Table 6.1-1 in TR 36.763.***
* ***Include MEO Set-5 parameters for link budget analysis in a new Table 6.2-8 in TR 36.763, as a representative characterization of NTN-IoT scenarios with MEO altitude and characteristics.***
* ***Add MEO Set-5 satellite parameters for system level simulator calibration in a new Table 6.2-9 in TR 36.763.***
* ***Add observation in TR 36.763: The doppler shift/variation and the delay variation for MEO are smaller than for LEO. The maximum delay for MEO is smaller than for GEO. The IoT-NTN enhancements for LEO and GEO should be sufficient to support MEO.***

|  |  |
| --- | --- |
| Company | Comments |
| Ericsson | It would be appreciated if proponents can clarify what would be the benefits of including MEO scenarios in TR 36.763, given this was not done in Rel-16 for TR 38.821. |
| ESA | This is a study-item phase, therefore it is helpful to capture different satellite configurations and specific parameters.  Of course, we agree that the intention is not to enlarge the number of use-cases for the normative case. |
| vivo | Need more clarification about the benefit of introducing MEO scenarios in IoT NTN. And in this stage, more discussion on adding the MEO scenarios may slow down the progress of IoT NTN SI. |
| CATT | In this stage, we don’t it is very essential part since it is a middle scenario between GEO and LEO. Spending much effort for this issue will delay the progress of SI. |
| Samsung | We support adding the MEO scenario in the TR. How to capture the results can be further discussed – if MEO results are from a single company, they could be captured separately from the other results. |
| Hughes/EchoStar | Including MEO scenario in the TR is important (the enhancements for LEO and GEO should mostly accommodate MEO). MEO is essential to satellite industry operators and especially for EchoStar/Hughes (major satellite operator/satellite gateway vendor). It will provide maximum flexibility and allow operators to deploy hybrid solutions that can deliver global IoT coverage and higher capacity.  Relevant parameters on MEO available in TR38.811. MEO was not directly studied in TR 38.821 but stated at the end of Table 4.2-2: Reference scenario parameters, there is a summary “The NTN study results apply to GEO scenarios as well as all NGSO scenarios with circular orbit at altitude greater than or equal to 600 km.” |
| Eutelsat | Agree with ESA (noting that this refers to capturing proposed configurations during the SI / TR document). |
| Sateliot | Agree with proposal and the views expressed by ESA and Samsung above. |
| Novamint | Agree with ESA |
| Huawei, HiSilicon | In our understanding, although MEO have smaller Doppler shift/variation and delay variation than LEO, the same conclusion and enhancement for LEO can be applied for MEO. So the benefit of adding MEO is not clear to us since it falls between LEO and GEO. |
| ZTE | More discussion and clarification is needed. W.r.t the parameters and results, please check followings:   |  |  | | --- | --- | | Set 5 | MEO | | 3 dB Beam width (HPBW) | 6.5 degrees | | Central beam center elevation | 90 degrees | | Central beam edge elevation | 86.1 degrees | | Central beam edge satellite-UE distance | ~~10042~~ km --> 10009 km |   The value of “sum of all losses” should be modified to 186.71 for the case elevation of 86.1 deg is used, parameters are listed below   |  |  |  | | --- | --- | --- | | FreeSpace Loss PLFS | dB | 178.48 | | Atmosphere Loss(clear sky) PLA | dB | 0.04 | | Scintilation Loss | dB | 2.20 | | UE Polarization Loss | dB | 3 | | Shadowing Margin PLS | dB | 3.00 | | Additional Loss PLAD | dB | 0.00 | | **Total Loss** | **dB** | **186.71** | |
| Nokia, NSB | Before any decision to add MEO, it should be evaluated and have consensus on what is the benefit and the impact of MEO, probability of utilization and impact on standard, e.g. new issue and solution requested. |
| Xiaomi | More clarification on the benefits and potential standard impact is needed. |
| CMCC | More clarification on the benefits and potential standard impact is needed. |
| SONY | In line with the views expressed in RANP#91, we would like to minimise the number of use cases and scenarios, rather than increase them. It is also not clear to use what new observations / insights can be made by studying a scenario that lies between LEO and GEO.  While this work is contribution driven, companies will need to understand and check the MEO results, so there is a burden on all companies.  We think that some of the entries in the tables need checking:   * Table 6.1-1   + Why is MEO in a “low” orbit, rather than a “medium” orbit?   + Why is the feeder link minimum elevation angle lower for MEO than for GEO / LEO? * Table 6.2-8   + Note 2: why should we use different antenna models and which different antenna models should be used? * Table 6.2.9   + Why does MEO assume high elevation angles (90 degrees) whereas other scenarios (GEO, LEO) consider low elevation angles (20.9 degrees, 45-ish degrees) * Link budget   + Agree with ZTE that the link budget needs modification. We assume that the “additional loss” is 3dB to account for the 3dB beamwidth   + If the DL system bandwidth is 180kHz, then why is there a C/N DL quoted for a bandwidth of 1080kHz?   The link budget numbers need calculating for both NB-IoT and eMTC |

### SECOND ROUND – Scenario D – MEO

In first round, it was discussed that this proposal needs further discussion. ESA commented this is a study-item phase, therefore it is helpful to capture different satellite configurations and specific parameters. The intention is not to enlarge the number of use-cases for the normative case. This view is shared by Eutelsat, Sateliot, Novamint, Samsung,

A NOTE was added to the first round proposal for second round. The proposal was further updated based on email discussions on the reflector

***First round proposal - Section 3.2.1***

* ***Include the following in TR 36.763***
* ***Add MEO scenario D in Table 4.2-1 in TR 36.763.***
* ***Add MEO IoT NTN reference scenario parameters in Table 6.1-1 in TR 36.763.***
* ***Include MEO Set-5 parameters for link budget analysis in a new Table 6.2-8 in TR 36.763, as a representative characterization of NTN-IoT scenarios with MEO altitude and characteristics.***
* ***Add MEO Set-5 satellite parameters for system level simulator calibration in a new Table 6.2-9 in TR 36.763.***
* ***Add observation in TR 36.763: The doppler shift/variation and the delay variation for MEO are smaller than for LEO. The maximum delay for MEO is smaller than for GEO. The IoT-NTN enhancements for LEO and GEO should be sufficient to support MEO.***
* ***NOTE: The parameter for MEO is only for information and evaluation/enhancements are mainly considered for GEO and LEO. These may be applicable for MEO.***

The proposal was further updated based on email discussions on the reflector

***Second round proposal - Section 3.2.1***

***Include the following in TR36.763***

* ***Add MEO scenario D in Table 4.2-1 in TR 36.763.***

*Table 4.2-1: IoT NTN reference scenarios (TR 36.763)*

|  |  |
| --- | --- |
| NTN Configurations | Transparent satellite |
| GEO based non-terrestrial access network | Scenario A |
| LEO based non-terrestrial access network generating steerable beams (altitude 1200 km and 600km) | Scenario B |
| LEO based non-terrestrial access network generating fixed beams whose footprints move with the satellite (altitude 1200 km and 600km) | Scenario C |
| MEO based non-terrestrial access network generating fixed beams whose footprints move with the satellite (altitude 10000 km) | Scenario D |

* ***Add MEO IoT NTN reference scenario parameters in Table 6.1-1 in TR 36.763:***

***Table 6.1-1: IoT NTN reference scenario parameters (TR 36.763)***

|  |  |  |  |
| --- | --- | --- | --- |
| Scenarios | **GEO based non-terrestrial access network - scenario A** | **LEO based non-terrestrial access network -Scenario B & C** | **MEO based non-terrestrial access network -Scenario D** |
| 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 | circular orbiting at medium altitude around the earth |
| Altitude | 35,786 km | 600 km  1,200 km | 10,000 km |
| Frequency Range | < 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 (UL)  -                  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 | Transparent type |
| Earth-fixed beams | Yes | Scenario B:  Yes (steerable beams), see NOTE 1  Scenario C: No (the beams move with the satellite) | Scenario D: The beams move with the satellite |
| Max beam footprint size (edge to edge) regardless of the elevation angle | 3500 km (NOTE 3) | 1000 km (NOTE 2) | 4018 km |
| 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 | 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) | 14018 km |
| 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) | 95.19 ms  (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 | 13.4 ms |
| Max Doppler shift (earth fixed user equipment) (NOTE 6) | 0.93 ppm | 24 ppm (600km)   21ppm(1200km) | 7.5 ppm |
| 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) | 0.003 ppm/s |
| 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 | 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 footprint 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 | | | |

* ***Include MEO Set-5 parameters for link budget analysis  in a new Table 6.2-8 in TR 36.763, as a representative characterization of NTN-IoT scenarios with MEO altitude and characteristics:***

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

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

* ***Add MEO Set-5 satellite parameters for system level simulator calibration   in a new Table 6.2-9 in TR 36.763:***

***Table 6.2-9: Set-5 parameters for link budget analysis***

|  |  |
| --- | --- |
| *Set 5* | *MEO* |
| *3 dB Beam width (HPBW)* | *6.5 degrees* |
| *Central beam center elevation* | *[90 degrees]* |
| *Central beam edge elevation* | *[86.1 degrees]* |
| *Central beam edge satellite-UE distance* | *[10042 km]* |

* ***Add observation in TR 36.763: The doppler shift/variation and the delay variation for MEO are smaller than for LEO. The maximum delay for MEO is smaller than for GEO. The IoT-NTN enhancements for LEO and GEO should be sufficient to support MEO.***
* ***NOTE: The parameter for MEO is only for information and evaluation/enhancements are mainly considered for GEO and LEO. These may be applicable for MEO.***

|  |  |
| --- | --- |
| Company | Comments |
| Hughes/EchoStar | Thanks to Sony and ZTE for catching some errors. Total loss is 186.9 dB. For Table 6.1.1, it should be “medium” orbit and minimum elevation is 10 degrees.  For clarification on benefits, requested above:  MEO is part of the NGSO constellation/family. There is tremendous opportunity in deploying global MEO constellations which can complement GEO/LEO satellites and terrestrial networks. This will enable the operator to deploy a hybrid network infrastructure with ubiquitous coverage, high capacity and low latency. This will also promote the most efficient utilization of the 3GPP standards. We should not delay broadening standards when this can help accelerate the growth of NTN-IoT and surpass the non-3GPP standard technology. With hybrid solutions, the communication path can be switched between MEO, GEO, and LEO to match application needs, provide resilience on a global basis.  *MEO satellites are considered to be a happy medium between the LEO and GEO types of satellite. MEO satellites orbit the earth at higher altitudes and therefore provide a greater coverage area to the extent that a company with 24 MEO satellites in position will have four covering any given spot on the earth at any time during the day.*  <https://www.capacitymedia.com/articles/2762462/medium-earth-orbit-satellites>  *A major change in the satellite business is the advent of NGSO satellites, or non-geostationary satellites, which span a wide range of sizes and orbital positions, including MEOs, GEOs and SmallSats. We have been in the geostationary (GEO) world for more than 50 years. But that world is changing. In the coming years, we will start to see hybrid networks where we have GEOs—like we are used to—complemented by Low Earth Orbit (LEO) and Medium Earth Orbit (MEO) satellites. With such a hybrid architecture, LEOs deliver ubiquitous coverage and low latency, while GEOs bring high capacity at the lowest possible cost wherever its needed—especially in exurban and rural areas with limited or no terrestrial access. We’ll then see the application decide whether the bits transmitted will go over GEO, LEO, MEO—or even over terrestrial technologies.*  <https://www.hughes.com/resources/blog/satellite-essential/what-future-satellite>  Agree with the above proposal from moderator with minor change to  ***NOTE: The parameter for MEO is only for information/reference and evaluation/enhancements are mainly considered for GEO and LEO. These ~~may~~ can be applicable for MEO.*** |
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## Deployment Modes

Qualcomm discussed that currently, terrestrial NB-IoT supports four deployment modes—standalone, guard-band (assumed an LTE guard band), in-band (with LTE) with same PCI (as underlying LTE cell), and in-band with different PCI.

For NB-IoT over NTN, it is proposed to not support an “in-band with LTE” mode. Instead, NB-IoT over NTN should be supported in an “in band/guard band NR” mode, since NR is the technology being defined for broadband NTN access, with distinct advantages over LTE—importantly, the absence of “always on” reference signals and control regions in a slot/subframe. Note that, due to the above fact, an in-band with NR deployment is essentially equivalent to a NR guard-band deployment.

Qualcomm proposed for NB-IoT over NTN, support only the following deployment modes

- Standalone

- In-band with / guard band of NR

Since eMTC is inherently based on an LTE carrier, interactions between eMTC and NR over NTN are proposed to be handled by Dynamic Spectrum Sharing (DSS) techniques.

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

***NB-IoT over NTN, support only the following deployment modes***

***- Standalone***

***- In-band with / guard band of NR***

|  |  |
| --- | --- |
| Company | Comments |
| Ericsson | We suggest adding a companion proposal for eMTC over NTN:  Proposal:  For eMTC over NTN, support at least the following deployment modes  Standalone  Dynamic spectrum sharing with NR |
| vivo | Agree with the Ericsson’s comment. |
| CATT | Support it. We also support Ericsson’s view. |
| Samsung | Agree. |
| Hughes/EchoStar | Agree |
| GateHouse | Agree with the assessment |
| Eutelsat | Agree with proposal. |
| Sateliot | Agree |
| Novamint | Agree with the proposal |
| Huawei, HiSilicon | Given that there is no need for NB-IoT NTN to share any common reference signals of NR, it is effectively stand-alone. It is not clear what “In-band with/guard band of NR” means here. |
| ZTE | Support |
| Nokia, NSB | Agree  For Ericsson’s view, we think R16 coexistence of eMTC and NR should be considered, but maybe not DSS. |
| CMCC | Standalone deployment mode is preferred.  Give that there are large doppler shift and propagation delay in NTN, effective frequency sharing between IoT over NTN and terrestrial NR seems challengeable. Thus, the motivation and benefit of In-band with / guard band of NR or Dynamic spectrum sharing with NR needs more clarification. |
| SONY | Agree with Ericsson that a companion proposal is needed for eMTC. Agree with Nokia that for eMTC, we should add R16 coexistence of eMTC with NR.  Wouldn’t it be simpler to just list out the supported modes for NB-IoT, rather than trying to incorporate multiple modes on one line? Couldn’t we just have:  ***NB-IoT over NTN, support only the following deployment modes***   * ***Standalone*** * ***In-band with NR*** * ***Guard band of NR***   Is the plan to capture which modes could be supported in the TR. What other impacts are there on the study? |
| MediaTek | We’re open to this proposal. |

### SECOND ROUND – Deployment nodes

In first round, the initial proposal on deployment mode had reasonable consensus from most companies. Nokia are not supportive of DSS. CMCC have preference for standalone.

***First round proposal - Section 3.3.1***

**NB-IoT over NTN, support only the following deployment modes**

* **Standalone**
* **“guard- band of NR-NTN”,**
  + **NOTE: a guard band deployment may have a different raster offset than a standalone deployment. The details are recommended to be worked out in the WI phase.**

**For eMTC over NTN, support at least the following deployment modes**

* **Standalone**
* **Dynamic spectrum sharing with NR-NTN**

During the second round email discussions, a number of issues were raised by Samsung.

* Samsung, Ericsson, MediaTek: Support” or “not support” is more a WI scope discussion. Discussing it in a SI phase is not needed.
* Ericsson, MediaTek: Coexistence is a complicated issue, usually requiring heavy RAN4 work (see the ongoing NR NTN RAN4 work). I feel RAN1 alone cannot decide on this. RAN and RAN4 involvement are needed.
* Ericsson, SONY commented the proposal is not needed. Without this proposal, any deployment option is possible. Then it’s WI scoping how to better support certain deployment option.
* CMCC, ZTE, THALES commented that with the large Doppler shift and propagation delay in NTN, it may be challenging for effective frequency sharing between IoT over NTN and terrestrial NR.
* CMCC, Huawei, ZTE: prefer to prioritize standalone. The support of in-band deployment mode may need further clarifications before taking any decision.
* Qualcomm commented that NB-IoT over NTN being deployed over LTE isn't a strong use case. SONY commented on why add FFS to the dynamic spectrum sharing with NR for eMTC and why exclude Rel-15 NR-LTE coexistence mechanisms (in 38.xxx specs) and Rel-16 LTE-NR coexistence mechanisms (in 36.xxx specs)
* MediaTek commented that EPC should be used for IoT NTN.
* Qualcomm agreed the more important use case is co-existence with an NR-NTN deployment. Qualcomm commented that it has already been concluded in RAN1 that NB-IoT can co-exist with NR. Release 16 TR 37.824 describes Coexistence between NB-IoT and NR (Sections 5.2.1.6 and 5.2.1.7 defines values of MDL to maintain orthogonality). Qualcomm proposed updated proposal

NB-IoT over NTN, support only the following deployment modes

* Standalone
* Co-existence with NR
  + NOTE 1: This can be achieved using the description of different cid:image005.png@01D73288.88E37CB0values, as described in TR 37.824
  + NOTE 2: This at least includes in-band coexistence with NR. FFS guard band
  + NOTE 3: This includes coexistence of NR-NTN and NB-IoT over NTN
* For eMTC over NTN, support the following deployment mode
  + Standalone
  + FFS: Dynamic Spectrum Sharing with NR
* Qualcomm further commented on whether all the current (terrestrial) NBIOT deployment modes (from RAN1 perspective, indicated in MIB) should be supported, and indicated that the first two bullets for inband can be excluded since there is no LTE NTN:
  + 1) inband-SamePCI
  + 2) inband-DifferentPCI
  + 3) guardband
  + 4) standalone
* Qualcomm commented the a deployment mode should ensure orthogonality between NBIOT and NR. RAN4 may decide later to do a coexistence study. From RAN1 perspective, the only difference between guardband and standalone is the raster offset. During the Rel-16 study on RAN1 coexistence between NBIOT and NR, it was mentioned that NBIOT can be deployed with “guardband” mode, but actually being in-band to NR. This allows to use one NR PRB for NBIOT and keep subcarrier orthogonality. Using “inband” is a waste of resources, since the channels will rate match around an LTE CRS that does not exist.

The moderator view is that the deployment modes can be further discussed to allow companies to align respective understanding. We encourage companies to discuss this issue offline, as it is likely that this would be discuss as part of the WI scoping exercise in RAN Plenary 92-e in June. It should also be taken into account that realistic goals for a normative phase of IoT NTN in Rel-17 should be the assumption for deployment modes.

***Second round Feature Lead recommendation - Section 3.3.1***

**Moderator encourage companies to contribute to discuss NB-IoT NTN and eMTC-NTN deployment modes in next RAN1 meeting.**

## Others

|  |  |
| --- | --- |
| Company | Comments |
| Ericsson | We provide initial results for the IoT NTN connection density evaluation, with the traffic assumption that the UE shall be able to deliver a 32 bytes packet in the uplink under 10s with an outage probably of less than 1%.  Connection density for IoT in TN and NTN.   |  |  |  |  | | --- | --- | --- | --- | | **Scenario** | **TN, Conf A** | **TN, Conf B** | **NTN** | | **Inter-site (or inter-spotbeam) distance (ISD)** | 500 m | 1732 m | 40 km | | **No. of devices supported per sq. km with 6 PRBs** | 5,680,683 | 393,600 | 467 |   It is observed that the achievable connection density for IoT in NTN is much smaller than that in TN mainly due to a larger inter-spotbeam distance in NTN.  We would like to make the following proposal:  ***Proposal:***  ***RAN1 to evaluate the connection density for IoT NTN.*** |
| vivo | Lower devices antenna gain should be considered for NB-IoT/eMTC over NTN, e.g. -5 dBi. |
| ZTE | We also prefer to capture the results for MCL distrubtion of IoT-NTN cases to show the whole picture of system performance. |
| Nokia, NSB | 1. Special deployment of IoT UE should be studied, e.g. additional loss because of carrier/container loss, vegetation loss, NLOS loss, etc, which are important deployment of IoT UE and impact on link budget/coverage, which will impact on the repetition number needed, GNSS accuracy/availability, power consumption etc. 2. While in RAN1, the requirement on connection density, data rate, latency to be supported should also be studied/evaluated. |
| SONY | Responses to other companies in this table:   * [vivo]. We should be considering essential functionality. We should consider 0dBi antennas. Support for lower antenna gains can be considered as R18 enhancements. * [Nokia]. We think we should consider clear sky scenarios in R17 and consider more challenging scenarios (including the extra losses discussed) as R18 enhancements.   [Nokia] we agree with the list of things that are important for IoT devices. We would add battery life and coverage to the list. However, if we are considering essential functionality in R17, we do not need to consider these extra requirements. We would like to see these IoT KPIs can be considered in R18 enhancements. |
| MediaTek | Open to this. It can be contribution driven. |
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### SECOND ROUND - Others

In first round, initial results for the IoT NTN connection density evaluation. Based on comments, the moderator made a Feature Lead recommendation and suggested companies may contribute further on the connection density in the next meeting

The first round FL recommendation is unchanged for second round.

***First round FL recommendation – Section 3.4:***

***Ericsson initial results are interesting and worthy capturing in the TR 36.763. Since these are initial results, moderator recommendation is that companies may contribute further on the connection density in the next meeting.***

# Conclusions

Input to GTW Session on Friday 16th April 2021

Link Budget Calibration:

***First round proposal – Section 2.1.1***

***Capture in TR 36.763 the summary of link budget results from contributing companies in Appendix 1, Section 6.1***

***NOTE 1: The summary in Appendix 1, Section 6.1 can be further checked and revised during the drafting of Text Proposal as necessary.***

***NOTE 2: The summary of link budget results will be captured with alignment between contributing companies***

***First round proposal – Section 2.3.1***

* ***Capture the detailed link budget results from contributing companies in a separate spreadsheet***

Scenario C – LEO Set 4:

***Second round proposal – Section 3.1.1***

***Capture parameters associated with Set 4 for maximum beam diameter of 1700 km in a separate table in TR 36.763:***

***NOTE: There is no impact on Table 6.1-1: IoT NTN reference scenario parameters in TR 36.763***

|  |  |  |  |
| --- | --- | --- | --- |
| ***3GPP TR 36.763 V0.1.0 Table 6.1-1 parameters that could be impacted by the beam size revision:*** | ***Current values in TR 36.763 V0.1.0 for LEO 600 km*** | ***Computed values under the consideration of beam pointed at Nadir with a beam footprint size of 1700 km:*** | ***Comment*** |
| ***Max distance between satellite and C-IoT device at min elevation angle*** | ***1,932 km*** | ***1075.8 km***  ***(Computed for a terminal located at the beam edge, corresponding to an elevation angle of 30 degrees)*** | ***Computed value is lower that current value in Table 6.1-1 in TR 36.763. No revision needed.*** |
| ***Max Round Trip Delay (propagation delay only)*** | ***25.77 ms (service and feeder links)*** | ***20.05 ms***  ***(Computed for a terminal located at the beam edge, corresponding to an elevation angle of 30 degrees. Service link kept at 10º)*** | ***Computed value is lower that current value in Table 6.1-1 in TR 36.763. No revision needed.*** |
| ***Max differential delay within a cell*** | ***3.12 ms*** | ***1.58 ms***  ***(Computed as the maximum differential delay between a device at beam edge and one at beam center)*** | ***Computed value is lower that current value in Table 6.1-1 in TR 36.763. No revision needed.*** |
| ***Max Doppler shift variation (earth fixed user equipment) (NOTE 6)”*** | ***24 ppm*** | ***19,95 ppm***  ***(Computed for a terminal at beam edge, corresponding to an elevation angle of 30 degrees)*** | ***Computed value is lower that current value in Table 6.1-1 in TR 36.763. No revision needed.*** |

Scenario D – MEO:

***Second round proposal - Section 3.2.1***

***Include the following in TR36.763***

* ***Add MEO scenario D in Table 4.2-1 in TR 36.763.***

*Table 4.2-1: IoT NTN reference scenarios (TR 36.763)*

|  |  |
| --- | --- |
| NTN Configurations | Transparent satellite |
| GEO based non-terrestrial access network | Scenario A |
| LEO based non-terrestrial access network generating steerable beams (altitude 1200 km and 600km) | Scenario B |
| LEO based non-terrestrial access network generating fixed beams whose footprints move with the satellite (altitude 1200 km and 600km) | Scenario C |
| MEO based non-terrestrial access network generating fixed beams whose footprints move with the satellite (altitude 10000 km) | Scenario D |

* ***Add MEO IoT NTN reference scenario parameters in Table 6.1-1 in TR 36.763:***

***Table 6.1-1: IoT NTN reference scenario parameters (TR 36.763)***

|  |  |  |  |
| --- | --- | --- | --- |
| Scenarios | **GEO based non-terrestrial access network - scenario A** | **LEO based non-terrestrial access network -Scenario B & C** | **MEO based non-terrestrial access network -Scenario D** |
| 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 | circular orbiting at medium altitude around the earth |
| Altitude | 35,786 km | 600 km  1,200 km | 10,000 km |
| Frequency Range | < 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 (UL)  -                  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 | Transparent type |
| Earth-fixed beams | Yes | Scenario B:  Yes (steerable beams), see NOTE 1  Scenario C: No (the beams move with the satellite) | Scenario D: The beams move with the satellite |
| Max beam footprint size (edge to edge) regardless of the elevation angle | 3500 km (NOTE 3) | 1000 km (NOTE 2) | 4018 km |
| 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 | 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) | 14018 km |
| 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) | 95.19 ms  (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 | 13.4 ms |
| Max Doppler shift (earth fixed user equipment) (NOTE 6) | 0.93 ppm | 24 ppm (600km)   21ppm(1200km) | 7.5 ppm |
| 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) | 0.003 ppm/s |
| 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 | 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 footprint 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 | | | |

* ***Include MEO Set-5 parameters for link budget analysis  in a new Table 6.2-8 in TR 36.763, as a representative characterization of NTN-IoT scenarios with MEO altitude and characteristics:***

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

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

* ***Add MEO Set-5 satellite parameters for system level simulator calibration   in a new Table 6.2-9 in TR 36.763:***

