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| 3GPP TR 36.763 V0.2.0 (2021-05) | |
| Technical Report | |
| 3rd Generation Partnership Project;  Technical Specification Group Radio Access Network;  Study on Narrow-Band Internet of Things (NB-IoT) / enhanced Machine Type Communication (eMTC) support for Non-Terrestrial Networks (NTN) (Release 17) | |
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# Foreword

This Technical Report has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

Version x.y.z

where:

x the first digit:

1 presented to TSG for information;

2 presented to TSG for approval;

3 or greater indicates TSG approved document under change control.

y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

z the third digit is incremented when editorial only changes have been incorporated in the document.

In the present document, modal verbs have the following meanings:

**shall** indicates a mandatory requirement to do something

**shall not** indicates an interdiction (prohibition) to do something

The constructions "shall" and "shall not" are confined to the context of normative provisions, and do not appear in Technical Reports.

The constructions "must" and "must not" are not used as substitutes for "shall" and "shall not". Their use is avoided insofar as possible, and they are not used in a normative context except in a direct citation from an external, referenced, non-3GPP document, or so as to maintain continuity of style when extending or modifying the provisions of such a referenced document.

**should** indicates a recommendation to do something

**should not** indicates a recommendation not to do something

**may** indicates permission to do something

**need not** indicates permission not to do something

The construction "may not" is ambiguous and is not used in normative elements. The unambiguous constructions "might not" or "shall not" are used instead, depending upon the meaning intended.

**can** indicates that something is possible

**cannot** indicates that something is impossible

The constructions "can" and "cannot" are not substitutes for "may" and "need not".

**will** indicates that something is certain or expected to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

**will not** indicates that something is certain or expected not to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

**might** indicates a likelihood that something will happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

**might not** indicates a likelihood that something will not happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

In addition:

**is** (or any other verb in the indicative mood) indicates a statement of fact

**is not** (or any other negative verb in the indicative mood) indicates a statement of fact

The constructions "is" and "is not" do not indicate requirements.

# 1 Scope

TBA

# 2 References

The following documents contain provisions, which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non‑specific.

- For a specific reference, subsequent revisions do not apply.

- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications"

[2] 3GPP TR 38.811 v15.2.0: "Study on New Radio (NR) to support non-terrestrial networks (Release 15)"

[3] 3GPP TR38.821 v16.0.0: " Solutions for NR to support non-terrestrial networks (NTN) (Release 16)"

[4] 3GPP TR 45.820 v13.1.0: "Cellular system support for ultra-low complexity and low throughput Internet of Things (CIoT) (Release 13)"

[5] 3GPP TS 22.261: "Service requirements for the 5G system; Stage 1 (Release 16)"

[6] R2-1901404: "IoT Device Density Models for Various Environments", Vodafone, RAN2 #105

[7] 3GPP TS 36.331: "E-UTRA Radio Resource Control (RRC) protocol specification (Release 16)"

[8] 3GPP TS 36.322: "E-UTRA Radio Link Control (RLC) protocol specification (Release 16)"

[9] 3GPP TS 36.323: "E-UTRA Packet Data Convergence Protocol (PDCP) specification (Release 16)"

[10] R2-2011275: "[IoT-NTN] Applicability of TR 38.821 (MediaTek)"

[11] 3GPP TS 36.304: "Evolved Universal Terrestrial Radio Access (E-UTRA); UE Procedures in Idle Mode (Release 16)"

[12] 3GPP TS 36.321: "Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification (Release 16)"

# 3 Definitions of terms, symbols and abbreviations

## 3.1 Terms

For the purposes of the present document, the terms and definitions given in TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in TR 21.905 [1].

**Availability:** % of time during which the RAN is available for the targeted communication. Unavailable communication for shorter period than [Y] ms shall not be counted. The RAN may contain several access network components.

**Feeder link:** Wireless link between NTN Gateway and satellite

**Geostationary Earth orbit:** Circular orbit at 35,786 km above the Earth's equator and following the direction of the Earth's rotation. An object in such an orbit has an orbital period equal to the Earth's rotational period and thus appears motionless, at a fixed position in the sky, to ground observers.

**Low Earth Orbit:** Orbit around the Earth with an altitude between 300 km, and 1500 km.

**Medium Earth Orbit:** region of space around the Earth above low Earth orbit and below geostationary Earth Orbit.

**Minimum Elevation angle**: minimum angle under which the satellite or UAS platform can be seen by a terminal.

**Mobile Services:** a radio-communication service between mobile and land stations, or between mobile stations

**Mobile Satellite Services:** A radio-communication service between mobile earth stations and one or more space stations, or between space stations used by this service; or between mobile earth stations by means of one or more space stations

**Non-Geostationary Satellites:** Satellites (LEO and MEO) orbiting around the Earth with a period that varies approximately between 1.5 hour and 10 hours..

**Non-terrestrial networks:** Networks, or segments of networks, using an airborne or space-borne vehicle to embark a transmission equipment relay node or base station.

**NTN-gateway:** an earth station or gateway is located at the surface of Earth, and provides sufficient RF power and RF sensitivity for accessing to the satellite. NTN Gateway is a transport network layer (TNL) node.

**On Board processing:** digital processing carried out on uplink RF signals aboard a satellite or an aerial.

**On board NTN eNB**: eNB implemented in the regenerative payload on board a satellite.

**On ground NTN eNB**: eNB of a transparent satellite payload implemented on ground.

**One-way latency:** time required to propagate through a telecommunication system from a terminal to the public data network or from the public data network to the terminal.

**Regenerative payload:** payload that transforms and amplifies an uplink RF signal before transmitting it on the downlink. The transformation of the signal refers to digital processing that may include demodulation, decoding, re-encoding, re-modulation and/or filtering.

**Round Trip Delay:** time required for a signal to travel from a terminal to the sat-gateway or from the sat-gateway to the terminal and back..

**Satellite:** a space-borne vehicle embarking a bent pipe payload or a regenerative payload telecommunication transmitter, placed into Low-Earth Orbit (LEO), Medium-Earth Orbit (MEO), or Geostationary Earth Orbit (GEO).

**Satellite beam:** A beam generated by an antenna on-board a satellite

**Service link:** Radio link between satellite and UE

**Transparent payload:** payload that changes the frequency carrier of the uplink RF signal, filters and amplifies it before transmitting it on the downlink

**User Connectivity:** capability to establish and maintain data transfer between networks and Terminals

**User Throughput:** data rate provided to a terminal

## 3.2 Symbols

Void

## 3.3 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [1].

CHO Conditional Handover

ECEF Earth-Centered, Earth-Fixed

EIRP Equivalent Isotropic Radiated Power

GEO Geostationary Earth Orbiting

eNB E-UTRAN Node B

GW Gateway

LEO Low Earth Orbiting

Mbps Mega bit per second

MEO Medium Earth Orbiting

MS Mobile Services

MSS Mobile Satellite Services

NGEO Non-Geostationary Earth Orbiting

NTN Non-Terrestrial Network

RAN Radio Access Network

RTD Round Trip Delay

Rx Receiver

SNR Signal-to-Noise Ratio

TA Tracking Area

TAC Tracking Area Code

TAU Tracking Area Update

TLE Two-Line Element

UAS Unmanned Aircraft System

UE User Equipment

# 4 IoT Non-Terrestrial Networks overview and scenarios

## 4.1 IoT Non-Terrestrial Networks overview

A non-terrestrial network refers to a network, or segment of networks using RF resources on board a satellite.

The typical scenario of a non-terrestrial network providing access to user equipment is depicted below:



Figure 4.1-1: Non-terrestrial network typical scenario based on transparent payload

Non-Terrestrial Network typically features the following elements:

- One or several sat-gateways that connect the Non-Terrestrial Network to a public data network

- a GEO satellite is fed by one or several sat-gateways which are to enable satellite coverage over the targeted area (e.g. regional or even continental coverage). It is assumed that UE in a cell are served by only one sat-gateway

- A Non-GEO satellite served successively by one or several sat-gateways at a time. The system ensures service and feeder link continuity between the successive serving sat-gateways with sufficient time duration to proceed with mobility anchoring and hand-over. Service discontinuity can also be deployed.

- A Feeder link or radio link between a sat-gateway and the satellite

- A service link or radio link between the user equipment and the satellite.

