|  |  |
| --- | --- |
| 3GPP TR 36.763 V1.0.0 (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) | |
|  | |
|  |  |
|  | |
| The present document has been developed within the 3rd Generation Partnership Project (3GPP TM) and may be further elaborated for the purposes of 3GPP. The present document has not been subject to any approval process by the 3GPPOrganizational Partners and shall not be implemented. This Specification is provided for future development work within 3GPPonly. The Organizational Partners accept no liability for any use of this Specification. Specifications and Reports for implementation of the 3GPP TM system should be obtained via the 3GPP Organizational Partners' Publications Offices. | |

|  |
| --- |
|  |
| ***3GPP***  Postal address  3GPP support office address  650 Route des Lucioles - Sophia Antipolis  Valbonne - FRANCE  Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16  Internet  http://www.3gpp.org |
| ***Copyright Notification***  No part may be reproduced except as authorized by written permission. The copyright and the foregoing restriction extend to reproduction in all media.  © 2019, 3GPP Organizational Partners (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC).  All rights reserved.  UMTS™ is a Trade Mark of ETSI registered for the benefit of its members  3GPP™ is a Trade Mark of ETSI registered for the benefit of its Members and of the 3GPP Organizational Partners LTE™ is a Trade Mark of ETSI registered for the benefit of its Members and of the 3GPP Organizational Partners  GSM® and the GSM logo are registered and owned by the GSM Association |

Contents

[Foreword 4](#_Toc70441838)

[1 Scope 6](#_Toc70441839)

[2 References 6](#_Toc70441840)

[3 Definitions of terms, symbols and abbreviations 6](#_Toc70441841)

[3.1 Terms 6](#_Toc70441842)

[3.2 Symbols 7](#_Toc70441843)

[3.3 Abbreviations 8](#_Toc70441844)

[4 IoT Non-Terrestrial Networks overview and scenarios 9](#_Toc70441845)

[4.1 IoT Non-Terrestrial Networks overview 9](#_Toc70441846)

[4.2 IoT Non-Terrestrial Networks reference scenarios 10](#_Toc70441847)

[5 IoT NTN Architecture and Capabilities 11](#_Toc70441848)

[5.1 IoT NTN Architecture 11](#_Toc70441849)

[5.2 IoT NTN UE Capabilities 11](#_Toc70441850)

[5.3 IoT NTN Features 11](#_Toc70441851)

[6 Radio Layer 1 issues and related solutions 12](#_Toc70441852)

[6.1 IoT NTN Reference Parameters 12](#_Toc70441853)

[6.2 Link Budget Analysis 13](#_Toc70441854)

[6.2.1 Link Budget Parameters 13](#_Toc70441855)

[6.2.2 Summary of Link Budget Results 18](#_Toc70441856)

[6.3 Time and Frequency Synchronization 22](#_Toc70441857)

[6.3.1 GNSS Position fix impact on UE power consumption 23](#_Toc70441858)

[6.3.2 NTN SIB reading impact on UE power consumption 29](#_Toc70441859)

[6.3.3 Long UL transmission on PUSCH 30](#_Toc70441860)

[6.3.4 Long UL transmission on PRACH 30](#_Toc70441861)

[6.3.5 DL Synchronization 30](#_Toc70441862)

[6.4 Timing Relationship Enhancements 30](#_Toc70441863)

[6.5 HARQ 31](#_Toc70441864)

[7 Radio Protocol Issues and Solutions 32](#_Toc70441865)

[7.1 Requirements and key issues 32](#_Toc70441866)

[7.1.1 Delay 32](#_Toc70441867)

[7.2 User plane enhancements 33](#_Toc70441868)

[7.2.1 MAC 33](#_Toc70441869)

[7.2.2 RLC 34](#_Toc70441870)

[7.2.3 PDCP 35](#_Toc70441871)

[7.3 Control plane enhancements 35](#_Toc70441872)

[7.3.1 Idle mode mobility enhancements 35](#_Toc70441873)

[7.3.2 Connected mode mobility enhancements 38](#_Toc70441874)

[7.3.3 Paging Capacity 39](#_Toc70441875)

[8 Recommendations on the way forward 39](#_Toc70441876)

[8.1 Recommendations from RAN1 39](#_Toc70441877)

[8.2 Recommendations from RAN2 39](#_Toc70441878)

[B.1 Key Performance Indicators 41](#_Toc70441879)

[B.2 Performance targets for evaluation purposes 41](#_Toc70441880)

[C.1 Introduction 42](#_Toc70441881)

[C.2 RAN2 Agreements 42](#_Toc70441882)

[C.2.1 Agreements at RAN2 #113bis-e (April 2021) 42](#_Toc70441883)

# 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

At the RAN#86 meeting, a new Study Item was approved for Internet of Things Non Terrestrial Network (IoT NTN) and revised in RAN#91 [4]. There was an email discussion on [91E][42][NTN\_IoT\_Roadmap] In RAN#91 with moderator summary and final proposal for GTW input in [5].

In RAN#91-e GTW session, the Chairman endorsed a Way Forward Proposal in [6] 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)*

The objectives for this document are, based on the outcomes of the Release-17 NR NTN WI [7] and Release-16 TR 38.821 [8], to study a set of necessary features/adaptations enabling the operation of the IoT NTN for 3GPP Release 17 with a priority on satellite access.

The first objective of this Study is to identify scenarios applicable to NB-IoT/eMTC [RAN1, RAN2], including:

- Bands of interest in sub 6 GHz

- Device type with PC3 or PC5 (LEO and GEO)

- Satellite constellation orbit LEO and GEO

- Transparent payload.

- Link budget

NOTE 1: This first objective will be based on the scenarios documented in TR 38.821.

NOTE 2: UE mobility assumptions follow terrestrial NB-IoT/eMTC assumptions.

The second objective is, for the above identified scenarios, to study and recommend necessary changes to support NB-IoT and eMTC over satellite, reusing as much as possible the conclusions of the studies performed for NR NTN in TR38.821. This objective will address the following items:

- Aspects related to random access procedure/signals [RAN1, RAN2]

- Mechanisms for time/frequency adjustment including Timing Advance, and UL frequency compensation indication [RAN1, RAN2]

- Timing offset related to scheduling and HARQ-ACK feedback [RAN1, RAN2]

- Aspects related to HARQ operation [RAN2, RAN1]

- General aspects related to timers (e.g. SR, DRX, etc.) [RAN2]

- RAN2 aspects related to idle mode and connected mode mobility [RAN2]

- RLF-based for NB-IoT

- Handover-based for eMTC

- System information enhancements [RAN2]

- Tracking area enhancements [RAN2]

NOTE 3: GNSS capability in the UE is taken as a working assumption in this study for both NB-IoT and eMTC devices. With this assumption, UE can estimate and pre-compensate timing and frequency offset with sufficient accuracy for UL transmission. Simultaneous GNSS and NTN NB-IoT/eMTC operation is not assumed.

Recommendations for NB-IoT and recommendations for eMTC will be documented in the conclusions.

# 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] RP-210868, “New Study WID on NB-IoT/eTMC support for NTN”, MediaTek, RAN#91-e, March 2021

[5] RP-210915, “Moderator's summary for email discussion [91E][42][NTN\_IoT\_roadmap]”, Ericsson (RAN1 Vice-Chair), RAN#91-e, March 2021

[6] RP-210906, Way forward on new proposals, Nokia (RAN Chair), RAN#91-e, March 2021

[7] RP-210908, “Solutions for NR to support non-terrestrial networks (NTN)”, Rapporteur (Thales), RAN#91-e, March 2021

[8] 3GPP TR 38.821 “Solutions for NR to support non-terrestrial networks”, V16.0.0 (2019-12)

[9] 3GPP TR 38.811 v15.2.0: "Study on New Radio (NR) to support non-terrestrial networks (Release 15)"

[10] 3GPP TS 37.340: "NR; Multi-connectivity; Overall description"

[11] R1-2103897, Rapporteur (MediaTek), Text proposal for TR 36.763 for RAN1#104bis-e Agreements, RAN1#104bis-e, Apr 2021

[12] 3GPP TR 45.820 v13.1.0: "Cellular system support for ultra-low complexity and low throughput Internet of Things (CIoT) (Release 13)"

[13] 3GPP TS 22.261: "Service requirements for the 5G system; Stage 1 (Release 16)"

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

[15] 3GPP TS 36.331: "E-UTRA Radio Resource Control (RRC) protocol specification (Release 16)"

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

[17] 3GPP TS 36.323: "E-UTRA Packet Data Convergence Protocol (PDCP) specification (Release 16)"

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

[19] 3GPP TS 36.304: "Evolved Universal Terrestrial Radio Access (E-UTRA); UE Procedures in Idle Mode (Release 16)"

[20] 3GPP TS 36.321: "Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification (Release 16)"

[21] R2-2106169: "Connection density evaluation for IoT NTN devices", Ericsson, RAN2 #114-e

[22] R2-2105662: "Paging evaluation for NTN IOT", Huawei, HiSilicon, RAN2 #114-e

[23] R2-2106729: "On Paging Capacity Evaluation for IoT-NTN", Nokia, Nokia Shanghai Bell, RAN2 #114-e

[24] R2-2105371: "Paging capacity evaluation for IoT NTN", ZTE Corporation, Sanechips, RAN2 #114-e

[25] R2-2104033: "Summary of [Post113-e][055][IoT NTN] Performance evaluation", Ericsson, RAN2 #113bis-e

[26] R1-2103962, Summary #3 of AI 8.15.1 Scenarios applicable to NB-IoT/eMTC, Moderator (MediaTek), RAN1#104bis-e, April 2021

[27] R1-2104573, Link budget result calibration Spreadsheet for IoT NTN, RAN1#104bis-e, April 2021

# 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

DRX Discontinuous Reception

ECEF Earth-Centered, Earth-Fixed

eDRX Extended DRX

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

PSM Power Saving Mode

PUR Preconfigured Uplink Resource

RAN Radio Access Network

RTD Round Trip Delay

Rx Receiver

SNR Signal-to-Noise Ratio

TA Timing Advance

TA Tracking Area

TAC Tracking Area Code

TAU Tracking Area Update

TLE Two-Line Element

UAS Unmanned Aircraft System

UE User Equipment

WI Work Item

WID Work Item Description

WUS Wake Up Signal

# 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 can be supported.

## 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.

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.

