**3GPP TSG RAN WG2 Meeting #114-e Draft R2- 2106784**

**May 19th - 27th, 2021**

**Source:** Eutelsat, MediaTek

**Title:** TP for TR 36.763 capturing RAN2 #114e agreements

**Agenda Item:** 9.2.1

**Document for:** Discussion and decision

1 Introduction

This document contains Text Proposals for TR 36.763 based on agreements in A.I. 9.2.1, 9.2.2 and 9.2.3 at RAN2#114 further to RAN2 email and meeting discussions for the Study on Narrow-Band Internet of Things (NB-IoT) / enhanced Machine Type Communication (eMTC) support for Non-Terrestrial Networks (NTN) [R2], [R1].

TPs are based on agreements as captured in the RAN2#114eChairman notes [R3] on:

- Open issues not covered by NR NTN

- Other open issues, including performances evaluation aspects

- IoT NTN essential functionality

In addition, this document proposes the resolution of a number of editor's note and RAN2 recommendations for a follow-up work item in preparation to the presentation of the TR no next RAN #92-e plenary meeting in June 2021.

2 Contact information

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3 Text Proposal for TR 36.763

Note: The revision marks used in this document are comparing to the draft TR version in [R2]

--- Start of text proposal (Sections 2-3) ---

# 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 TR 38.821 v16.0.0: "Solutions for NR to support non-terrestrial networks (NTN) (Release 16)"

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

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

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

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

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

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

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

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

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

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

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

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

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

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

# 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

WUS Wake Up Signal

--- End of text proposal (Sections 2-3) ---

--- Start of text proposal (Section 5) ---

# 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.

--- End of text proposal (Section 5) ---

--- Start of text proposal (Section 7) ---

# 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 [10]. 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 [10].

#### 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. [7, TS36.331]

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

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

*Solution Overview*

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

#### 7.2.1.4 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 [7]. After the expiry of *sr-ProhibitTimer*, a SR will be initiated. For GEO systems the value range may not be sufficient because of the large RTT.

*Solution Overview*

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

#### 7.2.1.5 HARQ

NOTE: The details of MAC Technical Specification [12] 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 [10].

#### 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 [7]. Large propagation delay might have impacts on *t-Reordering* timer.

*Solution Overview*

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

#### 7.2.2.2 RLC Sequence Numbers

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

### 7.2.3 PDCP

#### 7.2.3.1 Discard timer

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

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

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

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



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

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



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

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

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

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

*Solution Overview*

In order not to have TAU performed frequently by the UE triggered by the satellite motion, the tracking area 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.

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

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

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

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

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

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

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

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 [3] [10].

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.

--- End of text proposal (Section 7) ---

--- Start of text proposal (Section 8) ---

# 8 Recommendations on the way forward

## 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.

--- End of text proposal (Section 8) ---

--- Start of text proposal (Annex D / New section) ---

Annex D:
Examples of paging capacity evaluation

## D.1 Example 1 ([13])

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 ([14])

### 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 [17], 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 ([15])

### 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 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 ([16])

### 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 1700 km 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 |

--- End of text proposal (Annex D) ---

--- Start of text proposal (Annex E / clause number shift) ---

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 Rel-17 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.

--- End of text proposal (Annex E) ---

--- Start of text proposal (Annex F / clause number shift) ---

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#104eR1#104eR2#113eR2#113e | R1-2102258R1-2102255R2-2102492 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-eR2#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 | R!-210XXXX |  |  |  | Include missing Section 9 in endorsed R1-2103897 TP for TR 36.763 capturing RAN1 #104bis-e agreements  | 0.3.0 |
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--- End of text proposal (Annex F) ---

# 4 Conclusion

In this contribution, we provided Text Proposals for inclusion in TR 36.763 "Study on Narrow-Band Internet of Things (NB-IoT) / enhanced Machine Type Communication (eMTC) support for Non-Terrestrial Networks (NTN)" (Release 17) as captured in the RAN2#114e Chairman notes.

# 5 References

[R1] RP-210868: SID "Study on NB-IoT/eMTC support for Non-Terrestrial Networks", RAN#91-e, March 2021

[R2] 3GPP TR 36.673 v0.3.0: "Study on Narrow-Band Internet of Things (NB-IoT) / enhanced Machine Type Communication (eMTC) support for Non-Terrestrial Networks (NTN)", Release 17

[R3] Meeting notes (EOM), RAN2 Chairman (MediaTek), RAN2#114e, May 21, 2021 - RAN2-114-e