- A satellite which implements a transparent payload. The satellite typically generate several beams over a given service area bounded by its field of view. The beam could be either earth fixed beam or earth moving beam for LEO. The footprints of the beams are typically of elliptic shape. The field of view of a satellite depends on the on board antenna design and minimum elevation angle.

- A transparent payload: Radio Frequency filtering, Frequency conversion and amplification. Hence, the waveform signal repeated by the payload is un-changed;

- User Equipment are served by the satellite within the targeted service area.

There may be different types of satellites listed here under:

Table 4.1-1: Types of NTN platforms

|  |  |  |  |
| --- | --- | --- | --- |
| Platforms | Altitude range | Orbit | Typical beam footprint size |
| Low-Earth Orbit (LEO) satellite | 300 – 1500 km | Circular around the earth | 100 – 1000 km |
| Geostationary Earth Orbit (GEO) satellite | 35 786 km | notional station keeping position fixed in terms of elevation/azimuth with respect to a given earth point | 200 – 3500 km |

Typically

- GEO satellites are used to provide continental, regional or local service.

- A constellation of LEO satellites is used to provide services in both Northern and Southern hemispheres. In some case, the constellation can even provide global coverage including polar regions. For the later, this requires appropriate orbit inclination, sufficient beams generated.

## 4.2 IoT Non-Terrestrial Networks reference scenarios

The study captured in this Technical Report considers non-terrestrial networks for IoT service providing access to NB-IoT/eMTC user equipment in reference scenarios including:

- GEO and LEO orbiting scenarios

- No inter-satellite link

- Transparent payload

- Fixed or steerable beams resulting respectively in moving or fixed beam footprint on the ground

- Sub 6 GHz bands of interest.

IoT NTN scenarios A, B, and C are included in the study as shown in Table 4.2-1 below:

Table 4.2-1: IoT NTN reference scenarios

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

# 5 IoT NTN Architecture and Capabilities

## 5.1 IoT NTN Architecture

IoT NTN connectivity via EPC is supported.

IoT NTN connectivity via 5GC is assumed to be supported.

Editor’s Note: Companies in RAN2 assumed the support of 5GC with low priority. RAN2 has requested feedback from 3GPP WGs RAN3 and SA2 on the RAN2 assumption about the support for IoT NTN connectivity via both EPC and 5GC in R2-2102501.

## 5.2 IoT NTN UE Capabilities

GNSS capability in the UE is taken as a working assumption in this study for both NB-IoT and eMTC devices.

Editor’s Note: UE can estimate and pre-compensate timing and frequency offset with sufficient accuracy for UL transmission - FFS pending RAN1 decision.

Simultaneous GNSS and NTN NB-IoT/eMTC operation is not assumed.

## 5.3 IoT NTN Features

It is assumed that all cellular IoT features specified up to Rel-16 are supported for IoT NTN.

Editor’s Note: the above assumption is from a RAN2 perspective and may be revisited on a case by case basis when/if problems are found.

It is assumed that both NB-IoT multi-carrier operation and NB-IoT single-carrier operation are supported as a baseline.

Editor’s Note: the above assumption is from a RAN2 perspective.

# 6 Radio Layer 1 issues and related solutions

## 6.1 IoT NTN Reference Parameters

The IoT NTN reference scenario parameters are listed in Table 6.1-1 below:

Table 6.1-1: IoT NTN reference scenario parameters

|  |  |  |  |
| --- | --- | --- | --- |
| 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) | 186.9 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 | | | |

## 6.2 Link Budget Analysis

### 6.2.1 Link Budget Parameters

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 (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)

- Other losses:

Table 6.2-1: 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.

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

For the satellite parameter sets Set-3 and Set-4, 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 are given in Tables 6.2-2 and 6.2-3. These parameters correspond to the satellite parameter Set 3 and Set 4 given in Tables 6.2-6 and 6.2-7 respectively.

Table 6.2-2: Set-3 parameters for link budget analysis

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

Table 6.2-3: Set-4 parameters for link budget analysis

|  |  |
| --- | --- |
| 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.



Figure 6.2-1 Illustration of beam layout and elevation angles for IoT NTN

The following satellite set parameters Set-1, Set-2, Set-3, and Set-4 given in Tables 6.2-4, 6.2-5, 6.2-6 and 6.2-7, respectively, can be used for the for the system level simulator calibration.

Table 6.2-4: Set 1 satellite parameters for system-level simulation calibration

(based on TR 38.821, Table 6.1.1.1-1)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Satellite orbit | | GEO | LEO-1200 | LEO-600 |
| Satellite altitude | | 35786 km | 1200 km | 600 km |
| Satellite antenna pattern | | Section 6.4.1 in TR 38.811 | Section 6.4.1 in TR 38.811 | Section 6.4.1 in TR 38.811 |
| Central beam edge elevation | | 2.3 degrees | 26.3 degrees | 27.0 degrees |
| Central beam centre elevation | | 12.5 degrees | 30 degrees | 30 degrees |
| Payload characteristics for DL transmissions | | | | |
| Equivalent satellite antenna aperture (Note 1) | S-band  (i.e. 2 GHz) | 22 m | 2 m | 2 m |
| Satellite EIRP density | 59 dBW/MHz | 40 dBW/MHz | 34 dBW/MHz |
| Satellite Tx max Gain | 51 dBi | 30 dBi | 30 dBi |
| 3dB beamwidth | 0.4011 deg | 4.4127 deg | 4.4127 deg |
| Satellite beam diameter (Note 2) | 250 km | 90 km | 50 km |
| Payload characteristics for UL transmissions | | | | |
| Equivalent satellite antenna aperture (Note1) | S-band  (i.e. 2 GHz) | 22 m | 2 m | 2 m |
| G/T | 19 dB K-1 | 1.1 dB K-1 | 1.1 dB K-1 |
| Satellite Rx max Gain | 51 dBi | 30 dBi | 30 dBi |
| NOTE 1: This value is equivalent to the antenna diameter in Sec. 6.4.1 of [2].  NOTE 2: This beam size refers to the Nadir pointing of the satellite  NOTE 3: All these satellite parameters are applied per beam.  NOTE 4: The EIRP density values are considered identical for all frequency re-use factor options.  NOTE 5: The EIRP density values are provided assuming the satellite HPA is operated with a back-off of [5] dB.  NOTE 6: The parameters corresponding to Ka-band for DL and UL in TR 38.821 Table 6.1.1.1-1 were removed. | | | | |

Table 6.2-5: Set 2 satellite parameters for system-level simulation calibration

(based on TR 38.821, Table 6.1.1.1-2)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Satellite orbit | | GEO | LEO-1200 | LEO-600 |
| Satellite altitude | | 35786 km | 1200 km | 600 km |
| Satellite antenna pattern | | Section 6.4.1 in TR 38.811 | Section 6.4.1 in TR 38.811 | Section 6.4.1 in TR 38.811 |
| Central beam edge elevation | | 11.0 degrees | 22.2 degrees | 23.8 degrees |
| Central beam center elevation | | 20 degrees | 30 degrees | 30 degrees |
| Payload characteristics for DL transmissions | | | | |
| Equivalent satellite antenna aperture (Note 1) | S-band  (i.e. 2 GHz) | 12 m | 1 m | 1 m |
| Satellite EIRP density | 53.5 dBW/MHz | 34 dBW/MHz | 28 dBW/MHz |
| Satellite Tx max Gain | 45.5 dBi | 24 dBi | 24 dBi |
| 3dB beamwidth | 0.7353 degrees | 8.8320 degrees | 8.8320 degrees |
| Satellite beam diameter (Note 2) | 450 km | 190 km | 90 km |
| Payload characteristics for UL transmissions | | | | |
| Equivalent satellite antenna aperture (Note1) | S-band  (i.e. 2 GHz) | 12 m | 1 m | 1 m |
| G/T | 14 dB K-1 | -4.9 dB K-1 | -4.9 dB K-1 |
| Satellite Rx max Gain | 45.5 dBi | 24 dBi | 24 dBi |
| NOTE 1: This value is equivalent to the antenna diameter in Sec. 6.4.1 of [2].  NOTE 2: This beam size refers to the Nadir pointing of the satellite  NOTE 3: All these satellite parameters are applied per beam.  NOTE 4: The EIRP density values are considered identical for all frequency re-use factor options.  NOTE 5 : The parameters corresponding to Ka-band for DL and UL in TR 38.821 Table 6.1.1.1-1 were removed. | | | | |

Table 6.2-6: Set-3 satellite parameters for system level simulator calibration  
(based on R1-2101146 - Eutelsat)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 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 | 43.78 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. | | | | |

Table 6.2-7: Set-4 satellite parameters for system level simulator calibration  
(based on R1-2101019 - Thales, Sateliot, Gatehouse)

|  |  |  |
| --- | --- | --- |
| 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 (NOTE 1) | 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. | | |

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

(based on R1-2102750 – HUGUES / Echostar)

|  |  |
| --- | --- |
|  | **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. | |

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

(based on R1-2102750 – HUGUES / Echostar)

|  |  |
| --- | --- |
| **Set 5** | **MEO** |
| 3 dB Beam width (HPBW) | 6.5 degrees |
| Central beam center elevation | 90 degrees |
| Central beam edge elevation | 81.6 degrees |
| Central beam edge satellite-UE distance | 10042 km |

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 set for MEO is only for information/reference and evaluation/enhancements are mainly considered for GEO and LEO. These enhancements can be applicable for MEO.