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

# 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) | MEO (10000 km) |
| Scintillation losses | 2.2 | 2.2 | 2.2 | 2.2 dB |
| Atmospheric losses | 0.2 | 0.1 | 0.1 | 0.04 dB |
| Polarization loss | 3 | 3 | 3 | 3 dB |
| Shadow margin | 3 | 3 | 3 | 3 dB |

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

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

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

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

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

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 [9].  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 [10] 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 [9].  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 [26] is captured and further checked and revised as necessary in a Text Proposal to TR 36.763 [11]. The summary of link budget results will be captured with alignment between contributing companies. The detailed link budget results from contributing companies were captured in a separate spreadsheet [27].

#### 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 6.2.2.1-1: Satellite losses

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Other Losses | GEO (35786 km) | LEO (1200 km) | LEO (600 km) | MEO (10000 km) |
| Scintillation losses | 2.2 dB | 2.2 dB | 2.2 dB | 2.2 dB |
| Atmospheric losses | 0.2 dB | 0.1 dB | 0.1 dB | 0.04 dB |
| Polarization loss | 3 dB | 3 dB | 3 dB | 3 dB |
| Shadow margin | 3 dB | 3 dB | 3 dB | 3 dB |

Table 6.2.2.1-2: Maximum Free Space Path Loss

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| FSPL | GEO (35786 km) | LEO (1200 km) | LEO (600 km) | MEO (10000 km) |
| Set-1 | 190.8 dB | 165.1 dB | 159.7 dB |  |
| Set-2 | 190.6 dB | 165.8 dB | 160.4 dB |  |
| Set-3 | 190.6 dB | 164.5 dB | 159.1 dB |  |
| Set-4 | - | - | 159.1 dB |  |
| Set-5 |  |  |  | 178.5 dB |

Table 6.2.2.1-3: 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*** |
| 11 | MEO-10000 | Set 5 | 90 | 81.6 | 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 | -3.2 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 | -5.2 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 |

#### 6.2.2.1.5 Set-5

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| ***Cases*** | ***EIRP Density*** | ***EIRP per spot*** | ***DL C/N*** | ***G/T*** | ***UL C/N***  ***1080 kHz / 360 kHz / 180 kHz / 90 kHz / 45 kHz / 30 kHz / 15 kHz / 3.75 kHz*** |
| ***11*** | ***45.4 dBW/MHz*** | ***68 dBm*** | ***-4.5 dB*** | ***3.8 dB/K*** | ***-25.0 dB / -19.8 dB / -16.8 dB / -13.8 dB / -10.8 dB / -9.0 dB / -6.0 dB / -0.0 dB*** |

## 6.3 Time and Frequency Synchronization enhancements

The following aspects related to enhancements to time and frequency synchronization were 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)
* 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 [12] 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 [12] 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 and PRACH

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

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

A specification change is needed for UL transmission with repetitions R>1.

For segmented UE pre-compensation how the following is handled can be further discussed

* Phase discontinuity at subframe boundary when applying new pre-compensation
* Coherence time limitation due to delay/frequency drift rate during segment
* Signal overlapping between different TA segments

FFS: Need for more frequent new UL gaps during long transmission

FFS: Whether sampling frequency adjustment to avoid new UL gaps can be achieved by implementation

FFS: Value of N for the number of time units and what is the time unit for the segmented UE pre-compensation

A validity timer for UL synchronization (e.g., for satellite ephemeris and potentially other aspects) configured by the network is recommended.

* Details e.g. when to set/reset the timer, timer duration and UE behaviour upon timer expiry can be discussed in the normative phase

For sporadic short transmission:

* The idle UE wakes up from idle DRX / PSM, access the network, perform uplink and/or downlink communications for a short duration of time and go back to idle.
* Before accessing the network, the UE acquires GNSS position fix and does not need to re-acquire a GNSS position fix for the transmission of the packets.

Details of the duration of the short transmission, acquisition of the GNSS position and validity of the GNSS position can be discussed in normative phase.

### 6.3.4 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

### 6.3.5 GNSS Measurements

For sporadic short transmission:

* The idle UE wakes up from idle DRX / PSM, access the network, perform uplink and/or downlink communications for a short duration of time and go back to idle.
* Before accessing the network, the UE acquires GNSS position fix and does not need to re-acquire a GNSS position fix for the transmission of the packets.

Details of the duration of the short transmission, acquisition of the GNSS position and validity of the GNSS position can be discussed in normative phase.

With a GNSS position fix that can be assumed to be valid for some period of time X, the following apply for UE in RRC\_CONNECTED

* TA error due to UE velocity satisfies the requirements defined in RAN4
* Doppler shift error due to UE velocity satisfies the requirement defined in RAN4

FFS: Validity of a GNSS position fix and details of acquiring a GNSS position fix, value of X, in RRC CONNECTED mode

FFS: Potential impact on the existing closed loop TA maintenance mechanism

NOTE: The detailed requirement will be defined in RAN4 during normative work.

### 6.3.6 PRACH Congestion

It was concluded that the potential issue of RACH congestion is not to be studied further within Release-17 timeframe.

## 6.4 Timing Relationship Enhancements

The following aspects related to timing relationships enhancements were 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
* PDSCH 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 were studied

The following aspects of Koffset were not studied and can at least rely on decisions made in the NR NTN WI [7]:

* Explicit or implicit indication in system information

Apart from Timing advance command activation, the study did not identify any other 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 were 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
* PDSCH 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.

It was concluded that the description of timing relationships for eMTC and NB-IoT in Rel-16 do not take the TA into account in general.

* Note: Exceptions to this may be identified as work on eMTC and NB-IoT over NTN progresses further.

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.

The RAR window offset value for NR NTN, the parameters used for its calculation and how these are configured or signalled together form a starting point for IoT NTN.

Signalling aspects involved in UE-specific TA maintenance and reporting in Rel-17 IoT and techniques to reduce the signalling load have been discussed. Mechanisms to report the UE-specific TA and other means of determining the UE-specific TA have been discussed. Decisions on these aspects can be made during a subsequent normative phase.

Whether UE-specific K-Offsets are needed or not in Rel17 IoT NTN from a physical layer point of view was discussed but without arriving at a consensus. This issue can be further discussed during a future normative phase.

## 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 were 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.

Maintaining HARQ process continuity in serving cell change

It was discussed that if there are a large number of repetitions in NTN IoT, an UL/DL transmission may potentially have a duration larger than the time interval needed by the UE for cell reselection or handover. This may potentially be an issue especially for LEO satellite due to high mobility. Some repetitions may not be able to be transmitted before a cell change happens and this will cause a waste of resources. Combining repetitions from different cells is a potential solution. RAN1 has not reached consensus to recommend solutions in Rel-17.

Throughput enhancements

It was discussed to enable PDCCH monitoring during the time period between receiving NPDSCH and transmitting HARQ ACK in NB-IoT to enhance throughput. RAN1 has not reached consensus to recommend solutions to enhance throughput in Rel-17.

Disabling HARQ feedback

It was concluded that from a physical layer perspective, there is no consensus on disabling HARQ feedback for NTN IoT in Rel-17.

PDCCH monitoring

The monitoring of a PDCCH which indicates an ACK/NACK after transmission of a PUSCH was discussed. The reason for not monitoring PDCCH for a time period after transmission of the PUSCH is UE power saving.

* When a UE is configured with one HARQ process, it was discussed whether the UE can stop PDCCH monitoring after a PUSCH transmission as a new grant would not be received until after one RTT, or the UE cannot stop PDCCH monitoring because a new grant can be received before one RTT has passed and/or the UE may need to monitor DCI for other scheduling assignments e.g. paging, system information, etc.
* When a UE is configured with two (or more) HARQ processes, whether to stop monitoring PDCCH for a time period after transmission of the PUSCH needs also to consider the relative timing of the two HARQ processes.

RAN1 noted that reduced monitoring of PDCCH is closely related to DRX and should therefore be discussed in RAN1 and RAN2.

For NB-IoT and eMTC in NTN, it was concluded that enhancement~~s~~ to the Rel-16 procedure for the monitoring of a PDCCH which indicates an ACK/NACK after transmission of a PUSCH is not an essential feature for NTN IoT in Rel-17.

Additional feedback report

Reporting of additional information by a UE (such as timing information to inform the network that a sufficient number of repetitions has been transmitted, requested number of repetition, BLER-based triggering or bundling of feedback, buffer status, enabling/disabling HARQ feedback, etc.) was discussed.

It was concluded that reporting of additional feedback is not an essential feature for NTN IoT 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 are undergoing maximum delay constraints values of the same range, it is sufficient to consider 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

#### 7.2.1.1 General

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 [18]. The following sections are adopted from TR 38.821 [3] with suitable amendments for IoT operation.

#### 7.2.1.2 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 [18].

#### 7.2.1.3 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. [15, 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 [18].

#### 7.2.1.4 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 [15]. 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.