***Table 6.2-9: Set-5 parameters for link budget analysis***

|  |  |
| --- | --- |
| *Set 5* | *MEO* |
| *3 dB Beam width (HPBW)* | *6.5 degrees* |
| *Central beam center elevation* | *[90 degrees]* |
| *Central beam edge elevation* | *[86.1 degrees]* |
| *Central beam edge satellite-UE distance* | *[10042 km]* |

* ***Add observation in TR 36.763: The doppler shift/variation and the delay variation for MEO are smaller than for LEO. The maximum delay for MEO is smaller than for GEO. The IoT-NTN enhancements for LEO and GEO should be sufficient to support MEO.***
* ***NOTE: The parameter for MEO is only for information and evaluation/enhancements are mainly considered for GEO and LEO. These may be applicable for MEO.***

Deployment modes:

***First round FL recommendation - Section 3.3.1***

**Moderator encourage companies to contribute to discuss NB-IoT NTN and eMTC-NTN deployment modes in next RAN1 meeting.**

# References

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17. R1-2103266, Samsung, Initial link budget evaluation for NB-IoT/eMTC, RAN1#104bis-e, April 2021
18. R1-2103318, Sony, Scenarios for IoT- NTN, RAN1#104bis-e, April 2021
19. R1-2103716, Sateliot, Gatehouse, Thales, Link budget analysis for Set-4, RAN1#104bis-e, April 2021

# Appendix 1

## Moderator Summary

The following observations from individual company contributions were made:

* Huawei observed the worst CNR for the four sets of satellites are around -12 dB, -16 dB, -13dB and -17dB, respectively.
* Vivo observed device antenna with 0 dBi gain assumption is optimistic for link budget calculations, lower antenna gain can be considered for the worst case, e.g. -5dBi.
* CATT recommended smaller uplink transmission bandwidth for larger UL CNR when channel condition is poor. CNR in some cases reached below -20dB. Further consider whether we need to support the case with -20 dB CNR.
* MediaTek commented that NB-IoT can support the observed SNR UL and DL with moderate level of repetitions consistent with MCL=154 dB. MediaTek, Samsung results show lowest SNR observed are for Set 4 with -12 dB on DL and -2.4 dB or -8.5 dB (ST with SCS=3.75 kHz or 15 kHz) on UL.
* Nokia observed CNR is reduced as the channel bandwidth increases. CNR is reduced about 15.5 dB if the channel bandwidth increases from 30 kHz to 1080 kHz in uplink of eMTC. CNR of NB-IoT decreases about 16.8 dB when the channel bandwidth increases from 3.75 kHz to 180 kHz. Sets 1 and 2 results in positive maximum CNR (for NB-IoT), while set 3 and especially set 4 have challenging link budgets with low CNR.
* CMCC observed that: For GEO with Set 2 satellite parameter, the UL CNR will reach -18.8dB level for NB-IoT with 180kHz BW, and reach -26.5dB level for eMTC with 1080kHz BW. For LEO at 1200km with Set 3 satellite parameter, the UL CNR will reach -17.4dB level for NB-IoT with 180kHz BW, and reach -25.2dB level for eMTC with 1080kHz BW. For LEO at 600km with Set 4 satellite parameter, the UL CNR will reach -14.9dB level for NB-IoT with 180kHz BW, and reach -22.7dB level for eMTC with 1080kHz BW. Additional path loss can be observed in some deployment scenarios – i.e Carriage and container penetration loss (9~20 dB) for logistics application; Vegetation loss (e.g., 9 dB) for outdoor application.
* ZTE observed in all the cases, the coupling loss would be less than 164 dB, but in some cases of Set-3 LEO-1200 and Set-4 LEO-600, the coupling loss would be larger than 159 dB.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | GEO | LEO-600 | LEO-1200 |
| Set-1 | Coupling loss (dB) | 151.04 | 140.99 | 146.39 |
| Set-2 | Coupling loss (dB) | 156.50 | 147.71 | 153.15 |
| Set-3 | Coupling loss (dB) | 156.24 | 154.16 | 159.55 |
| Set-4 | Coupling loss (dB) |  | 159.38 |  |

* Xiaomi observed that low CNR is observed on the UL with maximum channel bandwidth is used, e.g, 180 kHz for NB-IoT and 1080 kHz for eMTC.
* Ericsson observed that Set 1 typically has the most favourable link budget results whereas Set 4 has the most challenging link budgets
* Qualcomm observed the uplink SNRs reduce significantly, which could make providing coverage at certain (especially low) elevation angles—e.g., those corresponding to the beam-edge, challenging. For Set 3, the uplink SNRs that are achievable will be lower than that in Set 2. At the edge of the beam approach -20 dB in Set 4, which could make providing coverage at these (low) elevation angles—e.g., those corresponding to the beam-edge—significantly challenging. A 15 kHz numerology and a full (one) PRB transmission (in the uplink) was used in the link budget results. Apple has similar obervations with full RB used on UL.

|  |  |  |
| --- | --- | --- |
| **Elevation Angle = 30 Degrees** | **Set 2** | **Set 3** |
| Uplink SNR (dB) @1200 km | -11.5 | **-19.4** |
| Uplink SNR (dB) @600 km | -6.2 | **-14** |

|  |  |  |  |
| --- | --- | --- | --- |
| **Elevation Angle**  **= 30 Degrees** | **Set 2** | **Set 3** | **Set 4** |
| Uplink SNR (dB) @600 km | -6.2 | -14 | **-19.9** |

|  |  |  |  |
| --- | --- | --- | --- |
| **Elevation Angle**  **= 30 Degrees** | **Set 2** | **Set 3** | **Set 4** |
| Downlink SNR (dB) @600 km | -4.3 | -4.3 | **-10.9** |

* Sony proposed to prioritize link budget study for PC3 devices (23dBm) with 7dB noise figure. An AWGN channel model is assumed for IoT-NTN link level simulations.
* Sateliot showed lowest SNR DL -13.98 dB and SNR UL -6.16 dB and best SNR DL 1.09 dB and SNR UL 6.19 dB for Set 4.

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | **Configuration A**  (Based on common assumptions in TR 36.763 v0.1.0 section 6.2.1) | **Configuration B**  (common assumptions + some enhancements) |
| **Downlink SNR** | Elevation angle=90º | -5.91 dB | 1.09 dB |
| Elevation angle=30º | -13.98 dB | -6.98 dB |
| **Uplink SNR**  **(ST 3.75 kHz)** | Elevation angle=90º | 1.90 dB | 6.90 dB |
| Elevation angle=30º | -6.16 dB | -1.16 dB |

### Calibration of link budget results

Contributing companies:

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Huawei | OPPO | Vivo | CATT | | MediaTek | | Nokia | | CMCC | | ZTE | |
| Xiaomi | Ericsson | Qualcomm | | Apple | | Samsung | | SONY | | Sateliot | |

OPPO, CATT, Huawei, Vivo, Nokia, CMCC, ZTE, Xiaomi, Ericsson, Apple, Sateliot (Configuration A) used agreed link budget assumptions for PC5 (20 dBm) and NF=9 dB in TR 36.763 for their simulations. MediaTek, Qualcomm, Samsung, Sony used link budget assumptions for PC3 (23 dBm) and NF=7 dB in the simulations.

A 3 dB difference between the two sets of results is due to different assumption of PC3 (23 dBm) and PC5 (20 dBm) for UL; there is also a difference of 2 dB due to a different assumption of Noise Figure (7 dB and 9 dB). To align assumptions for unified results, in the moderator summary we adjust figures of all companies with common assumptions for Noise Figure and PC5. When needed SNR DL figure is adjusted by 2 dB and SNR UL figure by 3 dB. With PC3 (23 dBm) there is a 3dB gain compared to the PC5 (20 dBm) assumption on UL. With NF=7 dB, there is a 2 dB gain compare to NF=9 dB. We used central beam edge elevations agreed in TR 36.763 for Set 1, Set 2, Set 3, and Set 4 for the determination of the FSPL. With these adjustments, we found reasonable consistency between the results from contributing companies

All contributing companies used agreed losses as shown in Table below

Table: Satellite losses

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

Table: Cases for link budget analysis

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| ***Case*** | ***Satellite orbit*** | ***Satellite parameter set*** | ***Central beam center elevation (deg)*** | ***Central beam edge elevation (deg)*** | ***Frequency Reuse Factor*** |
| **1** | ***GEO*** | ***Set 1*** | ***12.5*** | ***10*** | ***1*** |
| **2** | ***LEO-1200*** | ***Set 1*** | ***30*** | ***26.27*** | ***1*** |
| **3** | ***LEO-600*** | ***Set 1*** | ***30*** | ***26.98*** | ***1*** |
| **4** | ***GEO*** | ***Set 2*** | ***20*** | ***10.95*** | ***1*** |
| **5** | ***LEO-1200*** | ***Set 2*** | ***30*** | ***22.16*** | ***1*** |
| **6** | ***LEO-600*** | ***Set 2*** | ***30*** | ***23.80*** | ***1*** |
| **7** | ***GEO*** | ***Set 3*** | ***20.88*** | ***12.5*** | ***1*** |
| **8** | ***LEO-1200*** | ***Set 3*** | ***46.05*** | ***30*** | ***1*** |
| **9** | ***LEO-600*** | ***Set 3*** | ***43.78*** | ***30*** | ***1*** |
| **10** | ***LEO-600*** | ***Set 4*** | ***90*** | ***30*** | ***1*** |

#### Set 1

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| PC3 (23 dBm), NF=7 dB | | | | | |
| Cases | EIRP Density | EIRP per spot | DL C/N | G/T | UL C/N  180 kHz / 90 kHz / 45 kHz / 15 kHz / 3.75 kHz |
| 1 | 59 dBW/MHz | 81.6 dBm | -3.0 dB | 19 dB/K | -13.9 dB / -10.9 dB / -7.9 dB / -3.1 dB / 2.9 dB |
| 2 | 40 dBW/MHz | 62.6 dBm | 4.2 dB | 1.1 dB/K | -5.6 dB / -2.6 dB / 0.4 dB / 5.2 dB / 11.2 dB |
| 3 | 34 dBW/MHz | 56.6 dBm | 3.6 dB | 1.1 dB/K | -0.2 dB / 2.8 dB / 5.8 dB / 10.5 dB / 16.6 dB |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| PC5 (20 dBm), NF=9 dB | | | | | |
| Cases | EIRP Density | EIRP per spot | DL C/N | G/T | UL C/N  180 kHz / 90 kHz / 45 kHz / 15 kHz / 3.75 kHz |
| 1 | 59 dBW/MHz | 81.6 dBm | -5.0 dB | 19 dB/K | -16.9 dB / -13.9 dB / -10.9 dB / -6.1 dB / -0.1 dB |
| 2 | 40 dBW/MHz | 62.6 dBm | 2.2 dB | 1.1 dB/K | -8.6 dB / -5.6 dB / -2.6 dB / 2.2 dB / 8.2 dB |
| 3 | 34 dBW/MHz | 56.6 dBm | 1.6 dB | 1.1 dB/K | -3.2 dB / -0.2 dB / 2.8 dB / 7.5 dB / 13.6 dB |

#### Set 2

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| PC3 (23 dBm), NF=7 dB | | | | | |
| Cases | EIRP Density | EIRP per spot | DL C/N | G/T | UL C/N  180 kHz / 90 kHz / 45 kHz / 15 kHz / 3.75 kHz |
| 4 | 53.5 dBW/MHz | 76.1 dBm | -8.5 dB | 14 dB/K | -18.9 dB / -15.9 dB / -12.9 dB / -8.1 dB / -2.1 dB |
| 5 | 34 dBW/MHz | 56.6 dBm | -1.8 dB | -4.9 dB/K | -11.6 dB / -8.6 dB / -5.6 dB / -0.8 dB / -5.2 dB |
| 6 | 28 dBW/MHz | 50.6 dBm | -2.4 dB | -4.9 dB/K | -6.2 dB / -3.2dB / -0.2 dB / 4.5 dB / 10.6 dB |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| PC5 (20 dBm), NF=9 dB | | | | | |
| Cases | EIRP Density | EIRP per spot | DL C/N | G/T | UL C/N  180 kHz / 90 kHz / 45 kHz / 15 kHz / 3.75 kHz |
| 4 | 53.5 dBW/MHz | 76.1 dBm | -10.5 dB | 14 dB/K | -21.9 dB / -18.9 dB / -15.9 dB / -11.1 dB / -5.1 dB |
| 5 | 34 dBW/MHz | 56.6 dBm | -3.8 dB | -4.9 dB/K | -14.6 dB / -11.6 dB / -8.6 dB / -3.8 dB / -8.2 dB |
| 6 | 28 dBW/MHz | 50.6 dBm | -5.4 dB | -4.9 dB/K | -9.2 dB / -6.2dB / -3.2 dB / 1.5 dB / 7.6 dB |

#### Set 3

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| PC3 (23 dBm), NF=7 dB | | | | | |
| Cases | EIRP Density | EIRP per spot | DL C/N | G/T | UL C/N  180 kHz / 90 kHz / 45 kHz / 15 kHz / 3.75 kHz |
| 7 | 59.8 dBW/MHz | 84.4 dBm | -2.2 dB | 16.7 dB/K | -16.2 dB / -13.2 dB / -10.2 dB / -5.4 dB / 0.6 dB |
| 8 | 33.7 dBW/MHz | 56.3 dBm | -2.1 dB | -12.8 dB/K | -19.5 dB / -16.5 dB / -13.5 dB / -8.7 dB / -2.7 dB |
| 9 | 28.3 dBW/MHz | 50.9 dBm | -2.1 dB | -12.8 dB/K | -14.1 dB / -11.1 dB / -8.1 dB / -3.4 dB / 2.7 dB |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| PC5 (20 dBm), NF=9 dB | | | | | |
| Cases | EIRP Density | EIRP per spot | DL C/N | G/T | UL C/N  180 kHz / 90 kHz / 45 kHz / 15 kHz / 3.75 kHz |
| 7 | 59.8 dBW/MHz | 84.4 dBm | -4.2 dB | 16.7 dB/K | -19.2 dB / -16.2 dB / -13.2 dB / -8.4 dB / -2.4 dB |
| 8 | 33.7 dBW/MHz | 56.3 dBm | -4.1 dB | -12.8 dB/K | -22.5 dB / -19.5 dB / -16.5dB / -11.7dB / -5.7dB |
| 9 | 28.3 dBW/MHz | 50.9 dBm | -4.1 dB | -12.8 dB/K | -17.1 dB / -14.1 dB / -11.1 dB / -6.4 dB / -0.3 dB |

#### Set 4

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| PC3 (23 dBm), NF=7 dB | | | | | |
| Cases | EIRP Density | EIRP per spot | DL C/N | G/T | UL C/N  180 kHz / 90 kHz / 45 kHz / 15 kHz / 3.75 kHz |
| 10 | 21.4 dBW/MHz | 44 dBm | -12.0 dB | -18.6 dB/K | -19.2 dB / -16.2 dB / -13.2 dB / -8.5 dB / -2.4 dB |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| PC5 (25 dBm), NF=9 dB | | | | | |
| Cases | EIRP Density | EIRP per spot | DL C/N | G/T | UL C/N  180 kHz / 90 kHz / 45 kHz / 15 kHz / 3.75 kHz |
| 10 | 21.4 dBW/MHz | 44 dBm | -14.0 dB | -18.6 dB/K | -22.2 dB / -19.2 dB / -16.2dB / -11.5dB / -5.4dB |

### Distribution of CIR simulation results

The cdf of CIR for Set 1, Set 2, set 3 with Frequency Reuse Factor FRF=1 provided in [OPPO, R1-2102422] are shown below. The set 3 has lowest CIR, with 5% percentile at -3.9 dB for DL and -5.0 dB for UL.

**Table 4. CIR results for both DL and UL in Satellite set 3**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | | Ave. | 5% | 50% | 95% |
| DL | Scenario A  (GEO) | 2.0 | -2.1 | 1.9 | 6.1 |
| Scenario B&C-600km  (LEO-600) | -0.8 | -3.7 | -0.9 | 2.2 |
| Scenario B&C-1200km  (LEO-1200) | -1.0 | -3.9 | -1.0 | 1.7 |
| UL | Scenario A  (GEO) | 2.4 | -1.9 | 1.9 | 8.1 |
| Scenario B&C-600km  (LEO-600) | -2.7 | -4.8 | -2.8 | -0.5 |
| Scenario B&C-1200km  (LEO-1200) | -2.7 | -5.0 | -2.7 | -0.2 |

|  |  |
| --- | --- |
|  |  |
| 1. **GEO** | 1. **LEO-600** |
|  | |
| 1. **LEO-1200** | |

**Figure 3. CIR results for both DL and UL in Satellite set 3**

### Distribution of CL simulation results

#### Rural scenario

The cdf of Coupling Loss (CL) for DL for set 1, set 2, set 3, and set 4 in rural scenarios was provided in [ZTE, R1-2102916]. In rural scenarios, the Coupling Loss of about

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

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

#### Urban scenarios

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

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

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

#### Dense Urban scenarios

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

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

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

### Frequency Re-use Factor

The link budget for Set 1, Set 2, Set 3 with Frequency re-use 1 and Frequency reuse 3 was provided in [ZTE, R1-2102916]. It can be observed that the CINR gains depend on the scenario GEO and LEO, parameter sets, and bandwidth assumption. We make the following observations that CINR gain with FRF=3 compare to FRF=1 improves significantly the CINR at the lowest orbit, with the highest gains observed on UL with the smallest bandwidth 3.75 kHz.

Table : Set 1 – DL and UL

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | GEO | | LEO-600 | | LEO-1200 | |
| Frequency reuse factor | 1 | 3 | 1 | 3 | 1 | 3 |
| Coupling Loss (dB) | 151.04 | 151.04 | 140.99 | 140.99 | 146.39 | 146.39 |
| DL | | | | | | |
| CNR (dB) | -8.06 | -8.06 | -2.02 | -2.02 | -1.42 | -1.42 |
| CIR (dB) | 4.99 | 13.87 | -0.64 | 10.64 | -0.64 | 10.64 |
| CINR (dB) | -8.27 | -8.09 | -4.39 | -2.25 | -4.06 | -1.68 |
| UL | | | | | | |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| CNR (dB)  3.75 kHz (Tx 20 dBm)  15 kHz (Tx 20 dBm)  30 kHz (Tx 20 dBm)  45 kHz (Tx 20 dBm)  90 kHz (Tx 20 dBm)  180 kHz (Tx 20 dBm)  360 kHz (Tx 20 dBm)  1080 kHz (Tx 20 dBm) | -0.18  -6.20  -9.21  -10.97  -13.98  -16.99  -20.00  -24.77 | -0.18  -6.20  -9.21  -10.97  -13.98  -16.99  -20.00  -24.77 | 12.97  6.95  3.94  2.17  -0.84  -3.85  -6.86  -11.63 | 12.97  6.95  3.94  2.17  -0.84  -3.85  -6.86  -11.63 | 7.57  1.55  -1.46  -3.22  -6.23  -9.24  -12.25  -17.03 | 7.57  1.55  -1.46  -3.22  -6.23  -9.24  -12.25  -17.03 |
| CIR (dB) | 4.62 | 14.00 | -0.26 | 11.72 | -0.24 | 11.81 |
| CINR (dB)  3.75 kHz (Tx 20 dBm)  15 kHz (Tx 20 dBm)  30 kHz (Tx 20 dBm)  45 kHz (Tx 20 dBm)  90 kHz (Tx 20 dBm)  180 kHz (Tx 20 dBm)  360 kHz (Tx 20 dBm)  1080 kHz (Tx 20 dBm) | -1.42  -6.55  -9.39  -11.09  -14.04  -17.02  -20.02  -24.78 | -0.34  -6.24  -9.23  -10.99  -13.99  -17.00  -20.00  -24.77 | -0.46  -1.02  -1.66  -2.22  -3.57  -5.42  -7.72  -11.93 | 9.29  5.70  3.27  1.72  -1.07  -3.96  -6.92  -11.65 | -0.91  -2.45  -3.90  -4.99  -7.21  -9.76  -12.52  -17.12 | 6.18  1.16  -1.66  -3.36  -6.30  -9.28  -12.27  -17.03 |

Table : Set 2 – DL and UL

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | GEO | | LEO-600 | | LEO-1200 | |
| Frequency reuse factor | 1 | 3 | 1 | 3 | 1 | 3 |
| Coupling loss (dB) | 156.50 | 156.50 | 147.71 | 147.71 | 153.15 | 153.15 |
| DL | | | | | | |
| CNR (dB) | -13.52 | -13.52 | -8.73 | -8.73 | -8.17 | -8.17 |
| CIR (dB) | 1.48 | 13.90 | -0.50 | 11.38 | 1.45 | 13.87 |
| CINR (dB) | -13.66 | -13.53 | -9.34 | -8.77 | -8.62 | -8.20 |
| UL | | | | | | |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| CNR (dB)  3.75 kHz (Tx 20 dBm)  15 kHz (Tx 20 dBm)  30 kHz (Tx 20 dBm)  45 kHz (Tx 20 dBm)  90 kHz (Tx 20 dBm)  180 kHz (Tx 20 dBm)  360 kHz (Tx 20 dBm)  1080 kHz (Tx 20 dBm) | -5.14  -11.16  -14.17  -15.93  -18.94  -21.95  -24.96  -29.73 | -5.14  -11.16  -14.17  -15.93  -18.94  -21.95  -24.96  -29.73 | 6.25  0.23  -2.78  -4.54  -7.55  -10.56  -13.57  -18.34 | 6.25  0.23  -2.78  -4.54  -7.55  -10.56  -13.57  -18.34 | 0.81  -5.21  -8.22  -9.98  -12.99  -16.00  -19.01  -23.78 | 0.81  -5.21  -8.22  -9.98  -12.99  -16.00  -19.01  -23.78 |
| CIR (dB) | 2.36 | 14.10 | -0.14 | 11.75 | 1.75 | 12.68 |
| CINR (dB)  3.75 kHz (Tx 20 dBm)  15 kHz (Tx 20 dBm)  30 kHz (Tx 20 dBm)  45 kHz (Tx 20 dBm)  90 kHz (Tx 20 dBm)  180 kHz (Tx 20 dBm)  360 kHz (Tx 20 dBm)  1080 kHz (Tx 20 dBm) | -5.85  -11.35  -14.27  -16.00  -18.98  -21.97  -24.97  -29.74 | -5.19  -11.17  -14.18  -15.94  -18.95  -21.95  -24.96  -29.74 | -1.04  -2.97  -4.67  -5.89  -8.28  -10.94  -13.76  -18.41 | 5.17  -0.07  -2.93  -4.64  -7.60  -10.59  -13.58  -18.35 | -1.76  -6.01  -8.64  -10.26  -13.14  -16.08  -19.05  -23.80 | 0.54  -5.28  -8.26  -10.01  -13.00  -16.01  -19.02  -23.79 |

Table : Set 3 – DL and UL

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | GEO | | LEO-600 | | LEO-1200 | |
| Frequency reuse factor | 1 | 3 | 1 | 3 | 1 | 3 |
| Coupling loss (dB) | 156.24 | 156.24 | 154.16 | 154.16 | 159.55 | 159.55 |
| DL | | | | | | |
| CNR (dB) | -7.17 | -7.17 | -7.08 | -7.08 | -7.08 | -7.08 |
| CIR (dB) | 1.48 | 13.90 | 1.13 | 13.86 | 1.38 | 13.87 |
| CINR (dB) | -7.72 | -7.20 | -7.69 | -7.12 | -7.66 | -7.11 |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| UL | | | | | | |
| CNR (dB)  3.75 kHz (Tx 20 dBm)  15 kHz (Tx 20 dBm)  30 kHz (Tx 20 dBm)  45 kHz (Tx 20 dBm)  90 kHz (Tx 20 dBm)  180 kHz (Tx 20 dBm)  360 kHz (Tx 20 dBm)  1080 kHz (Tx 20 dBm) | -2.38  -8.40  -11.41  -13.17  -16.18  -19.20  -22.21  -26.98 | -2.38  -8.40  -11.41  -13.17  -16.18  -19.20  -22.21  -26.98 | -0.30  -6.32  -9.33  -11.09  -14.10  -17.11  -20.12  -24.89 | -0.30  -6.32  -9.33  -11.09  -14.10  -17.11  -20.12  -24.89 | -5.69  -11.71  -14.72  -16.48  -19.49  -22.50  -25.52  -30.29 | -5.69  -11.71  -14.72  -16.48  -19.49  -22.50  -25.52  -30.29 |
| CIR (dB) | 2.34 | 14.44 | 2.39 | 12.44 | 1.33 | 12.62 |
| CINR (dB)  3.75 kHz (Tx 20 dBm)  15 kHz (Tx 20 dBm)  30 kHz (Tx 20 dBm)  45 kHz (Tx 20 dBm)  90 kHz (Tx 20 dBm)  180 kHz (Tx 20 dBm)  360 kHz (Tx 20 dBm)  1080 kHz (Tx 20 dBm) | -3.64  -8.75  -11.59  -13.29  -16.25  -19.23  -22.22  -26.98 | -2.47  -8.43  -11.42  -13.18  -16.19  -19.20  -22.21  -26.98 | -2.17  -6.87  -9.61  -11.28  -14.20  -17.16  -20.15  -24.90 | -0.53  -6.38  -9.36  -11.11  -14.11  -17.12  -20.13  -24.90 | -6.48  -11.92  -14.83  -16.56  -19.53  -22.52  -25.52  -30.29 | -5.76  -11.73  -14.73  -16.49  -19.50  -22.51  -25.52  -30.29 |

### Conclusion for link budget results:

There is reasonable consistency in link budget results and observations from contributing companies. The above summary of company contributions on link budget can be captured in a TP to TR 36.763.