### 6.2.2 Summary of Link Budget Results

It was agreed in RAN1#104bis-e that the summary of link budget results from contributing companies in Appendix 1, Section 6.1.1 is captured and further checked and revised as necessary in a Text Proposal to TR 36.763 [6]. The summary of link budget results will be captured with alignment between contributing companies. The detailed link budget results from contributing companies will be captured in a separate spreadsheet

#### 6.2.2.1 Calibration of link budget results

Contributing companies:

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

It was observed that 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, 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 Power Classes. 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 dB | 2.2 dB | 2.2 dB |
| Atmospheric losses | 0.2 dB | 0.1 dB | 0.1 dB |
| Polarization loss | 3 dB | 3 dB | 3 dB |
| Shadow margin | 3 dB | 3 dB | 3 dB |

Table: Maximum Free Space Path Loss

|  |  |  |  |
| --- | --- | --- | --- |
| FSPL | GEO (35786 km) | LEO (1200 km) | LEO (600 km) |
| Set-1 | 190.8 dB | 164.5 dB | 159.1 dB |
| Set-2 | 190.3 dB | 164.5 dB | 159.1 dB |
| Set-3 | 190.6 dB | 164.5 dB | 159.1 dB |
| Set-4 | - | - | 159.1 dB |

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*** | ***2.3*** | ***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*** |

We’ve captured and summarized the individual company calibrated results based on calibration spreadsheet in the sub-sections below. The tables below are based on calibration results are available in the spreadsheet. In order to align contributing companies, the spreadsheet provided guidance as follows:

* PC3 (23 dBm) for UL and NF=7 dB for DL are used in link budget analysis
* The central beam edge DL SNR and UL SNR are reported in the spreadsheet
* When considering PC5 with 20dB, lower CNR will be achieved comparing with PC3 and the coverage would be impacted by power reduction
* For PC5 (20 dBm) and NF=9 dB, ADD 3 dB and 2 dB respectively to align CNR UL and DL figures
* UL CNR includes 3 dB additional loss due to beamwidth defined by HPBW at edge of the beam
* DL SNR may include a 3 dB additional loss due to beamwidth defined by HPBW at the edge of the beam; for SET-1, SET-2, SET-3, a 0 dB additional loss is used in the spreadsheet calculation with the assumption that the DL EIRP is the EIRP at the beam edge; for SET-4, a 3 dB additional loss is used in the spreadsheet calculation with the assumption that the DL EIRP is the EIRP at the Nadir.

#### 6.2.2.1.1 Set-1

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| PC3 (23 dBm), NF=7 dB | | | | | |
| Cases | EIRP Density | EIRP per spot | DL C/N | G/T | UL C/N  1080 kHz / 360 kHz /180 kHz / 90 kHz / 45 kHz / 30 kHz / 15 kHz / 3.75 kHz |
| 1 | 59 dBW/MHz | 81.6 dBm | -3.3 dB | 19 dB/K | -22.0 dB / -17.3 dB / -14.2 dB / -11.2 dB / -8.2 dB / -6.5 dB / -3.5 dB / 2.6 dB |
| 2 | 40 dBW/MHz | 62.6 dBm | 3.6 dB | 1.1 dB/K | -14.0 dB / -9.3 dB / -6.3 dB / -3.3 dB / -0.3 dB / 1.5 dB / 4.5 dB / 10.5 dB |
| 3 | 34 dBW/MHz | 56.6 dBm | 3.0 dB | 1.1 dB/K | -8.6 dB / -3.9 dB / -0.9 dB / 2.2 dB / 5.2 dB / 6.9 dB / 9.9 dB / 16.0 dB |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| PC5 (20 dBm), NF=9 dB | | | | | |
| Cases | EIRP Density | EIRP per spot | DL C/N | G/T | UL C/N  1080 kHz / 360 kHz /180 kHz / 90 kHz / 45 kHz / 30 kHz / 15 kHz / 3.75 kHz |
| 1 | 59 dBW/MHz | 81.6 dBm | -5.3 dB | 19 dB/K | -25.0 dB / -20.3 dB / -17.2 dB / -14.2 dB / -11.2 dB / -9.5 dB / -6.5 dB / -0.4 dB |
| 2 | 40 dBW/MHz | 62.6 dBm | 1.6 dB | 1.1 dB/K | -17.0 dB / -12.3 dB / -9.3 dB / -6.3 dB / -3.3 dB / -1.4 dB / 1.5 dB / 7.5 dB |
| 3 | 34 dBW/MHz | 56.6 dBm | 1.0 dB | 1.1 dB/K | -11.6 dB / -6.9 dB / -3.9 dB / -0.8 dB / 2.2 dB / 3.9 dB / 6.9 dB / 13.0 dB |

#### 6.2.2.1.2 Set-2

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| PC3 (23 dBm), NF=7 dB | | | | | |
| Cases | EIRP Density | EIRP per spot | DL C/N | G/T | UL C/N  1080 kHz / 360 kHz / 180 kHz / 90 kHz / 45 kHz / 30 kHz / 15 kHz / 3.75 kHz |
| 4 | 53.5 dBW/MHz | 76.1 dBm | -8.5 dB | 14 dB/K | -26.7 dB / -22.0 dB / -19.0 dB / -16.0 dB / -13.0 dB / -11.2 dB / -8.2 dB / -2.2 dB |
| 5 | 34 dBW/MHz | 56.6 dBm | -3.4 dB | -4.9 dB/K | -20.8 dB / -16.0 dB / -13.0 dB / -10.0 dB / -7.0 dB / -5.2 dB / -2.2 dB / 3.8 dB |
| 6 | 28 dBW/MHz | 50.6 dBm | -3.7 dB | -4.9 dB/K | -15.4 dB / -10.6 dB / -7.6 dB / -4.6 dB / -1.5 dB / 0.2 dB / 3.2 dB / 9.3 dB |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| PC5 (20 dBm), NF=9 dB | | | | | |
| Cases | EIRP Density | EIRP per spot | DL C/N | G/T | UL C/N  1080 kHz / 360 kHz /180 kHz / 90 kHz / 45 kHz / 30 kHz / 15 kHz / 3.75 kHz |
| 4 | 53.5 dBW/MHz | 76.1 dBm | -10.5 dB | 14 dB/K | -29.7 dB / -25.0 dB / -22.0 dB / -19.0 dB / -16.0 dB / -14.2 dB / -11.2 dB / -5.2 dB |
| 5 | 34 dBW/MHz | 56.6 dBm | -5.4 dB | -4.9 dB/K | -23.8 dB / -19.0 dB / -16.0 dB / -13.0 dB / -10.0 dB / -8.2 dB / -5.2 dB / 0.8 dB |
| 6 | 28 dBW/MHz | 50.6 dBm | -5.7 dB | -4.9 dB/K | -18.4 dB / -13.6 dB / -10.6 dB / -7.6 dB / -4.5 dB / -2.8 dB / 0.2 dB / 6.3 dB |