#### 7.2.1.5 HARQ

NOTE: The details of MAC Technical Specification [20] changes and other signalling aspects of HARQ will be discussed during the Work Item phase.

#### 7.2.1.6 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 at least for NB-IoT NTN as latency is not a critical performance requirement for IoT devices [18].

#### 7.2.1.7 Preconfigured Uplink Resource

An offset can be added to the start of the *pur-ResponseWindowTimer*. If the start of the *pur-ResponseWindowTimer* is accurately compensated by UE-gNB RTT, there is no need to extend the *pur-ResponseWindowTimer* value range.

### 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 [15]. 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 [17]. 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.

NOTE: PDCP *discardTimer* enhancements can be considered during the Work Item phase provided the impact to the Technical Specifications is minimal.

#### 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

### 7.3.1 Idle mode mobility enhancements

#### 7.3.1.1 Tracking Area

*Problem Statement*

As outlined in 38.821 [17], 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 is 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 a cell beam 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.

****

**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.

NOTE: For the TA handling, the details are expected to be settled in the Work Item phase, e.g. the requirements for UE to update/re-read System Information.

#### 7.3.1.2 Using satellite assistance 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].

Satellite assistance information (e.g. ephemeris information), can be used for the handling of coverage holes or discontinuous satellite coverage in a power efficient way. For a UE, it should be possible to predict discontinuous coverage based on the satellite assistance information. To the extent that is possible/reasonable, the UE is expected to not attempt to camp or connect when there is no satellite coverage. To the extent that is possible/reasonable, the network is expected not try to reach UEs that are out of coverage.

NOTE 1: It is an expected requirement that the UE and the network are synchronized w.r.t. when the UE is awake and reachable (e.g. for paging).

NOTE 2: Provisioning of satellite assistance information can be performed using System Information (SI) message(s) for IoT NTN.

#### 7.3.1.3 Enhancements to UE Idle mode mobility

Cell selection/reselection mechanisms specified for NB-IoT/eMTC [19] will be reused as a baseline. Enhancements introduced for cell selection/re-selection procedures in NR NTN [8] [18] will be considered if applicable to IoT NTN.

NOTE: It is assumed that existing Qoffset parameter(s) can be used for cell re-selection between TN and IoT NTN.

#### 7.3.1.4 Further enhancements to System Information acquisition

For some IoT UEs, it is expected that System Information (SI) enhancements, based on same SI provided in multiple cells, can bring power consumption benefits.

### 7.3.2 Connected mode mobility enhancements

#### 7.3.2.1 General

Similar to NR NTN [8], 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.

RLF and RRC connection re-establishment procedures, as specified up to Release 16, are used as a baseline in NB-IoT NTN. Release-17 enhancements to reduce the time taken for RRC re-establishment can be considered in NB-IoT NTN, if applicable. Further minor 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 [8] [18].

RLF and RRC connection re-establishment procedures, as specified up to Release 16, are used as a baseline in eMTC NTN. Further minor enhancements can be considered.

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 measurement 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.

- Enhancements to CHO, e.g., location-based and time-based triggering events related to CHO in eMTC NTN, should be based on enhancements to CHO in NR NTN.

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.

For determining the paging capacity, the following parameters and configuration possibilities are considered for LTE-M and NB-IoT [13]:

- , number of paging occasions per paging frame determined by the RRC parameter nB (maximum value of 4).

- , number of configured paging frames per second, determined by the configured paging cycle.

- , number of carriers, determined by the RRC parameter *paging-narrowBands-r13* for LTE-M and *maxNonAnchorCarriers-NB-r14* for NB-IoT.

*- Wcarrier*, pagingweight of the carrier for NB-IoT. The paging load is equally distributed across the carriers for the purpose of the evaluation.

- , number of records in a paging message (maximum number of records of 16).

- , where is the paging area, is the cell area, and is the number of cells in a tracking area. The area of a cell can roughly be calculated as where is the larger radius of the hexagonal area.

- , number of average paging attempts per second for a UE.

- ,fraction of UEs in the cell with network originated traffic (see NOTE 1).

- , UE density per square kilometre in a traffic model for Network Command application types.

NOTE 1: The traffic model used in TR 45.820 [4] section 5.2 (Capacity evaluation methodology) defines a split of the UEs population in 80% of devices for periodic Mobile Autonomous Reporting application types and 20% for Network Command application types (.

Although there are some differences in terms of how LTE-M and NB-IoT would work in practice, for paging capacity based on what is configurable by the standard, they can be typically controlled by the same parameters. In the evaluation we only consider the average UE in terms of coverage and thus do not include factors such as percentage of UEs in deep coverage.

The supported maximum number of UEs that can be paged per second for the LTE-M/NB-IoT cell is computed as:

The paging channel load is given as:

The achievable density of UEs using a Network Command traffic model (see NOTE 1) assuming a UE is paged only in one cell in the tracking area is given as:

For the number of paging attempts , we consider the traffic model given in TR 45.820 [4] sub-clause E.2.3, that indicates that the periodic inter-arrival time is distributed as 40% of UEs having 1 day inter-arrival time, 40% of UEs having 2 hours inter-arrival time, 15% of UEs having 1 hour inter-arrival time and 5% of UEs having 30 minutes inter-arrival time. On average per UE, this means paging attempts per second.

# 8 Recommendations on the way forward

## 8.1 Recommendations from RAN1

### 8.1.1 Recommendation for enhancements common to NR NTN and IoT NTN

The recommendations for NB-IoT and eMTC NTN Time and frequency synchronization enhancements in Release 17 timeframe can follow NTN NR agreements as baseline for the following:

* UE Pre-compensation including Ephemeris Format (orbital / Position -Velocity)
* Timing Advance TTA formula (granularity of the timing advance may be different)
* UE pre-compensation for UL synchronization in RRC\_IDLE and RRC\_INACTIVE and RRC\_CONNECTED states based at least on its GNSS-acquired position and the serving satellite ephemeris
* Combination of Open (i.e. UE autonomous TA estimation, and common TA estimation) and Closed TA (i.e., received TA commands) control loops in RRC\_CONNECTED state

NOTE 1: The above is up to the decision in NR-NTN WI

NOTE 2: The NR NTN WI enhancements for UE pre-compensation do not include IoT NTN specific aspects for long transmission on PUSCH and PRACH.

NOTE 3: The NR NTN WI enhancements for UE pre-compensation do not include:

* Restriction on the use of GNSS module, where simultaneous GNSS and NTN NB-IoT/eMTC operation is not assumed.
* IoT NTN aspects of validity timer for UL synchronization and GNSS measurement for sporadic short transmission.

NR NTN have different requirements than IoT NTN for cost, complexity, power consumption, and IoT-specific scenarios.

NOTE 4: It is assumed baseline functions in NB-IoT/eMTC terrestrial work without enhancement unless certain issue is found, that will require essential enhancements

### 8.1.2 Recommendation for IoT NTN specific enhancements

#### 8.1.2.1 IoT NTN Scenarios

Prioritize standalone deployment for NB-IoT / eMTC for support in Rel-17 timeframe

#### 8.1.2.2 Time and frequency synchronization enhancements

Recommendations for NB-IoT / eMTC Time and frequency synchronization enhancements in Release 17 timeframe

* Long PUSCH and PRACH Transmission enhancements:

A specification change is needed for UL transmission with repetitions R>1.

Segmented UE pre-compensation done per N time units for long transmission on PUSCH and on PRACH, where the pre-compensation does not vary within a block of N time units.

For segmented UE pre-compensation how the following is handled can be further discussed

* Phase discontinuity at subframe boundary when applying new pre-compensation
* Coherence time limitation due to delay/frequency drift rate during segment
* Signal overlapping between different TA segments

It can be further studied during the normative phase (i) Need for more frequent new UL gaps during long transmission; (ii) Whether sampling frequency adjustment to avoid new UL gaps can be achieved by implementation; (iii) Value of N for the number of time units and what is the time unit for the segmented UE pre-compensation.

* DL synchronization enhancements:

The following should be considered during the normative phase

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

For sporadic short transmission:

* The idle UE wakes up from idle DRX / PSM, access the network, perform uplink and/or downlink communications for a short duration of time and go back to idle.
* Before accessing the network, the UE acquires GNSS position fix and does not need to re-acquire a GNSS position fix for the transmission of the packets.

Details of the duration of the short transmission, acquisition of the GNSS position and validity of the GNSS position can be discussed in normative phase.

With a GNSS position fix that can be assumed to be valid for some period of time X, the following apply for UE in RRC\_CONNECTED

* TA error due to UE velocity satisfies the requirements defined in RAN4
* Doppler shift error due to UE velocity satisfies the requirement defined in RAN4

FFS: Validity of a GNSS position fix and details of acquiring a GNSS position fix, value of X, in RRC CONNECTED mode

FFS: Potential impact on the existing closed loop TA maintenance mechanism

NOTE: The detailed requirement will be defined in RAN4 during normative work.

#### 8.1.2.3 Timing relationship enhancements

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 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
* PDSCH 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.

It was concluded that the description of timing relationships for eMTC and NB-IoT in Rel-16 do not take the TA into account in general.

* Note: Exceptions to this may be identified as work on eMTC and NB-IoT over NTN progresses further.

Signalling aspects involved in UE-specific TA maintenance and reporting in Rel-17 IoT and techniques to reduce the signalling load have been discussed. Mechanisms to report the UE-specific TA and other means of determining the UE-specific TA have been discussed. Decisions on these aspects can be made during a subsequent normative phase.

#### 8.1.2.4 HARQ enhancements

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

It was concluded that from a physical layer perspective, there is no consensus on disabling HARQ feedback for NTN IoT in Rel-17.