## Huawei link budget results (R1-2102343)

Table 1 Link budget results

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Parameter set** | **Satellite orbit** | **UL/DL** | **B(kHZ)** | **Elevation angle** | **UE Location** | **TX: EIRP/spot/BW [dBW]** | **RX: G/T [dB/T]** |  | **[dBi]** | **Sat. EIRP density [dBW/MHz]** | **Shadow fading margin [dB]** | **Scintillation Loss [dB]** | **Additional losses [dB]** | **Free space path loss [dB]** | **Atmospheric path loss [dB]** | **CNR [dB]** |
| Set1 | GEO | DL | 180 | 12.5 | centre | 51.55 | -36.62 | 51 | 0 | 59 | 3 | 2.2 | 0 | 190.58 | 0.00 | -4.804 |
| 180 | 2.3 | edge | 51.55 | -36.62 | 51 | 0 | 59 | 3 | 2.2 | 0 | 190.58 | 0.87 | -5.910 |
| UL | 180 | 12.5 | centre | -10.00 | 19.00 | 0 | 51 |  | 3 | 2.2 | 0 | 190.58 | 0.00 | -10.733 |
| 180 | 2.3 | edge | -10.00 | 19.00 | 0 | 51 | 3 | 2.2 | 0 | 190.81 | 0.87 | -11.839 |
| 90 | 12.5 | centre | -10.00 | 19.00 | 0 | 51 | 3 | 2.2 | 0 | 190.58 | 0.00 | -7.723 |
| 90 | 2.3 | edge | -10.00 | 19.00 | 0 | 51 | 3 | 2.2 | 0 | 190.81 | 0.87 | -8.829 |
| 45 | 12.5 | centre | -10.00 | 19.00 | 0 | 51 | 3 | 2.2 | 0 | 190.58 | 0.00 | -4.712 |
| 45 | 2.3 | edge | -10.00 | 19.00 | 0 | 51 | 3 | 2.2 | 0 | 190.81 | 0.87 | -5.819 |
| 15 | 12.5 | centre | -10.00 | 19.00 | 0 | 51 | 3 | 2.2 | 0 | 190.58 | 0.00 | 0.059 |
| 15 | 2.3 | edge | -10.00 | 19.00 | 0 | 51 | 3 | 2.2 | 0 | 190.81 | 0.87 | -1.047 |
| 3.75 | 12.5 | centre | -10.00 | 19.00 | 0 | 51 | 3 | 2.2 | 0 | 190.58 | 0.00 | 6.079 |
| 3.75 | 2.3 | edge | -10.00 | 19.00 | 0 | 51 | 3 | 2.2 | 0 | 190.81 | 0.87 | 4.973 |
| LEO600 | DL | 180 | 30 | centre | 26.55 | -36.62 | 30 | 0 | 34 | 3 | 2.2 | 0 | 159.10 | 0.00 | 1.677 |
| 180 | 27 | edge | 26.55 | -36.62 | 30 | 0 | 34 | 3 | 2.2 | 0 | 159.71 | 0.00 | 1.063 |
| UL | 180 | 30 | centre | -10.00 | 1.10 | 0 | 30 |  | 3 | 2.2 | 0 | 159.10 | 0.00 | 2.848 |
| 180 | 27 | edge | -10.00 | 1.10 | 0 | 30 | 3 | 2.2 | 0 | 159.71 | 0.00 | 2.235 |
| 90 | 30 | centre | -10.00 | 1.10 | 0 | 30 | 3 | 2.2 | 0 | 159.10 | 0.00 | 5.858 |
| 90 | 27 | edge | -10.00 | 1.10 | 0 | 30 | 3 | 2.2 | 0 | 159.71 | 0.00 | 5.245 |
| 45 | 30 | centre | -10.00 | 1.10 | 0 | 30 | 3 | 2.2 | 0 | 159.10 | 0.00 | 8.868 |
| 45 | 27 | edge | -10.00 | 1.10 | 0 | 30 | 3 | 2.2 | 0 | 159.71 | 0.00 | 8.255 |
| 15 | 30 | centre | -10.00 | 1.10 | 0 | 30 | 3 | 2.2 | 0 | 159.10 | 0.00 | 13.640 |
| 15 | 27 | edge | -10.00 | 1.10 | 0 | 30 | 3 | 2.2 | 0 | 159.71 | 0.00 | 13.026 |
| 3.75 | 30 | centre | -10.00 | 1.10 | 0 | 30 | 3 | 2.2 | 0 | 159.10 | 0.00 | 19.660 |
| 3.75 | 27 | edge | -10.00 | 1.10 | 0 | 30 | 3 | 2.2 | 0 | 159.71 | 0.00 | 19.047 |
| LEO1200 | DL | 180 | 30 | centre | 32.55 | -36.62 | 30 | 0 | 40 | 3 | 2.2 | 0 | 164.49 | 0.00 | 2.290 |
| 180 | 26.3 | edge | 32.55 | -36.62 | 30 | 0 | 40 | 3 | 2.2 | 0 | 165.11 | 0.00 | 1.669 |
| UL | 180 | 30 | centre | -10.00 | 1.10 | 0 | 30 |  | 3 | 2.2 | 0 | 164.49 | 0.00 | -2.539 |
| 180 | 26.3 | edge | -10.00 | 1.10 | 0 | 30 | 3 | 2.2 | 0 | 165.11 | 0.00 | -3.160 |
| 90 | 30 | centre | -10.00 | 1.10 | 0 | 30 | 3 | 2.2 | 0 | 164.49 | 0.00 | 0.471 |
| 90 | 26.3 | edge | -10.00 | 1.10 | 0 | 30 | 3 | 2.2 | 0 | 165.11 | 0.00 | -0.150 |
| 45 | 30 | centre | -10.00 | 1.10 | 0 | 30 | 3 | 2.2 | 0 | 164.49 | 0.00 | 3.482 |
| 45 | 26.3 | edge | -10.00 | 1.10 | 0 | 30 | 3 | 2.2 | 0 | 165.11 | 0.00 | 2.861 |
| 15 | 30 | centre | -10.00 | 1.10 | 0 | 30 | 3 | 2.2 | 0 | 164.49 | 0.00 | 8.253 |
| 15 | 26.3 | edge | -10.00 | 1.10 | 0 | 30 | 3 | 2.2 | 0 | 165.11 | 0.00 | 7.632 |
| 3.75 | 30 | centre | -10.00 | 1.10 | 0 | 30 | 3 | 2.2 | 0 | 164.49 | 0.00 | 14.273 |
| 3.75 | 26.3 | edge | -10.00 | 1.10 | 0 | 30 | 3 | 2.2 | 0 | 165.11 | 0.00 | 13.653 |
|  | | | | | | | | | | | | | | | | |
| Set2 | GEO | DL | 180 | 20 | centre | 46.05 | -36.62 | 45.5 | 0 | 53.5 | 3 | 2.2 | 0 | 190.41 | 0.00 | -10.138 |
| 180 | 11 | edge | 46.05 | -36.62 | 45.5 | 0 | 53.5 | 3 | 2.2 | 0 | 190.61 | 0.00 | -10.338 |
| UL | 180 | 20 | centre | -10.00 | 14.00 | 0 | 45.5 |  | 3 | 2.2 | 0 | 190.41 | 0.00 | -15.566 |
| 180 | 11 | edge | -10.00 | 14.00 | 0 | 45.5 | 3 | 2.2 | 0 | 190.61 | 0.00 | -15.767 |
| 90 | 20 | centre | -10.00 | 14.00 | 0 | 45.5 | 3 | 2.2 | 0 | 190.41 | 0.00 | -12.556 |
| 90 | 11 | edge | -10.00 | 14.00 | 0 | 45.5 | 3 | 2.2 | 0 | 190.61 | 0.00 | -12.757 |
| 45 | 20 | centre | -10.00 | 14.00 | 0 | 45.5 | 3 | 2.2 | 0 | 190.41 | 0.00 | -9.546 |
| 45 | 11 | edge | -10.00 | 14.00 | 0 | 45.5 | 3 | 2.2 | 0 | 190.61 | 0.00 | -9.746 |
| 15 | 20 | centre | -10.00 | 14.00 | 0 | 45.5 | 3 | 2.2 | 0 | 190.41 | 0.00 | -4.775 |
| 15 | 11 | edge | -10.00 | 14.00 | 0 | 45.5 | 3 | 2.2 | 0 | 190.61 | 0.00 | -4.975 |
| 3.75 | 20 | centre | -10.00 | 14.00 | 0 | 45.5 | 3 | 2.2 | 0 | 190.41 | 0.00 | 1.246 |
| 3.75 | 11 | edge | -10.00 | 14.00 | 0 | 45.5 | 3 | 2.2 | 0 | 190.61 | 0.00 | 1.045 |
| LEO600 | DL | 180 | 30 | centre | 20.55 | -36.62 | 24 | 0 | 28 | 3 | 2.2 | 0 | 159.10 | 0.00 | -4.323 |
| 180 | 23.8 | edge | 20.55 | -36.62 | 24 | 0 | 28 | 3 | 2.2 | 0 | 160.42 | 0.00 | -5.647 |
| UL | 180 | 30 | centre | -10.00 | -4.90 | 0 | 24 |  | 3 | 2.2 | 0 | 159.10 | 0.00 | -3.152 |
| 180 | 23.8 | edge | -10.00 | -4.90 | 0 | 24 | 3 | 2.2 | 0 | 160.42 | 0.00 | -4.475 |
| 90 | 30 | centre | -10.00 | -4.90 | 0 | 24 | 3 | 2.2 | 0 | 159.10 | 0.00 | -0.142 |
| 90 | 23.8 | edge | -10.00 | -4.90 | 0 | 24 | 3 | 2.2 | 0 | 160.42 | 0.00 | -1.465 |
| 45 | 30 | centre | -10.00 | -4.90 | 0 | 24 | 3 | 2.2 | 0 | 159.10 | 0.00 | 2.868 |
| 45 | 23.8 | edge | -10.00 | -4.90 | 0 | 24 | 3 | 2.2 | 0 | 160.42 | 0.00 | 1.545 |
| 15 | 30 | centre | -10.00 | -4.90 | 0 | 24 | 3 | 2.2 | 0 | 159.10 | 0.00 | 7.640 |
| 15 | 23.8 | edge | -10.00 | -4.90 | 0 | 24 | 3 | 2.2 | 0 | 160.42 | 0.00 | 6.316 |
| 3.75 | 30 | centre | -10.00 | -4.90 | 0 | 24 | 3 | 2.2 | 0 | 159.10 | 0.00 | 13.660 |
| 3.75 | 23.8 | edge | -10.00 | -4.90 | 0 | 24 | 3 | 2.2 | 0 | 160.42 | 0.00 | 12.337 |
| LEO1200 | DL | 180 | 30 | centre | 26.55 | -36.62 | 24 | 0 | 34 | 3 | 2.2 | 0 | 164.49 | 0.00 | -3.710 |
| 180 | 22.2 | edge | 26.55 | -36.62 | 24 | 0 | 34 | 3 | 2.2 | 0 | 165.85 | 0.00 | -5.075 |
| UL | 180 | 30 | centre | -10.00 | -4.90 | 0 | 24 |  | 3 | 2.2 | 0 | 164.49 | 0.00 | -8.539 |
| 180 | 22.2 | edge | -10.00 | -4.90 | 0 | 24 | 3 | 2.2 | 0 | 165.85 | 0.00 | -9.903 |
| 90 | 30 | centre | -10.00 | -4.90 | 0 | 24 | 3 | 2.2 | 0 | 164.49 | 0.00 | -5.529 |
| 90 | 22.2 | edge | -10.00 | -4.90 | 0 | 24 | 3 | 2.2 | 0 | 165.85 | 0.00 | -6.893 |
| 45 | 30 | centre | -10.00 | -4.90 | 0 | 24 | 3 | 2.2 | 0 | 164.49 | 0.00 | -2.518 |
| 45 | 22.2 | edge | -10.00 | -4.90 | 0 | 24 | 3 | 2.2 | 0 | 165.85 | 0.00 | -3.883 |
| 15 | 30 | centre | -10.00 | -4.90 | 0 | 24 | 3 | 2.2 | 0 | 164.49 | 0.00 | 2.253 |
| 15 | 22.2 | edge | -10.00 | -4.90 | 0 | 24 | 3 | 2.2 | 0 | 165.85 | 0.00 | 0.888 |
| 3.75 | 30 | centre | -10.00 | -4.90 | 0 | 24 | 3 | 2.2 | 0 | 164.49 | 0.00 | 8.273 |
| 3.75 | 22.2 | edge | -10.00 | -4.90 | 0 | 24 | 3 | 2.2 | 0 | 165.85 | 0.00 | 6.909 |
|  | | | | | | | | | | | | | | | | |
| Set3 | GEO | DL | 180 | 20.9 | centre | 52.35 | -36.62 | 45.7 | 0 | 59.8 | 3 | 2.2 | 0 | 190.39 | 0.00 | -3.818 |
| 180 | 12.5 | edge | 52.35 | -36.62 | 45.7 | 0 | 59.8 | 3 | 2.2 | 0 | 190.58 | 0.00 | -4.004 |
| UL | 180 | 20.9 | centre | -10.00 | 16.70 | 0 | 45.7 |  | 3 | 2.2 | 0 | 190.39 | 0.00 | -12.847 |
| 180 | 12.5 | edge | -10.00 | 16.70 | 0 | 45.7 | 3 | 2.2 | 0 | 190.58 | 0.00 | -13.033 |
| 90 | 20.9 | centre | -10.00 | 16.70 | 0 | 45.7 | 3 | 2.2 | 0 | 190.39 | 0.00 | -9.837 |
| 90 | 12.5 | edge | -10.00 | 16.70 | 0 | 45.7 | 3 | 2.2 | 0 | 190.58 | 0.00 | -10.023 |
| 45 | 20.9 | centre | -10.00 | 16.70 | 0 | 45.7 | 3 | 2.2 | 0 | 190.39 | 0.00 | -6.826 |
| 45 | 12.5 | edge | -10.00 | 16.70 | 0 | 45.7 | 3 | 2.2 | 0 | 190.58 | 0.00 | -7.012 |
| 15 | 20.9 | centre | -10.00 | 16.70 | 0 | 45.7 | 3 | 2.2 | 0 | 190.39 | 0.00 | -2.055 |
| 15 | 12.5 | edge | -10.00 | 16.70 | 0 | 45.7 | 3 | 2.2 | 0 | 190.58 | 0.00 | -2.241 |
| 3.75 | 20.9 | centre | -10.00 | 16.70 | 0 | 45.7 | 3 | 2.2 | 0 | 190.39 | 0.00 | 3.966 |
| 3.75 | 12.5 | edge | -10.00 | 16.70 | 0 | 45.7 | 3 | 2.2 | 0 | 190.58 | 0.00 | 3.779 |
| LEO600 | DL | 180 | 43.8 | centre | 20.85 | -36.62 | 16.2 | 0 | 28.3 | 3 | 2.2 | 0 | 156.85 | 0.00 | -1.772 |
| 180 | 30 | edge | 20.85 | -36.62 | 16.2 | 0 | 28.3 | 3 | 2.2 | 0 | 159.10 | 0.00 | -4.023 |
| UL | 180 | 43.8 | centre | -10.00 | -12.80 | 0 | 16.2 |  | 3 | 2.2 | 0 | 156.85 | 0.00 | -8.801 |
| 180 | 30 | edge | -10.00 | -12.80 | 0 | 16.2 | 3 | 2.2 | 0 | 159.10 | 0.00 | -11.052 |
| 90 | 43.8 | centre | -10.00 | -12.80 | 0 | 16.2 | 3 | 2.2 | 0 | 156.85 | 0.00 | -5.791 |
| 90 | 30 | edge | -10.00 | -12.80 | 0 | 16.2 | 3 | 2.2 | 0 | 159.10 | 0.00 | -8.042 |
| 45 | 43.8 | centre | -10.00 | -12.80 | 0 | 16.2 | 3 | 2.2 | 0 | 156.85 | 0.00 | -2.781 |
| 45 | 30 | edge | -10.00 | -12.80 | 0 | 16.2 | 3 | 2.2 | 0 | 159.10 | 0.00 | -5.032 |
| 15 | 43.8 | centre | -10.00 | -12.80 | 0 | 16.2 | 3 | 2.2 | 0 | 156.85 | 0.00 | 1.991 |
| 15 | 30 | edge | -10.00 | -12.80 | 0 | 16.2 | 3 | 2.2 | 0 | 159.10 | 0.00 | -0.260 |
| 3.75 | 43.8 | centre | -10.00 | -12.80 | 0 | 16.2 | 3 | 2.2 | 0 | 156.85 | 0.00 | 8.011 |
| 3.75 | 30 | edge | -10.00 | -12.80 | 0 | 16.2 | 3 | 2.2 | 0 | 159.10 | 0.00 | 5.760 |
| LEO1200 | DL | 180 | 46.05 | centre | 26.25 | -36.62 | 16.2 | 0 | 33.7 | 3 | 2.2 | 0 | 162.33 | 0.00 | -1.851 |
| 180 | 30 | edge | 26.25 | -36.62 | 16.2 | 0 | 33.7 | 3 | 2.2 | 0 | 164.49 | 0.00 | -4.010 |
| UL | 180 | 46.05 | centre | -10.00 | -12.80 | 0 | 16.2 |  | 3 | 2.2 | 0 | 162.33 | 0.00 | -14.280 |
| 180 | 30 | edge | -10.00 | -12.80 | 0 | 16.2 | 3 | 2.2 | 0 | 164.49 | 0.00 | -16.439 |
| 90 | 46.05 | centre | -10.00 | -12.80 | 0 | 16.2 | 3 | 2.2 | 0 | 162.33 | 0.00 | -11.269 |
| 90 | 30 | edge | -10.00 | -12.80 | 0 | 16.2 | 3 | 2.2 | 0 | 164.49 | 0.00 | -13.429 |
| 45 | 46.05 | centre | -10.00 | -12.80 | 0 | 16.2 | 3 | 2.2 | 0 | 162.33 | 0.00 | -8.259 |
| 45 | 30 | edge | -10.00 | -12.80 | 0 | 16.2 | 3 | 2.2 | 0 | 164.49 | 0.00 | -10.418 |
| 15 | 46.05 | centre | -10.00 | -12.80 | 0 | 16.2 | 3 | 2.2 | 0 | 162.33 | 0.00 | -3.488 |
| 15 | 30 | edge | -10.00 | -12.80 | 0 | 16.2 | 3 | 2.2 | 0 | 164.49 | 0.00 | -5.647 |
| 3.75 | 46.05 | centre | -10.00 | -12.80 | 0 | 16.2 | 3 | 2.2 | 0 | 162.33 | 0.00 | 2.533 |
| 3.75 | 30 | edge | -10.00 | -12.80 | 0 | 16.2 | 3 | 2.2 | 0 | 164.49 | 0.00 | 0.373 |
|  | | | | | | | | | | | | | | | | |
| Set 4 | LEO600 | DL | 180 | 90 | centre | 14.00 | -36.62 | 11 | 0 | 21.45 | 3 | 2.2 | 0 | 154.03 | 0.00 | -5.808 |
| 180 | 30 | edge | 14.00 | -36.62 | 11 | 0 | 21.45 | 3 | 2.2 | 0 | 159.10 | 0.00 | -10.873 |
| UL | 180 | 90 | centre | -10.00 | -18.60 | 0 | 11 |  | 3 | 2.2 | 0 | 154.03 | 0.00 | -11.786 |
| 180 | 30 | edge | -10.00 | -18.60 | 0 | 11 | 3 | 2.2 | 0 | 159.10 | 0.00 | -16.852 |
| 90 | 90 | centre | -10.00 | -18.60 | 0 | 11 | 3 | 2.2 | 0 | 154.03 | 0.00 | -8.776 |
| 90 | 30 | edge | -10.00 | -18.60 | 0 | 11 | 3 | 2.2 | 0 | 159.10 | 0.00 | -13.842 |
| 45 | 90 | centre | -10.00 | -18.60 | 0 | 11 | 3 | 2.2 | 0 | 154.03 | 0.00 | -5.766 |
| 45 | 30 | edge | -10.00 | -18.60 | 0 | 11 | 3 | 2.2 | 0 | 159.10 | 0.00 | -10.832 |
| 15 | 90 | centre | -10.00 | -18.60 | 0 | 11 | 3 | 2.2 | 0 | 154.03 | 0.00 | -0.995 |
| 15 | 30 | edge | -10.00 | -18.60 | 0 | 11 | 3 | 2.2 | 0 | 159.10 | 0.00 | -6.060 |
| 3.75 | 90 | centre | -10.00 | -18.60 | 0 | 11 | 3 | 2.2 | 0 | 154.03 | 0.00 | 5.026 |
| 3.75 | 30 | edge | -10.00 | -18.60 | 0 | 11 | 3 | 2.2 | 0 | 159.10 | 0.00 | -0.040 |

## OPPO link budget results (R1-2102422)

Satellite set 1:

Table 1 and Table 2 provide the link budget results for NB-IoT and eMTC in scenario A, scenario B&C-600km, scenario B&C-1200km respectively, with satellite parameter set 1.

**Table 1. Link budget results for NB-IoT in Satellite set 1**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| NB-IoT | | DL | UL | | | | |
| Channel bandwidth (kHz) | | 180 | 180 | 90 | 45 | 15 | 3.75 |
| Scenario A | CNR (dB) | -5.03 | -13.95 | -10.94 | -7.93 | -3.16 | 2.86 |
| CIR (dB) | 1.10 | 2.20 | 2.20 | 2.20 | 2.20 | 2.20 |
| CINR (dB) | -5.97 | -14.06 | -11.15 | -8.34 | -4.27 | -0.49 |
| Scenario B&C-600km | CNR (dB) | 1.58 | -0.25 | 2.76 | 5.77 | 10.54 | 16.56 |
| CIR (dB) | -0.20 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| CINR (dB) | -2.41 | -3.09 | -1.78 | -0.94 | -0.28 | 0.00 |
| Scenario B&C-1200km | CNR (dB) | 2.18 | -5.65 | -2.64 | 0.37 | 5.14 | 11.16 |
| CIR (dB) | -0.10 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |
| CINR (dB) | -2.12 | -6.66 | -4.46 | -2.73 | -1.01 | -0.13 |

**Table 2. Link budget results for eMTC in Satellite set 1**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| eMTC | | DL | UL | | | | |
| Channel bandwidth (kHz) | | 1080 | 360 | 180 | 90 | 45 | 30 |
| Scenario A | CNR (dB) | -5.03 | -16.96 | -13.95 | -10.94 | -7.93 | -6.17 |
| CIR (dB) | 1.10 | 2.20 | 2.20 | 2.20 | 2.20 | 2.20 |
| CINR (dB) | -5.97 | -17.02 | -14.06 | -11.15 | -8.34 | -6.76 |
| Scenario B&C-600km | CNR (dB) | 1.58 | -3.26 | -0.25 | 2.76 | 5.77 | 7.53 |
| CIR (dB) | -0.20 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| CINR (dB) | -2.41 | -4.91 | -3.09 | -1.78 | -0.94 | -0.62 |
| Scenario B&C-1200km | CNR (dB) | 2.18 | -8.66 | -5.65 | -2.64 | 0.37 | 2.13 |
| CIR (dB) | -0.10 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |
| CINR (dB) | -2.12 | -9.19 | -6.66 | -4.46 | -2.73 | -1.95 |

|  |  |
| --- | --- |
|  |  |
| 1. **GEO** | 1. **LEO-600** |
|  | |
| 1. **LEO-1200** | |

**Figure 1. CIR results for both DL and UL in Satellite set 1**

Satellite set 2:

Table 3 and Table 4 provide the link budget results for NB-IoT and eMTC in scenario A, scenario B&C-600km, scenario B&C-1200km respectively, with satellite parameter set 2.

**Table 3. Link budget results for NB-IoT in Satellite set 2**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| NB-IoT | | DL | UL | | | | |
| Channel bandwidth (kHz) | | 180 | 180 | 90 | 45 | 15 | 3.75 |
| Scenario A | CNR (dB) | -10.53 | -18.95 | -15.94 | -12.93 | -8.16 | -2.14 |
| CIR (dB) | 1.90 | 2.30 | 2.30 | 2.30 | 2.30 | 2.30 |
| CINR (dB) | -10.77 | -18.99 | -16.01 | -13.06 | -8.54 | -3.48 |
| Scenario B&C-600km | CNR (dB) | -4.42 | -6.25 | -3.24 | -0.23 | 4.54 | 10.56 |
| CIR (dB) | 0.00 | -0.80 | -0.80 | -0.80 | -0.80 | -0.80 |
| CINR (dB) | -5.76 | -7.34 | -5.20 | -3.54 | -1.91 | -1.11 |
| Scenario B&C-1200km | CNR (dB) | -3.82 | -11.65 | -8.64 | -5.63 | -0.86 | 5.16 |
| CIR (dB) | 0.00 | -0.50 | -0.50 | -0.50 | -0.50 | -0.50 |
| CINR (dB) | -5.33 | -11.97 | -9.26 | -6.79 | -3.69 | -1.54 |

**Table 4. Link budget results for eMTC in Satellite set 2**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| eMTC | | DL | UL | | | | |
| Channel bandwidth (kHz) | | 1080 | 360 | 180 | 90 | 45 | 30 |
| Scenario A | CNR (dB) | -10.53 | -21.96 | -18.95 | -15.94 | -12.93 | -11.17 |
| CIR (dB) | 1.90 | 2.30 | 2.30 | 2.30 | 2.30 | 2.30 |
| CINR (dB) | -10.77 | -21.98 | -18.99 | -16.01 | -13.06 | -11.36 |
| Scenario B&C-600km | CNR (dB) | -4.42 | -9.26 | -6.25 | -3.24 | -0.23 | 1.53 |
| CIR (dB) | 0.00 | -0.80 | -0.80 | -0.80 | -0.80 | -0.80 |
| CINR (dB) | -5.76 | -9.84 | -7.34 | -5.20 | -3.54 | -2.80 |
| Scenario B&C-1200km | CNR (dB) | -3.82 | -14.66 | -11.65 | -8.64 | -5.63 | -3.87 |
| CIR (dB) | 0.00 | -0.50 | -0.50 | -0.50 | -0.50 | -0.50 |
| CINR (dB) | -5.33 | -14.83 | -11.97 | -9.26 | -6.79 | -5.52 |

|  |  |
| --- | --- |
|  |  |
| 1. **GEO** | 1. **LEO-600** |
|  | |
| 1. **LEO-1200** | |

**Figure 2. CIR results for both DL and UL in Satellite set 2**

Satellite set 3:

Table 5 and Table 6 provide the link budget results for NB-IoT and eMTC in scenario A, scenario B&C-600km, scenario B&C-1200km respectively, with satellite parameter set 3.