#### 6.2.2.1.3 Set-3

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| PC3 (23 dBm), NF=7 dB | | | | | |
| Cases | EIRP Density | EIRP per spot | DL C/N | G/T | UL C/N  1080 kHz / 360 kHz / 180 kHz / 90 kHz / 45 kHz /30 kHz / 15 kHz / 3.75 kHz |
| 7 | 59.8 dBW/MHz | 84.4 dBm | -2.2 dB | 16.7 dB/K | -24.0 dB / -19.3 dB / -16.3 dB / -13.3 dB / -10.3 dB / -8.5 dB / -5.5 dB / 0.6 dB |
| 8 | 33.7 dBW/MHz | 56.3 dBm | -2.1 dB | -12.8 dB/K | -27.3 dB / -22.5 dB / -19.5 dB / -16.5 dB / -13.5 dB / -11.7 dB / -8.7 dB / -2.7 dB |
| 9 | 28.3 dBW/MHz | 50.9 dBm | -2.1 dB | -12.8 dB/K | -21.9 dB / -17.2 dB / -14.1 dB / -11.1 dB / -8.1 dB / -6.4 dB / -3.3 dB / 2.7 dB |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| PC5 (20 dBm), NF=9 dB | | | | | |
| Cases | EIRP Density | EIRP per spot | DL C/N | G/T | UL C/N  1080 kHz / 360 kHz /180 kHz / 90 kHz / 45 kHz / 30 kHz / / 15 kHz / 3.75 kHz |
| 7 | 59.8 dBW/MHz | 84.4 dBm | -4.2 dB | 16.7 dB/K | -27.0 dB / -22.3 dB / -19.3 dB / -16.3 dB / -13.3 dB / -11.5 dB / -8.5 dB / -2.4 dB |
| 8 | 33.7 dBW/MHz | 56.3 dBm | -4.1 dB | -12.8 dB/K | -30.3 dB / -25.5 dB / -22.5 dB / -19.5 dB / -16.5 dB / -14.7 dB / -11.7 dB / -5.7 dB |
| 9 | 28.3 dBW/MHz | 50.9 dBm | -4.1 dB | -12.8 dB/K | -24.9 dB / -20.2 dB / -17.1 dB / -14.1 dB / -11.1 dB / -9.4 dB / -6.3 dB / -0.3 dB |

#### 6.2.2.1.4 Set-4

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| PC3 (23 dBm), NF=7 dB | | | | | |
| Cases | EIRP Density | EIRP per spot | DL C/N | G/T | UL C/N  1080 kHz / 360 kHz / 180 kHz / 90 kHz / 45 kHz / 30 kHz / 15 kHz / 3.75 kHz |
| 10 | 21.4 dBW/MHz | 44 dBm | -12.0 dB | -20.9 dB/K | -27.0 dB / -23.0 dB / -20.0 dB / -16.9 dB / -13.9 dB / -12.2 dB / -9.2 dB / -3.1 dB |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| PC5 (25 dBm), NF=9 dB | | | | | |
| Cases | EIRP Density | EIRP per spot | DL C/N | G/T | UL C/N  1080 kHz / 360 kHz /180 kHz / 90 kHz / 45 kHz / 30 kHz / 15 kHz / 3.75 kHz |
| 10 | 21.4 dBW/MHz | 44 dBm | -12.0 dB | -20.9 dB/K | -30.0 dB / -26.0 dB / -23.0 dB / -19.9 dB / -16.9 dB / -15.2 dB / -12.2 dB / -6.1 dB |

## 6.3 Time and Frequency Synchronization

The following aspects related to enhancements to time and frequency synchronization will be studied:

* GNSS measurement window for initial access.
* Potential impact of GNSS Position fix on UE power consumption using battery life methodology in Rel-13 TR 45.820 (Section 5.4)
  + FFS: Details of the study
* For the study of potential impact of GNSS Position fix on UE power consumption considering at least the following parameters
  + GNSS power consumption value
  + GNSS position Time To First Fix
* Potential impact of NTN SIB carrying the satellite ephemeris on
  + UE power consumption in NB-IoT and eMTC
  + Accuracy of satellite location tracking
  + PRACH congestion
* UE pre-compensation of satellite delay and satellite Doppler shift during long UL transmission on (N-)PUSCH in NB-IoT and eMTC.
* UE pre-compensation of satellite delay and satellite Doppler shift during long UL transmission on PRACH in NB-IoT and eMTC.

### 6.3.1 GNSS Position fix impact on UE power consumption

It was agreed in RAN1#104bis-e that the summary of GNSS Position fix impact on UE power consumption based on Appendix A Section 5.1 in [7] is captured and further checked and revised as necessary in a Text Proposal to TR 36.763. The individual companies battery life analysis in Appendix A in [7] are captured in Annex C in TR 36.763.

#### 6.3.1.1 Assumptions for UE power consumption analysis

TR 45.820 Section 7.2.4.5.2 provide power consumption assumptions for energy consumption model.

Table 5.4-1: Key input parameters for energy consumption analysis

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| (1) Battery capacity  (Wh) | (2) Battery power during Tx  (mW) | (3) Battery power for Rx (mW) | (4) Battery power when Idle but not in PSS (mW) | (5) Battery power in Power Save State (PSS) (mW) | (6) Time between end of IP packet carrying "report" and start of IP packet carrying "ack" on radio (ms) | (7) Number of reports per day |
| 5 |  |  |  | [0,015] | 1000 |  |
| For each report (refer to Figure 5.4-1): | | | | | | |
| (8) Rx time from PSS exit to re-entry into PSS  (ms) | (9) Idle time from PSS exit to re-entry into PSS  (ms) | (10) Tx time from PSS exit to re-entry into PSS  (ms) | (11) Time from last Rx or Tx activity to entry into PSS1  (ms) |  |  |  |
|  |  |  | 20000 |  |  |  |

Table 7.2.4.5-1: Power consumption assumptions

|  |  |  |
| --- | --- | --- |
| ***Activity*** | ***Power consumption***  ***(mW)*** | ***Comments*** |
| TX active | 545 | Transmitter active at +23 dBm, assuming 44% PA efficiency and 90 mW for other analog and baseband circuitry |
| RX active | 90 | Analog RF and digital baseband processing for active receiver |
| Idle  (light sleep) | 3 | Maintenance of precision oscillator reference for RF synthesizers |
| Deep Sleep | 0.015 | Low power crystal, sleep counters and state machine |



Huawei mention conditions for GNSS TTFF with cold start, warm start, hot start:

* The first is cold start with which no almanac information is stored in the receiver. The UE have to search signals from all the possible satellites and at least 4 satellites are needed for the positioning. Therefore, the duration will be affected by the rate of GNSS signal transmission and quality of reception. The time duration of cold start can range from tens of seconds to more than ten minutes. The typical values of cold start is 30 s if the GNSS signal is received with not much interruption.
* The second start is warm start which is based on the assumption that the some ephemeris information and clock correction data is already obtained. With some available information, the positioning time will be reduced to several seconds.
* The third start is hot start which is based on the assumption that GNSS receiver has valid ephemeris, clock correction and GNSS time reference with time for positioning can be as low as 1~2s.

Assumptions used by contributing companies in battery life analysis with NGSS position fix every UL transmissions:

* GNSS power consumption
  + Integrated GNSS and IoT module:
  + Separate GNSS module and IoT Module: Huawei, MediaTek (100 mW)
* GNSS Position Time To First Fix (TTFF)
  + Hot start: Huawei (1s or 2 s),
  + Warm start: Huawei (several seconds)
  + Cold start: Huawei (30 s)

In order to compare battery life analysis from contributing companies, we align their simulation results case by case based on assumption for reporting (2h and 6h), packet size (50 Bytes), GNSS position TTFF (2s and 5s), MCL = 154 dB assumption (this determines active time for Rx, Tx). This is to ensure there is convergence of methodology. The methodology included all transmissions and receptions in device in energy consumption models.