### 8.1.3 Summary of RAN1 recommendations in Release-17 Timeframe

IoT NTN scenarios:

Prioritize standalone deployment for NB-IoT / eMTC for support in Rel-17 timeframe

Time and frequency synchronization enhancements:

IoT NTN can follow NTN NR agreements as baseline for UE pre-compensation, timing advance formula, and combination of open and closed Timing Advance control loops that are up to the decision in NR-NTN WI. The NR NTN WI enhancements for UE pre-compensation do not include:

* Restriction on the use of GNSS module, where simultaneous GNSS and NTN NB-IoT/eMTC operation is not assumed.
* IoT NTN aspects of validity timer for UL synchronization and GNSS measurement for sporadic short transmission.
* IoT NTN specific aspects for long transmission on PUSCH and PRACH

NOTE 1: NR NTN have different requirements than IoT NTN for cost, complexity, power consumption, and IoT-specific scenarios.

NOTE 2: It is assumed baseline functions in NB-IoT/eMTC terrestrial work without enhancement unless certain issue is found, that will require essential enhancements.

IoT NTN specific time and frequency synchronization enhancements are listed below:

* Long PUSCH and PRACH Transmission enhancements: segmented UE pre-compensations, new UL gaps and/or implementation solutions, time units and duration of segments…
* Validity timer for UL synchronization: satellite ephemeris, and potentially other aspects
* DL synchronization enhancements: new channel raster, (part of) ARFCN-indication-in-MIB
* GNSS Measurements: Validity of a GNSS position fix and details of acquiring a GNSS position fix, duration of validity, in RRC CONNECTED mode for sporadic short transmission

Timing relationships enhancements:

* Timing relationships for NB-IoT / eMTC: as listed in Section 8.1.2.3 in TR 36.763
* UL scheduling for FDD-HD: Use of UE-specific TA and/or K\_offset to avoid UL-DL collisions in FDD-HD
* Signalling aspects in UE-specific TA maintenance and reporting, techniques to reduce the signalling load and determination of the UE-specific TA can be decided in normative phase.

NOTE 3: GNSS capability in the UE is taken as a working assumption in this work item for both NB-IoT and eMTC devices. With this assumption, UE can estimate and pre-compensate timing and frequency offset with sufficient accuracy for UL transmission. Simultaneous GNSS and NTN NB-IoT/eMTC operation is not assumed.

HARQ enhancements:

* Increasing the number of HARQ processes for NB-IoT and for eMTC in NTN is recommended not to be supported in Rel-17.
* It was concluded that from a physical layer perspective, there is no consensus on disabling HARQ feedback for NTN IoT in Rel-17.

NOTE 4: RAN2 agreed that disabling of HARQ feedback is not essential

NOTE 5: Details on RAN1 recommendations for IoT NTN are given in Section 8.1.1 and 8.1.2 of TR 36.763

## 8.2 Recommendations from RAN2

RAN2 recommends to establish an IoT NTN Work Item for Rel-17 whose scope should include a number of features that have been identified as essential by the Working Group during the corresponding feasibility study of IoT NTN. These essential features are listed below:

1. Support for EPC is essential. RAN2 believes that support for 5GC is not essential, however the impact in RAN2 to additionally support 5GC is small and is feasible.
2. Enhancements to *ra-ResponseWindow* and *mac-ContentionResolutionTimer* are considered essential. RAN2 assume that design can follow NR NTN agreements as baseline.
3. Enhancements to HARQ RTT timer and UL HARQ RTT timer are essential. RAN2 assume that design can follow NR NTN agreements as baseline.
4. Enhancements to *sr-ProhibitTimer* are essential. RAN2 assume that design can follow NR NTN agreements as baseline.
5. Enhancement to *pur-ResponseTimer* is needed. An offset is suggested to be added to the start of *pur-ResponseWindowTimer*.
6. Enhancements to RLC *t-Reordering* timer are considered essential. There is no need for further study as design can follow NR NTN agreements.
7. Provisioning of ephemeris is essential. NR NTN agreements can be used as the baseline.
8. Enhancements to tracking area management are essential. Similar to NR-NTN, both “hard-switch” and “soft-switch” options are included.
9. The network may broadcast more than one TACs per PLMN in a cell is considered for IoT NTN. TAU details based on agreements regarding TAU made in the NR-NTN WI is handled in the IoT NTN WI as a part of using the earth-fixed TA concept. The details are expected to be settled during the normative phase, e.g. the requirements for UE to update/reread SI.
10. Support of legacy (Rel-16) cell selection/reselection mechanisms without major enhancements is considered essential. Minor adjustments to existing mobility mechanisms, such as a new parameter values, change to timing etc. can be considered to adapt functionality to NTN.
11. Support of discontinuous coverage without excessive UE power consumption and without excessive failures / recovery actions, is considered essential. From RAN2 point of view, the existing power saving mechanisms e.g. DRX, PSM, eDRX, relaxed monitoring, and WUS can be reused without enhancement. Enhancements to these mechanisms can be considered, to support discontinuous coverage.
12. Support of legacy (Rel-16) Handover and RLF/reestablishment mechanisms without major enhancements is considered essential. For eMTC, Rel-16 LTE CHO procedure can be considered without major enhancements. Minor adjustments to existing mobility mechanisms, such as a new parameter values, change to timing etc. can be considered to adapt functionality to NTN.

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 [12] Annex E.2 "Traffic models for Cellular IoT" |
| NOTE 1: As defined in TS 22.261 [13]  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:  
Individual Company battery life analysis

## C.1 Huawei battery life analysis (R1-2102344)

**Table 1. Power consumption with 2 hours report period**

|  |  |  |  |
| --- | --- | --- | --- |
| **Report, 2hours** | | | |
| **Flow assumptions** | **Duration(ms)/each report** | **Power(mW)** | **Power consumption(mWh)** |
| **GNSS(DL)** | 2000 | 100 | 0.055556 |
| **NPSS(DL)** | 20 | 80 | 0.000444 |
| **NSSS(DL)** | 20 | 80 | 0.000444 |
| **NTN SIB(DL, 256bits)** | 24 | 70 | 0.000467 |
| **MIB-NB(DL)** | 60 | 70 | 0.001167 |
| **Msg1(UL)** | 102.4 | 500 | 0.014222 |
| **NPDCCH(DL)** | 8 | 70 | 0.000156 |
| **Msg2(DL, 56bits)** | 12 | 70 | 0.000233 |
| **Msg3(UL)** | 96 | 500 | 0.013333 |
| **NPDCCH(DL)** | 8 | 70 | 0.000156 |
| **Msg4(DL, 256bits)** | 24 | 70 | 0.000467 |
| **ACK/NACK for Msg4(UL)** | 16 | 500 | 0.002222 |
| **PDCCH(DL)** | 8 | 70 | 0.000156 |
| **Msg5(105bytes)** | 320 | 500 | 0.044444 |
| **Idle** | 30000 | 3 | 0.025000 |
| **Sleep(NTN)** | 7167281.6 | 0.015 | 0.029864 |
| **Sleep(TN)** | 7169305.6 | 0.015 | 0.029872 |
| **Total (TN, mWh)** | 0.132317 | | |
| **Total (NTN,mWH)** | 0.188330 | | |
| **Battery(Wh)** | 5.000000 | | |
| **Battery lifte**  **(TN, year)** | 8.627436 | | |
| **Battery lifte**  **(NTN, year)** | 6.061437 | | |

**Table 2. Power consumption with 6 hours report period**

|  |  |  |  |
| --- | --- | --- | --- |
| **Report, 6hours** | | | |
| **Flow assumptions** | **Duration(ms)/each report** | **Power(mW)** | **Power consumption(mWh)** |
| **GNSS(DL)** | 5000 | 100 | 0.138889 |
| **NPSS(DL)** | 20 | 80 | 0.000444 |
| **NSSS(DL)** | 20 | 80 | 0.000444 |
| **NTN SIB(DL, 256bits)** | 24 | 70 | 0.000467 |
| **MIB-NB(DL)** | 60 | 70 | 0.001167 |
| **Msg1(UL)** | 102.4 | 500 | 0.014222 |
| **NPDCCH(DL)** | 8 | 70 | 0.000156 |
| **Msg2(DL, 56bits)** | 12 | 70 | 0.000233 |
| **Msg3(UL)** | 96 | 500 | 0.013333 |
| **NPDCCH(DL)** | 8 | 70 | 0.000156 |
| **Msg4(DL, 256bits)** | 24 | 70 | 0.000467 |
| **ACK/NACK for Msg4(UL)** | 16 | 500 | 0.002222 |
| **PDCCH(DL)** | 8 | 70 | 0.000156 |
| **Msg5(105bytes)** | 320 | 500 | 0.044444 |
| **Idle** | 30000 | 3 | 0.025000 |
| **Sleep(NTN)** | 21564281.6 | 0.015 | 0.089851 |
| **Sleep(TN)** | 21569305.6 | 0.015 | 0.089872 |
| **Total (TN, mWh)** | 0.192317 | | |
| **Total (NTN,mWH)** | 0.331651 | | |
| **Battery(Wh)** | 5.000000 | | |
| **Battery lifte**  **(TN, year)** | 17.807399 | | |
| **Battery lifte**  **(NTN, year)** | 10.326083 | | |