**Table 5. Link budget results for NB-IoT in Satellite set 3**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| NB-IoT | | DL | UL | | | | |
| Channel bandwidth (kHz) | | 180 | 180 | 90 | 45 | 15 | 3.75 |
| Scenario A | CNR (dB) | -4.23 | -16.25 | -13.24 | -10.23 | -5.46 | 0.56 |
| CIR (dB) | 2.00 | 2.40 | 2.40 | 2.40 | 2.40 | 2.40 |
| CINR (dB) | -5.15 | -16.31 | -13.36 | -10.46 | -6.12 | -1.63 |
| Scenario B&C-600km | CNR (dB) | -4.12 | -14.15 | -11.14 | -8.13 | -3.36 | 2.66 |
| CIR (dB) | -0.80 | -2.70 | -2.70 | -2.70 | -2.70 | -2.70 |
| CINR (dB) | -5.78 | -14.45 | -11.72 | -9.23 | -6.05 | -3.81 |
| Scenario B&C-1200km | CNR (dB) | -4.12 | -19.55 | -16.54 | -13.53 | -8.76 | -2.74 |
| CIR (dB) | -1.00 | -2.70 | -2.70 | -2.70 | -2.70 | -2.70 |
| CINR (dB) | -5.85 | -19.64 | -16.72 | -13.88 | -9.72 | -5.73 |

**Table 6. Link budget results for eMTC in Satellite set 3**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| eMTC | | DL | UL | | | | |
| Channel bandwidth (kHz) | | 1080 | 360 | 180 | 90 | 45 | 30 |
| Scenario A | CNR (dB) | -4.23 | -19.26 | -16.25 | -13.24 | -10.23 | -8.47 |
| CIR (dB) | 2.00 | 2.40 | 2.40 | 2.40 | 2.40 | 2.40 |
| CINR (dB) | -5.15 | -19.29 | -16.31 | -13.36 | -10.46 | -8.81 |
| Scenario B&C-600km | CNR (dB) | -4.12 | -17.16 | -14.15 | -11.14 | -8.13 | -6.37 |
| CIR (dB) | -0.80 | -2.70 | -2.70 | -2.70 | -2.70 | -2.70 |
| CINR (dB) | -5.78 | -17.32 | -14.45 | -11.72 | -9.23 | -7.92 |
| Scenario B&C-1200km | CNR (dB) | -4.12 | -22.56 | -19.55 | -16.54 | -13.53 | -11.77 |
| CIR (dB) | -1.00 | -2.70 | -2.70 | -2.70 | -2.70 | -2.70 |
| CINR (dB) | -5.85 | -22.61 | -19.64 | -16.72 | -13.88 | -12.28 |

|  |  |
| --- | --- |
|  |  |
| 1. **GEO** | 1. **LEO-600** |
|  | |
| 1. **LEO-1200** | |

**Figure 3. CIR results for both DL and UL in Satellite set 3**

Satellite set 4:

Table 7 and Table 8 provide the link budget results for NB-IoT and eMTC in scenario B&C-600km respectively, with satellite parameter set 4.

**Table 7. Link budget results for NB-IoT in Satellite set 4**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| NB-IoT | | DL | UL | | | | |
| Channel bandwidth (kHz) | | 180 | 180 | 90 | 45 | 15 | 3.75 |
| Scenario B&C-600km | CNR (dB) | -10.97 | -19.95 | -16.94 | -13.93 | -9.16 | -3.14 |
| CINR (dB) | -10.97 | -19.95 | -16.94 | -13.93 | -9.16 | -3.14 |

**Table 8. Link budget results for eMTC in Satellite set 4**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| eMTC | | DL | UL | | | | |
| Channel bandwidth (kHz) | | 1080 | 360 | 180 | 90 | 45 | 30 |
| Scenario B&C-600km | CNR (dB) | -10.97 | -22.96 | -19.95 | -16.94 | -13.93 | -12.17 |
| CINR (dB) | -10.97 | -22.96 | -19.95 | -16.94 | -13.93 | -12.17 |

## Vivo link budget results (R1-2102550)

**Table 1. Link budget results for Set-1 satellites and NB-IoT/eMTC devices**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Device type | UL/DL | Bandwidth | GEO | | LEO-1200 | | LEO-600 | |
| Free space path loss[dB] | CNR [dB] | Free space path loss[dB] | CNR [dB] | Free space path loss[dB] | CNR [dB] |
| NB-IoT | DL | 180kHz | 190.58 | -4.97 | 164.49 | 2.22 | 159.10 | 1.61 |
| UL | 12\*15kHz | 190.58 | -13.89 | 164.49 | -5.61 | 159.10 | -0.22 |
| 6\*15kHz | 190.58 | -10.88 | 164.49 | -2.60 | 159.10 | 2.79 |
| 3\*15kHz | 190.58 | -7.87 | 164.49 | 0.41 | 159.10 | 5.8 |
| 1\*15kHz | 190.58 | -3.10 | 164.49 | 5.18 | 159.10 | 10.57 |
| 1\*3.75kHz | 190.58 | 2.92 | 164.49 | 11.2 | 159.10 | 16.59 |
| eMTC | DL | 1080kHz | 190.58 | -4.97 | 164.49 | 2.22 | 159.10 | 1.61 |
| UL | 1080kHz | 190.58 | -21.68 | 164.49 | -13.39 | 159.10 | -8.00 |
| 2\*180kHz | 190.58 | -16.91 | 164.49 | -8.62 | 159.10 | -3.23 |
| 180kHz | 190.58 | -13.89 | 164.49 | -5.61 | 159.10 | -0.22 |
| 6\*15kHz | 190.58 | -10.88 | 164.49 | -2.60 | 159.10 | 2.79 |
| 3\*15kHz | 190.58 | -7.87 | 164.49 | 0.41 | 159.10 | 5.80 |
| 2\*15kHz | 190.58 | -3.10 | 164.49 | 5.18 | 159.10 | 10.57 |

**Table 2. Link budget results for Set-2 satellites and NB-IoT/eMTC devices**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Device type | UL/DL | Bandwidth | GEO | | LEO-1200 | | LEO-600 | |
| Free space path loss[dB] | CNR [dB] | Free space path loss[dB] | CNR [dB] | Free space path loss[dB] | CNR [dB] |
| NB-IoT | DL | 180kHz | 190.58 | -10.47 | 164.49 | -3.78 | 159.10 | -4.39 |
| UL | 12\*15kHz | 190.58 | -18.89 | 164.49 | -11.61 | 159.10 | -6.22 |
| 6\*15kHz | 190.58 | -15.88 | 164.49 | -8.60 | 159.10 | -3.21 |
| 3\*15kHz | 190.58 | -12.87 | 164.49 | -5.59 | 159.10 | -0.20 |
| 1\*15kHz | 190.58 | -8.10 | 164.49 | -0.82 | 159.10 | 4.57 |
| 1\*3.75kHz | 190.58 | -2.08 | 164.49 | 5.20 | 159.10 | 10.59 |
| eMTC | DL | 1080kHz | 190.58 | -10.47 | 164.49 | -3.78 | 159.10 | -4.39 |
| UL | 1080kHz | 190.58 | -26.68 | 164.49 | -19.39 | 159.10 | -14.00 |
| 2\*180kHz | 190.58 | -21.91 | 164.49 | -14.62 | 159.10 | -9.23 |
| 180kHz | 190.58 | -18.89 | 164.49 | -11.61 | 159.10 | -6.22 |
| 6\*15kHz | 190.58 | -15.88 | 164.49 | -8.60 | 159.10 | -3.21 |
| 3\*15kHz | 190.58 | -12.87 | 164.49 | -5.59 | 159.10 | -0.20 |
| 2\*15kHz | 190.58 | -8.10 | 164.49 | -0.82 | 159.10 | 4.57 |

**Table 3. Link budget results for Set-3 satellites and NB-IoT/eMTC devices**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Device type | UL/DL | Bandwidth | GEO | | LEO-1200 | | LEO-600 | |
| Free space path loss[dB] | CNR [dB] | Free space path loss[dB] | CNR [dB] | Free space path loss[dB] | CNR [dB] |
| NB-IoT | DL | 180kHz | 190.58 | -4.17 | 164.49 | -4.08 | 159.10 | -4.09 |
| UL | 12\*15kHz | 190.58 | -16.19 | 164.49 | -19.51 | 159.10 | -14.12 |
| 6\*15kHz | 190.58 | -13.18 | 164.49 | -16.50 | 159.10 | -11.11 |
| 3\*15kHz | 190.58 | -10.17 | 164.49 | -13.49 | 159.10 | -8.10 |
| 1\*15kHz | 190.58 | -5.40 | 164.49 | -8.72 | 159.10 | -3.33 |
| 1\*3.75kHz | 190.58 | 0.62 | 164.49 | -2.70 | 159.10 | 2.69 |
| eMTC | DL | 1080kHz | 190.58 | -4.17 | 164.49 | -4.08 | 159.10 | -4.09 |
| UL | 1080kHz | 190.58 | -23.98 | 164.49 | -27.29 | 159.10 | -21.90 |
| 2\*180kHz | 190.58 | -19.21 | 164.49 | -22.52 | 159.10 | -17.13 |
| 180kHz | 190.58 | -16.19 | 164.49 | -19.51 | 159.10 | -14.12 |
| 6\*15kHz | 190.58 | -13.18 | 164.49 | -16.50 | 159.10 | -11.11 |
| 3\*15kHz | 190.58 | -10.17 | 164.49 | -13.49 | 159.10 | -8.10 |
| 2\*15kHz | 190.58 | -5.40 | 164.49 | -11.73 | 159.10 | -6.34 |

**Table 4. Link budget results for Set-4 satellites and NB-IoT/eMTC devices**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Device type | UL/DL | Bandwidth | LEO-600 | |
| Free space path loss[dB] | CNR [dB] |
| NB-IoT | DL | 180kHz | 159.10 | -10.94 |
| UL | 12\*15kHz | 159.10 | -19.92 |
| 6\*15kHz | 159.10 | -16.91 |
| 3\*15kHz | 159.10 | -13.90 |
| 1\*15kHz | 159.10 | -9.13 |
| 1\*3.75kHz | 159.10 | -3.11 |
| eMTC | DL | 1080kHz | 159.10 | -10.94 |
| UL | 1080kHz | 159.10 | -27.70 |
| 2\*180kHz | 159.10 | -22.93 |
| 180kHz | 159.10 | -19.92 |
| 6\*15kHz | 159.10 | -16.91 |
| 3\*15kHz | 159.10 | -13.90 |
| 2\*15kHz | 159.10 | -12.14 |

## CATT link budget results (R1-2102617)

Link budget results for Set-1

**Table 1 Link budget result for eMTC NTN with Set-1**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Satellite orbit** | **GEO** | | | | | | | | **LEO1200** | | | | | | | | | **LEO600** | | | | | | | | |
| **B(KHZ)** | **DL** | | **UL** | | | | | | **DL** | | **UL** | | | | | | | **DL** | | **UL** | | | | | | |
| **1080** | | **360** | | **180** | **90** | **45** | **30** | **1080** | | **360** | | **180** | | **90** | **45** | **30** | **1080** | | **360** | | **180** | | **90** | **45** | **30** |
| **Frequency (GHz)** | **2** | | **2** | | | | | | **2** | | **2** | | | | | | | **2** | | **2** | | | | | | |
| **TX: EIRP [DL:dBW/MHz**  **UL;dBW]** | **59** | | **-10** | | | | | | **40** | | **-10** | | | | | | | **34** | | **-10** | | | | | | |
| **RX: G/T [dB/K]** | **-33.62** | | **19** | | | | | | **-33.62** | | **1.1** | | | | | | | **-33.62** | | **1.1** | | | | | | |
| **Additional losses [dB]** | **0** | | **0** | | | | | | **0** | | **0** | | | | | | | **0** | | **0** | | | | | | |
| **Central beam edge elevation [degrees] & Free space path loss [dB]** | **Central beam edge elevation: 2.3**  **FSPL: 190.81** | | | | | | | | **Central beam edge elevation: 26.3**  **FSPL: 165.11** | | | | | | | | | **Central beam edge elevation: 27.0**  **FSPL: 159.71** | | | | | | | | |
| **CNR [dB]**  **(with different bandwidth)** | **-5.2** | **-17.1** | | **-14.1** | | **-11.1** | **-8.1** | **-6.3** | **1.5** | **-9.2** | | **-6.2** | | **-3.2** | | **-0.2** | **1.5** | **0.9** | **-3.8** | | **-0.8** | | **2.1** | | **5.1** | **6.9** |
| **Central beam centre elevation [degrees] & Free space path loss [dB]** | **Central beam centre elevation: 12.5**  **FSPL: 190.58** | | | | | | | | **Central beam centre elevation: 30**  **FSPL: 164.49** | | | | | | | | | **Central beam centre elevation: 30**  **FSPL: 159.10** | | | | | | | | |
| **CNR [dB]**  **(with different bandwidth)** | **-5.0** | **-16.9** | | **-13.9** | | **-10.9** | **-7.9** | **-6.1** | **2.1** | **-8.6** | | **-5.6** | | **-2.6** | | **0.3** | **2.1** | **1.5** | **-3.2** | | **-0.2** | | **2.7** | | **5.7** | **7.5** |

**Table 2 Link budget result for NB-IoT NTN with Set-1**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Satellite orbit** | **GEO** | | | | | | | | | | **LEO1200** | | | | | | | **LEO600** | | | | | | |
| **B(KHZ)** | **DL** | | | **UL** | | | | | | | **DL** | | **UL** | | | | | **DL** | | **UL** | | | | |
| **180** | | | **180** | | **90** | | **45** | **15** | **3.75** | **180** | | **180** | **90** | **45** | **15** | **3.75** | **180** | | **180** | **90** | **45** | **15** | **3.75** |
| **Frequency (GHz)** | **2** | | | **2** | | | | | | | **2** | | **2** | | | | | **2** | | **2** | | | | |
| **TX: EIRP [DL:dBW/MHz**  **UL;dBW]** | **59** | | | **-10** | | | | | | | **40** | | **-10** | | | | | **34** | | **-10** | | | | |
| **RX: G/T [dB/K]** | **-33.62** | | | **19** | | | | | | | **-33.62** | | **1.1** | | | | | **-33.62** | | **1.1** | | | | |
| **Additional losses [dB]** | **0** | | | **0** | | | | | | | **0** | | **0** | | | | | **0** | | **0** | | | | |
| **Central beam edge elevation [degrees] & Free space path loss [dB]** | **Central beam edge elevation: 2.3**  **FSPL: 190.81** | | | | | | | | | | **Central beam edge elevation: 26.3**  **FSPL: 165.11** | | | | | | | **Central beam edge elevation: 27.0**  **FSPL: 159.71** | | | | | | |
| **CNR [dB]**  **(with different bandwidth)** | **-5.2** | | **-14.1** | | **-11.1** | | **-8.1** | | **-3.3** | **2.6** | **1.5** | **-6.2** | | **-3.2** | **-0.2** | **4.5** | **10.5** | **0.9** | **-0.8** | | **2.1** | **5.1** | **9.9** | **15.9** |
| **Central beam centre elevation [degrees] & Free space path loss [dB]** | **Central beam centre elevation: 12.5**  **FSPL: 190.58** | | | | | | | | | | **Central beam centre elevation: 30**  **FSPL: 164.49** | | | | | | | **Central beam centre elevation: 30**  **FSPL: 159.10** | | | | | | |
| **CNR [dB]**  **(with different bandwidth)** | **-5.0** | **-13.9** | | | **-10.9** | | **-7.9** | | **-3.1** | **2.8** | **2.1** | **-5.6** | | **-2.6** | **0.3** | **5.1** | **11.1** | **1.5** | **-0.2** | | **2.7** | **5.7** | **10.5** | **16.5** |

Link budget results for Set-2

**Table 3 Link budget result for eMTC NTN with Set-2**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Satellite orbit** | **GEO** | | | | | | | | | **LEO1200** | | | | | | | | **LEO600** | | | | | | | | |
| **B(KHZ)** | **DL** | | **UL** | | | | | | | **DL** | | **UL** | | | | | | **DL** | | **UL** | | | | | | |
| **1080** | | **360** | | **180** | | **90** | **45** | **30** | **1080** | | **360** | | **180** | **90** | **45** | **30** | **1080** | | **360** | | **180** | | **90** | **45** | **30** |
| **Frequency (GHz)** | **2** | | **2** | | | | | | | **2** | | **2** | | | | | | **2** | | **2** | | | | | | |
| **TX: EIRP [DL:dBW/MHz**  **UL;dBW]** | **53.5** | | **-10** | | | | | | | **34** | | **-10** | | | | | | **28** | | **-10** | | | | | | |
| **RX: G/T [dB/K]** | **-33.62** | | **14** | | | | | | | **-33.62** | | **-4.9** | | | | | | **-33.62** | | **-4.9** | | | | | | |
| **Additional losses [dB]** | **0** | | **0** | | | | | | | **0** | | **0** | | | | | | **0** | | **0** | | | | | | |
| **Central beam edge elevation [degrees] & Free space path loss [dB]** | **Central beam edge elevation: 11**  **FSPL: 190.61** | | | | | | | | | **Central beam edge elevation: 22.2**  **FSPL: 165.85** | | | | | | | | **Central beam edge elevation: 23.8**  **FSPL: 160.42** | | | | | | | | |
| **CNR [dB]**  **(with different bandwidth)** | **-10.5** | **-21.9** | | **-18.9** | | **-15.9** | | **-12.9** | **-11.1** | **-5.1** | **-16.0** | | **-13.0** | | **-9.9** | **-6.9** | **-5.2** | **-5.7** | **-10.5** | | **-7.5** | | **-4.5** | | **-1.5** | **0.2** |
| **Central beam centre elevation [degrees] & Free space path loss [dB]** | **Central beam centre elevation: 20**  **FSPL: 190.41** | | | | | | | | | **Central beam centre elevation: 30**  **FSPL: 164.49** | | | | | | | | **Central beam centre elevation: 30**  **FSPL: 159.10** | | | | | | | | |
| **CNR [dB]**  **(with different bandwidth)** | **-10.3** | **-21.7** | | **-18.7** | | **-15.7** | | **-12.7** | **-10.9** | **-3.8** | **-14.6** | | **-11.6** | | **-8.6** | **-5.6** | **-3.8** | **-4.4** | **-9.2** | | **-6.2** | | **-3.2** | | **-0.2** | **1.5** |

**Table 4 Link budget result for NB-IoT NTN with Set-2**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Satellite orbit** | **GEO** | | | | | | **LEO1200** | | | | | | **LEO600** | | | | | |
| **B(KHZ)** | **DL** | **UL** | | | | | **DL** | **UL** | | | | | **DL** | **UL** | | | | |
| **180** | **180** | **90** | **45** | **15** | **3.75** | **180** | **180** | **90** | **45** | **15** | **3.75** | **180** | **180** | **90** | **45** | **15** | **3.75** |
| **Frequency (GHz)** | **2** | **2** | | | | | **2** | **2** | | | | | **2** | **2** | | | | |
| **TX: EIRP [DL:dBW/MHz**  **UL;dBW]** | **53.5** | **-10** | | | | | **34** | **-10** | | | | | **28** | **-10** | | | | |
| **RX: G/T [dB/K]** | **-33.62** | **14** | | | | | **-33.62** | **-4.9** | | | | | **-33.62** | **-4.9** | | | | |
| **Additional losses [dB]** | **0** | **0** | | | | | **0** | **0** | | | | | **0** | **0** | | | | |
| **Central beam edge elevation [degrees] & Free space path loss [dB]** | **Central beam edge elevation: 11**  **FSPL: 190.61** | | | | | | **Central beam edge elevation: 22.2**  **FSPL: 165.85** | | | | | | **Central beam edge elevation: 23.8**  **FSPL: 160.42** | | | | | |
| **CNR [dB]**  **(with different bandwidth)** | **-10.5** | **-18.9** | **-15.9** | **-12.9** | **-8.1** | **-2.1** | **-5.1** | **-13.0** | **-9.9** | **-6.9** | **-2.2** | **3.8** | **-5.7** | **-7.5** | **-4.5** | **-1.5** | **3.2** | **9.2** |
| **Central beam centre elevation [degrees] & Free space path loss [dB]** | **Central beam centre elevation: 20**  **FSPL: 190.41** | | | | | | **Central beam centre elevation: 30**  **FSPL: 164.49** | | | | | | **Central beam centre elevation: 30**  **FSPL: 159.10** | | | | | |
| **CNR [dB]**  **(with different bandwidth)** | **-10.3** | **-18.7** | **-15.7** | **-12.7** | **-7.9** | **-1.9** | **-3.8** | **-11.6** | **-8.6** | **-5.6** | **-0.8** | **5.1** | **-4.4** | **-6.2** | **-3.2** | **-0.2** | **4.5** | **10.5** |

Link budget results for Set-3

**Table 5 Link budget result for eMTC NTN with Set-3**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Satellite orbit** | **GEO** | | | | | | | | **LEO1200** | | | | | | | **LEO600** | | | | | |
| **B(KHZ)** | **DL** | **UL** | | | | | | | **DL** | | **UL** | | | | | **DL** | **UL** | | | | |
| **1080** | **360** | **180** | | **90** | | **45** | **30** | **1080** | | **360** | **180** | **90** | **45** | **30** | **1080** | **360** | **180** | **90** | **45** | **30** |
| **Frequency (GHz)** | **2** | **2** | | | | | | | **2** | | **2** | | | | | **2** | **2** | | | | |
| **TX: EIRP [DL:dBW/MHz**  **UL;dBW]** | **59.8** | **-10** | | | | | | | **33.7** | | **-10** | | | | | **28.3** | **-10** | | | | |
| **RX: G/T [dB/K]** | **-33.62** | **16.7** | | | | | | | **-33.62** | | **-12.8** | | | | | **-33.62** | **-12.8** | | | | |
| **Additional losses [dB]** | **0** | **0** | | | | | | | **0** | | **0** | | | | | **0** | **0** | | | | |
| **Central beam edge elevation [degrees] & Free space path loss [dB]** | **Central beam edge elevation: 12.5**  **FSPL: 190.58** | | | | | | | | **Central beam edge elevation: 30**  **FSPL: 164.49** | | | | | | | **Central beam edge elevation: 30**  **FSPL: 159.10** | | | | | |
| **CNR [dB]**  **(with different bandwidth)** | **-4.2** | **-19.2** | | **-16.2** | | **-13.2** | **-10.2** | **-8.4** | **-4.1** | | **-22.5** | **-19.5** | **-16.5** | **-13.5** | **-11.7** | **-4.1** | **-17.1** | **-14.1** | **-11.1** | **-8.1** | **-6.3** |
| **Central beam centre elevation [degrees] & Free space path loss [dB]** | **Central beam centre elevation: 20.9**  **FSPL: 190.39** | | | | | | | | **Central beam centre elevation: 46.05**  **FSPL: 162.33** | | | | | | | **Central beam centre elevation: 43.78**  **FSPL: 156.85** | | | | | |
| **CNR [dB]**  **(with different bandwidth)** | **-4.0** | **-19.0** | **-16.0** | | **-13.0** | | **-10.0** | **-8.2** | **-1.9** | **-20.3** | | **-17.3** | **-14.3** | **-11.3** | **-9.6** | **-1.8** | **-14.9** | **-11.9** | **-8.8** | **-5.8** | **-4.1** |

**Table 6 Link budget result for NB-IoT NTN with Set-3**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Satellite orbit** | **GEO** | | | | | | | | | | **LEO1200** | | | | | | | | | | **LEO600** | | | | | | | |
| **B(KHZ)** | **DL** | | **UL** | | | | | | | | **DL** | | **UL** | | | | | | | | **DL** | **UL** | | | | | | |
| **180** | | **180** | | **90** | | **45** | **15** | **3.75** | | **180** | | **180** | | **90** | **45** | **15** | | **3.75** | | **180** | **180** | | **90** | **45** | **15** | **3.75** | |
| **Frequency (GHz)** | **2** | | **2** | | | | | | | | **2** | | **2** | | | | | | | | **2** | **2** | | | | | | |
| **TX: EIRP [DL:dBW/MHz**  **UL;dBW]** | **59.8** | | **-10** | | | | | | | | **33.7** | | **-10** | | | | | | | | **28.3** | **-10** | | | | | | |
| **RX: G/T [dB/K]** | **-33.62** | | **16.7** | | | | | | | | **-33.62** | | **-12.8** | | | | | | | | **-33.62** | **-12.8** | | | | | | |
| **Additional losses [dB]** | **0** | | **0** | | | | | | | | **0** | | **0** | | | | | | | | **0** | **0** | | | | | | |
| **Central beam edge elevation [degrees] & Free space path loss [dB]** | **Central beam edge elevation: 12.5**  **FSPL: 190.58** | | | | | | | | | | **Central beam edge elevation: 30**  **FSPL: 164.49** | | | | | | | | | | **Central beam edge elevation: 30**  **FSPL: 159.10** | | | | | | | |
| **CNR [dB]**  **(with different bandwidth)** | **-4.2** | **-16.2** | | **-13.2** | | **-10.2** | | **-5.4** | | **0.5** | **-4.1** | **-19.5** | | **-16.5** | | **-13.5** | | **-8.7** | | **-2.7** | **-4.1** | | **-14.1** | **-11.1** | **-8.1** | **-3.3** | | **2.6** |
| **Central beam centre elevation [degrees] & Free space path loss [dB]** | **Central beam centre elevation: 20.9**  **FSPL: 190.39** | | | | | | | | | | **Central beam centre elevation: 46.05**  **FSPL: 162.33** | | | | | | | | | | **Central beam centre elevation: 43.78**  **FSPL: 156.85** | | | | | | | |
| **CNR [dB]**  **(with different bandwidth)** | **-4.0** | **-16.0** | | | **-13.0** | | **-10.0** | **-5.2** | | **0.7** | **-1.9** | **-17.3** | | **-14.3** | | **-11.3** | | **-6.5** | | **-0.5** | **-1.8** | | **-11.9** | **-8.8** | **-5.8** | **-1.1** | | **4.9** |