#### 6.3.1.2 Separate GNSS module and IoT Module

Separate GNSS module and IoT Module assumptions for power consumption assumed in the analysis were as follows:

* Huawei, MediaTek (100 mW)
* CATT (216 mW)

For MediaTek and CATT simulation results we used scaling by 2 to provide figures from 1 day to 12 h to align with Huawei. Note that CATT used GNSS module power consumption of 216 mW; Huawei and MediaTek figures are shown with GNSS module power consumption of 100 mW. The results from companies show reasonable agreement and consistency in observations. At a medium MCL=154 dB, the battery life in NTN is in range 6 years to 16 years; the reduction in battery life is in range 10 % to 40 %.

|  |  |  |
| --- | --- | --- |
| GNSS TTFF (hot start 2s), 2h report | | |
| Source | Huawei  MCL=154 dB, 105 bytes UL, 320 ms report, GNSS 100 mW | MediaTek  MCL=154 dB, 50 bytes UL, 238 ms report, GNSS 100 mW |
| Total active IoT Rx time | 164 ms | 371 ms |
| Total active IoT Tx time | 534 ms | 335 ms |
| Battery life (TN) | 8.6 years | 10.5 years |
| Battery life (NTN) | 6.0 years | 6.9 years |
| Reduction in battery life | 30.2 % | 34.3 % |

|  |  |  |  |
| --- | --- | --- | --- |
| GNSS TTFF (warm start 5s), 12h report | | | |
| Source | Huawei  MCL=154 dB, 105 bytes UL, 320 ms report, GNSS 100 mW | MediaTek  MCL=154 dB, 50 bytes UL, 238 ms report, GNSS 100 mW | CATT  MCL=154 dB, 50 bytes UL, 320 ms report, **GNSS 216 mW** |
| Total active IoT Rx time | 164 ms | 371 ms | 641 ms |
| Total active IoT Tx time | 534 ms | 335 ms | 400 ms |
| Battery life (TN) | 24.3 years | 15.6 years | 15.6 years |
| Battery life (NTN) | 16.2 years | 11.9 years | 9.3 years |
| Reduction in battery life | 33.3% | 23.7 % | 40.4% |

#### 6.3.1.3 Integrated GNSS module and IoT Module

Separate GNSS module and IoT Module assumptions for power consumption assumed in the analysis were as follows:

* Ericsson, MediaTek, Nokia (37 mW)

Ericsson observed for eMTC/NB-IoT, the reduction in battery life can be up to around 6% at 164 dB MCL and up to around 17% at 144 dB MCL depending on the UL reporting interval, packet size, and RRC procedure. Similar observations can be made from ANNEX A in MediaTek contribution where the reduction in battery life can be around 2.6 % at 164 dB MCL and around 11.7% at 144 dB MCL with similar assumptions.

|  |  |  |
| --- | --- | --- |
| GNSS TTFF (hot start 1s), 2h report | | |
| Source | MediaTek  MCL=154 dB, 50 bytes UL, 238 ms report, GNSS 37 mW | Ericsson  MCL=154 dB, 50 bytes UL EDT, 238 ms report, GNSS 37 mW |
| Total active IoT Rx time | 371 ms | - |
| Total active IoT Tx time | 335 ms | - |
| Battery life (TN, years) | 10.5 years | 14.6 years |
| Battery life (NTN, years) | 9.5 years | 12.9 years |
| Reduction in battery life | 9.5 % | 11.6 % |

|  |  |  |
| --- | --- | --- |
| GNSS TTFF (warm start 5s), 24h report | | |
| Source | MediaTek  MCL=154 dB, 50 bytes UL, 238 ms report, GNSS 37 mW | Ericsson  MCL=154 dB, 50 bytes UL EDT, 238 ms report, GNSS 37 mW |
| Total active IoT Rx time | 371 ms | - |
| Total active IoT Tx time | 335 ms | - |
| Battery life (TN, years) | 31.2 years | 33.8 years |
| Battery life (NTN, years) | 27.9 years | 30.0 years |
| Reduction in battery life | 10.2 % | 11.2 % |

Nokia observed that for packet size 50byte case, battery life reduction as 2.33% if 1s hot-start GNSS measurement assumed and 10.66% if 5s warm-start GNSS measurement assumed. While for 200bytes case, reduction will be 1.1% and 5.29% separately for hot-start and warm-start case. More battery life reduction when GNSS start is larger than 5 seconds.

|  |  |  |
| --- | --- | --- |
| GNSS TTFF (hot start 1s), 2h report | | |
| Source | Nokia | MediaTek |
| MCL=164 dB, 50 bytes UL, GNSS 37 mW | MCL=164 dB, 50 bytes UL, GNSS 37 mW (integrated) |
| Total active IoT Rx time | 2171 ms | 2290 ms |
| Total active IoT Tx time | 2193 ms | 2110 ms |
| Battery life (TN) | 2.65 years | 2.68 years |
| Battery life (NTN) | 2.59 years | 2.61 years |
| Reduction in battery life | 2.33% | 2.61% |

|  |  |  |
| --- | --- | --- |
| GNSS TTFF (warm start 5s), 2h report | | |
| Source | Nokia | CATT |
| MCL=164 dB, 50 bytes UL, GNSS 37 mW | MCL=164 dB, 50 bytes UL, GNSS 20 mW |
| Total active IoT Rx time | 2171 ms | 3035 ms |
| Total active IoT Tx time | 2193 ms | 2560 ms |
| Battery life (TN) | 2.65 years | 2.3 years |
| Battery life (NTN) | 2.37 years | 2.2 years |
| Reduction in battery life | 10.66% | 4.35% |

|  |  |  |  |
| --- | --- | --- | --- |
| GNSS TTFF (warm start 5s), 24h report | | | |
| Source | Nokia | MediaTek | CATT |
| MCL=164 dB, 50 bytes UL, GNSS 37 mW | MCL=164 dB, 50 bytes UL, GNSS 37 mW (integrated) | MCL=164 dB, 50 bytes UL, GNSS 20 mW |
| Total active IoT Rx time | 2171 ms | 2290 ms | 3035 ms |
| Total active IoT Tx time | 2193 ms | 2110 ms | 2560 ms |
| Battery life (TN) | 18.01 years | 18.12 years | 16.6 years |
| Battery life (NTN) | 16.87 years | 16.95 years | 16.0 years |
| Reduction in battery life | 6.33% | 6.46% | 3.61% |

#### 6.3.1.4 Power consumption—short, sporadic connections

Qualcomm considered case IoT UE transmit its payload once every hrs, once every hrs, etc; after transmitting the payload, the UE’s connection is released, and it goes back into deep sleep mode, until before the next transmission occasion. GNSS TTFF assumption is 2s. A typical NB-IoT over NTN scenario (e.g., a good coverage LEO satellite setting for Set 2) corresponding to a downlink SNR (for 15 kHz 1 PRB reception) of 0 dB and an uplink SNR (for 15 kHz 1 PRB transmission) of -5 dB (with a PC5 UE transmitting at the max. power of 20 dBm).



Figure 3: Short, sporadic transmissions for IoT over NTN.

**Under the studied scenario of short, sporadic connections, a GNSS fix before every connection consumes approximately of the UE’s total available energy.**

For UEs that are *mobile*, e.g., say tracking devices, etc., that are operating in this *short, sporadic connection* paradigm, this power penalty due to GNSS cannot be mitigated significantly, under the purview of Release 17 assumptions of GNSS-based uplink pre-compensation. However, for UEs that are *fixed*, e.g., smart meters, etc, these UEs may be able to save power by having a much more relaxed (e.g., once a week, or once a month, depending on the setting) GNSS fixing schedule.

#### 6.3.1.5 Power consumption— long connections (e.g., based on CDRX)

Qualcomm considered case *long connection* according. The IoT UE may remain in connected mode for a significantly longer duration of time than the short, sporadic connections described above. These may be facilitated e.g., via connected mode DRX (CDRX), wherein much larger payloads are transmitted or received by the UE during the longer connection. 

Figure 4: Long connection with connected mode DRX for IoT over NTN.

A GNSS fix before every uplink transmission occasion (which, in the absence of other mechanisms, may end up being required to maintain uplink synchronization accuracy within specified limits) results in  **of the UE’s total power consumption resulting from GNSS fixes**. While we can mitigate this somewhat for fixed UEs, for mobile UEs (especially UEs moving at high speeds), without other enhancements to connected mode synchronization, we may not be able to avoid this hit to the UE’s power consumption on account of GNSS fixes.

**Under the studied scenario of a long connection employing connected mode DRX (with a DRX cycle of ), a GNSS fix before every uplink transmission consumes approximately of the UE’s total available energy without additional enhancements w.r.t uplink synchronization. This is especially true for mobile UEs that cannot depend on a prior acquired GNSS fix.**

#### 6.3.1.6 Other observations from power consumption evaluation

MediaTek observed a general trend with smallest battery life reduction in the order of 1% to 3% when battery life is in the order of 1 year; and largest battery life reduction in the order of 30% to 68% when battery life is in the order of 10 years or longer. GNSS TTFF hot start 1s, 2s and warm start 5s, 30s were simulated.

Ericsson observed that the reduction in battery life can be up to around 6% at 164 dB MCL and up to around 17% at 144 dB MCL depending on the UL reporting interval, packet size, and RRC procedure.