**Table 3. Power consumption with 6 hours report period**

|  |  |  |  |
| --- | --- | --- | --- |
| **Report, 12hours** | | | |
| **Flow assumptions** | **Duration(ms)/each report** | **Power(mW)** | **Power consumption(mWh)** |
| **GNSS(DL)** | 5000 | 100 | 0.13889 |
| **NPSS(DL)** | 20 | 80 | 0.00044 |
| **NSSS(DL)** | 20 | 80 | 0.00044 |
| **NTN SIB(DL, 256bits)** | 24 | 70 | 0.00047 |
| **MIB-NB(DL)** | 60 | 70 | 0.00117 |
| **Msg1(UL)** | 102.4 | 500 | 0.01422 |
| **NPDCCH(DL)** | 8 | 70 | 0.00016 |
| **Msg2(DL, 56bits)** | 12 | 70 | 0.00023 |
| **Msg3(UL)** | 96 | 500 | 0.01333 |
| **NPDCCH(DL)** | 8 | 70 | 0.00016 |
| **Msg4(DL, 256bits)** | 24 | 70 | 0.00047 |
| **ACK/NACK for Msg4(UL)** | 16 | 500 | 0.00222 |
| **PDCCH(DL)** | 8 | 70 | 0.00016 |
| **Msg5(105bytes)** | 320 | 500 | 0.04444 |
| **Idle** | 30000 | 3 | 0.02500 |
| **Sleep(NTN)** | 43164281.6 | 0.015 | 0.17985 |
| **Sleep(TN)** | 43169305.6 | 0.015 | 0.17987 |
| **Total (TN, mWh)** | 0.282317 | | |
| **Total (NTN,mWH)** | 0.421651 | | |
| **Battery(Wh)** | 5.000000 | | |
| **Battery lifte**  **(TN, year)** | 24.261118 | | |
| **Battery lifte**  **(NTN, year)** | 16.244032 | | |

## C.2 CATT battery life analysis (R1-2102618)

Table 5 The operation assumptions of protocol flow and GNSS for IoT NTN

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Battery capacity(Wh)** | **5** | **MCL 154dBm** | | **MCL 164dBm** | |
| **Protocol flow assumptions** | **Power(mW)** | **Duration(ms)/each report** | **Power consumption(mWh)** | **Duration(ms)/each report** | **Power consumption(mWh)** |
| **GNSS signal reception** | X | Y | X\*Y/36e5 | Y | X\*Y/36e5 |
| **NPSCH(DL)** | 80 | 291 | 0.006467 | 445 | 0.009889 |
| **NPBCH(DL)** | 70 | 10 | 0.000194 | 30 | 0.000583 |
| **NPRACH(UL)** | 500 | 40 | 0.005556 | 320 | 0.044444 |
| **NPDCCH(DL)** | 70 | 30 | 0.000583 | 220 | 0.004278 |
| **NPUSCH(UL, 50bytes)** | 500 | 320 | 0.044444 | 1920 | 0.266667 |
| **NPUSCH(UL, 200bytes)** | 500 | 960 | 0.133333 | 3840 | 0.533333 |
| **NPDCCH(DL)** | 70 | 30 | 0.000583 | 220 | 0.004278 |
| **NPDCCH(DL)** | 70 | 30 | 0.000583 | 220 | 0.004278 |
| **NPDSCH(DL)** | 70 | 100 | 0.001944 | 800 | 0.015556 |
| **NPUSCH(UL)** | 500 | 40 | 0.005556 | 320 | 0.044444 |
| **NPDCCH(DL)** | 70 | 30 | 0.000583 | 220 | 0.004278 |
| **NPDCCH(DL, monitor)** | 70 | 120 | 0.002333 | 880 | 0.017111 |
| **idle** | 3 | 11040 | 0.009200 | 60595 | 0.050496 |
| **Standby(50bytes,2 hr)** | 0.015 | 7137919 | 0.029741 | 7083810 | 0.029516 |
| **Standby(200bytes,2 hr)** | 0.015 | 7137279 | 0.029739 | 7081890 | 0.029508 |
| **Standby(50bytes,24 hr)** | 0.015 | 86337919 | 0.359741 | 86283810 | 0.359516 |
| **Standby(200bytes,24 hr)** | 0.015 | 86337279 | 0.359739 | 86281890 | 0.359508 |

Table 6 The battery life with and without GNSS reception

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **power(mw)/duration(s)**  **Packet size, reporting interval,MCL** | **Battery life (years)** | | | | | | | | | | |
| **no GNSS** | **20mw/5s** | **20mw/10s** | **20mw/20s** | **20mw/40s** | **20mw/50s** | **216mw/5s** | **216mw/10s** | **216mw/20s** | **216mw/40s** | **216mw/50s** |
| **50bytes,2 hrs,MCL154** | 10.6 | 8.4 | 7.0 | 5.2 | 3.5 | 3.0 | 2.8 | 1.6 | 0.9 | 0.5 | 0.4 |
| **200bytes,2 hrs,MCL154** | 5.8 | 5.1 | 4.5 | 3.7 | 2.7 | 2.4 | 2.3 | 1.4 | 0.8 | 0.4 | 0.4 |
| **50bytes,24 hrs,MCL154** | 31.3 | 29.4 | 27.8 | 25.0 | 20.8 | 19.1 | 18.6 | 13.2 | 8.4 | 4.8 | 4.0 |
| **200bytes,24 hrs,MCL154** | 26.0 | 24.7 | 23.5 | 21.5 | 18.3 | 17.0 | 16.6 | 12.2 | 7.9 | 4.7 | 3.9 |
| **50bytes,2 hrs,MCL164** | 2.3 | 2.2 | 2.1 | 1.9 | 1.6 | 1.5 | 1.4 | 1.0 | 0.7 | 0.4 | 0.3 |
| **200bytes,2 hrs,MCL164** | 1.5 | 1.4 | 1.4 | 1.3 | 1.2 | 1.1 | 1.1 | 0.8 | 0.6 | 0.4 | 0.3 |
| **50bytes,24 hrs,MCL164** | 16.6 | 16.0 | 15.5 | 14.6 | 13.1 | 12.4 | 12.2 | 9.6 | 6.8 | 4.2 | 3.6 |
| **200bytes,24 hrs,MCL164** | 12.5 | 12.2 | 11.9 | 11.4 | 10.4 | 10.0 | 9.8 | 8.1 | 6.0 | 3.9 | 3.3 |

Battery life with and without GNSS

## C.3 Qualcomm battery life analysis (R1-2103071)

Table 1: Parameters for evaluating power consumption in IoT over NTN.

|  |  |  |
| --- | --- | --- |
| Operation | Current  (Referenced to downlink current ) | Duration |
| GNSS reception |  | **ms** |
| Downlink Reception |  | 1. PDCCH:  **ms** 2. PDSCH (RAR):  **ms** 3. PDSCH (Msg4): **ms** 4. PDSCH (Conn. Release):  **ms** |
| Uplink Transmission |  | 1. PRACH:  **ms** 2. Msg3:  **ms** 3. PUSCH (data):  **ms per ~ bits**   (*simulated with 8000 bits per ON-duration*)   1. HARQ-ACK:  **ms** |
| Sleep |  | 1. PSM: **8 hrs** 2. CDRX: |



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.**



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

**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.**

## C.4 MediaTek battery life analysis (R1-2102755)







|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| EVERY 2 HOUR (GNSS TTFF HOT START + NTN SIB 16B Reading) | | | | | | | |
|  |  | **50 BYTES** | | | **200 BYTES** | | |
| **GNSS TTFF** | **MCL** | **CIoT** | **Integrated** | **Module** | **CioT** | **Integrated** | **Module** |
| 0 s | 144 dB | 18.73 | | | 17.35 | | |
| 154 dB | 10.51 | | | 5.43 | | |
| 164 dB | 2.68 | | | 1.27 | | |
| 1 s | 144 dB | 18.73 | 15.8 | 12.72 | 17.35 | 14.81 | 12.07 |
| 154 dB | 10.51 | 9.52 | 8.31 | 5.43 | 5.16 | 4.78 |
| 164 dB | 2.68 | 2.61 | 2.51 | 1.27 | 1.26 | 1.23 |
| 2 s | 144 dB | 18.73 | 13.84 | 9.71 | 17.35 | 13.07 | 9.33 |
| 154 dB | 10.51 | 8.77 | 6.91 | 5.43 | 4.93 | 4.28 |
| 164 dB | 2.68 | 2.55 | 2.37 | 1.27 | 1.24 | 1.2 |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| EVERY DAY (GNSS TTFF WARM START + NTN SIB 16B Reading) | | | | | | | |
|  |  | **50 BYTES** | | | **200 BYTES** | | |
| **GNSS TTFF** | **MCL** | **CIoT** | **Integrated** | **Module** | **CioT** | 1. **Integrated** | 1. **Module** |
| 0 s | 144 dB | 35.04 | | | 34.61 | | |
| 154 dB | 31.23 | | | 25.36 | | |
| 164 dB | 18.12 | | | 11.16 | | |
| 5 s | 144 dB | 35.04 | 30.9 | 23.81 | 34.61 | 19.56 | 11.18 |
| 154 dB | 31.23 | 27.9 | 23.68 | 25.36 | 18.32 | 10.76 |
| 164 dB | 18.12 | 16.95 | 15.29 | 11.16 | 12.86 | 8.61 |
| 30 s | 144 dB | 35.04 | 30.56 | 25.57 | 34.61 | 19.43 | 11.14 |
| 154 dB | 31.23 | 23.12 | 20.14 | 25.36 | 16.13 | 9.57 |
| 164 dB | 18.12 | 10.7 | 10.02 | 11.16 | 8.91 | 6.64 |

## C.5 Ericsson battery life analysis (R1-2103061)



Figure 1 NB-IoT RRC Resume procedure with UL and DL data transmissions.



Figure 2 NB-IoT EDT procedure with UL data transmission.