Link budget results for Set-4

**Table 7 Link budget result with Set-4**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Satellite orbit** | **LEO600-eMTC** | | | | | | **LEO600-NB-IoT** | | | | | |
| **B(KHZ)** | **DL** | **UL** | | | | | **DL** | **UL** | | | | |
| **1080** | **360** | **180** | **90** | **45** | **30** | **180** | **180** | **90** | **45** | **15** | **3.75** |
| **Frequency (GHz)** | **2** | **2** | | | | | **2** | **2** | | | | |
| **TX: EIRP [DL:dBW/MHz**  **UL;dBW]** | **21.45** | **-10** | | | | | **21.45** | **-10** | | | | |
| **RX: G/T [dB/K]** | **-33.62** | **-18.6** | | | | | **-33.62** | **-18.6** | | | | |
| **Additional losses [dB]** | **0** | **0** | | | | | **0** | **0** | | | | |
| **Central beam edge elevation [degrees] & Free space path loss [dB]** | **Central beam edge elevation: 30**  **FSPL: 159.10** | | | | | | **Central beam edge elevation: 30**  **FSPL: 159.10** | | | | | |
| **CNR [dB]**  **(with different bandwidth)** | **-10.9** | **-22.9** | **-19.9** | **-16.9** | **-13.9** | **-12.1** | **-10.9** | **-19.9** | **-16.9** | **-13.9** | **-9.1** | **-3.1** |
| **Central beam centre elevation [degrees] & Free space path loss [dB]** | **Central beam centre elevation: 90**  **FSPL: 154.03** | | | | | | **Central beam centre elevation: 90**  **FSPL: 154.03** | | | | | |
| **CNR [dB]**  **(with different bandwidth)** | **-5.9** | **-17.9** | **-14.8** | **-11.8** | **-8.8** | **-7.1** | **-5.9** | **-14.8** | **-11.8** | **-8.8** | **-4.0** | **1.9** |

## MediaTek link budget results (R1-2102754)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Case | Satellite orbit | Parameter Set | Central beam edge elevation | Terminal | Frequency band |
| 1 | GEO | Set 1 | 2.3 deg | CIoT | S-band |
| 2 | LEO-1200 km | Set 1 | 26.3 deg | CIoT | S-band |
| 3 | LEO-600 km | Set 1 | 27 deg | CIoT | S-band |
| 4 | GEO | Set 2 | 11 deg | CIoT | S-band |
| 5 | LEO-1200 km | Set 2 | 22.2 deg | CIoT | S-band |
| 6 | LEO-600 km | Set 2 | 23.8 deg | CIoT | S-band |
| 7 | GEO | Set 3 | 12.5 deg | CIoT | S-band |
| 8 | LEO-1200 km | Set 3 | 30 deg | CIoT | S-band |
| 9 | LEO-600 km | Set 3 | 30 deg | CIoT | S-band |
| 10 | LEO-600 km | Set 4 | 30 deg | CIoT | S-band |

***Table 1****: List of Cases for Link Budget for NB-IoT / eMTC*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Cases | EIRP Density | EIRP per spot | DL C/N | G/T | UL C/N  3.75 kHz / 15 kHz / 3\*15 kHz / 6\*15 kHz / 180 kHz |
| 1 | 59 dBW/MHz | 81.6 dBm | -3.0 dB | 19 dB/K | 2.9 dB / -3.1 dB / -7.9 dB / -10.9 dB / -13.9 dB |
| 2 | 40 dBW/MHz | 62.6 dBm | 4.2 dB | 1.1 dB/K | 11.2 dB / 5.2 dB / 0.4 dB / -2.6 dB / -5.6 dB |
| 3 | 34 dBW/MHz | 56.6 dBm | 3.6 dB | 1.1 dB/K | 16.6 dB / 10.5 dB / 5.8 dB / 2.8 dB / -0.2 dB |
| 4 | 53.5 dBW/MHz | 76.1 dBm | -8.5 dB | 14 dB/K | -2.1 dB / -8.1 dB / -12.9 dB / -15.9 dB / -18.9 dB |
| 5 | 34 dBW/MHz | 56.6 dBm | -1.8 dB | -4.9 dB/K | 5.2 dB / -0.8 dB / -5.6 dB / -8.6 dB / -11.6 dB |
| 6 | 28 dBW/MHz | 50.6 dBm | -2.4 dB | -4.9 dB/K | 10.6 dB / 4.5 dB / -0.2 dB / -3.2 dB / -6.2 dB |
| 7 | 59.8 dBW/MHz | 84.4 dBm | -2.2 dB | 16.7 dB/K | 0.6 dB / -5.4 dB / -10.2 dB / -13.2 dB / -16.2 dB |
| 8 | 33.7 dBW/MHz | 56.3 dBm | -2.1 dB | -12.8 dB/K | -2.7 dB / -8.7 dB / -13.5 dB / -16.5 dB / -19.5 dB |
| 9 | 28.3 dBW/MHz | 50.9 dBm | -2.1 dB | -12.8 dB/K | 2.7 dB / -3.4 dB / -8.1 dB / -11.1 dB / -14.1 dB |
| 10 | 21.45 dBW/MHz | 44 dBm | -12.0 dB | -20.9 dB/K | -2.4 dB / -8.5 dB / -13.2 dB / -16.2 dB / -19.2 dB |

***Table 2****: Link Budget results*

## Nokia link budget results (R1-2102831)

Table 4 Downlink link budget for eMTC and NB-IoT with Set 1 parameters

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Scenario | Transmission mode | Elevation angle | Frequency [GHz] | TX: EIRP [dBm] | RX: G/T [dB/T] | Bandwidth [MHz] | Free space path loss [dB] | Atmospheric loss [dB] | Shadow fading margin [dB] | Scintillation Loss [dB] | Polarization loss [dB] | Additional losses [dB] | CNR [dB] |
| eMTC, GEO | DL | 12.5 | 2 | 89.33 | -33.62 | 1.08 | 190.58 | 0.2 | 3 | 2.2 | 3 | 0 | -5.01 |
| eMTC, LEO1200 | DL | 30 | 2 | 70.33 | -33.62 | 1.08 | 164.49 | 0.1 | 3 | 2.2 | 3 | 0 | 2.19 |
| eMTC, LEO600 | DL | 30 | 2 | 64.33 | -33.62 | 1.08 | 159.10 | 0.1 | 3 | 2.2 | 3 | 0 | 1.58 |
| NB-IoT, GEO | DL | 12.5 | 2 | 81.55 | -33.62 | 0.18 | 190.58 | 0.2 | 3 | 2.2 | 3 | 0 | -5.01 |
| NB-IoT, LEO1200 | DL | 30 | 2 | 62.55 | -33.62 | 0.18 | 164.49 | 0.1 | 3 | 2.2 | 3 | 0 | 2.19 |
| NB-IoT, LEO600 | DL | 30 | 2 | 56.55 | -33.62 | 0.18 | 159.10 | 0.1 | 3 | 2.2 | 3 | 0 | 1.58 |

Table 5 Uplink link budget for eMTC with Set 1 parameters

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Scenario | Transmission mode | Elevation angle | Frequency [GHz] | TX: EIRP [dBm] | RX: G/T [dB/T] | Bandwidth [MHz] | Free space path loss [dB] | Atmospheric loss [dB] | Shadow fading margin [dB] | Scintillation Loss [dB] | Polarization loss [dB] | Additional losses [dB] | CNR [dB] |
| eMTC, GEO | UL | 12.5 | 2 | 20 | 19.0 | 1.08 | 190.58 | 0.2 | 3.0 | 2.2 | 3 | 0 | -21.72 |
| UL | 12.5 | 2 | 20 | 19.0 | 0.36 | 190.58 | 0.2 | 3.0 | 2.2 | 3 | 0 | -16.94 |
| UL | 12.5 | 2 | 20 | 19.0 | 0.18 | 190.58 | 0.2 | 3.0 | 2.2 | 3 | 0 | -13.93 |
| UL | 12.5 | 2 | 20 | 19.0 | 0.09 | 190.58 | 0.2 | 3.0 | 2.2 | 3 | 0 | -10.92 |
| UL | 12.5 | 2 | 20 | 19.0 | 0.045 | 190.58 | 0.2 | 3.0 | 2.2 | 3 | 0 | -7.91 |
| UL | 12.5 | 2 | 20 | 19.0 | 0.03 | 190.58 | 0.2 | 3.0 | 2.2 | 3 | 0 | -6.15 |
| eMTC, LEO1200 | UL | 30 | 2 | 20 | 1.1 | 1.08 | 164.49 | 0.1 | 3.0 | 2.2 | 3 | 0 | -13.42 |
| UL | 30 | 2 | 20 | 1.1 | 0.36 | 164.49 | 0.1 | 3.0 | 2.2 | 3 | 0 | -8.65 |
| UL | 30 | 2 | 20 | 1.1 | 0.18 | 164.49 | 0.1 | 3.0 | 2.2 | 3 | 0 | -5.64 |
| UL | 30 | 2 | 20 | 1.1 | 0.09 | 164.49 | 0.1 | 3.0 | 2.2 | 3 | 0 | -2.63 |
| UL | 30 | 2 | 20 | 1.1 | 0.045 | 164.49 | 0.1 | 3.0 | 2.2 | 3 | 0 | 0.38 |
| UL | 30 | 2 | 20 | 1.1 | 0.03 | 164.49 | 0.1 | 3.0 | 2.2 | 3 | 0 | 2.14 |
| eMTC, LEO600 | UL | 30 | 2 | 20 | 1.1 | 1.08 | 159.10 | 0.1 | 3.0 | 2.2 | 3 | 0 | -8.03 |
| UL | 30 | 2 | 20 | 1.1 | 0.36 | 159.10 | 0.1 | 3.0 | 2.2 | 3 | 0 | -3.26 |
| UL | 30 | 2 | 20 | 1.1 | 0.18 | 159.10 | 0.1 | 3.0 | 2.2 | 3 | 0 | -0.25 |
| UL | 30 | 2 | 20 | 1.1 | 0.09 | 159.10 | 0.1 | 3.0 | 2.2 | 3 | 0 | 2.76 |
| UL | 30 | 2 | 20 | 1.1 | 0.045 | 159.10 | 0.1 | 3.0 | 2.2 | 3 | 0 | 5.77 |
| UL | 30 | 2 | 20 | 1.1 | 0.03 | 159.10 | 0.1 | 3.0 | 2.2 | 3 | 0 | 7.53 |

Table 6 Uplink link budget for NB-IoT with Set 1 parameters

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Scenario | Transmission mode | Elevation angle | Frequency [GHz] | TX: EIRP [dBm] | RX: G/T [dB/T] | Bandwidth [MHz] | Free space path loss [dB] | Atmospheric loss [dB] | Shadow fading margin [dB] | Scintillation Loss [dB] | Polarization loss [dB] | Additional losses [dB] | CNR [dB] |
| NB-IoT, GEO | UL | 12.5 | 2 | 20 | 19.0 | 0.18 | 190.58 | 0.2 | 3.0 | 2.2 | 3 | 0 | -13.93 |
| UL | 12.5 | 2 | 20 | 19.0 | 0.09 | 190.58 | 0.2 | 3.0 | 2.2 | 3 | 0 | -10.92 |
| UL | 12.5 | 2 | 20 | 19.0 | 0.045 | 190.58 | 0.2 | 3.0 | 2.2 | 3 | 0 | -7.91 |
| UL | 12.5 | 2 | 20 | 19.0 | 0.015 | 190.58 | 0.2 | 3.0 | 2.2 | 3 | 0 | -3.14 |
| UL | 12.5 | 2 | 20 | 19.0 | 0.00375 | 190.58 | 0.2 | 3.0 | 2.2 | 3 | 0 | 2.88 |
| NB-IoT, LEO1200 | UL | 30 | 2 | 20 | 1.1 | 0.18 | 164.49 | 0.1 | 3.0 | 2.2 | 3 | 0 | -5.64 |
| UL | 30 | 2 | 20 | 1.1 | 0.09 | 164.49 | 0.1 | 3.0 | 2.2 | 3 | 0 | -2.63 |
| UL | 30 | 2 | 20 | 1.1 | 0.045 | 164.49 | 0.1 | 3.0 | 2.2 | 3 | 0 | 0.38 |
| UL | 30 | 2 | 20 | 1.1 | 0.015 | 164.49 | 0.1 | 3.0 | 2.2 | 3 | 0 | 5.15 |
| UL | 30 | 2 | 20 | 1.1 | 0.00375 | 164.49 | 0.1 | 3.0 | 2.2 | 3 | 0 | 11.17 |
| NB-IoT, LEO600 | UL | 30 | 2 | 20 | 1.1 | 0.18 | 159.10 | 0.1 | 3.0 | 2.2 | 3 | 0 | -0.25 |
| UL | 30 | 2 | 20 | 1.1 | 0.09 | 159.10 | 0.1 | 3.0 | 2.2 | 3 | 0 | 2.76 |
| UL | 30 | 2 | 20 | 1.1 | 0.045 | 159.10 | 0.1 | 3.0 | 2.2 | 3 | 0 | 5.77 |
| UL | 30 | 2 | 20 | 1.1 | 0.015 | 159.10 | 0.1 | 3.0 | 2.2 | 3 | 0 | 10.54 |
| UL | 30 | 2 | 20 | 1.1 | 0.00375 | 159.10 | 0.1 | 3.0 | 2.2 | 3 | 0 | 16.56 |

Table 7 Downlink link budget for eMTC and NB-IoT with Set 2 parameters.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Scenario | Transmission mode | Elevation angle | Frequency [GHz] | TX: EIRP [dBm] | RX: G/T [dB/T] | Bandwidth [MHz] | Free space path loss [dB] | Atmospheric loss [dB] | Shadow fading margin [dB] | Scintillation Loss [dB] | Polarization loss [dB] | Additional losses [dB] | CNR [dB] |
| eMTC, GEO | DL | 20 | 2 | 83.83 | -33.62 | 1.08 | 190.41 | 0.2 | 3 | 2.2 | 3 | 0 | -10.34 |
| eMTC, LEO1200 | DL | 30 | 2 | 64.33 | -33.62 | 1.08 | 164.49 | 0.1 | 3 | 2.2 | 3 | 0 | -3.81 |
| eMTC, LEO600 | DL | 30 | 2 | 58.33 | -33.62 | 1.08 | 159.10 | 0.1 | 3 | 2.2 | 3 | 0 | -4.42 |
| NB-IoT, GEO | DL | 20 | 2 | 76.05 | -33.62 | 0.18 | 190.41 | 0.2 | 3 | 2.2 | 3 | 0 | -10.34 |
| NB-IoT, LEO1200 | DL | 30 | 2 | 56.55 | -33.62 | 0.18 | 164.49 | 0.1 | 3 | 2.2 | 3 | 0 | -3.81 |
| NB-IoT, LEO600 | DL | 30 | 2 | 50.55 | -33.62 | 0.18 | 159.10 | 0.1 | 3 | 2.2 | 3 | 0 | -4.42 |

Table 8 Uplink link budget for eMTC with Set 2 parameters

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Scenario | Transmission mode | Elevation angle | Frequency [GHz] | TX: EIRP [dBm] | RX: G/T [dB/T] | Bandwidth [MHz] | Free space path loss [dB] | Atmospheric loss [dB] | Shadow fading margin [dB] | Scintillation Loss [dB] | Polarization loss [dB] | Additional losses [dB] | CNR [dB] |
| eMTC, GEO | UL | 20 | 2 | 20 | 14.0 | 1.08 | 190.41 | 0.2 | 3.00 | 2.2 | 3 | 0 | -26.55 |
| UL | 20 | 2 | 20 | 14.0 | 0.36 | 190.41 | 0.2 | 3.00 | 2.2 | 3 | 0 | -21.78 |
| UL | 20 | 2 | 20 | 14.0 | 0.18 | 190.41 | 0.2 | 3.00 | 2.2 | 3 | 0 | -18.77 |
| UL | 20 | 2 | 20 | 14.0 | 0.09 | 190.41 | 0.2 | 3.00 | 2.2 | 3 | 0 | -15.76 |
| UL | 20 | 2 | 20 | 14.0 | 0.045 | 190.41 | 0.2 | 3.00 | 2.2 | 3 | 0 | -12.75 |
| UL | 20 | 2 | 20 | 14.0 | 0.03 | 190.41 | 0.2 | 3.00 | 2.2 | 3 | 0 | -10.99 |
| eMTC, LEO1200 | UL | 30 | 2 | 20 | -4.9 | 1.08 | 164.49 | 0.1 | 3.00 | 2.2 | 3 | 0 | -19.42 |
| UL | 30 | 2 | 20 | -4.9 | 0.36 | 164.49 | 0.1 | 3.00 | 2.2 | 3 | 0 | -14.65 |
| UL | 30 | 2 | 20 | -4.9 | 0.18 | 164.49 | 0.1 | 3.00 | 2.2 | 3 | 0 | -11.64 |
| UL | 30 | 2 | 20 | -4.9 | 0.09 | 164.49 | 0.1 | 3.00 | 2.2 | 3 | 0 | -8.63 |
| UL | 30 | 2 | 20 | -4.9 | 0.045 | 164.49 | 0.1 | 3.00 | 2.2 | 3 | 0 | -5.62 |
| UL | 30 | 2 | 20 | -4.9 | 0.03 | 164.49 | 0.1 | 3.00 | 2.2 | 3 | 0 | -3.86 |
| eMTC, LEO600 | UL | 30 | 2 | 20 | -4.9 | 1.08 | 159.10 | 0.1 | 3.00 | 2.2 | 3 | 0 | -14.03 |
| UL | 30 | 2 | 20 | -4.9 | 0.36 | 159.10 | 0.1 | 3.00 | 2.2 | 3 | 0 | -9.26 |
| UL | 30 | 2 | 20 | -4.9 | 0.18 | 159.10 | 0.1 | 3.00 | 2.2 | 3 | 0 | -6.25 |
| UL | 30 | 2 | 20 | -4.9 | 0.09 | 159.10 | 0.1 | 3.00 | 2.2 | 3 | 0 | -3.24 |
| UL | 30 | 2 | 20 | -4.9 | 0.045 | 159.10 | 0.1 | 3.00 | 2.2 | 3 | 0 | -0.23 |
| UL | 30 | 2 | 20 | -4.9 | 0.03 | 159.10 | 0.1 | 3.00 | 2.2 | 3 | 0 | 1.53 |

Table 9 Uplink link budget for NB-IoT with Set 2 parameters

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Scenario | Transmission mode | Elevation angle | Frequency [GHz] | TX: EIRP [dBm] | RX: G/T [dB/T] | Bandwidth [MHz] | Free space path loss [dB] | Atmospheric loss [dB] | Shadow fading margin [dB] | Scintillation Loss [dB] | Polarization loss [dB] | Additional losses [dB] | CNR [dB] |
| NB-IoT, GEO | UL | 20 | 2 | 20 | 14.0 | 0.18 | 190.41 | 0.2 | 3.00 | 2.2 | 3 | 0 | -18.77 |
| UL | 20 | 2 | 20 | 14.0 | 0.09 | 190.41 | 0.2 | 3.00 | 2.2 | 3 | 0 | -15.76 |
| UL | 20 | 2 | 20 | 14.0 | 0.045 | 190.41 | 0.2 | 3.00 | 2.2 | 3 | 0 | -12.75 |
| UL | 20 | 2 | 20 | 14.0 | 0.015 | 190.41 | 0.2 | 3.00 | 2.2 | 3 | 0 | -7.98 |
| UL | 20 | 2 | 20 | 14.0 | 0.00375 | 190.41 | 0.2 | 3.00 | 2.2 | 3 | 0 | -1.95 |
| NB-IoT, LEO1200 | UL | 30 | 2 | 20 | -4.9 | 0.18 | 164.49 | 0.1 | 3.00 | 2.2 | 3 | 0 | -11.64 |
| UL | 30 | 2 | 20 | -4.9 | 0.09 | 164.49 | 0.1 | 3.00 | 2.2 | 3 | 0 | -8.63 |
| UL | 30 | 2 | 20 | -4.9 | 0.045 | 164.49 | 0.1 | 3.00 | 2.2 | 3 | 0 | -5.62 |
| UL | 30 | 2 | 20 | -4.9 | 0.015 | 164.49 | 0.1 | 3.00 | 2.2 | 3 | 0 | -0.85 |
| UL | 30 | 2 | 20 | -4.9 | 0.00375 | 164.49 | 0.1 | 3.00 | 2.2 | 3 | 0 | 5.17 |
| NB-IoT, LEO600 | UL | 30 | 2 | 20 | -4.9 | 0.18 | 159.10 | 0.1 | 3.00 | 2.2 | 3 | 0 | -6.25 |
| UL | 30 | 2 | 20 | -4.9 | 0.09 | 159.10 | 0.1 | 3.00 | 2.2 | 3 | 0 | -3.24 |
| UL | 30 | 2 | 20 | -4.9 | 0.045 | 159.10 | 0.1 | 3.00 | 2.2 | 3 | 0 | -0.23 |
| UL | 30 | 2 | 20 | -4.9 | 0.015 | 159.10 | 0.1 | 3.00 | 2.2 | 3 | 0 | 4.54 |
| UL | 30 | 2 | 20 | -4.9 | 0.00375 | 159.10 | 0.1 | 3.00 | 2.2 | 3 | 0 | 10.56 |

Table 10 Downlink link budget for eMTC and NB-IoT with Set 3 parameters.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Scenario | Transmission mode | Elevation angle | Frequency [GHz] | TX: EIRP [dBm] | RX: G/T [dB/T] | Bandwidth [MHz] | Free space path loss [dB] | Atmospheric loss [dB] | Shadow fading margin [dB] | Scintillation Loss [dB] | Polarization loss [dB] | Additional losses [dB] | CNR [dB] |
| GEO | DL | 12.5 | 2 | 90.13 | -33.62 | 1.08 | 190.58 | 0.2 | 3 | 2.2 | 3 | 0 | -4.20 |
| LEO1200 | DL | 30 | 2 | 64.03 | -33.62 | 1.08 | 164.48 | 0.1 | 3 | 2.2 | 3 | 0 | -4.11 |
| LEO600 | DL | 30 | 2 | 58.63 | -33.62 | 1.08 | 159.09 | 0.1 | 3 | 2.2 | 3 | 0 | -4.11 |
| GEO | DL | 12.5 | 2 | 82.35 | -33.62 | 0.18 | 190.58 | 0.2 | 3 | 2.2 | 3 | 0 | -4.20 |
| LEO1200 | DL | 30 | 2 | 56.25 | -33.62 | 0.18 | 164.48 | 0.1 | 3 | 2.2 | 3 | 0 | -4.11 |
| LEO600 | DL | 30 | 2 | 50.85 | -33.62 | 0.18 | 159.09 | 0.1 | 3 | 2.2 | 3 | 0 | -4.11 |

Table 11 Uplink link budget for eMTC with Set 3 parameters.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Scenario | Transmission mode | Elevation angle | Frequency [GHz] | TX: EIRP [dBm] | RX: G/T [dB/T] | Bandwidth [MHz] | Free space path loss [dB] | Atmospheric loss [dB] | Shadow fading margin [dB] | Scintillation Loss [dB] | Polarization loss [dB] | Additional losses [dB] | CNR [dB] |
| eMTC, GEO | UL | 12.5 | 2 | 20 | 16.7 | 1.08 | 190.58 | 0.2 | 3.00 | 2.2 | 3 | 0 | -24.01 |
| UL | 12.5 | 2 | 20 | 16.7 | 0.36 | 190.58 | 0.2 | 3.00 | 2.2 | 3 | 0 | -19.24 |
| UL | 12.5 | 2 | 20 | 16.7 | 0.18 | 190.58 | 0.2 | 3.00 | 2.2 | 3 | 0 | -16.23 |
| UL | 12.5 | 2 | 20 | 16.7 | 0.09 | 190.58 | 0.2 | 3.00 | 2.2 | 3 | 0 | -13.22 |
| UL | 12.5 | 2 | 20 | 16.7 | 0.045 | 190.58 | 0.2 | 3.00 | 2.2 | 3 | 0 | -10.21 |
| UL | 12.5 | 2 | 20 | 16.7 | 0.03 | 190.58 | 0.2 | 3.00 | 2.2 | 3 | 0 | -8.45 |
| eMTC, LEO1200 | UL | 30 | 2 | 20 | -12.8 | 1.08 | 164.48 | 0.1 | 3.00 | 2.2 | 3 | 0 | -27.32 |
| UL | 30 | 2 | 20 | -12.8 | 0.36 | 164.48 | 0.1 | 3.00 | 2.2 | 3 | 0 | -22.55 |
| UL | 30 | 2 | 20 | -12.8 | 0.18 | 164.48 | 0.1 | 3.00 | 2.2 | 3 | 0 | -19.54 |
| UL | 30 | 2 | 20 | -12.8 | 0.09 | 164.48 | 0.1 | 3.00 | 2.2 | 3 | 0 | -16.52 |
| UL | 30 | 2 | 20 | -12.8 | 0.045 | 164.48 | 0.1 | 3.00 | 2.2 | 3 | 0 | -13.51 |
| UL | 30 | 2 | 20 | -12.8 | 0.03 | 164.48 | 0.1 | 3.00 | 2.2 | 3 | 0 | -11.75 |
| eMTC, LEO600 | UL | 30 | 2 | 20 | -12.8 | 1.08 | 159.09 | 0.1 | 3.00 | 2.2 | 3 | 0 | -21.92 |
| UL | 30 | 2 | 20 | -12.8 | 0.36 | 159.09 | 0.1 | 3.00 | 2.2 | 3 | 0 | -17.15 |
| UL | 30 | 2 | 20 | -12.8 | 0.18 | 159.09 | 0.1 | 3.00 | 2.2 | 3 | 0 | -14.14 |
| UL | 30 | 2 | 20 | -12.8 | 0.09 | 159.09 | 0.1 | 3.00 | 2.2 | 3 | 0 | -11.13 |
| UL | 30 | 2 | 20 | -12.8 | 0.045 | 159.09 | 0.1 | 3.00 | 2.2 | 3 | 0 | -8.12 |
| UL | 30 | 2 | 20 | -12.8 | 0.03 | 159.09 | 0.1 | 3.00 | 2.2 | 3 | 0 | -6.36 |