MediaTek observed that in scenarios of fixed IoT Sensors, or GNSS position available in Application Layer for Asset tracking / Fleet management, the impact on battery life is 0 %. There is either no need for UE to get a GNSS position fix (because the UE is fixed position with GNSS position acquired only once during fitting) or the GNSS position is available in the application layer because the UE needs to include it in the report.

CATT observed over 1 year battery life with transmission every 2hr of 200B, and over 2 years battery life with transmission every 2hr of 50B (on 216 mW), and over 10 years with transmission every day of 50B or 200B on 20mw GNSS power consumption of integrated architecture.

Nokia observed GNSS measurement may cause for packet size 50byte case, battery life reduction as 2.33% if 1s hot-start GNSS measurement assumed and 10.66% if 5s warm-start GNSS measurement assumed. While for 200bytes case, reduction will be 1.1% and 5.29% separately for hot-start and warm-start case. More battery life reduction when GNSS start is larger than 5s.

Ericsson proposed RAN1 to discuss and agree on the assumptions for IoT NTN battery life evaluation such as MCL, transmit power, bandwidth and noise figure.

CMCC, APT proposed the study of potential impact of GNSS Position fix on UE power consumption to be de-prioritized.

The following observations are made based on contributing companies:

* Contributing companies have shown consistent observations when using similar assumptions for reporting interval, packet size, GNSS TTFF and power consumption and MCL
* Impact on battery life is 0 % for use case fixed IoT sensors with GNSS position acquired once during fitting, or use case GNSS position available in IoT application Layer for Asset tracking / Fleet management
* In use case where the IoT device is not fixed position and GNSS position in not available in IoT application Layer, the following were observed based on contributing companies:
  + Reduction in battery life is around 6% at 164 dB MCL and around 17% at 144 dB MCL depending on the UL reporting interval, packet size, and RRC procedure with GNSS TTFF hot start 1s and warm start 5s and GNSS power consumption of 37 mW (integrated IoT and GNSS modules).
  + Reduction in battery life is around 1% to 3% when battery life is around 1 year; and 30% to 68% when battery life is around 10 years or longer with GNSS TTFF hot start 1s and warm start 5s and GNSS power consumption of 37 mW (integrated IoT and GNSS modules) and 100 mW (separate IoT and GNSS modules).
  + GNSS measurement may cause for packet size 50byte case, battery life reduction as 2.33% if 1s hot-start GNSS measurement assumed and 10.66% if 5s warm-start GNSS measurement assumed. While for 200bytes case, reduction will be 1.1% and 5.29% separately for hot-start and warm-start case. More battery life reduction when GNSS start is larger than 5s.
  + For short, sporadic connections, a GNSS fix before every connection consumes 34% of the UE’s total available energy; and in long connection employing connected mode DRX (with a DRX cycle of ~10s), a GNSS fix before every uplink transmission consumes 45% of the UE’s total available energy.
  + For long connection employing connected mode DRX (with a DRX cycle of ~10s), a GNSS fix before every uplink transmission consumes approximately 45% of the UE’s total available energy without additional enhancements w.r.t uplink synchronization.
  + Over 1 year battery life with transmission every 2hr of 200B, and over 2 years battery life with transmission every 2hr of 50B (on 216 mW), and over 10 years with transmission every day of 50B or 200B on 20mw GNSS power consumption of integrated architecture.

The battery life evaluation using in Rel-13 TR 45.820 (Section 5.4) has shown that overall the impact of GNSS can be moderate to significant, while allowing battery life of several years in case of significant reduction. The results would suggest that mitigation of power consumption due to GNSS could be a promising area of research that would be beneficial in case of high battery life comparable with cellular IoT of 10 years or beyond would be target for NTN IoT. The evaluation based on contributing companies would suggest the battery life in NTN IoT is sufficient for a working solution in worst case for power consumption where GNSS position fix is assumed to be needed before each UL transmission. In typical IoT applications, the impact on battery life would be 0 % for fixed IoT sensors or GNSS position available in Application Layer.

### 6.3.2 NTN SIB reading impact on UE power consumption

The required power consumption to read SIB containing satellite ephemeris information for the short sporadic connections use case is not significant.

* Note: For this conclusion, it is assumed that the UE need not read broadcast SIB for the purpose of obtaining satellite ephemeris information in CONNECTED mode.

### 6.3.3 Long UL transmission on PUSCH

UE pre-compensation done per N time units for long PUSCH is the baseline solution.

* The pre-compensation does not vary within a block of N time units
* FFS: the definition and value of N

### 6.3.4 Long UL transmission on PRACH

UE pre-compensation done per N time units for long PRACH is the baseline solution.

* The pre-compensation does not vary within a block of N time units
* FFS: the definition and value of N

### 6.3.5 DL Synchronization

For DL synchronization in the Rel-17 timeframe, the following should be considered

* New Channel raster with a step size increased to be greater than 100 kHz
* (part of) ARFCN-indication-in-MIB

## 6.4 Timing Relationship Enhancements

The following aspects related to timing relationships enhancements will be studied to check whether enhancement is necessary and beneficial:

For NB-IoT:

* NPDCCH to NPUSCH format 1
* RAR grant to NPUSCH format 1
* NPDSCH to HARQ-ACK on NPUSCH format 2
* NPDCCH order to NPRACH
* Timing advance command activation
* FFS: Other NB-IoT timing relationships

For eMTC:

* MPDCCH to PUSCH
* RAR grant to PUSCH
* PDCCH order to PRACH
* MPDCCH to scheduled uplink SPS
* PUSCH to HARQ-ACK on PUCCH
* CSI reference resource timing
* MPDCCH to aperiodic SRS
* Timing advance command activation
* FFS: Other eMTC timing relationships

Impact of large RTD (which impacts TA) on HD-FDD UL-DL timing relationships

The study will identify IoT-NTN configurations needing activation/de-activation via MAC CE and their timing relationships.

The impact on any timing relationships for IoT-NTN due to the need to perform GNSS measurements for time and frequency synchronization will be studied

The following NB-IoT timing relationships need enhancing for essential minimum functionality of IoT NTN:

* NPDCCH to NPUSCH format 1
* RAR grant to NPUSCH format 1
* NPDSCH to HARQ-ACK on NPUSCH format 2
* Timing advance command activation
* FFS: NPDCCH order to NPRACH
* FFS: Other NB-IoT timing relationships

The enhancement based on extending the timing relationship, by e.g. Koffset, adopted in NR NTN should be the starting point for enhancement of NB-IoT timing relationships in IoT NTN. Details can be further discussed considering IoT NTN.

The following eMTC timing relationships need enhancing for **essential minimum functionality of** IoT NTN:

* MPDCCH to PUSCH
* RAR grant to PUSCH
* MPDCCH to scheduled uplink SPS
* PUSCH to HARQ-ACK on PUCCH
* CSI reference resource timing
* MPDCCH to aperiodic SRS
* Timing advance command activation
* FFS: MPDCCH order to PRACH
* FFS: Other eMTC timing relationships

The enhancement based on extending the timing relationship, by e.g. Koffset, adopted in NR NTN should be the starting point for enhancement of eMTC timing relationships in IoT NTN. Details can be further discussed considering IoT NTN.

The UE-specific TA and/or K\_offset can be used by the eNB in its scheduling to avoid UL-DL collisions in FDD-HD.

## 6.5 HARQ

For NTN IoT, potential HARQ enhancements need to consider the main characteristics of an IoT device, which are low complexity, low cost, low power consumption and low throughput, and key requirements of IoT services which are extended coverage, delay-tolerant and infrequent data transmissions, and support of massive communications.

The peak throughput of IoT UEs operating over NTN is not expected to be higher than the peak throughput of IoT UEs operating over TN.

The following aspects related to HARQ enhancements will be studied:

Whether HARQ stalling happens at least in the GEO satellite scenario

Necessity, potential benefits and/or drawbacks

* Increasing the number of HARQ processes on throughput, latency, power consumption and complexity
* Disabling HARQ feedback for NB-IoT
* Disabling HARQ feedback for eMTC
* Any other potential HARQ feedback mechanisms
* Reduced PDCCH monitoring
* Coverage enhancements
* Uplink transmission gaps with multiple HARQ processes
* Maintaining HARQ process continuity in serving cell change
* Multiple Transport Blocks scheduling
* Throughput enhancements

Increasing the number of HARQ processes for NB-IoT and for eMTC in NTN is recommended not to be supported in Rel-17.