Table 1 GNSS parameters for battery life evaluation.

|  |  |  |
| --- | --- | --- |
|  | GNSS TTFF  (sec) | Power consumption  (mW) |
| Hot start | 1 | 37 |
| Warm start | 5 | 37 |

Table 2 eMTC and NB-IoT power consumption for battery life evaluation.

|  |  |
| --- | --- |
| Mode | Power consumption (mW) |
| TX | 545 |
| RX | 90 |
| RRC Connected | 3 |
| RRC Idle | 0.015 |

Table 3 eMTC battery life with 200 bytes UL data and 50 bytes DL data for various values of MCL and UL reporting interval.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| eMTC, 200 bytes UL, 50 bytes DL | | Battery life TN (year) | Battery life NTN (year) | Change (%) | Battery life TN (year) | Battery life NTN (year) | Change (%) | Battery life TN (year) | Battery life NTN (year) | Change (%) |
| MCL (dB) | | 164 | | | 154 | | | 144 | | |
| 2 hr | EDT | 1.0 | 1.0 | ~0 | 8.8 | 8.2 | 6.82 | 22 | 18.4 | 16.36 |
| 2 hr | RRC Resume | 0.9 | 0.9 | ~0 | 8.2 | 7.6 | 7.32 | 22 | 18.4 | 16.36 |
| 24 hr | EDT | 9.1 | 9.1 | ~0 | 30.0 | 27.0 | 10.0 | 37.0 | 32.5 | 12.16 |
| 24 hr | RRC Resume | 8.4 | 8.4 | ~0 | 29.4 | 26.5 | 9.86 | 37.0 | 32.5 | 12.16 |

Table 4 eMTC battery life with 50 bytes UL data and 50 bytes DL data for various values of MCL and UL reporting interval.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| eMTC, 50 bytes UL, 50 bytes DL | | Battery life TN (year) | Battery life NTN (year) | Change (%) | Battery life TN (year) | Battery life NTN (year) | Change (%) | Battery life TN (year) | Battery life NTN (year) | Change (%) |
| MCL (dB) | | 164 | | | 154 | | | 144 | | |
| 2 hr | EDT | 2.6 | 2.5 | 3.85 | 14.6 | 12.9 | 11.64 | 23.4 | 19.4 | 17.09 |
| 2 hr | RRC Resume | 2.0 | 2.0 | ~0 | 13.2 | 11.8 | 10.61 | 23.5 | 19.4 | 17.45 |
| 24 hr | EDT | 17.9 | 16.8 | 6.14 | 33.8 | 30.0 | 11.24 | 36.3 | 32.1 | 11.57 |
| 24 hr | RRC Resume | 15.4 | 14.5 | 5.84 | 33.1 | 29.5 | 10.88 | 36.4 | 32.1 | 11.81 |

Table 5 NB-IoT battery life with 200 bytes UL data and 50 bytes DL data for various values of MCL and UL reporting interval.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| NB-IoT, 200 bytes UL, 50 bytes DL | | Battery life TN (year) | Battery life NTN (year) | Change (%) | Battery life TN (year) | Battery life NTN (year) | Change (%) | Battery life TN (year) | Battery life NTN (year) | Change (%) |
| MCL (dB) | | 164 | | | 154 | | | 144 | | |
| 2 hr | EDT | 1.4 | 1.4 | ~0 | 7.9 | 7.3 | 7.59 | 19.8 | 16.9 | 14.65 |
| 2 hr | RRC Resume | 1.1 | 1.1 | ~0 | 7.4 | 7.0 | 5.41 | 19.3 | 16.5 | 14.51 |
| 24 hr | EDT | 11.4 | 11.4 | ~0 | 29.0 | 26.2 | 9.65 | 36.4 | 32.1 | 11.81 |
| 24 hr | RRC Resume | 9.7 | 9.7 | ~0 | 28.5 | 25.7 | 9.82 | 36.3 | 31.9 | 12.12 |

Table 6 NB-IoT battery life with 50 bytes UL data and 50 bytes DL data for various values of MCL and UL reporting interval.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| NB-IoT, 50 bytes UL, 50 bytes DL | | Battery life TN (year) | Battery life NTN (year) | Change (%) | Battery life TN (year) | Battery life NTN (year) | Change (%) | Battery life TN (year) | Battery life NTN (year) | Change (%) |
| MCL (dB) | | 164 | | | 154 | | | 144 | | |
| 2 hr | EDT | 3.4 | 3.3 | 2.94 | 13.4 | 12.0 | 10.45 | 22.2 | 18.5 | 16.67 |
| 2 hr | RRC Resume | 2.6 | 2.5 | 3.85 | 12.4 | 11.2 | 9.67 | 21.6 | 18.1 | 16.20 |
| 24 hr | EDT | 20.5 | 19.1 | 6.83 | 33.2 | 29.6 | 10.84 | 36.2 | 31.9 | 11.88 |
| 24 hr | RRC Resume | 17.8 | 16.7 | 6.18 | 32.7 | 29.1 | 11.01 | 36.0 | 31.8 | 11.67 |

## C.6 Nokia battery life analysis (R1-210832)

In first step, GNSS measurement by UE are assumed to be ideally accurate (although there may be some issue as analysis above), then considering 50Bytes and 200Bytes packet, reporting (data) interval as 2hour or 1day, battery life reduction because of GNSS related power consumption will be as in Figure 1, where we assume a hot start >=1s and warm start >=5s and with other assumption as Table 2&3 aligned with [R1-157251, Nokia Networks, “NB IoT – Battery lifetime evaluation in standalone operation”, 3GPP RAN1 #83]. Annex A Table 4&5 provide the original results.

**Table 2 Assumption for requested time for each item in Tx/Rx**

|  |  |  |
| --- | --- | --- |
| Activity | State | ms |
| Synchronization | RX | 215 |
| MIB acquisition | Rx | 64 |
| Idle | 576 |
| PRACH | Tx | 160 |
| Idle | 640 |
| DCI + RAR | Rx | 72 |
| Msg3 | Tx | 340 |
| DCI + Msg4 | Rx | 72 |
| DCI (UL grant) | Rx | 36 |
| Report (50 bytes) | Tx | 1405 |
| Report (200 bytes) | Tx | 4648 |
| HARQ ACK | Rx | 36 |
| DCI | Rx | 36 |
| IP Ack | Rx | 200 |
| HARQ ACK | Tx | 288 |
| PDCCH monitoring | Rx | 1440 |
| Extra wait time | Idle | 22000 |

**Table 3 Assumption for battery capacity and battery power consumption**

|  |  |
| --- | --- |
| Battery capacity (Wh) | 5 |
| Battery power during Tx (mW) | 543 |
| Battery power for Rx (mW) | 90 |
| Battery power when Idle but not in PSS (mW) | 2.4 |
| Battery power in Power Save State (PSS) (mW) | 0.015 |
| battery power for GNSS Rx (mW) | **37** |

**Table 4 battery life reduction because of GNSS measurement**



**Figure 1 battery life reduction because of GNSS measuerement**

Another points that will reduce battery life for IoT over NTN is SIB reading for satellite ephemeris. If assuming power consumption for SIB reading is 90mW, then battery life reduction will be as in Figure 2.



**Figure 2 battery life reduction because of SIB reading for satellite ephemeris (90mW)**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| packet size = 50Bytes |  | Reporting  interval (hour) | Number of reports per day | Rx time of GNSS measurement (ms) | Reduced battery life (%) |  | Reporting  interval (hour) | Number of reports per day | Rx time of GNSS measurement (ms) | Reduced battery life (%) |
|  |  | 2 | 12 | 1000 | 2.332 |  | 24 | 1 | 5000 | 6.329 |
|  |  | 2 | 12 | 2000 | 4.557 |  | 24 | 1 | 10000 | 11.905 |
|  |  | 2 | 12 | 3000 | 6.683 |  | 24 | 1 | 15000 | 16.854 |
|  |  | 2 | 12 | 4000 | 8.717 |  | 24 | 1 | 20000 | 21.277 |
|  |  | 2 | 12 | 5000 | 10.663 |  | 24 | 1 | 25000 | 25.253 |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
| packet size = 200Bytes |  | Reporting  interval (hour) | Number of reports per day | Rx time of GNSS measurement (ms) | Reduced battery life (%) |  | Reporting  interval (hour) | Number of reports per day | Rx time of GNSS measurement (ms) | Reduced battery life (%) |
|  |  | 2 | 12 | 1000 | 1.105 |  | 24 | 1 | 5000 | 3.950 |
|  |  | 2 | 12 | 2000 | 2.186 |  | 24 | 1 | 10000 | 7.599 |
|  |  | 2 | 12 | 3000 | 3.244 |  | 24 | 1 | 15000 | 10.982 |
|  |  | 2 | 12 | 4000 | 4.279 |  | 24 | 1 | 20000 | 14.125 |
|  |  | 2 | 12 | 5000 | 5.292 |  | 24 | 1 | 25000 | 17.054 |