Table 12 Uplink link budget for NB-IoT with Set 3 parameters.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Scenario | Transmission mode | Elevation angle | Frequency [GHz] | TX: EIRP [dBm] | RX: G/T [dB/T] | Bandwidth [MHz] | Free space path loss [dB] | Atmospheric loss [dB] | Shadow fading margin [dB] | Scintillation Loss [dB] | Polarization loss [dB] | Additional losses [dB] | CNR [dB] |
| NB-IoT, GEO | UL | 12.5 | 2 | 20 | 16.7 | 0.18 | 190.58 | 0.2 | 3.00 | 2.2 | 3 | 0 | -16.23 |
| UL | 12.5 | 2 | 20 | 16.7 | 0.09 | 190.58 | 0.2 | 3.00 | 2.2 | 3 | 0 | -13.22 |
| UL | 12.5 | 2 | 20 | 16.7 | 0.045 | 190.58 | 0.2 | 3.00 | 2.2 | 3 | 0 | -10.21 |
| UL | 12.5 | 2 | 20 | 16.7 | 0.015 | 190.58 | 0.2 | 3.00 | 2.2 | 3 | 0 | -5.44 |
| UL | 12.5 | 2 | 20 | 16.7 | 0.00375 | 190.58 | 0.2 | 3.00 | 2.2 | 3 | 0 | 0.58 |
| NB-IoT, LEO1200 | UL | 30 | 2 | 20 | -12.8 | 0.18 | 164.48 | 0.1 | 3.00 | 2.2 | 3 | 0 | -19.54 |
| UL | 30 | 2 | 20 | -12.8 | 0.09 | 164.48 | 0.1 | 3.00 | 2.2 | 3 | 0 | -16.52 |
| UL | 30 | 2 | 20 | -12.8 | 0.045 | 164.48 | 0.1 | 3.00 | 2.2 | 3 | 0 | -13.51 |
| UL | 30 | 2 | 20 | -12.8 | 0.015 | 164.48 | 0.1 | 3.00 | 2.2 | 3 | 0 | -8.74 |
| UL | 30 | 2 | 20 | -12.8 | 0.00375 | 164.48 | 0.1 | 3.00 | 2.2 | 3 | 0 | -2.72 |
| NB-IoT, LEO600 | UL | 30 | 2 | 20 | -12.8 | 0.18 | 159.09 | 0.1 | 3.00 | 2.2 | 3 | 0 | -14.14 |
| UL | 30 | 2 | 20 | -12.8 | 0.09 | 159.09 | 0.1 | 3.00 | 2.2 | 3 | 0 | -11.13 |
| UL | 30 | 2 | 20 | -12.8 | 0.045 | 159.09 | 0.1 | 3.00 | 2.2 | 3 | 0 | -8.12 |
| UL | 30 | 2 | 20 | -12.8 | 0.015 | 159.09 | 0.1 | 3.00 | 2.2 | 3 | 0 | -3.35 |
| UL | 30 | 2 | 20 | -12.8 | 0.00375 | 159.09 | 0.1 | 3.00 | 2.2 | 3 | 0 | 2.67 |

Table 13 Downlink link budget for eMTC and NB-IoT with Set 4 parameters.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Scenario | Transmission mode | Elevation angle | Frequency [GHz] | TX: EIRP [dBm] | RX: G/T [dB/T] | Bandwidth [MHz] | Free space path loss [dB] | Atmospheric loss [dB] | Shadow fading margin [dB] | Scintillation Loss [dB] | Polarization loss [dB] | Additional losses [dB] | CNR [dB] |
| LEO600 | DL | 30 | 2 | 51.78 | -33.62 | 1.08 | 159.11 | 0.1 | 3 | 2.2 | 3 | 0 | -10.98 |
| LEO600 | DL | 30 | 2 | 44.00 | -33.62 | 0.18 | 159.11 | 0.1 | 3 | 2.2 | 3 | 0 | -10.98 |

Table 14 Uplink link budget for eMTC with Set 4 parameters.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Scenario | Transmission mode | Elevation angle | Frequency [GHz] | TX: EIRP [dBm] | RX: G/T [dB/T] | Bandwidth [MHz] | Free space path loss [dB] | Atmospheric loss [dB] | Shadow fading margin [dB] | Scintillation Loss [dB] | Polarization loss [dB] | Additional losses [dB] | CNR [dB] |
| eMTC, LEO600 | UL | 30 | 2 | 20 | -18.6 | 1.08 | 159.11 | 0.1 | 3.00 | 2.2 | 3 | 0 | -27.74 |
| UL | 30 | 2 | 20 | -18.6 | 0.36 | 159.11 | 0.1 | 3.00 | 2.2 | 3 | 0 | -22.97 |
| UL | 30 | 2 | 20 | -18.6 | 0.18 | 159.11 | 0.1 | 3.00 | 2.2 | 3 | 0 | -19.96 |
| UL | 30 | 2 | 20 | -18.6 | 0.09 | 159.11 | 0.1 | 3.00 | 2.2 | 3 | 0 | -16.95 |
| UL | 30 | 2 | 20 | -18.6 | 0.045 | 159.11 | 0.1 | 3.00 | 2.2 | 3 | 0 | -13.94 |
| UL | 30 | 2 | 20 | -18.6 | 0.03 | 159.11 | 0.1 | 3.00 | 2.2 | 3 | 0 | -12.18 |

Table 15 Uplink link budget for NB-IoT with Set 4 parameters.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Scenario | Transmission mode | Elevation angle | Frequency [GHz] | TX: EIRP [dBm] | RX: G/T [dB/T] | Bandwidth [MHz] | Free space path loss [dB] | Atmospheric loss [dB] | Shadow fading margin [dB] | Scintillation Loss [dB] | Polarization loss [dB] | Additional losses [dB] | CNR [dB] |
| NB-IoT, LEO600 | UL | 30 | 2 | 20 | -18.6 | 0.18 | 159.11 | 0.1 | 3.00 | 2.2 | 3 | 0 | -19.96 |
| UL | 30 | 2 | 20 | -18.6 | 0.09 | 159.11 | 0.1 | 3.00 | 2.2 | 3 | 0 | -16.95 |
| UL | 30 | 2 | 20 | -18.6 | 0.045 | 159.11 | 0.1 | 3.00 | 2.2 | 3 | 0 | -13.94 |
| UL | 30 | 2 | 20 | -18.6 | 0.015 | 159.11 | 0.1 | 3.00 | 2.2 | 3 | 0 | -9.17 |
| UL | 30 | 2 | 20 | -18.6 | 0.00375 | 159.11 | 0.1 | 3.00 | 2.2 | 3 | 0 | -3.15 |

## CMCC link budget results (R1-2102905)

**Table 5: Summary of preliminary link budget for calibration.**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | |  | **Set-1** | | | **Set 2** | | | **Set 3** | | | **Set 4** |
| **Satellite orbit** | GEO | LEO-1200 | LEO-600 | GEO | LEO-1200 | LEO-600 | GEO | LEO-1200 | LEO-600 | LEO-600 |
| **Satellite altitude (km)** | 35786 | 1200 | 600 | 35786 | 1200 | 600 | 35786 | 1200 | 600 | 600 |
| **Central beam center elevation (deg)** | 12.5 | 30 | 30 | 20 | 30 | 30 | 20.88 | 46.05 | 43.78 | 90 |
| **FSPL (dB)** | 190.6 | 164.5 | 159.1 | 190.4 | 164.5 | 159.1 | 190.4 | 162.3 | 156.9 | 154.0 |
|  | **UL/DL** | **BW (kHz)** |  |  | | | | | | | | | |
| **NB-IoT** | DL | 180 | CNR (dB) | -5.0 | 2.2 | 1.6 | -10.3 | -3.8 | -4.4 | -4.0 | -2.0 | -1.9 | -5.9 |
| UL | 180 | -13.9 | -5.6 | -0.3 | -18.8 | -11.6 | -6.3 | -16.0 | -17.4 | -11.9 | -14.9 |
| UL | 3.75 | 2.9 | 11.2 | 16.6 | -2.0 | 5.2 | 10.6 | 0.8 | -0.6 | 4.9 | 1.9 |
| **eMTC** | DL | 1080 | -5.0 | 2.2 | 1.6 | -10.3 | -3.8 | -4.4 | -4.0 | -2.0 | -1.9 | -5.9 |
| UL | 1080 | -21.7 | -13.4 | -8.0 | -26.5 | -19.4 | -14.0 | -23.8 | -25.2 | -19.7 | -22.7 |
| UL | 30 | -6.2 | 2.1 | 7.5 | -11.0 | -3.9 | 1.5 | -8.3 | -9.6 | -4.1 | -7.1 |

**Table 6: Summary of FSPL for some other elevation angles.**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **Set-1** | | | **Set 2** | | | **Set 3** | | | **Set 4** |
| **Satellite orbit** | GEO | LEO-1200 | LEO-600 | GEO | LEO-1200 | LEO-600 | GEO | LEO-1200 | LEO-600 | LEO-600 |
| **Satellite altitude (km)** | 35786 | 1200 | 600 | 35786 | 1200 | 600 | 35786 | 1200 | 600 | 600 |
| **Elevation angle (deg)** | **Center of a central beam** | 12.5 | 30 | 30 | 20 | 30 | 30 | 20.88 | 46.05 | 43.78 | 90 |
| **Edge of a central beam** | 2.3 | 26.3 | 27 | 11 | 22.2 | 23.8 | 12.5 | 30 | 30 | 30 |
| **Minimum elevation** | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| **FSPL (dB)** | **Center of a central beam** | 190.6 | 164.5 | 159.1 | 190.4 | 164.5 | 159.1 | 190.4 | 162.3 | 156.9 | 154.0 |
| **Edge of a central beam** | 190.8 | 165.1 | 159.7 | 190.6 | 165.9 | 160.4 | 190.6 | 164.5 | 159.1 | 159.1 |
| **Maximum FSPL** | 190.6 | 168.4 | 164.2 | 190.6 | 168.4 | 164.2 | 190.6 | 168.4 | 164.2 | 164.2 |

## ZTE link budget results (R1-2102916)

Table 3 DL CNR for NB-IoT/eMTC

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | GEO | LEO-600 | LEO-1200 |
| Set-1 | Minimum DL CNR (dB) | -8.06 | -2.02 | -1.41 |
| Set-2 | Minimum DL CNR (dB) | -13.52 | -8.73 | -8.17 |
| Set-3 | Minimum DL CNR (dB) | -7.17 | -7.08 | -7.08 |
| Set-4 | Minimum DL CNR (dB) |  | -13.95 |  |

Table 4 UL CNR for NB-IoT/eMTC

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Bandwidth | GEO | LEO-600 | LEO-1200 |
| Set-1 | 3.75 kHz  15 kHz  30 kHz  45 kHz  90 kHz  180 kHz  360 kHz  1080 kHz | -0.18  -6.20  -9.21  -10.97  -13.98  -16.99  -20.00  -24.77 | 12.97  6.95  3.94  2.17  -0.84  -3.85  -6.86  -11.63 | 7.57  1.55  -1.46  -3.22  -6.23  -9.24  -12.25  -17.03 |
| Set-2 | 3.75 kHz  15 kHz  30 kHz  45 kHz  90 kHz  180 kHz  360 kHz  1080 kHz | -5.14  -11.16  -14.17  -15.93  -18.94  -21.95  -24.96  -29.73 | 6.25  0.23  -2.78  -4.54  -7.55  -10.56  -13.57  -18.34 | 0.81  -5.21  -8.22  -9.98  -12.99  -16.00  -19.01  -23.78 |
| Set-3 | 3.75 kHz  15 kHz  30 kHz  45 kHz  90 kHz  180 kHz  360 kHz  1080 kHz | -2.38  -8.40  -11.41  -13.17  -16.18  -19.20  -22.21  -26.98 | -0.30  -6.32  -9.33  -11.09  -14.10  -17.11  -20.12  -24.89 | -5.69  -11.71  -14.72  -16.48  -19.49  -22.50  -25.52  -30.29 |
| Set-4 | 3.75 kHz  15 kHz  30 kHz  45 kHz  90 kHz  180 kHz  360 kHz  1080 kHz |  | -6.12  -12.14  -15.15  -16.91  -19.92  -22.93  -25.94  -30.71 |  |

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

|  |  |
| --- | --- |
|  |  |
| Figure 3 Illustration of DL CL for LEO-1200 in rural |  |
|  |  |
| Figure 4 Illustration of DL CL for GEO in ubran | Figure 5 Illustration of DL CL for LEO-600 in urban |
|  |  |
| Figure 6 Illustration of DL CL for LEO-1200 in urban |  |
|  |  |
| Figure 7 Illustration of DL CL for GEO in Dense urban | Figure 8 Illustration of DL CL for LEO-600 in Dense urban |
|  |  |
| Figure 9 Illustration of DL CL for LEO-1200 in Dense urban |  |

## Xiaomi link budget results (R1-2102972)

**Table 1. Link budgets for Set-1 satellites**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Satellite orbit | | | GEO | | LEO-1200 | | LEO-600 | |
| Transmission mode | | | DL | UL | DL | UL | DL | UL |
| EIRP[dBW] | NB-IOT | | 51.55 | -10 | 32.55 | -10 | 26.55 | -10 |
| eMTC | | 59.33 | -10 | 40.33 | -10 | 34.33 | -10 |
| G/T[dB/K] | | | -33.62 | 19 | -33.62 | 1.1 | -33.62 | 1.1 |
| FSPL[dB] | | | 190.96 | 190.96 | 164.49 | 164.49 | 159.10 | 159.10 |
| Frequency [GHz] | | | 2 | 2 | 2 | 2 | 2 | 2 |
| Elevation angle[°] | | | 12.5 | 12.5 | 30 | 30 | 30 | 30 |
| CNY[dB] | | NB-IOT | -5.39 | -14.31 | 2.18 | -5.64 | 1.57 | -0.25 |
| eMTC | -5.39 | -22.10 | 2.18 | -13.42 | 1.57 | -8.03 |

**Table 2. Link budgets for Set-2 satellites**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Satellite orbit | | | GEO | | LEO-1200 | | LEO-600 | |
| Transmission mode | | | DL | UL | DL | UL | DL | UL |
| EIRP[dBW] | NB-IOT | | 46.05 | -10 | 26.55 | -10 | 20.55 | -10 |
| eMTC | | 53.83 | -10 | 34.33 | -10 | 28.33 | -10 |
| G/T[dB/K] | | | -33.62 | 14 | -33.62 | -4.9 | -33.62 | -4.9 |
| FSPL[dB] | | | 189.66 | 189.66 | 164.49 | 164.49 | 159.10 | 159.10 |
| Frequency [GHz] | | | 2 | 2 | 2 | 2 | 2 | 2 |
| Elevation angle[°] | | | 20 | 20 | 30 | 30 | 30 | 30 |
| CNY[dB] | | NB-IOT | -9.59 | -18.01 | -3.82 | -11.64 | -4.43 | -6.25 |
| eMTC | -9.59 | -25.80 | -3.82 | -19.42 | -4.43 | -14.03 |

**Table 3. Link budgets for Set-3 satellites**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Satellite orbit | | | GEO | | LEO-1200 | | LEO-600 | |
| Transmission mode | | | DL | UL | DL | UL | DL | UL |
| EIRP[dBW] | NB-IOT | | 52.35 | -10 | 26.25 | -10 | 20.85 | -10 |
| eMTC | | 60.13 | -10 | 34.03 | -10 | 28.63 | -10 |
| G/T[dB/K] | | | -33.62 | 16.7 | -33.62 | -12.8 | -33.62 | -12.8 |
| FSPL[dB] | | | 190.96 | 190.96 | 164.49 | 164.49 | 159.10 | 159.10 |
| Frequency [GHz] | | | 2 | 2 | 2 | 2 | 2 | 2 |
| Elevation angle[°] | | | 12.5 | 12.5 | 30 | 30 | 30 | 30 |
| CNY[dB] | | NB-IOT | -4.59 | -16.61 | -4.12 | -19.54 | -4.13 | -14.15 |
| eMTC | -4.59 | -24.40 | -4.12 | -27.32 | -4.13 | -21.93 |

**Table 4. Link budgets for Set-4 satellites**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Satellite orbit | | | LEO-600 | |
| Transmission mode | | | DL | UL |
| EIRP[dBW] | NB-IOT | | 14 | -10 |
| eMTC | | 21.78 | -10 |
| G/T[dB/K] | | | -33.62 | -18.6 |
| Frequency [GHz] | | | 2 | 2 |
| FSPL[dB] | | | 159.10 | 159.10 |
| Elevation angle[°] | | | 30 | 30 |
| CNY[dB] | | NB-IOT | -10.98 | -19.95 |
| eMTC | -10.98 | -27.73 |

## Ericsson link budget results (R1-2103060)

Table 1 Ranking of simulation scenarios starting with most favourable to least favourable in terms of expected SNR for LEO and GEO.

|  |  |  |
| --- | --- | --- |
|  | **UL** | **DL** |
| **LEO (600 km)** | Set 1, Set 2, Set 3, Set 4 | Set 1, Set 3, Set 2, Set 4 |
| **LEO (1200 km)** | Set 1, Set 2, Set 3 | Set 1, Set 2, Set 3 |
| **GEO** | Set 1, Set 3, Set 2 | Set 3, Set 1, Set 2 |

Table 2 Connection density for eMTC in TN and NTN.

|  |  |  |  |
| --- | --- | --- | --- |
| **Scenario** | **LTE-M, TN, Conf A** | **LTE-M, TN, Conf B** | **NTN** |
| **Inter-site (or inter-spotbeam) distance (ISD)** | 500 m | 1732 m | 40 km |
| **No. of devices supported per sq. km with 6 PRBs** | 5,680,683 | 393,600 | 467 |

600 km LEO

Table 4 Link budget for 600 km LEO satellite for Set 1.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| System | NB-IoT | | eMTC | |
|  | DL | UL | DL | UL |
| TX: EIRP/spotbeam [dBm] | 56.6 | 20.0 | 64.3 | 20.0 |
| RX: G/T [dB/T] | -33.6 | 1.1 | -33.6 | 1.1 |
| Bandwidth [Hz] | 1.80E+05 | 1.80E+05 | 1.08E+06 | 1.80E+05 |
| Free space path loss (PL) [dB] | 159.1 | 159.1 | 159.1 | 159.1 |
| Atmospheric loss (LA) | 0.1 | 0.1 | 0.1 | 0.1 |
| Shadow fading margin (SF) [dB] | 3 | 3 | 3 | 3 |
| Scintillation loss (SL) [dB] | 2.2 | 2.2 | 2.2 | 2.2 |
| Polarization loss [dB] | 3 | 3 | 3 | 3 |
| Additional losses (AD) [dB] | 3 | 3 | 3 | 3 |
| Target SNR [dB] | **-1.4** | **-3.2** | **-1.4** | **-3.2** |

Table 5 Link budget for 600 km LEO satellite for Set 2.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| System | NB-IoT | | eMTC | |
|  | DL | UL | DL | UL |
| TX: EIRP/spotbeam [dBm] | 50.6 | 20.0 | 58.3 | 20.0 |
| RX: G/T [dB/T] | -33.6 | -4.9 | -33.6 | -4.9 |
| Bandwidth [Hz] | 1.80E+05 | 1.80E+05 | 1.08E+06 | 1.80E+05 |
| Free space path loss (PL) [dB] | 159.1 | 159.1 | 159.1 | 159.1 |
| Atmospheric loss (LA) | 0.1 | 0.1 | 0.1 | 0.1 |
| Shadow fading margin (SF) [dB] | 3 | 3 | 3 | 3 |
| Scintillation loss (SL) [dB] | 2.2 | 2.2 | 2.2 | 2.2 |
| Polarization loss [dB] | 3 | 3 | 3 | 3 |
| Additional losses (AD) [dB] | 3 | 3 | 3 | 3 |
| Target SNR [dB] | **-7.4** | **-9.2** | **-7.4** | **-9.2** |

Table 6 Link budget for 600 km LEO satellite for Set 3.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| System | NB-IoT | | eMTC | |
|  | DL | UL | DL | UL |
| TX: EIRP/spotbeam [dBm] | 50.9 | 20.0 | 58.6 | 20.0 |
| RX: G/T [dB/T] | -33.6 | -12.8 | -33.6 | -12.8 |
| Bandwidth [Hz] | 1.80E+05 | 1.80E+05 | 1.08E+06 | 1.80E+05 |
| Free space path loss (PL) [dB] | 159.1 | 159.1 | 159.1 | 159.1 |
| Atmospheric loss (LA) | 0.1 | 0.1 | 0.1 | 0.1 |
| Shadow fading margin (SF) [dB] | 3 | 3 | 3 | 3 |
| Scintillation loss (SL) [dB] | 2.2 | 2.2 | 2.2 | 2.2 |
| Polarization loss [dB] | 3 | 3 | 3 | 3 |
| Additional losses (AD) [dB] | 3 | 3 | 3 | 3 |
| Target SNR [dB] | **-7.1** | **-17.1** | **-7.1** | **-17.1** |

Table 7 Link budget for 600 km LEO satellite for Set 4.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| System | NB-IoT | | eMTC | |
|  | DL | UL | DL | UL |
| TX: EIRP/spotbeam [dBm] | 44.0 | 20.0 | 51.8 | 20.0 |
| RX: G/T [dB/T] | -33.6 | -18.6 | -33.6 | -18.6 |
| Bandwidth [Hz] | 1.80E+05 | 1.80E+05 | 1.08E+06 | 1.80E+05 |
| Free space path loss (PL) [dB] | 159.1 | 159.1 | 159.1 | 159.1 |
| Atmospheric loss (LA) | 0.1 | 0.1 | 0.1 | 0.1 |
| Shadow fading margin (SF) [dB] | 3 | 3 | 3 | 3 |
| Scintillation loss (SL) [dB] | 2.2 | 2.2 | 2.2 | 2.2 |
| Polarization loss [dB] | 3 | 3 | 3 | 3 |
| Additional losses (AD) [dB] | 3 | 3 | 3 | 3 |
| Target SNR [dB] | **-13.9** | **-22.9** | **-13.9** | **-22.9** |

1200 km LEO

Table 8 Link budget for 1200 km LEO satellite for Set 1.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| System | NB-IoT | | eMTC | |
|  | DL | UL | DL | UL |
| TX: EIRP/spotbeam [dBm] | 62.6 | 20.0 | 70.3 | 20.0 |
| RX: G/T [dB/T] | -33.6 | 1.1 | -33.6 | 1.1 |
| Bandwidth [Hz] | 1.80E+05 | 1.80E+05 | 1.08E+06 | 1.80E+05 |
| Free space path loss (PL) [dB] | 164.5 | 164.5 | 164.5 | 164.5 |
| Atmospheric loss (LA) | 0.1 | 0.1 | 0.1 | 0.1 |
| Shadow fading margin (SF) [dB] | 3 | 3 | 3 | 3 |
| Scintillation loss (SL) [dB] | 2.2 | 2.2 | 2.2 | 2.2 |
| Polarization loss [dB] | 3 | 3 | 3 | 3 |
| Additional losses (AD) [dB] | 3 | 3 | 3 | 3 |
| Target SNR [dB] | **-0.8** | **-8.6** | **-0.8** | **-8.6** |

Table 9 Link budget for 1200 km LEO satellite for Set 2.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| System | NB-IoT | | eMTC | |
|  | DL | UL | DL | UL |
| TX: EIRP/spotbeam [dBm] | 56.6 | 20.0 | 64.3 | 20.0 |
| RX: G/T [dB/T] | -33.6 | -4.9 | -33.6 | -4.9 |
| Bandwidth [Hz] | 1.80E+05 | 1.80E+05 | 1.08E+06 | 1.80E+05 |
| Free space path loss (PL) [dB] | 164.5 | 164.5 | 164.5 | 164.5 |
| Atmospheric loss (LA) | 0.1 | 0.1 | 0.1 | 0.1 |
| Shadow fading margin (SF) [dB] | 3 | 3 | 3 | 3 |
| Scintillation loss (SL) [dB] | 2.2 | 2.2 | 2.2 | 2.2 |
| Polarization loss [dB] | 3 | 3 | 3 | 3 |
| Additional losses (AD) [dB] | 3 | 3 | 3 | 3 |
| Target SNR [dB] | **-6.8** | **-14.6** | **-6.8** | **-14.6** |

Table 10 Link budget for 1200 km LEO satellite for Set 3.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| System | NB-IoT | | eMTC | |
|  | DL | UL | DL | UL |
| TX: EIRP/spotbeam [dBm] | 56.3 | 20.0 | 64.0 | 20.0 |
| RX: G/T [dB/T] | -33.6 | -12.8 | -33.6 | -12.8 |
| Bandwidth [Hz] | 1.80E+05 | 1.80E+05 | 1.08E+06 | 1.80E+05 |
| Free space path loss (PL) [dB] | 164.5 | 164.5 | 164.5 | 164.5 |
| Atmospheric loss (LA) | 0.1 | 0.1 | 0.1 | 0.1 |
| Shadow fading margin (SF) [dB] | 3 | 3 | 3 | 3 |
| Scintillation loss (SL) [dB] | 2.2 | 2.2 | 2.2 | 2.2 |
| Polarization loss [dB] | 3 | 3 | 3 | 3 |
| Additional losses (AD) [dB] | 3 | 3 | 3 | 3 |
| Target SNR [dB] | **-7.1** | **-22.5** | **-7.1** | **-22.5** |

GEO

Table 11 Link budget for GEO satellite for Set 1.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| System | NB-IoT | | eMTC | |
|  | DL | UL | DL | UL |
| TX: EIRP/spotbeam [dBm] | 81.6 | 20.0 | 89.3 | 20.0 |
| RX: G/T [dB/T] | -33.6 | 19.0 | -33.6 | 19.0 |
| Bandwidth [Hz] | 180000.0 | 180000.0 | 1080000.0 | 180000.0 |
| Free space path loss (PL) [dB] | 190.57 | 190.57 | 190.57 | 190.57 |
| Atmospheric loss (LA) | 0.2 | 0.2 | 0.2 | 0.2 |
| Shadow fading margin (SF) [dB] | 3 | 3 | 3 | 3 |
| Scintillation loss (SL) [dB] | 2.2 | 2.2 | 2.2 | 2.2 |
| Polarization loss [dB] | 3 | 3 | 3 | 3 |
| Additional losses (AD) [dB] | 3 | 3 | 3 | 3 |
| Target SNR [dB] | **-8** | **-16.92** | **-8** | **-16.92** |

Table 12 Link budget for GEO satellite for Set 2.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| System | NB-IoT | | eMTC | |
|  | DL | UL | DL | UL |
| TX: EIRP/spotbeam [dBm] | 76.1 | 20.0 | 83.8 | 20.0 |
| RX: G/T [dB/T] | -33.6 | 14.0 | -33.6 | 14.0 |
| Bandwidth [Hz] | 180000.0 | 180000.0 | 1080000.0 | 180000.0 |
| Free space path loss (PL) [dB] | 190.41 | 190.41 | 190.41 | 190.41 |
| Atmospheric loss (LA) | 0.2 | 0.2 | 0.2 | 0.2 |
| Shadow fading margin (SF) [dB] | 3 | 3 | 3 | 3 |
| Scintillation loss (SL) [dB] | 2.2 | 2.2 | 2.2 | 2.2 |
| Polarization loss [dB] | 3 | 3 | 3 | 3 |
| Additional losses (AD) [dB] | 3 | 3 | 3 | 3 |
| Target SNR [dB] | **-13.33** | **-21.76** | **-13.33** | **-21.76** |

Table 13 Link budget for GEO satellite for Set 3.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| System | NB-IoT | | eMTC | |
|  | DL | UL | DL | UL |
| TX: EIRP/spotbeam [dBm] | 82.4 | 20.0 | 90.1 | 20.0 |
| RX: G/T [dB/T] | -33.6 | 16.7 | -33.6 | 16.7 |
| Bandwidth [Hz] | 180000.0 | 180000.0 | 1080000.0 | 180000.0 |
| Free space path loss (PL) [dB] | 190.57 | 190.57 | 190.57 | 190.57 |
| Atmospheric loss (LA) | 0.2 | 0.2 | 0.2 | 0.2 |
| Shadow fading margin (SF) [dB] | 3 | 3 | 3 | 3 |
| Scintillation loss (SL) [dB] | 2.2 | 2.2 | 2.2 | 2.2 |
| Polarization loss [dB] | 3 | 3 | 3 | 3 |
| Additional losses (AD) [dB] | 3 | 3 | 3 | 3 |
| Target SNR [dB] | **-7.20** | **-19.22** | **-7.20** | **-19.22** |

## Qualcomm link budget results (R1-2103070)

Link Budgets for Set 2 (LEO)

Table 1: Assumptions for calculating uplink link budgets in S-band LEO satellites (Set 2 in [2])

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Orbit Alt. (km)** | **Sat Antenna Gain (dBi)** | **G/T (dB/K)** | **UE Power (dBm)** | **UE antenna gain (dBi)** | **Shadowing Margin (dB)** | **Polarization loss (dB)** | **Signal BW**  **(kHz)** | **Channel Condition** |
| 1200/600 | 24 | -4.9 | 23  *(20)* | 0 | 3 | 3 (1 Tx ant) | 180 | Clear Sky and LOS |

Table 2: Uplink link budgets for beam center UEs with a full PRB UL transmission to S-band LEO satellites (Set 2 in [2]). The numbers in parentheses represent the achievable SNRs with 20 dBm power class UEs.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Elevation Angle (Deg)** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** |
| SNR (dB) @1200 km | -12.4  *(-15.4)* | -10.3  *(-13.3)* | -8.5  *(-11.5)* | -7.1  *(-10.1)* | -6.0  *(-9.0)* | -5.1  *(-8.1)* | -4.6  *(-7.6)* | -4.2  *(-7.2)* | -4.1  *(-7.1)* |
| SNR (dB) @600 km | -8.2  *(-11.2)* | -5.4  *(-8.4)* | -3.2  *(-6.2)* | -1.4  *(-4.4)* | 0.1  *(-3.1)* | 1.2  *(-2.2)* | 2.6  *(-1.6)* | 2.2  *(-1.2)* | 2.1  *(-1.1)* |

Table 3: Assumptions for calculating downlink link budgets in LEO satellites (Set 2 in [2])

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Orbit Alt. (km)** | **Baseline Sat EIRP** | **UE antenna gain (dBi)** | **UE NF (dB)** | **Shadowing Margin (dB)** | **No. of UE antennas** | **Channel Condition** |
| 1200 | 64dBm/MHz | 0 | 9 | 3 | 1 | Clear Sky and LOS |
| 600 | 58dBm/MHz | 0 | 9 | 3 | 1 | Clear Sky and LOS |

Table 4: Downlink link budgets for transmission from LEO satellites (Set 2 in [2]).

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Elevation Angle (Deg)** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** |
| SNR (dB) @1200 km | -7.58 | -5.47 | -3.69 | -2.24 | -2.88 | -1.72 | 0.30 | 0.63 | 0.75 |
| SNR (dB) @600 km | -9.39 | -6.54 | -4.30 | -2.58 | -2.70 | -1.64 | 0.28 | 0.65 | 0.77 |

Link Budgets for Set 3 (LEO)

Table 5: Comparing Set 3 vs Set 2 UL link budgets for LEO satellites, at beam edge elevation for Set 3

|  |  |  |
| --- | --- | --- |
| **Elevation Angle = 30 Degrees** | **Set 2** | **Set 3** |
| Uplink SNR (dB) @1200 km | -11.5 | **-19.4** |
| Uplink SNR (dB) @600 km | -6.2 | **-14** |

Link Budgets for Set 4 (LEO 600 km orbit only)

Table 6: Comparing Set 4 vs Set 2 vs Set 3 UL link budgets for LEO satellites, at beam edge elevation for Set 4

|  |  |  |  |
| --- | --- | --- | --- |
| **Elevation Angle**  **= 30 Degrees** | **Set 2** | **Set 3** | **Set 4** |
| Uplink SNR (dB) @600 km | -6.2 | -14 | **-19.9** |

Table 7: Comparing Set 4 vs Set 2 vs Set 3 DL link budgets for LEO satellites, at beam edge elevation for Set 4

|  |  |  |  |
| --- | --- | --- | --- |
| **Elevation Angle**  **= 30 Degrees** | **Set 2** | **Set 3** | **Set 4** |
| Downlink SNR (dB) @600 km | -4.3 | -4.3 | **-10.9** |

## Apple link budget results (R1-2103132)

*Link budget for Set 1:*

Table 1: DL NB-IoT/eMTC link budget based on set 1 satellite parameters in [5]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Satellite orbit | GEO | | LEO-1200 | | LEO-600 | |
|  | NB-IoT | eMTC | NB-IoT | eMTC | NB-IoT | eMTC |
| Satellite EIRP density (dBW/MHz) | 59 | | 40 | | 34 | |
| Channel bandwidth (MHz) | 0.18 | 1.08 | 0.18 | 1.08 | 0.18 | 1.08 |
| **Satellite EIRP (dBm)** | **81.55** | **89.33** | **62.55** | **70.33** | **56.55** | **64.33** |
|  |  | |  | |  | |
| Central beam edge elevation (degree) | 12.5 | | 30 | | 30 | |
| Max. distance between satellite and IoT device (km) | 40308 | | 1998 | | 1075 | |
| Carrier frequency (GHz) | 2 | | 2 | | 2 | |
| **Free space path loss (dB)** | **190.58** | | **164.48** | | **159.10** | |
| Shadowing (dB) | 3 | | 3 | | 3 | |
| Atmospheric path loss (dB) | 0.2 | | 0.1 | | 0.1 | |
| Scintillation loss (dB) | 2.2 | | 2.2 | | 2.2 | |
| Polarization loss (dB) | 3 | | 3 | | 3 | |
|  |  | |  | |  | |
| IoT antenna temperature (K) | 290 | | 290 | | 290 | |
| Thermal noise (dBW/Hz) | -174 | | -174 | | -174 | |
| **Noise floor (dBm)** | **-121.45** | **-113.67** | **-121.45** | **-113.67** | **-121.45** | **-113.67** |
| IoT noise figure (dB) | 9 | | 9 | | 9 | |
| IoT device antenna gain (dBi) | 0 | | 0 | | 0 | |
|  |  | |  | |  | |
| **CNR (dB)** | **-4.98** | **-4.98** | **2.22** | **2.22** | **1.60** | **1.60** |

Table 2: UL NB-IoT/eMTC link budget based on set 1 satellite parameters in [5]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Satellite orbit | GEO | | LEO-1200 | | LEO-600 | |
|  | NB-IoT | eMTC | NB-IoT | eMTC | NB-IoT | eMTC |
| IoT device max Tx power (dBm) | 20 | | 20 | | 20 | |
| IoT device antenna gain (dBi) | 0 | | 0 | | 0 | |
| **IoT device EIRP (dBm)** | **20** | | **20** | | **20** | |
|  |  | |  | |  | |
| Central beam edge elevation (degree) | 12.5 | | 30 | | 30 | |
| Max. distance between satellite and IoT device (km) | 40308 | | 1998 | | 1075 | |
| Carrier frequency (GHz) | 2 | | 2 | | 2 | |
| **Free space path loss (dB)** | **190.58** | | **164.48** | | **159.10** | |
| Shadowing (dB) | 3 | | 3 | | 3 | |
| Atmospheric path loss (dB) | 0.2 | | 0.1 | | 0.1 | |
| Scintillation loss (dB) | 2.2 | | 2.2 | | 2.2 | |
| Polarization loss (dB) | 3 | | 3 | | 3 | |
|  |  | |  | |  | |
| Antenna temperature (K) | 290 | | 290 | | 290 | |
| G/T (dB/K) | 19 | | 1.1 | | 1.1 | |
| Satellite Rx gain (dBi) | 43.63 | | 25.72 | | 25.72 | |
| Channel bandwidth (MHz) | 0.015 | 0.18 | 0.015 | 0.18 | 0.015 | 0.18 |
|  |  | |  | |  | |
| **CNR (dB)** | **-3.12** | **-13.91** | **5.18** | **-5.61** | **10.56** | **-0.23** |

*Link budget for Set 2:*

Table 3: DL NB-IoT/eMTC link budget based on set 2 satellite parameters in [5]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Satellite orbit | GEO | | LEO-1200 | | LEO-600 | |
|  | NB-IoT | eMTC | NB-IoT | eMTC | NB-IoT | eMTC |
| Satellite EIRP density (dBW/MHz) | 53.5 | | 34 | | 28 | |
| Channel bandwidth (MHz) | 0.18 | 1.08 | 0.18 | 1.08 | 0.18 | 1.08 |
| **Satellite EIRP (dBm)** | **76.05** | **83.83** | **56.55** | **64.33** | **50.55** | **58.33** |
|  |  | |  | |  | |
| Central beam edge elevation (degree) | 12.5 | | 30 | | 30 | |
| Max. distance between satellite and IoT device (km) | 40308 | | 1998 | | 1075 | |
| Carrier frequency (GHz) | 2 | | 2 | | 2 | |
| **Free space path loss (dB)** | **190.58** | | **164.48** | | **159.10** | |
| Shadowing (dB) | 3 | | 3 | | 3 | |
| Atmospheric path loss (dB) | 0.2 | | 0.1 | | 0.1 | |
| Scintillation loss (dB) | 2.2 | | 2.2 | | 2.2 | |
| Polarization loss (dB) | 3 | | 3 | | 3 | |
|  |  | |  | |  | |
| IoT antenna temperature (K) | 290 | | 290 | | 290 | |
| Thermal noise (dBW/Hz) | -174 | | -174 | | -174 | |
| **Noise floor (dBm)** | **-121.45** | **-113.67** | **-121.45** | **-113.67** | **-121.45** | **-113.67** |
| IoT noise figure (dB) | 9 | | 9 | | 9 | |
| IoT device antenna gain (dBi) | 0 | | 0 | | 0 | |
|  |  | |  | |  | |
| **CNR (dB)** | **-10.48** | **-10.48** | **-3.78** | **-3.78** | **-4.40** | **-4.40** |

Table 4: UL NB-IoT/eMTC link budget based on set 2 satellite parameters in [5]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Satellite orbit | GEO | | LEO-1200 | | LEO-600 | |
|  | NB-IoT | eMTC | NB-IoT | eMTC | NB-IoT | eMTC |
| IoT device max Tx power (dBm) | 20 | | 20 | | 20 | |
| IoT device antenna gain (dBi) | 0 | | 0 | | 0 | |
| **IoT device EIRP (dBm)** | **20** | | **20** | | **20** | |
|  |  | |  | |  | |
| Central beam edge elevation (degree) | 12.5 | | 30 | | 30 | |
| Max. distance between satellite and IoT device (km) | 40308 | | 1998 | | 1075 | |
| Carrier frequency (GHz) | 2 | | 2 | | 2 | |
| **Free space path loss (dB)** | **190.58** | | **164.48** | | **159.10** | |
| Shadowing (dB) | 3 | | 3 | | 3 | |
| Atmospheric path loss (dB) | 0.2 | | 0.1 | | 0.1 | |
| Scintillation loss (dB) | 2.2 | | 2.2 | | 2.2 | |
| Polarization loss (dB) | 3 | | 3 | | 3 | |
|  |  | |  | |  | |
| Antenna temperature (K) | 290 | | 290 | | 290 | |
| G/T (dB/K) | 14 | | -4.9 | | -4.9 | |
| Satellite Rx gain (dBi) | 38.62 | | 19.72 | | 19.72 | |
| Channel bandwidth (MHz) | 0.015 | 0.18 | 0.015 | 0.18 | 0.015 | 0.18 |
|  |  | |  | |  | |
| **CNR (dB)** | **-8.12** | **-18.91** | **-0.82** | **-11.61** | **4.56** | **-6.23** |

*Link budget for Set 3:*

Table 5: DL NB-IoT/eMTC link budget based on set 3 satellite parameters in [2]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Satellite orbit | GEO | | LEO-1200 | | LEO-600 | |
|  | NB-IoT | eMTC | NB-IoT | eMTC | NB-IoT | eMTC |
| Satellite EIRP density (dBW/MHz) | 59.8 | | 33.7 | | 28.3 | |
| Channel bandwidth (MHz) | 0.18 | 1.08 | 0.18 | 1.08 | 0.18 | 1.08 |
| **Satellite EIRP (dBm)** | **82.35** | **90.13** | **56.25** | **64.03** | **50.85** | **58.63** |
|  |  | |  | |  | |
| Central beam edge elevation (degree) | 12.5 | | 30 | | 30 | |
| Max. distance between satellite and IoT device (km) | 40308 | | 1998 | | 1075 | |
| Carrier frequency (GHz) | 2 | | 2 | | 2 | |
| **Free space path loss (dB)** | **190.20** | | **164.48** | | **159.10** | |
| Shadowing (dB) | 3 | | 3 | | 3 | |
| Atmospheric path loss (dB) | 0.2 | | 0.1 | | 0.1 | |
| Scintillation loss (dB) | 2.2 | | 2.2 | | 2.2 | |
| Polarization loss (dB) | 3 | | 3 | | 3 | |
|  |  | |  | |  | |
| IoT antenna temperature (K) | 290 | | 290 | | 290 | |
| Thermal noise (dBW/Hz) | -174 | | -174 | | -174 | |
| **Noise floor (dBm)** | **-121.45** | **-113.67** | **-121.45** | **-113.67** | **-121.45** | **-113.67** |
| IoT noise figure (dB) | 9 | | 9 | | 9 | |
| IoT device antenna gain (dBi) | 0 | | 0 | | 0 | |
|  |  | |  | |  | |
| **CNR (dB)** | **-4.18** | **-4.18** | **-4.08** | **-4.08** | **-4.10** | **-4.10** |

Table 6: UL NB-IoT/eMTC link budget based on set 3 satellite parameters in [2]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Satellite orbit | GEO | | LEO-1200 | | LEO-600 | |
|  | NB-IoT | eMTC | NB-IoT | eMTC | NB-IoT | eMTC |
| IoT device max Tx power (dBm) | 20 | | 20 | | 20 | |
| IoT device antenna gain (dBi) | 0 | | 0 | | 0 | |
| **IoT device EIRP (dBm)** | **20** | | **20** | | **20** | |
|  |  | |  | |  | |
| Central beam edge elevation (degree) | 12.5 | | 30 | | 30 | |
| Max. distance between satellite and IoT device (km) | 40308 | | 1998 | | 1075 | |
| Carrier frequency (GHz) | 2 | | 2 | | 2 | |
| **Free space path loss (dB)** | **190.58** | | **164.48** | | **159.10** | |
| Shadowing (dB) | 3 | | 3 | | 3 | |
| Atmospheric path loss (dB) | 0.2 | | 0.1 | | 0.1 | |
| Scintillation loss (dB) | 2.2 | | 2.2 | | 2.2 | |
| Polarization loss (dB) | 3 | | 3 | | 3 | |
|  |  | |  | |  | |
| Antenna temperature (K) | 290 | | 290 | | 290 | |
| G/T (dB/K) | 16.7 | | -12.8 | | -12.8 | |
| Satellite Rx gain (dBi) | 41.32 | | 11.82 | | 11.82 | |
| Channel bandwidth (MHz) | 0.015 | 0.18 | 0.015 | 0.18 | 0.015 | 0.18 |
|  |  | |  | |  | |
| **CNR (dB)** | **-5.42** | **-16.21** | **-8.72** | **-19.51** | **-3.34** | **-14.13** |

*Link budget for Set 4:*

Table 7: DL NB-IoT/eMTC link budget based on set 4 satellite parameters in [2]

|  |  |  |
| --- | --- | --- |
| Satellite orbit | LEO-600 (DL) | |
|  | NB-IoT | eMTC |
| Satellite EIRP density (dBW/MHz) | 21.45 | |
| Channel bandwidth (MHz) | 0.18 | 1.08 |
| **Satellite EIRP (dBm)** | **44.00** | **51.78** |
|  |  | |
| Central beam edge elevation (degree) | 30 | |
| Max. distance between satellite and IoT device (km) | 1075 | |
| Carrier frequency (GHz) | 2 | |
| **Free space path loss (dB)** | **159.10** | |
| Shadowing (dB) | 3 | |
| Atmospheric path loss (dB) | 0.1 | |
| Scintillation loss (dB) | 2.2 | |
| Polarization loss (dB) | 3 | |
|  |  | |
| IoT antenna temperature (K) | 290 | |
| Thermal noise (dBW/Hz) | -174 | |
| **Noise floor (dBm)** | **-121.45** | **-113.67** |
| IoT noise figure (dB) | 9 | |
| IoT device antenna gain (dBi) | 0 | |
|  |  | |
| **CNR (dB)** | **-10.95** | **-10.95** |

Table 8: UL NB-IoT/eMTC link budget based on set 4 satellite parameters in [2]

|  |  |  |
| --- | --- | --- |
| Satellite orbit | LEO-600 | |
|  | NB-IoT | eMTC |
| IoT device max Tx power (dBm) | 20 | |
| IoT device antenna gain (dBi) | 0 | |
| **IoT device EIRP (dBm)** | **20** | |
|  |  | |
| Central beam edge elevation (degree) | 30 | |
| Max. distance between satellite and IoT device (km) | 1075 | |
| Carrier frequency (GHz) | 2 | |
| **Free space path loss (dB)** | **159.10** | |
| Shadowing (dB) | 3 | |
| Atmospheric path loss (dB) | 0.1 | |
| Scintillation loss (dB) | 2.2 | |
| Polarization loss (dB) | 3 | |
|  |  | |
| Antenna temperature (K) | 290 | |
| G/T (dB/K) | -18.6 | |
| Satellite Rx gain (dBi) | 6.02 | |
| Channel bandwidth (MHz) | 0.015 | 0.18 |
|  |  | |
| **CNR (dB)** | **-9.14** | **-19.93** |

## Samsung link budget results (R1-2103266)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **SET 1 - Downlink link budget** | GEO  35786 km | LEO  1200 km | LEO  600 km | units |
| Elevation angle | 12.5 | 30 | 30 | degree |
| EIRP Density | 59 | 40 | 34 | dBW/MHz |
| EIRP per spot (1080 kHz) | 59.3 | 40.3 | 34.3 | dBW |
| EIRP per spot (180 kHz) | 51.6 | 32.6 | 26.6 | dBW |
| RX antenna gain | 0 | 0 | 0 | dBi |
| Path length UE-Satellite | 40316.7 | 1998.9 | 1075.1 | Km |
| FSPL | 190.6 | 164.5 | 159.1 | dB |
| FPSL + other losses | 199.0 | 172.8 | 167.4 | dB |
| Received power | -117.1 | -109.9 | -110.5 | dBW |
| **(C/N)\_DL (1080 kHz)** | **-3.0** | **4.2** | **3.6** | **dB** |
| **(C/N)\_DL (180 kHz)** | **-3.0** | **4.2** | **3.6** | **dB** |
| G/T = Ga – NF – 10\*LOG (To+(Ta-To)/(100.1\*NF)) | -31.6 | -31.6 | -31.6 | dB/K |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **SET 1 - Uplink link budget** | GEO 35786 km | LEO 1200 km | LEO 600 km | units |
| Elevation angle | 12.5 | 30 | 30 | degree |
| Transmitted power | -7 | -7 | -7 | dBW |
| TX antenna gain | 0 | 0 | 0 | dBi |
| EIRP | -7 | -7 | -7 | dBW |
| RX antenna gain | 51 | 24.1 | 24.1 | dBi |
| Path length UE-Satellite | 40316.7 | 1998.9 | 1075.1 | Km |
| FSPL | 190.6 | 164.5 | 159.1 | dB |
| FPSL + other losses | 199.0 | 172.8 | 167.4 | dB |
| Received power | -155.0 | -155.7 | -150.3 | dBW |
| **(C/N)\_UL (45 kHz)** | **-7.9** | **0.4** | **5.8** | **dB** |
| **(C/N)\_UL (15 kHz)** | **-3.1** | **5.2** | **10.5** | **dB** |
| **(C/N)\_UL (3.75 kHz)** | **2.9** | **11.2** | **16.6** | **dB** |
| G/T  [TR 38.821 SET1, NR NTN] | 19 | 1.1 | 1.1 | dB/K |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **SET 2 - Downlink link budget** | GEO 35786 km | LEO 1200 km | LEO 600 km | units |
| Elevation angle | 12.5 | 30 | 30 | degree |
| EIRP Density | 53.5 | 34 | 28 | dBW/MHz |
| EIRP per spot (1080 kHz) | 53.8 | 34.3 | 28.3 | dBW |
| EIRP per spot (180 kHz) | 46.1 | 26.6 | 20.6 | dBW |
| RX antenna gain | 0 | 0 | 0 | dBi |
| Carrier frequency | 2 | 2 | 2 | GHz |
| Path length UE-Satellite | 40316.7 | 1998.9 | 1075.1 | Km |
| FSPL | 190.6 | 164.5 | 159.1 | dB |
| FPSL + other losses | 199.0 | 172.8 | 167.4 | dB |
| Received power | -122.6 | -115.9 | -116.5 | dBW |
| **(C/N)\_DL (1080 kHz)** | **-8.5** | **-1.8** | **-2.4** | **dB** |
| **(C/N)\_DL (180 kHz)** | **-8.5** | **-1.8** | **-2.4** | **dB** |
| G/T = Ga – NF – 10\*LOG (To+(Ta-To)/(100.1\*NF)) | -31.6 | -31.6 | -31.6 | dB/K |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **SET 2 - Uplink link budget** | GEO 35786 km | LEO 1200 km | LEO 600 km | units |
| Elevation angle | 12.5 | 30 | 30 | degree |
| Transmitted power | -7 | -7 | -7 | dBW |
| TX antenna gain | 0 | 0 | 0 | dBi |
| EIRP | -7 | -7 | -7 | dBW |
| RX antenna gain | 51 | 24.1 | 24.1 | dBi |
| Path length UE-Satellite | 40316.7 | 1998.9 | 1075.1 | Km |
| FSPL | 190.6 | 164.5 | 159.1 | dB |
| FPSL + other losses | 199.0 | 172.8 | 167.4 | dB |
| Received power | -155.0 | -155.7 | -150.3 | dBW |
| **(C/N)\_UL (45 kHz)** | **-12.9** | **-5.6** | **-0.2** | **dB** |
| **(C/N)\_UL (15 kHz)** | **-8.1** | **-0.8** | **4.5** | **dB** |
| **(C/N)\_UL (3.75 kHz)** | **-2.1** | **5.2** | **10.6** | **dB** |
| G/T [TR 38.821 SET1, NR NTN] | 14 | -4.9 | -4.9 | dB/K |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **SET 3 - Downlink link budget** | GEO 35786 km | LEO 1200 km | LEO 600 km | units |
| Elevation angle | 12.5 | 30 | 30 | degree |
| EIRP Density | 59.8 | 33.7 | 28.3 | dBW/MHz |
| EIRP per spot (1080 kHz) | 60.1 | 34.0 | 28.6 | dBW |
| EIRP per spot (180 kHz) | 52.4 | 26.3 | 20.9 | dBW |
| RX antenna gain | 0 | 0 | 0 | dBi |
| Path length UE-Satellite | 40316.7 | 1998.9 | 1075.1 | Km |
| FSPL | 190.6 | 164.5 | 159.1 | dB |
| FPSL + other losses | 199.0 | 172.8 | 167.4 | dB |
| Received power | -116.3 | -116.2 | -116.2 | dBW |
| **(C/N)\_DL (1080 kHz)** | **-2.2** | **-2.1** | **-2.1** | **dB** |
| **(C/N)\_DL (180 kHz)** | **-2.2** | **-2.1** | **-2.1** | **dB** |
| G/T = Ga – NF – 10\*LOG (To+(Ta-To)/(100.1\*NF)) | -31.6 | -31.6 | -31.6 | dB/K |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **SET 3 - Uplink link budget** | GEO 35786 km | LEO 1200 km | LEO 600 km | units |
| Elevation angle | 12.5 | 30 | 30 | degree |
| Transmitted power | -7 | -7 | -7 | dBW |
| TX antenna gain | 0 | 0 | 0 | dBi |
| EIRP | -7 | -7 | -7 | dBW |
| RX antenna gain | 51 | 24.1 | 24.1 | dBi |
| Path length UE-Satellite | 40316.7 | 1998.9 | 1075.1 | Km |
| FSPL | 190.6 | 164.5 | 159.1 | dB |
| FPSL + other losses | 199.0 | 172.8 | 167.4 | dB |
| Received power | -155.0 | -155.7 | -150.3 | dBW |
| **(C/N)\_UL (45 kHz)** | **-10.2** | **-13.5** | **-8.1** | **dB** |
| **(C/N)\_UL (15 kHz)** | **-5.4** | **-8.7** | **-3.4** | **dB** |
| **(C/N)\_UL (3.75 kHz)** | **0.6** | **-2.7** | **2.7** | **dB** |
| G/T [EUTELSAT (NB-IoT)] | 16.7 | -12.8 | -12.8 | dB/K |

|  |  |  |  |
| --- | --- | --- | --- |
| **SET 4 - Downlink link budget** | SINGLE BEAM  LEO 600 km | MULTIPLE BEAM  LEO 600 km | units |
| Elevation angle | 56.8 | 30 | degree |
| EIRP Density | 21.45 | 21.45 | dBW/MHz |
| EIRP per spot (1080 kHz) | 21.8 | 21.8 | dBW |
| EIRP per spot (180 kHz) | 14.0 | 14.0 | dBW |
| RX antenna gain | 0 | 0 | dBi |
| Path length UE-Satellite | 704.3 | 1075.1 | Km |
| FSPL | 155.4 | 159.1 | dB |
| FPSL + other losses | 163.7 | 167.4 | dB |
| Received power | -119.4 | -123.1 | dBW |
| **(C/N)\_DL (1080 kHz)** | **-8.3** | **-12.0** | **dB** |
| **(C/N)\_DL (180 kHz)** | **-8.3** | **-12.0** | **dB** |
| G/T = Ga – NF – 10\*LOG (To+(Ta-To)/(100.1\*NF)) | -31.6 | -31.6 | dB/K |

|  |  |  |  |
| --- | --- | --- | --- |
| **SET 4 - Uplink link budget** | SINGLE-BEAM LEO 600 km | MULTIPLE BEAM LEO 600 km | units |
| Elevation angle | 56.8 | 30 | degree |
| Transmitted power | -7 | -7 | dBW |
| TX antenna gain | 0 | 0 | dBi |
| EIRP | -7 | -7 | dBW |
| RX antenna gain | 24.1 | 24.1 | dBi |
| Path length UE-Satellite | 704.3 | 1075.1 | Km |
| FSPL | 155.4 | 159.1 | dB |
| FPSL + other losses | 163.7 | 167.4 | dB |
| Received power | -146.6 | -150.3 | dBW |
| **(C/N)\_UL (45 kHz)** | **-6.6** | **-13.2** | **dB** |
| **(C/N)\_UL (15 kHz)** | **-1.8** | **-8.5** | **dB** |
| **(C/N)\_UL (3.75 kHz)** | **4.2** | **-2.4** | **dB** |
| G/T [SATELIOT (NB-IoT)] | -17.9 | -20.9 | dB/K |

## Sony link budget results (R1-2103318)

Table 1 - Link budget evaluation for Rel-15 eMTC (sub-PRB PUSCH)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | GEO | | LEO-1200 | | LEO-600 | |
| Transmission mode | DL | UL | DL | UL | DL | UL |
| Frequency [GHz] | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| TX: EIRP [dBm] | 90.13 | 23.00 | 64.03 | 23.00 | 58.63 | 23.00 |
| RX: G/T [dB/T] | -31.62 | 16.70 | -31.62 | -12.80 | -31.62 | -12.80 |
| Bandwidth [MHz] | 1.08 | 0.015 | 1.08 | 0.015 | 1.08 | 0.015 |
| Free space path loss [dB] | 190.58 | 190.58 | 164.49 | 164.49 | 159.10 | 159.10 |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Atmospheric loss [dB] | 0.12 | 0.12 | 0.11 | 0.11 | 0.10 | 0.10 |
| Shadow fading margin [dB] | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| Scintillation Loss [dB] | 2.20 | 2.20 | 2.20 | 2.20 | 2.20 | 2.20 |
| Polarization loss [dB] | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| Additional losses [dB] | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| CNR [dB] | -5.124 | -5.361 | -5.120 | -8.757 | -5.123 | -3.360 |

**Table 2 - Link budget evaluation for Rel-13 eMTC (full-PRB PUSCH)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | GEO | | LEO-1200 | | LEO-600 | |
| Transmission mode | DL | UL | DL | UL | DL | UL |
| Frequency [GHz] | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| TX: EIRP [dBm] | 90.13 | 23.00 | 64.03 | 23.00 | 58.63 | 23.00 |
| RX: G/T [dB/T] | -31.62 | 16.70 | -31.62 | -12.80 | -31.62 | -12.80 |
| Bandwidth [MHz] | 1.08 | 0.180 | 1.08 | 0.180 | 1.08 | 0.180 |
| Free space path loss [dB] | 190.58 | 190.58 | 164.49 | 164.49 | 159.10 | 159.10 |
| Atmospheric loss [dB] | 0.12 | 0.12 | 0.11 | 0.11 | 0.10 | 0.10 |
| Shadow fading margin [dB] | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| Scintillation Loss [dB] | 2.20 | 2.20 | 2.20 | 2.20 | 2.20 | 2.20 |
| Polarization loss [dB] | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| Additional losses [dB] | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| CNR [dB] | -5.124 | -16.153 | -5.120 | -19.549 | -5.123 | -14.152 |

**Table 3 - Link budget evaluation for NB-IoT**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | GEO | | LEO-1200 | | LEO-600 | |
| Transmission mode | DL | UL | DL | UL | DL | UL |
| Frequency [GHz] | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| TX: EIRP [dBm] | 82.35 | 23.00 | 56.25 | 23.00 | 50.85 | 23.00 |
| RX: G/T [dB/T] | -31.62 | 16.70 | -31.62 | -12.80 | -31.62 | -12.80 |
| Bandwidth [MHz] | 0.180 | 0.015 | 0.180 | 0.015 | 0.180 | 0.015 |
| Free space path loss [dB] | 190.58 | 190.58 | 164.49 | 164.49 | 159.10 | 159.10 |
| Atmospheric loss [dB] | 0.12 | 0.12 | 0.11 | 0.11 | 0.10 | 0.10 |
| Shadow fading margin [dB] | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| Scintillation Loss [dB] | 2.20 | 2.20 | 2.20 | 2.20 | 2.20 | 2.20 |
| Polarization loss [dB] | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| Additional losses [dB] | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| CNR [dB] | -5.124 | -5.361 | -5.120 | -8.757 | -5.123 | -3.360 |

## Sateliot, Gatehouse, Thales link budget results (R1-2103716)

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | **Configuration A**  (Based on common assumptions in TR 36.763 v0.1.0 section 6.2.1) | **Configuration B**  (common assumptions + some enhancements - marked in bold) |
| Satellite platform | Altitude | 600 km, circular orbit | 600 km, circular orbit |
| Transmit power | 33 dBm | **36 dBm** |
| Tx/Rx Antenna Gain | 11 dBi | 11 dBi |
| H-HPBW | 104.7 degrees | 104.7 degrees |
| V-HPBW | 40 degrees | 40 degrees |
| Antenna polarization | Circular | Circular |
| Antenna temperature | 290 K | 290 K |
| Noise Figure (NF) | 5 dB | **3 dB** |
| G/T | -18.6 dB/K | **-16.6 dB/K** |
| IoT device | Transmit power | 20 dBm | **23 dBm** |
| Tx/Rx Antenna Gain | 0 dBi | 0 dBi |
| Antenna polarization | Linear | Linear |
| Antenna temperature | 290 K | 290 K |
| Noise Figure (NF) | 9 dB | **5 dB** |
| G/T | -33.6 dB/K | **-29.6 dB/K** |
| NB-IoT protocol | Downlink channel bandwidth | 180 kHz | 180 kHz |
| Uplink channel bandwidth | 3.75 kHz | 3.75 kHz |
| Other losses | Polarization | 3 dB | 3 dB |
| Scintillation | 2.2 dB | 2.2 dB |
| Atmospheric absorption | 0.1 dB | 0.1 dB |
| Shadow margin | 3 dB | 3 dB |

**Table 1 -** Assumptions for link budget computation

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | **Configuration A**  (Based on common assumptions in TR 36.763 v0.1.0 section 6.2.1) | **Configuration B**  (common assumptions + some enhancements) |
| **Downlink SNR** | Elevation angle=90º | -5.91 dB | 1.09 dB |
| Elevation angle=30º | -13.98 dB | -6.98 dB |
| **Uplink SNR**  **(ST 3.75 kHz)** | Elevation angle=90º | 1.90 dB | 6.90 dB |
| Elevation angle=30º | -6.16 dB | -1.16 dB |

**Table 2 -** Link budget results at worst and best beam footprint locations.

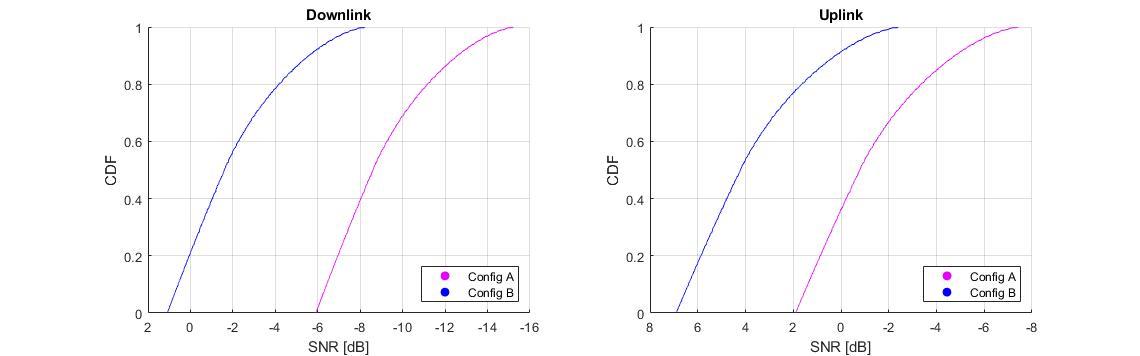


Figure 3 – CDF for SNR values within the beam coverage footprint

# Appendix 2

|  |  |
| --- | --- |
| Contribution | Observation/Proposals |
| Echostar (R1-2102750) | ***Proposal 1****: To add MEO scenario D in Table 4.2-1 in TR 36.763.*  ***Proposal 2****: To add MEO IoT NTN reference scenario parameters in Table 6.1-1 in TR 36.763.*  ***Proposal 3****: To include MEO Set-5 parameters for link budget analysis in a new Table 6.2-8 in TR 36.763, as a representative characterization of NTN-IoT scenarios with MEO altitude and characteristics.*  ***Proposal 4****: To add MEO Set-5 satellite parameters for system level simulator calibration in a new Table 6.2-9 in TR 36.763.*  ***Observation****: The doppler shift/variation and the delay variation for MEO are smaller than for LEO. The maximum delay for MEO is smaller than for GEO. The IoT-NTN enhancements for LEO and GEO should be sufficient to support MEO.* |
| Huawei (R1-2102344) | ***Proposal 1:*** *RAN1 agrees on the performance requirements of typical use cases in IoT over NTN**to ensure that the system design can fulfil such requirements.*  ***Proposal 2:*** *RAN1 agrees on the evaluation methodology and performance metrics, e.g. DL/UL peak data rate, latency, user density, power consumption, etc., for the candidate solutions targeting optimization of IoT over NTN.*  ***Proposal 3:*** *Capture the link budget results in the Appendix into TR 36.763.* |
| OPPO (R1-2102422) | ***Observation****: The evaluated link budget results for the scenarios of NB-IoT/eMTC over NTN are provided in Table 1~Table 8.*  ***Proposal 1****: Coverage enhancements should be studied and specified for IoT over NTN in Rel-17.*  ***Proposal 2****: Power consumption enhancements should be studied and specified for IoT over NTN in Rel-17.*  ***Proposal 3****: The features beneficial but not essential for IoT over NTN in Rel-17 should be studied and specified in later release.* |
| Vivo (R1-2102550) | ***Observation 1****: Free space path losses are 190.58 dB, 164.49 dB and 159.10 dB for GEO, LEO-1200, LEO-600, respectively.*  ***Observation 2****: Uplink channels with the largest bandwidth have the lowest CNRs.*  ***Observation 3****: Set-3 satellites and Set-4 satellites have quite lower achievable CNRs in UL.*  ***Observation 4****: FSPLs exceeds the MCL requirements in some scenarios.*  ***Proposal 1****: Lower devices antenna gain should be considered for NB-IoT/eMTC over NTN, e.g. -5 dBi.*  ***Proposal 2****: It is necessary to enhance UL coverage for NB-IoT/eMTC over NTN.*  ***Proposal 3****: MCL evaluation methodology in NR NTN can be reused for NB-IoT/eMTC over NTN.* |
| CATT (R1-2102617) | Regarding the scenario prioritization, observations and proposals are as follows:  ***Observation 1****: If LEO with earth moving cell is prioritized, we should further consider the solutions for idle/connected mode mobility, to adapt the frequent change of the cell coverage caused by the movement of the LEO satellites.*  ***Proposal 1****: Both GEO and LEO should be considered for IoT NTN in Rel-17.*  ***Proposal 2****: LEO-600km could be prioritized. However, the other orbits for LEO may also need to be considered for IoT NTN in Rel-17.*  ***Proposal 3****: Both earth moving cell and earth fixed cell should be considered for LEO in Rel-17 to allow the flexibility of network deployment.*  ***Proposal 4****: Both NB-IoT and eMTC should be supported in Rel-17 to support different commercial requirements.*  Regarding the evaluation result for link budget, observations and proposals are as follows:  ***Observation 2****: In eMTC system, the UL CNR’s difference in uplink bandwidth between 360khz and 30khz is about 10dB.*  ***Observation 3****: In NB-IoT system, the UL CNR’s difference in uplink bandwidth between 180khz and 3.75khz is about 15dB.*  ***Observation 4****: For Set-1, the worst UL CNR for the GEO system reaches -17dB, and the worst UL CNR for the LEO system is about -9dB.*  ***Observation 5****: For Set-2, the worst UL CNR for the GEO system reaches -22dB, and the worst UL CNR for the LEO system is about -16dB.*  ***Observation 6****: For Set-3, the worst UL CNR for the GEO system reaches -19dB, and the worst UL CNR for the LEO system is about -22dB.*  ***Observation 7****: For Set-4, the worst UL CNR for the LEO600-eMTC is close to -23dB, and the worst UL CNR for the LEO600-NB-IoT is close to -20dB.*  ***Observation 8****: For Set-4, the cell radius is 1700km, the UL CNR gap between the cell edge user and the center user is close to 5dB, and the UL CNR of the cell center user for the LEO600-eMTC is close to -7dB although the bandwidth decreases to 30khz.*  ***Proposal 5****: Capture Table 1-Table 7 results into TR 36.763.*  ***Proposal 6****: Based on evaluated results, the use case with below -10dB is not recommanded to support in IoT over NTN.* |
| MediaTek (R1-2102754) | ***Proposal 1****: Link Budget results for Set 1, Set 2, Set 3, and Set 4 in Table 1 and Table 2 are included in TR 36.763*  ***Observation 1****: A UE may only need a new GNSS position solely for UE pre-compensation for UL synchronization in corner case scenarios where (i) it is not fixed; (ii) reporting of the GNSS position is not needed by application layer.*  ***Observation 2****: The satellite system design should fix key parameters such as EIRP and G/T in the satellite to ensure the link budget can be closed on DL and UL.*  ***Observation 2****: NB-IoT can support minimum performance requirement for NB-IoT NTN Set 1, Set 2, Set 3 and Set 4 by using specified range of repetitions*  *- NPDSCH, NPDCCH, NPUSCH format 1 and 2*  *- NPRACH*  ***Observation 3****: NB-IoT can support minimum performance requirement for NPBCH.*  ***Observation 4****: 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.* |
| Nokia (R1-2102831) | ***Observation 1****: Including the proposed outdoor-to-indoor penetration loss requires link budget improvements.*  ***Observation 2****: Including the proposed vegetation loss requires link budget improvements.*  ***Observation 3****: Elevation angle smaller than agreed parameter set for outer tiers may cause more loss.*  ***Observation 4****: None-zero probability of NLOS shadow fading may impact much in link budget.*  ***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 indoor and/or vegetation-impacted UEs are in scope of the NTN IoT study.*  ***Proposal 2****: RAN1 to discuss how to handle poor GNSS performance in indoor and vegetation-impacted scenarios.*  ***Proposal 3****: RAN1 to define outdoor-to-indoor penetration loss of 25 dB for further link budget analysis.*  ***Proposal 4****: RAN1 to define vegetation loss of 10 dB for further link budget analysis.*  ***Proposal 5****: RAN1 to define the maximum number of repetitions and corresponding gain to apply in the link budget analysis, to provide worst coverage case.*  ***Proposal 6****: RAN1 to discuss impact of GNSS-based pre-compensation on combining gain of repetitions.*  ***Proposal 7****: Smaller elevation angle for outer tiers and NLOS shadow fading loss should also be considered in link budget for the worst coverage case.*  ***Proposal 8****: The link budget evaluations in Table 4, Table 5, Table 6, Table 7, Table 8, Table 9, Table 10, Table 11, Table 12, Table 13, Table 14, and Table 15 shall be included in the study item report.* |
| CMCC (R1-2102905) | ***Observation 1****: Based on the latest parameters for link budget calibration, it can be observed that:*  *- For GEO with Set 2 satellite parameter, the UL CNR will reach -18.8dB level for NB-IoT with 180kHz BW, and reach -26.5dB level for eMTC with 1080kHz BW.*  *- For LEO at 1200km with Set 3 satellite parameter, the UL CNR will reach -17.4dB level for NB-IoT with 180kHz BW, and reach -25.2dB level for eMTC with 1080kHz BW.*  *- For LEO at 600km with Set 4 satellite parameter, the UL CNR will reach -14.9dB level for NB-IoT with 180kHz BW, and reach -22.7dB level for eMTC with 1080kHz BW.*  ***Observation 2****: Additional path loss can be observed in some deployment scenarios.*  *- Carriage and container penetration loss (9~20 dB) for logistics application.*  *- Vegetation loss (e.g., 9 dB) for outdoor application.*  ***Observation 3****: Additional 0~10 dB FSPL can be experienced by a UE in locations other than in the center of the central beam.*  ***Proposal 1****: Compare with link budget results for calibration, additional path loss should be considered for evaluating the basic coverage performance of IoT NTN in real deployment conditions.*  *- Carriage and container penetration loss for logistics application.*  *- Vegetation loss for outdoor application.*  *- Additional FSPL for lower elevation angle.* |
| ZTE (R1-2102916) | ***Observation 1****: For Set-3 and Set-4, coupling loss of LOS UE in some cases will be larger than 159 dB.*  ***Observation 2****: 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 target SNR.*  ***Observation 3****: A large number of UEs would experience a worse coupling loss larger than 164 dB for urban and dense urban scenarios. And even for rural scenario, there are about 5% UEs which experience coupling loss larger than 164 dB.*  ***Proposal 1****: Cases listed in Table-1 within consideration on the different FR factor should be considered for link budget evaluation.*  ***Proposal 2****: Capturing the link budget results for cases listed in Table-1 into the TR.*  ***Proposal 3****: Further enhancement on the transmission may be needed to support cases with large coupling loss and/or low CNR.* |
| Xiaomi (R1-2102972) | ***Observation:*** *The CNR is quite low for some cases especially on the UL.*  ***Proposal 1:*** *Transmission enhancement may be needed for NB-IoT/eMTC over NTN based on the link budget results.* |
| Ericsson (R1-2103060) | ***Observation*** *1: eMTC and NB-IoT can address different types of IoT use cases based on their unique capabilities and thus complement each other.*  ***Observation 2****: NB-IoT supports ultra-low complexity devices with very narrow bandwidth, while eMTC can achieve higher data rates, more accurate device positioning, and supports voice calls and connected mode mobility.*  ***Observation 3****: The approved Rel-17 IoT NTN SID is dedicated to LEO and GEO satellite communication, while HAPS/HIBS and A2G are not in the scope.*  ***Observation 4****: Rel-17 IoT NTN study should equally treat eMTC and NB-IoT. The study item will be incomplete unless each of them is properly studied for its feasibility for NTN.*  ***Observation 5****: It was agreed at RAN2#112e that support for EPC is assumed for IoT NTN.*  ***Observation 6****: Identifying specific bands of interest in sub 6 GHz can be a topic for RAN4 to discuss when a potential normative phase begins.*  ***Observation 7****: The approved Rel-17 IoT NTN SID is dedicated to transparent payload.*  ***Observation 8****: To study the feasibility of NTN for eMTC and NB-IoT, it is important to properly evaluate the various design targets originally envisioned for eMTC and NB-IoT in the new context of NTN, taking into account factors such as the additional complexity, cost, and power consumption associated with GNSS operation.*  ***Observation 9****: The achievable connection density for IoT in NTN is much smaller than that in TN mainly due to a larger inter-spotbeam distance in NTN.*  *Based on the discussion in the previous sections we propose the following:*  ***Proposal 1****: IoT NTN study should focus on essential adaptations for NTN, while generic enhancements motivated by non-NTN are outside the scope.*  ***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.*  ***Proposal 4****: In Rel-17 IOT NTN SI, prioritize earth fixed beams.*  ***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.* |
| Qualcomm (R1-2103070) | ***Proposal 1****: RAN1 to define the downlink frequency accuracy of initial cell acquisition for eMTC and NB-IoT over NTN. This includes defining:*  *- Accuracy of crystal oscillator at the UE (in ppm)*  *- Maximum doppler frequency offset during initial acquisition*  ***Proposal 2****: RAN1 to discuss how accurately (e.g., in ppm) an eMTC/NB-IoT UE can be expected to maintain time and frequency synchronization for uplink transmissions, by tracking the location of the serving satellite and that of the UE itself.*  ***Proposal 3****: RAN1 to define solutions for maintaining uplink time and frequency synchronization, that are specific to the length of connections for eMTC/NB-IoT over NTN.*  ***Proposal 4****: For LEO satellites with fixed (non-steerable) satellite beams, define 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* |
| Apple (R1-2103132) | ***Observation 1****: For set 1 satellite parameters, the CNR for DL NB-IoT/eMTC is -4.98, 2.22 and 1.60 dB for GEO, LEO-1200 and LEO-600, respectively.*  ***Observation 2****: For set 1 satellite parameters, the CNR for UL NB-IoT/eMTC with bandwidth 15 kHz/180 kHz is -3.12/-13.91, 5.18/-5.61 and 10.56/-0.23 dB for GEO, LEO-1200 and LEO-600, respectively.*  ***Observation 3****: For set 2 satellite parameters, the CNR for DL NB-IoT/eMTC is -10.48, -3.78 and -4.40 dB for GEO, LEO-1200 and LEO-600, respectively.*  ***Observation 4****: For set 2 satellite parameters, the CNR for UL NB-IoT/eMTC with bandwidth 15 kHz/180 kHz is -8.12/-18.91, -0.82/-11.61 and 4.56/-6.23 dB for GEO, LEO-1200 and LEO-600, respectively.*  ***Observation 5****: For set 3 satellite parameters, the CNR for DL NB-IoT/eMTC is -4.18, -4.08 and -4.10 dB for GEO, LEO-1200 and LEO-600, respectively.*  ***Observation 6****: For set 3 satellite parameters, the CNR for UL NB-IoT/eMTC with bandwidth 15 kHz/180 kHz is -5.42/-16.21, -8.72/-19.51 and -3.34/-14.13 dB for GEO, LEO-1200 and LEO-600, respectively.*  ***Observation 7****: For set 4 satellite parameters, the CNR for DL NB-IoT/eMTC is -10.95 dB.*  ***Observation 8****: For set 4 satellite parameters, the CNR for UL NB-IoT/eMTC with bandwidth 15 kHz/180 kHz is -9.14/-19.93 dB.* |
| Sony (R1-2103318) | ***Proposal 1****: In the current stage of the study item, link budget study for PC3 devices (23dBm) with 7dB noise figure is prioritized.*  ***Proposal 2****: An AWGN channel model is assumed for IoT-NTN link level simulations.* |
| Sateliot, Gatehouse, Thales (R1-2103716) | ***Proposal 1****: Revise the “Max beam footprint size (edge to edge) regardless of the elevation angle” parameter for LEO scenarios indicated in 3GPP TR 36.763 V0.1.0 Table 6.1-1: “IoT NTN reference scenario parameters” to 1700 km (currently the parameter is set to 1000 km for LEO scenarios).* |
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