# 7 Radio Protocol Issues and Solutions

## 7.1 Requirements and key issues

### 7.1.1 Delay

The table below is amended from TR 38.821 [3] to identify the worst case IoT NTN scenarios to be considered.

Table 7.1-1: NTN scenarios versus delay constraints, Source [3]

| NTN scenarios | GEO transparent payload | LEO transparent payload |
| --- | --- | --- |
| Satellite altitude | 35786 km | 600 km |
| Relative speed of Satellite with respect to earth | negligible | 7.56 km per second |
| Min elevation for both feeder and service links | 10° for service link and 10° for feeder link | |
| Typical Min / Max NTN beam footprint diameter (Note 2) | 100 km / 3500 km | 50 km / 1000 km |
| Maximum propagation delay contribution to the Round Trip Delay on the radio interface between the gNB and the UE | 541.46ms (Worst case) | 25.77ms |
| Minimum propagation delay contribution to the Round Trip Delay on the radio interface between the gNB and the UE | 477.48ms | 8ms |
| Maximum Delay variation seen by the UE (Note 3) | Negligible | Up to +/- 40 µs/sec (Worst case) |
| NOTE 1: The beam footprint diameter is indicative. The diameter depends on the orbit, earth latitude, antenna design, and radio resource management strategy in a given system.  NOTE 2: The delay variation measures how fast the round trip delay (function of UE-satellite-NTN gateway distance) varies over time when the satellite moves towards/away from the UE. It is expressed in µs/s and is negligible for GEO scenario.  NOTE 3: Speed of light used for delay calculation is 299792458 m/s. | | |

When several non-terrestrial network scenarios feature a maximum in terms of delay constraints, it is sufficient to study only one of these scenarios.

- NTN Scenario based on GEO with transparent payload for RTT and delay difference constraints

- NTN Scenario based on LEO with transparent payload and moving beams for the delay variation related constraint.

## 7.2 User plane enhancements

### 7.2.1 MAC

The challenges associated with the expiry of MAC timers in NR NTN remain the same in IoT NTN and high RTT of NTN is the primary cause of this [10]. The following sections are adopted from TR 38.821 [3] with suitable amendments for IoT operation.

#### 7.2.1.1 Random Access

**Enhancement to random access (RA) response window**

*Problem Statement*

After transmitting the Random Access Preamble (Msg1), the UE monitors the PDCCH for the Random Access Response (RAR) message (Msg2). The RA Response window starts at a determined time interval after the preamble transmission. If no valid response is received during the RA Response window, a new preamble is transmitted. If more than a certain number of preambles have been transmitted with no valid response during the RA Response window, a random access problem is indicated to upper layers.

In NTN the propagation delay is much larger and therefore, RAR message cannot be received by the UE within the time interval specified for terrestrial communications. Therefore, the starting time of RA Response window should be modified to support IoT NTN.

*Solution Overview*

Similar to NR NTN [3], the offset can be adjusted to delay the start of the RA Response window for IoT NTN [10]. If the start of the ra-ResponseWindow is accurately compensated and no extension of repetition is required, there is no need to extend the ra-ResponseWindowSize for IoT NTN.

**Enhancement to contention resolution timer**

Problem Statement

When the UE sends an RRC Connection Request (Msg3), it will monitor for Msg4 in order to resolve a possible random-access contention. The mac-ContentionResolutionTimer starts after Msg3 transmission. The maximum configurable value of mac-ContentionResolutionTimer is large enough to cover the Round Trip Delay in NTN. However, to save UE power, the behavior of mac-ContentionResolutionTimer should be modified to support NTN.

*Solution Overview*

Similar to NR NTN [3], introduce an offset to delay the start of the *mac-ContentionResolutionTimer* for IoT NTN [10].

#### 7.2.1.2 Discontinuous Reception (DRX)

*Problem Statement*

The Discontinuous Reception (DRX) supports UE battery saving by reducing the PDCCH monitoring time. Several RRC configurable parameters are used to configure DRX. [7, TS36.331]

HARQ RTT Timer is the minimum duration before a downlink assignment for HARQ retransmission is expected by the MAC entity. UL HARQ RTT Timer is the same as DL HARQ RTT Timer, just for the uplink. If HARQ is supported by IoT NTN, the handling of DL HARQ RTT Timerand UL HARQ RTT Timer, should be modified to support IoT NTN.

Modification of the remaining timers related to DRX is not needed to support IoT NTN, similar to NR NTN [3].

*Solution Overview*

As the challenges associated with the expiry of MAC timers in NR NTN [3] remain the same in IoT NTN, it is assumed that the same solutions as NR NTN for the start of DL HARQ RTT Timer and UL HARQ RTT Timer can be reused as a baseline to support IoT NTN [10].

#### 7.2.1.3 Scheduling Request

*Problem Statement*

A UE can use a Scheduling Request (SR) to request UL-SCH resources from the eNB for a new transmission or a transmission with a higher priority. SR transmission is configured by RRC. While the prohibit timer (*sr-ProhibitTimer*) is active, no further SR is initiated. The *sr-ProhibitTimer* will at latest expire after 7 SR periods for eMTC or after 7 NPRACH opportunities for NB-IoT [7]. After the expiry of *sr-ProhibitTimer*, a SR will be initiated. For GEO systems the value range may not be sufficient because of the large RTT.

*Solution Overview*

The *sr-ProhibitTimer* will be modified for including larger values to support IoT NTN. Alignment to NR NTN can be considered.

#### 7.2.1.4 HARQ

Editor’s Note: This section will be updated based on further agreements on HARQ, e.g., whether to disable HARQ feedback.

#### 7.2.1.5 Uplink scheduling

The typical procedure when data arrives in the buffer is to trigger a Buffer Status Report and if the UE does not have any uplink resources for transmitting the BSR, the UE will go on to do a Scheduling Request to ask for resources. Since the scheduling request is only an indication telling the network that the UE requires scheduling, the network will not know the full extent of the resources required to schedule the UE, thus first the network may typically schedule the UE with a grant large enough to send a BSR so that the network may schedule the UE more accurately.

In non-terrestrial networks the drawback of this procedure is that it would take at least 2 round-trip times from data arriving in the buffer at the UE side until it can be properly scheduled with resources that would fit the data. Due to the large propagation delays this may become prohibitively large. Based on these reasons, some enhancements for UL scheduling are discussed for NR NTN. However, unlike NR NTN, UL scheduling enhancements for delay reduction is not needed for NB-IoT NTN as latency is not a critical performance requirement for IoT devices [10].

Editor’s Note: UL scheduling enhancements for delay reduction might be needed for LTE-M UEs over NTN.

### 7.2.2 RLC

#### 7.2.2.1 Reordering timer

*Problem Statement*

Both AM and UM modes use the *t-Reordering* timer to control the RLC wait interval for out-of-order MAC data before considering the missing data as lost and handing any received data off to the PDCP layer. The *t-Reordering* timer can be configured with fixed values between 0 and 1600ms [7]. Large propagation delay might have impacts on *t-Reordering* timer.

*Solution Overview*

The value range of the RLC *t-Reordering* timer will be extended to support IoT NTN.

#### 7.2.2.2 RLC Sequence Numbers

In NB-IoT, the RLC sequence number (SN) size is 7 bits for AM and 5 bits for UM. In eMTC, 10bit and 16bit are specified as the maximum possible UM and AM SN field lengths [8]. The sequence number space needed for a radio bearer depends on the data rate that is to be supported, the retransmission time (i.e. the RTT, the number of retransmissions and the scheduling delay) as well as the average size of the RLC SDUs. As the data rates for IoT NTN are significantly lower than NR NTN, there is no need to extend the RLC SN length for IoT NTN.

### 7.2.3 PDCP

#### 7.2.3.1 Discard timer

The transmitting PDCP entity shall discard the PDCP SDU when the *discardTimer* expires for a PDCP SDU or when a status report confirms the successful delivery [9]. The *discardTimer* can be configured up to 1500ms for eMTC and up to 81920ms for NB-IoT, or can be switched off by choosing infinity. The *discardTimer* mainly reflects the QoS requirements of the packets belonging to a service.

Editor’s Note: It is FFS if there is a need to extend PDCP discardTimer in IoT NTN.

#### 7.2.3.2 PDCP Sequence Numbers

In NB-IoT, the PDCP sequence number (SN) size is 7 bits. In eMTC, the maximum possible PDCP SN field length is 18bits [9]. As the data rates for IoT NTN are significantly lower than NR NTN, there is no need to extend the PDCP SN length for IoT NTN.

## 7.3 Control plane enhancements

Editor’s Note: RAN2 should wait for RAN1’s input on supporting multiple beams per cell for IoT NTN.

### 7.3.1 Idle mode mobility enhancements

#### 7.3.1.1 Tracking Area

*Problem Statement*

As outlined in 38.821 [3], satellites may provide very large cells, covering hundreds of kilometres, and consequently would lead to large tracking areas. In this scenario the tracking area updates (TAUs) are minimal, however the paging load could be high because it then relates to the number of devices in the tracking area.

Moving cells and consequently moving tracking areas would be difficult to manage in the network as the contrast between the TAU and the paging signalling load would be too extreme to find a practical compromise.

On one hand, small tracking areas would lead to massive TAU signalling for UE at the boundary between 2 TAs as illustrated in figure 7.3.1.1-1.



Figure 7.3.1.1-1: Moving Cells and Small tracking areas leading to massive TAU signalling

On the other hand, wide tracking areas would lead to high paging load in the satellite beams as illustrated in figure 7.3.1.1-2.



Figure 7.3.1.1-2: Moving Cells and wide tracking areas leading to higher Paging load

However, tracking areas must be dimensioned to minimise the TAUs as this is more signalling-intensive than paging on the network.

In practical tracking area design, one of the criteria affecting the performance and capacity is the limiting capabilities of MME/AMF platforms and the radio channel capacity.

Ping-pong effect generating excessive TAU, and it can be minimised by ensuring 10-20% overlaps between the adjacent cells and appropriate allocation of TAI List to UEs especially at the edge of cells/TAs.

*Solution Overview*

In order not to have TAU performed frequently by the UE triggered by the satellite motion, the tracking area should be designed to be fixed on ground (i.e. earth-fixed TA similar to NR NTN). For NTN LEO, this implies that while the cells sweep on the ground, the tracking area code (i.e. TAC) broadcasted is changed, when the cell arrives to the area of next planned earth fixed tracking area location. The TAC broadcasted by the eNB needs to be updated as the eNB enters to the area of next planned tracking area. When the UE detects entering a tracking area that is not in the list of tracking areas that the UE previously registered in the network, a mobility registration update procedure will be triggered.



Figure 7.3.1.1-3: An example of updating TAC and PLMN ID in real-time for LEO with moving beams

As shown in Figure 7.3.1.1-3, network updates the broadcast TAC in real time according to the ephemeris and confirms that the broadcast TAC is associated with the geographical area covered by the satellite beam. UE listens to TAI = PLMN ID + TAC and determines to trigger registration area update procedure based on the broadcast TAC and PLMN ID when it moves out of the registration area.

The two signalling options to update the broadcast TAC for IoT NTN are described as follows:

**(1) "Hard switch" option:**

One cell broadcast only one TAC per PLMN. The new TAC replaces the old TAC and there may be some fluctuation at the border area. As shown in Figure 7.3.1.1-4, the UE will see its TAC changing like TAC-2 -> TAC-1 -> TAC-2 from T1 to T3.

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**Figure 7.3.1.1-4: TAC fluctuation at the border area**

**(2) "Soft switch" option:**

One cell can broadcast more than one TAC per PLMN. The cell adds the new TAC in its system information in addition to the old TAC, and subsequently removes the old TAC. If there is a chain of Tracking Areas, the TA list adds one TAC more and removes one old TAC while the cell sweeps the ground. This also reduces the amount of TAUs for UEs that happen to be located at the border area. However, for the "soft switch" option, the more TACs a cell broadcast, the heavier paging load it experiences, which usually leads to a significant imbalance distribution of paging load among cells. Thus, there is a trade-off between paging load and balancing the fluctuation of actual TA area enabled by the soft switch to be considered in network planning and implementation.

Editor’s Note: RAN2 will wait for progress in NR NTN for possible updates, if applicable to IoT NTN.

#### 7.3.1.2 Using ephemeris information and UE location information

Satellite assistance (e.g. Ephemeris information) and UE location information can be used to help UEs in IoT NTN perform measurement and cell selection/reselection, in addition to PCI and frequency information included in the broadcast system information [3] [10].

Editor’s Note: Provisioning of satellite ephemeris data and other information using System Information (SI) message for IoT NTN is FFS.

Editor’s Note: RAN2 will wait for RAN1 progress about the details of satellite ephemeris information.

#### 7.3.1.3 Enhancements to UE Idle mode mobility

Cell selection/reselection mechanisms specified for NB-IoT/eMTC [11] will be reused as a baseline. Enhancements introduced for cell selection/re-selection procedures in NR NTN [3] [10] will be considered if applicable to IoT NTN.

### 7.3.2 Connected mode mobility enhancements

7.3.2.1 General

Similar to NR NTN [3], for LEO NTN, mobility management procedures should take satellite movement into account, while for GEO NTN, the large propagation delay needs to be accommodated.

#### 7.3.2.2 Connected Mode Mobility for NB-IoT NTN

There are no connected mode mobility procedures defined for NB-IoT. When an NB-IoT UE goes out of service coverage of the source cell, it experiences a Radio Link Failure (RLF). This triggers the UE to perform RRC connection re-establishment.

Release-16 RRC connection re-establishment procedure is used as a baseline in NB-IoT NTN. Release-17enhancements to reduce the time taken for RRC re-establishment can be considered in NB-IoT NTN, if applicable. Further enhancements can be considered, e.g. by using satellite assistance (ephemeris) information.

#### 7.3.2.3 Connected Mode Mobility for eMTC NTN

Challenges in connected mode mobility for eMTC NTN are similar to the connected mode mobility issues in NR NTN. These include (1) high latency associated with handover signalling, (2) measurement validity, (3) frequent handovers, (4) dynamic neighbour cell list, (4) handover of a large number of UEs and (5) impact of propagation delay difference in measurements [3] [10].

Conditional Handover (CHO) can be used for both the moving cell and the fixed cell scenarios. The CHO procedure and execution conditions as defined in Release-16 are taken as the baseline, with the following considerations:

- The existing measurement framework for CHO (e.g. measurement configuration, execution) is the baseline.

- The existing measurement criteria and events applicable to eMTC can be used for IoT NTN. Support for new measurements types would need justification, but is not precluded, e.g. for enhanced coverage.

- Time or timer based and location based CHO triggering event, in combination with the existing Release-16 CHO measurement based event, can be introduced for both moving cell and fixed cell scenarios. Support for new triggering events is not precluded.

NOTE 1: CHO for IoT NTN does not apply for E-UTRA connected to 5GC (a similar limitation applies in Release-16).

7.3.3 Paging Capacity

The paging capacity and the impact on the size of the Tracking Area are evaluated considering the target IoT NTN device density captured in Annex B.2.

Editor’s Note: Paging capacity is evaluated using the methodology captured in TR 38.821 as the baseline.

# 8 Recommendations on the way forward

## 8.1 Recommendations from RAN1

TBA

## 8.2 Recommendations from RAN2

TBA

# Annex A: Satellite ephemeris

Annex B: KPI and evaluation assumptions

# B.1 Key Performance Indicators

KPIs defined in TR38.913 are considered.

# B.2 Performance targets for evaluation purposes

Based on RAN2#105 conclusion on contribution R2-1901404 and SA1 specification requirements, the Non-Terrestrial network target performances per usage scenario for IoT connectivity (low power wide area service capability) was recommended in TR 38.821 as shown in Table B.2-1:

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

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

# Annex C (Informative): Change history

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Change history | | | | | | | |
| **Date** | **Meeting** | **TDoc** | **CR** | **Rev** | **Cat** | **Subject/Comment** | **New version** |
| 2021-01 | R2-113e | R2-2101455 |  |  |  | Skeleton TR | 0.0.1 |
| 2021-02 | R1#104e  R1#104e  R2#113e  R2#113e | R1-2102258  R1-2102255  R2-2102492 R2-2102502 |  |  |  | - Text proposal for TR 36.763 chapter related to RAN1  - Text proposal for TR 36.763 for RAN1#104e Agreements  - Text proposal for TR 36.763 related to RAN2 (from RAN2#112e)  - Text proposal for TR 36.763 capturing R2#113e agreements | 0.0.2 |
| 2021-03 | R1#104e | R1-2102272 |  |  |  | Updated version with revision marks removed | 0.1.0 |
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