**Table 5 battery life reduction because of SIB reading for satellite ephemeris**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| packet size = 50Bytes |  | Reporting  interval (hour) | Number of reports per day | Rx time of NTN SIB (ms) | Reduced battery life (%) |  | Reporting  interval (hour) | Number of reports per day | Rx time of NTN SIB (ms) | Reduced battery life (%) |
|  |  | 2 | 12 | 20 | 0.116 |  | 24 | 1 | 20 | 0.066 |
|  |  | 2 | 12 | 30 | 0.174 |  | 24 | 1 | 30 | 0.099 |
|  |  | 2 | 12 | 40 | 0.232 |  | 24 | 1 | 40 | 0.131 |
|  |  | 2 | 12 | 50 | 0.289 |  | 24 | 1 | 50 | 0.164 |
|  |  | 2 | 12 | 60 | 0.347 |  | 24 | 1 | 60 | 0.197 |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |
| packet size = 200Bytes |  | Reporting  interval (hour) | Number of reports per day | Rx time of NTN SIB (ms) | Reduced battery life (%) |  | Reporting  interval (hour) | Number of reports per day | Rx time of NTN SIB (ms) | Reduced battery life (%) |
|  |  | 2 | 12 | 20 | 0.054 |  | 24 | 1 | 20 | 0.040 |
|  |  | 2 | 12 | 30 | 0.081 |  | 24 | 1 | 30 | 0.060 |
|  |  | 2 | 12 | 40 | 0.109 |  | 24 | 1 | 40 | 0.080 |
|  |  | 2 | 12 | 50 | 0.136 |  | 24 | 1 | 50 | 0.100 |
|  |  | 2 | 12 | 60 | 0.163 |  | 24 | 1 | 60 | 0.120 |

Annex D:  
Examples of paging capacity evaluation

## D.1 Example 1 ([21])

To evaluate the paging capacity, Table D.1-1 gives a number of examples. The rationale for the selected cases are (the corresponding sets parameters are given in section 6.1 of the present Technical Report):

- Case 1: IoT dense paging configuration at 600 km altitude Set 1, considering UEs are in good radio conditions not requiring any repetitions and thus more paging occasions can be used.

- Case 2: IoT sparse paging configuration at 600 km altitude Set 1, considering somewhat more UEs being in worse radio conditions requiring more repetitions for the paging occasions.

- Case 3: IoT sparse paging configuration (to allow for repetitions) for GEO altitude Set 1 considering UEs in decent radio conditions.

- Case 4: IoT sparse paging configuration (to allow for repetitions) for Set 4 with repetitions configured for paging occasions to overcome link budget conditions thus requiring more sparse paging.

Table D.1-1: Parameters for the selected cases

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Case | Paging Parameters | | | | Paging area |
|  |  |  |  |
| Paging Case 1 | 1 | 100 | 16 | 2 | R=25 km, km2 |
| Paging Case 2 | 1 | 50 | 16 | 1 | R=25 km, km2 |
| Paging Case 3 | 1 | 100 | 16 | 1 | R=125 km, km2 |
| Paging Case 4 | 1 | 50 | 16 | 1 | R=850 km, km2 |

The results can be found in the following Table D.1-2 and Table D.1-3. For Table D.1-2 we have assumed a UEs density of 400 UE/km2 following [3]. In Table D.1-3 we evaluate the achievable UEs density.

Table D.1-2: Paging channel load for a given UEs density

|  |  |  |
| --- | --- | --- |
| Case | UE density [UE/km2] | Paging channel load |
| Paging Case 1 | 400 | 2.63 % |
| Paging Case 2 | 400 | 10.52 % |
| Paging Case 3 | 400 | 131.6 % |
| Paging Case 4 | 400 | 12166 % |

Table D.1-3: Supported UEs density

|  |  |
| --- | --- |
| Case | Achievable UEs density [UE/km2] |
| Paging Case 1 | 15210 |
| Paging Case 2 | 3803 |
| Paging Case 3 | 304 |
| Paging Case 4 | 3.29 |

## D.2 Example 2 ([22])

### D.2.1 Calculation for paging capacity and paging load

**Parameters for paging capacity and paging load evaluation**

Following parameters should be considered for calculation of the paging capacity:

- Paging Frames (PF) per second: NPF

- Paging Occasions (PO) per PF: NPOperPF

- Maximum number of paging records in paging message: NUEperPO

- User density (UEs/km2)

- Satellite beam diameter: in km

- NO\_Traffic: fraction of UEs in the cell with network originated traffic

- Arrival session or call rate: average requested paging occasions per hour and per UE

- Number of cells per tracking area: M

- Number of paging carriers (NB-IoT) or paging narrow bands (eMTC): NCarrier

- Paging carrier weight in NB-IoT

**Paging capacity**

In [25], it was agreed to consider equal weight for all paging carriers in NB-IoT and to use the following formula derived from [3] to calculate the paging capacity per second:

Supported paging capacity per second: NCarrier \* NPF \* NPOperPF \* NUEperPO

In NB-IoT and eMTC, there may not be a PF/PO in each radio frame (e.g. due to the need for coverage enhancements) and the paging occasions density is given per nB and T, i.e. the number of POs per second is equal to 100 \* nB / T.

We propose to update the above formula accordingly, i.e.:

**Supported paging capacity per second**: NCarrier \* (100 \* nB / T) \* NUEperP

**Paging load**

The required paging load per cell in [3] is calculated as:

**expected arrival rate per cell per second** = A \* UE density \* arrival session rate

In the traffic model defined for IoT [4], it is specified in section 5.2.2 that only 20% (NO\_traffic) of the UEs in the cell are pageable.

In the traffic model defined for IoT [4], the distribution of paging session arrival rate is defined in section E.2.3 and E.2.1.

Thus we propose to update the formula as below:

**paging load per cell per second** = A \* (0.2 \* UE density) \* (0.4 \* AR1d + 0.4 \* AR2h + 0. 15 \* AR1h + 0.0.5 \* AR30m)

### D.2.2 Examples of calculation

As described in section D.2.1, the parameters defining the actual paging capacity and paging load are:

- paging capacity: NCarrier, T and nB

- paging load: A and User density

In the following tables we provide results for different values of the parameters.

**Paging capacity for NB-IoT:**

T can take the values 128, 256, 512 and 1024. Usual values in TN deployments are 128 and 256. We use these T = 128 for the calculations below.

nB can take the values 4T, 2T, T, T/2, T/4, T/8, T/16, T/32, T/64, T/128, T/256, T/512, T/1024. nB should be chosen so POs overlapping is avoided, i.e. nB depends on the level of coverage enhancements needed (i.e. the number of NPDCCH repetitions). Considering that in NTN most UEs will be in relative good coverage, we use nB= T, T/2, T/4, T/8, T16 and T/32 for the calculations below.

NCarrier can take the values 1..16.

NUEperPO is equal to 16.

Table D.2.2-1: Paging capacity per second per carrier

|  |  |  |
| --- | --- | --- |
| **T** | **nB** | **Paging capacity** |
| 128 | T | 1600 |
| T/2 | 800 |
| T/4 | 400 |
| T/8 | 200 |
| T/16 | 100 |
| T/32 | 50 |

**Paging load:**

Given the cell area of a hexagonal cell has a radius of r, the cell area can be expressed as A= 3 \* √3 /2 \* r2.

For example, for the cell radius of r = 250km, the area is A = 163 000km2.

Table D.2.2-2: Paging load and number of required carriers for a given UE density

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | | | Number of needed carriers  (T=128) | | | | | | |
| UE density [UE/km2] | r [km] | No UEs per cell | Paging load per second | | nB=T | nB=T/2 | nB=T/4 | nB=T/8 | nB=T/16 | nB=T/32 | |
| 400 | 250 | 65,200,000 | **1690** | | **1** | **2** | **4** | **8** | **16** | **32** | |
| 20 | 250 | 3,260,000 | **85** | | **1** | **1** | **1** | **1** | **1** | **2** | |

## D.3 Example 3 ([23])

### D.3.1 Parameters for paging capacity calculation

Following are the parameters used to calculate the paging capacity of IoT-NTN cells:

- Paging Frames (PF) per second:

- Paging Occasions (PO) per PF:

- Maximum number of paging records in paging message:

Out of the above parameters, number of PF and number of PO are based on DRX cycle configuration, NB value configured in system information of NB-IoT and eMTC cell. Maximum number of paging records applicable for NB-IOT/eMTC is 16.

The paging capacity of NB-IoT cell can be extended with additional non-anchor carriers configured for paging. For eMTC additional paging narrow-bands can be configured to handle additional paging load. So the following parameter can also be used for calculation of paging capacity of base station.

- Number of paging carriers or paging narrowband.

### D.3.2 Paging traffic load estimation

Estimated paging traffic load in IoT-NTN cell depends on the following parameters:

- Estimated Idle mode UE as per the connection density given in Annex B.2

- Percentage of IoT users expecting network command and network command Traffic model. Network command traffic model used to deduce arrival rate is given in TR45.820 [4] Annex H.

If single cell is covering one tracking area or if the device is stationary and base station only paging in the last connected cell, the paging load is calculated as below.

***Expected Paging Load in cell = A\* Used Density \* Arrival session rate.***

In case if the Tracking area consists of more than one cell and the network needs to schedule the paging over all cells of the tracking area blindly the expected paging load is calculated as below.

***Expected Paging Load in Tracking Area = M\* A\* Used Density \* Arrival session rate***

### D.3.3 Paging Capacity Evaluation

Following table illustrates the paging load estimation for given UE density based on the paging capacity and arrival rates calculated as per the information given in earlier sections.

Table D.3.3-1: Paging channel load

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| (NB,DRX cycle, Paging Record per message) | UE density [UE/km2] | Arrival session rate per hour  (As per NW command Traffic model in TR45.820) | M | r [km] | Paging Load  (pages/sec) | Paging Capacity per Carrier  (pages/sec) | Required number of carriers |
| T,1024,16 | 400 | 0.46 | 1 | 250 | 1690 | 1600 | 1 |
| 4T,1024,16 | 400 | 0.46 | 1 | 250 | 1690 | 6400 | 1 |
| T,1024,16 | 20 | 0.46 | 1 | 250 | 420 | 1600 | 1 |
| 4T,1024,16 | 20 | 0.46 | 1 | 250 | 420 | 6400 | 1 |

When extended coverage is supported for paging transmission beyond 4 repetitions, the number of available paging occasions needs to be reduced depending on the maximum repetitions required in the cell. In the below table the paging capacity calculations are provided for cell with configuration of NB value which is fraction of DRX cycle.

Table D.3.3-2: Paging channel load / Extended coverage

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| (NB,DRX cycle, Paging Record per message) | UE density [U/km2] | Arrival session rate per hour  (As per NW command Traffic model in TR45.820) | M | r [km] | Paging Load  (pages/sec) | Paging Capacity per Carrier  (pages/sec) | Required number of carriers |
| T/4,1024,16 | 400 | 0.46 | 1 | 250 | 1690 | 400 | 4 |
| T/4,1024,16 | 20 | 0.46 | 1 | 250 | 420 | 400 | 1 |

Furthermore, the supported UE density given the UE arrival session rate per UE, which is highly dependent on the size of the beam, can be calculated by:

Table D.3.3-3: Supported UE densities for a given arrival session rate per carrier

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Arrival session rate | M | r [km] | UE density [UE/km2] |
| 4T,1024,16 | 0.46 | 1 | 250 | 1520 |
| T,1024,16 | 0.46 | 1 | 250 | 380 |
| T/4,1024,16 | 0.46 | 1 | 250 | 95 |

NOTE: Paging capacity calculation for tracking area wide paging depending on number of cells per tracking area and capacity calculations considering additional carriers in IoT-NTN base station needs to be updated in next revision.

## D.4 Example 4 ([24])

### D.4.1 Paging capacity

For NB-IoT, considering the multi-carrier and the repetition, two cases are evaluated.

Table D.4.1-1: Details of Case 1 and Case 2

|  |  |  |  |
| --- | --- | --- | --- |
|  | paging record in a paging message | Multi carrier | PO per PF, PF per second, paging records per PO per carrier |
| Case 1 (NB-IoT, normal coverage) | 16 | 16 | 4, 100, 16 |
| Case 2 (NB-IoT, enhanced coverage) | 16 | 16 | Anchor: 1, 1, 16  Non-anchor: 1, 4, 16 |

The supported number of paging records per second are as following:

Case 1: *Cpaging* = *Ncarrier* × *NPF* × *NPO* × *Nrecords* = 102400

Case 2: *Cpaging* = *NPF\_anchor* × *NPO\_anchor* × *Nrecords + Ncarrier\_nonanchor* × *NPF\_nonanchor* × *NPO\_nonanchor* × *Nrecords* = 976

Moreover, the area of the cell A has impact on results of the paging channel load and achievable UE density. Considering that satellite parameter Set 4 may be special, e.g., having the issue of discontinuous coverage, satellite beam diameter of 1700km in Set 4 also need to be taken into account. For example, *R*=250 km, *A*=162379 km2; *R* =850 km, *A*=1877110 km2.

The results can be found in the following Table D.4.1-2 and Table D.4.1-3:

Table D.4.1-2: Paging channel load for a given number of paging attempts and UE density

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| PO per PF, PF per second, paging records per PO per carrier | UE density [UE/km2] | *Npages* | M | *R* [km] | Paging channel load |
| 4, 100, 16 | 400 | 1 per hour | 1 | 250 | 18% |
| 400 | 1 per 24 hours | 1 | 250 | 1% |
| 400 | 1 per hour | 1 | 850 | 204% |
| 400 | 1 per 24 hours | 1 | 850 | 8% |
| Anchor: 1, 1, 16  Non-anchor: 1, 4, 16 | 400 | 1 per hour | 1 | 250 | 1849% |
| 400 | 1 per 24 hours | 1 | 250 | 77% |
| 400 | 1 per hour | 1 | 850 | 21370% |
| 400 | 1 per 24 hours | 1 | 850 | 890% |

Table D.4.1-3: Supported UE density for a given number of paging attempts

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| PO per PF, PF per second, paging records per PO per carrier | *Npages* | *M* | *R* [km] | Achievable UE density [UE/km2] |
| 4, 100, 16 | 1 per hour | 1 | 250 | 2240 |
| 1 per 24 hours | 1 | 250 | 54485 |
| 1 per hour | 1 | 850 | 196 |
| 1 per 24 hours | 1 | 850 | 4713 |
| Anchor: 1, 1, 16  Non-anchor: 1, 4, 16 | 1 per hour | 1 | 250 | 21 |
| 1 per 24 hours | 1 | 250 | 519 |
| 1 per hour | 1 | 850 | 2 |
| 1 per 24 hours | 1 | 850 | 45 |

Annex E:  
IoT NTN essential parts

# E.1 Introduction

This annex captures the agreements related to the evaluation of solutions addressing essential functionality of IoT NTN scenarios further to RAN plenary meeting #91e (March 2021).

# E.2 RAN2 Agreements

## E.2.1 Agreements at RAN2 #113bis-e (April 2021)

* The following points are endorsed:

Enhancements to ra-ResponseWindow and mac-ContentionResolutionTimer are essential. R2 assume that design can follow NR NTN agreements as baseline.

Enhancements to HARQ-RTT-Timer and UL-HARQ-RTT-Timer are essential. R2 assume that design can follow NR NTN agreements as baseline.

Enhancements to sr-ProhibitTimer are essential. R2 assume that design can follow NR NTN agreements as baseline.

Enhancements to RLC SN and PDCP SN are not essential.

Enhancements to tracking area management are essential.

Provisioning of ephemeris is essential. NR NTN agreements can be used as the baseline.

* There is significant interest for Power saving in idle mode for NTN IOT devices, e.g. there is significant interest for enhancements to eDRX/PSM (discontinuous coverage) and to relaxed monitoring, SI acquisition and WUS.
* The following points are endorsed:

Enhancements to UL scheduling for latency reduction are not essential.

Enhancements to PUR are not essential. Enhancement to pur-ResponseTimer is needed and feasibility of PUR in GEO and LEO scenarios needs to be checked by RAN1.

Enhancements to RLC t-Reordering timer are essential. There is no need for further study as design can follow NR NTN agreements.

## E.2.2 Agreements at RAN2 #114-e (May 2021)

* Disabling of HARQ feedback is not essential.
* No need has been identified in RAN2 for further R17 IoT NTN enhancement regarding eMTC and NB-IoT Coverage Enhancement features. They are assumed applicable to IoT NTN. Layer 1 issues if any, and the potential related need for further enhancement, are assumed to be addressed by RAN1.
* Enhancement to PDCP discard timer is not essential but can be considered in the WI as TS impact is very small.
* No additional agreements on "earth-moving cell" are needed in the Technical Report for Tracking Area Handling, as this is included in the already made agreements.
* Referring to a previous agreement: "The NR-NTN agreements, where the network may broadcast more than one TACs per PLMN in a cell is considered for IoT NTN (other options not excluded for now)", remove the text "*(other options not excluded for now)*" from previous agreement.
* Referring to a previous agreement, "[035] 15: RAN2 should wait until agreements regarding TAU are made in the NR-NTN WI, and use those for eMTC/NB-IoT over NTN, if applicable.", TAU details based on agreements regarding TAU made in the NR NTN WI is handled in the IoT NTN WI as a part of using the earth-fixed TA concept.
* Enhancements for SON and channel quality reporting for NTN have not been found to be essential.
* Support of legacy (Rel-16) cell selection/reselection mechanisms without major enhancements is considered essential. Minor adjustments to existing mobility mechanisms, such as a new parameter values, change to timing etc. can be considered to adapt functionality to NTN.
* From RAN2 point of view, the existing power saving mechanisms e.g. DRX, PSM, eDRX, relaxed monitoring, and WUS can be reused without enhancement. Can consider enhancements if found needed, to support discontinuous coverage.
* Support of discontinuous coverage without excessive UE power consumption and without excessive failures / recovery actions, is essential, Expectation that this needs to be taken into account at least for Idle mode, and that this is applicable for all reference scenarios (GEO, MEO and LEO).
* Enhancements for power saving in connected mode are not essential. Minor adaptations to enable support in NTN deployment of existing features e.g. EDT, PUR for GEO may be considered in the WI phase (no major changes for adaptation is assumed).
* Support for EPC is essential. RAN2 believes that support for 5GC is not essential, however the impact in RAN2 to additionally support 5GC is small and is feasible.
* The Study Item can be closed from a RAN2 perspective.
* Support of legacy (Rel-16) Handover and RLF/reestablishment mechanisms without major enhancements is considered essential. For eMTC, Rel-16 LTE CHO procedure can be considered without major enhancements. Minor adjustments to existing mobility mechanisms, such as a new parameter values, change to timing etc. can be considered to adapt functionality to NTN.

Annex F (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 of TR 36.763 with revision marks removed | 0.1.0 |
| 2021-04 | R1#104bis-e  R2#113bis-e | R1-2103897 R2-2104648 |  |  |  | TP for TR 36.763 capturing RAN1 #104bis-e agreements  TP for TR 36.763 capturing RAN2 #113bis-e agreements | 0.2.0 |
| 2021-04 | R1#104bis-e | R1-2104146 |  |  |  | Updated version of TR 36.763 with revision marks removed | 0.2.0 |
| 2021-05 | R1#105-e | R1-2105815 |  |  |  | Include missing Section 9 in endorsed R1-2103897 TP for TR 36.763 capturing RAN1 #104bis-e agreements | 0.3.0 |
| 2021-05 | R1#105-e | R1-2106106 |  |  |  | Updated version of TR 36.763 with revision marks removed | 0.3.0 |
|  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |