3GPP TSG-RAN WG2 #113bis-e Tdoc R2-xxxxxx

Electronic meeting, 2021-04-12 – 2021-04-20

Agenda Item: x.x.x.x

Source: Ericsson

Title: Summary of [Post113-e][055][IoT NTN] Performance evaluation [Ericsson]

Document for: Discussion, Decision

# 1 Introduction

In RAN#86, a SI was approved to determine and evaluate the minimum necessary specifications to introduce NB-IoT/LTE-M support for non-terrestrial networks (NTN). The description for the SI was updated in RAN#90 [5] and it was agreed to use the existing work on NR NTN captured in TR 38.821 [1] as a baseline.

This document concerns the following e-mail discussion:

* [Post113-e][055][IoT NTN] Performance Evaluation (Ericsson)

 Scope: First round of discussion on performance evaluation, paging performance and connection density. Determine what should be captured in the TR. Can discuss pre-assumption, e.g. traffic model etc. Note that there are no specific requirements, so the objective is to assess performance for sanity check and to avoid surprises rather than doing a detailed comparative analysis. To the extent available, can include performance results numbers.

 Intended outcome: Report

 Deadline: Friday March 26th 11:00 UTC

The purpose of this e-mail discussion is to kick off a first round discussion on performance evaluation, paging performance and connection density in IoT NTN. The goal is to establish a common understanding on the assumptions, e.g., traffic model, methodology and metrics to be used to assess the performance and determine what should be captured in the TR.

The discussion is structured in two sections:

* **Paging capacity evaluation**
	+ Introduce/summarize how paging capacity was evaluated in TR 38.821 for NR NTN.
	+ Discussion on what sort of assumptions, e.g., traffic model, methodology and metrics should be used specifically when NB-IoT and LTE-M devices in NTN are considered to assess the paging capacity.
	+ Determine what should be captured in the TR.
* **Connection Density evaluation**
	+ Introduce/summarize connection density evaluations for IMT-2020 and the assumptions, methodology and metrics for LTE-M and NB-IoT.
	+ Discussion on what sort of assumptions, e.g., traffic model, methodology and metrics should be used specifically when NB-IoT and LTE-M devices in NTN are considered to assess the connection density.

# 3 Paging capacity evaluation

## 3.1 Methodology

The paging capacity was assessed for NR NTN in Section 7.3.3 in [1]. The assessment was made considering the parameters that affect the paging performance. This, for instance, includes the number of paging frames and the number of paging occasions that can be configured in NR. These figures were then used along with a specific paging configuration and a specific mobile terminated traffic arrival rate to compute the paging channel load, which would essentially be the needed paging channel load divided by the available paging capacity given the configuration. The supported UE density, given an arrival session rate, was also evaluated.

------------------------------------TR 38.821------------------------------------

#### 7.3.3.1 Paging Capacity

Following parameters should be considered for calculation of paging capacity

* Paging Frames (PF) per second: $N\_{PF}$
* Paging Occasions (PO) per PF: $N\_{POperPF}$
* Maximum number of paging records in paging message: $N\_{UEperPO}$
* 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 in per tracking area: M

##### 7.3.3.1.1 Paging capacity of non-multibeam cell

In a non-multibeam scenario 4 out of 10 subframes per PF can be used for paging that is there can be at most 4 PO per PF. A paging message can only be sent in a PO. The paging message can at most include 32 paging records in the paging message where each paging record includes the UE identities of the UEs being paged. The theoretical paging capacity as maximum number of UEs paged per second in an NR non-multibeam cell is thus limited by:

$Supported Paging Capacity per second=N\_{PF}×N\_{POperPF}×N\_{UEperPO}$.

As each RF can be configured to be a PF, the resulting maximum paging capacity with 100 PF per second is thus $4 × 100 = 400$ PO per second. This implies that theoretically, an NR cell can page $32 × 400 = 12 800$ UEs per second, or equivalently, more than 46 Million UEs per hour $(12 800 × 60 × 60)$.

The supported paging capacity should be compared with the required paging per cell, which can be calculated as:
$$Expected arrival rate per cell per second= A x UE density x arrival session rate$$

If the tracking area is larger than one cell and the base station needs to blindly page all the UEs that it want to reach in all cells, then in the worst case the required arrival rate would be:

$$Expected arrival rate per TA per second= M x A x UE density x arrival session rate$$

The paging capacity should also be considered together with the cell’s capacity to support UEs accessing the cell. After being paged, the UE accesses the cell using a random-access procedure which starts by the UE transmitting a random-access preamble on the physical random-access channel (PRACH). PRACH capacity is calculated in Section X.

------------------------------------TR 38.821------------------------------------

For both NB-IoT and LTE-M, there are several differences compared to NR NTN; the maximum number of paging records in a paging message is different, one needs to consider the repetitions required for M/NPDCCH that schedules the paging message and M/NPDSCH that carries the paging message with respect to different enhanced coverage levels and the possibility to allocate narrowbands/paging carriers which enhances the capacity utilizing Frequency Division Multiplexing. The mobile terminated traffic model is also important here and one should keep in mind that paging messages may need to be retransmitted due to decoding failures or UE not being present in that particular cell or tracking area.

We assume that a paging capacity evaluation similar to what has been captured in TR 38.821, will be considered as a baseline in this study item. In the questions below, the intention is to first confirm this understanding to find out whether such assumption is shared and to discuss what else needs to be considered regarding the traffic model, methodology and metrics specially for NB-IoT and LTE-M devices.

**Question 1: Do you confirm that the baseline for the methodology is the evaluation method used in TR 38.821? Please comment especially if you think otherwise and/or different methodologies need to be used for NB-IoT or LTE-M.**

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| **Company** | **Yes/No** | **Comments** |
| OPPO | Yes | We agree to use paging capacity evaluation method captured in TR38.821 as baseline. |
| Gatehouse | Yes |  |
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**Question 2: Are there any additional aspects that need to be considered in particular when evaluating the paging capacity for NB-IoT/LTE-M devices with respect to such evaluation in NR NTN? e.g., # of repetitions required, CE levels, paging narrowbands or carriers etc. Please comment on the details if you think so and indicate any aspect if it is specific for NB-IoT or LTE-M.**

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| **Company** | **Yes/No** | **Comments** |
| OPPO | Yes | For both NB-IoT and eMTC, paging narrowbands number or carrier number should be taken into account, and the supported paging capacity should be expressed as $Supported Paging Capacity per second=N\_{carrier}×N\_{PF}×N\_{POperPF}×N\_{UEperPO}$.where the $N\_{carrier}$ is the paging narrowbands number for eMTC and carrier number for NB-IoT.Regarding the paging repetition number, it may affect the value of $N\_{PF}$ and $N\_{POperPF}$ . |
| Gatehouse | Yes | Agree with OPPO on that multiple (anchored) carriers can be used for paging. Additionally, in for NB-IoT, repetitions will have a negative effect on the paging capacity. IoT devices will be likely equipment with lesser antenna (and thus lower gain, more loss, lesser SNR) |
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In TR 38.821 [1] two different paging traffic models are used; 1 page per UE per hour and 1 page per UE per 24 hours.

**Question 3: Do you agree that the paging traffic models used in TR 38.821 are assumed when evaluating the paging capacity for NB-IoT and LTE-M in IoT NTN scenarios? Please comment especially if you think otherwise and provide your suggestion on the paging traffic models that should be assumed,**

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| **Company** | **Yes/No** | **Comments** |
| OPPO | Yes |  |
| Gatehouse | Yes, but | It might be necessary to evaluate also the moving beam scenario, and not only fixed beam |
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**Question 4: What metrics need to be considered when evaluating the paging capacity for NB-IoT and LTE-M? e.g., paging capacity requirement. Please indicate the metrics, if any, in case it is specific for NB-IoT or LTE-M.**

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**Question 5: Please comment if there are any other aspects/questions that would be good to discuss regarding the evaluation for paging capacity.**

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# 4 Connection density evaluation

During the study on self-evaluations towards 5G, evaluations were performed to confirm that 3GPP technologies fulfil the IMT-2020 requirements for 5G [3]. In particular, one requirement for the massive MTC use case was that the 5G standard(s) should support a device density of at least 106 devices/km2 where 99% of the users have successfully delivered a 32-byte packet within 10s.

In this section we will describe a methodology that can be used to evaluate the IMT-2020 requirement on connection density for LTE-M and NB-IoT based NTN and discuss specific scenarios to be used with the methodology.

## 4.1 Connection density evaluation for IMT-2020

In [3], two different methods are described: the full buffer system level simulation and the non-full buffer system level simulation. In the full buffer simulation, ideal resource allocation is assumed, and the system access procedures are disregarded.

In the non-full buffer simulation, there is a more detailed level of modelling by including the system access procedures (idle to connected mode procedures being either RRC resume or EDT), the scheduling procedures (scheduling request, N/MPDCCH scheduling N/PUSCH/PDSCH) as well as release procedures. Thus, the QoS requirement means that the UE shall perform access procedures (random access procedures as well as needed configuration) and then deliver the payload within 10 seconds.

For both evaluation methods, the Urban Macro – mMTC test environment is used where an ISD of 500 meters and 1732 meters are considered.

## 4.2 Connection density evaluation for IoT NTN

In this section we propose the methodology that can be used when evaluating connection density in NTN scenarios. Detailed system level evaluation methodology is introduced in TR 38.821 [1]. Several simulation assumptions such as the ones for satellite antennae, EIRP, transmit gain and satellite antenna placements can be inherited directly. For simplicity we suggested considering one scenario for LEO and one for GEO.

One aspect that can be problematic for connection density evaluation is the number of cells/spotbeams that are used. TR 38.821 [1] describes beam layouts and the number of spotbeams to evaluate as shown in Figure 1 below, where it is noted that wrap-around is not used. Thus, for a frequency reuse factor (FRF) of 1, an additional 2 tiers of beams are introduced to account for no wrap-around, meaning 61 cells need to be simulated but only the statistics of the inner 19 cells are used. Similarly, for a frequency reuse factor (FRF) of 3, 128 cells need to be simulated with only the inner 19 cells are used.

Since the 99th percentile needs to reach 10 seconds to determine the achievable connection density, the number of users required in the system level evaluation may be very large.



Figure 1. Illustrations of the additional tiers of beams to be wrapped around based on the FRF configurations [1].

For non-full buffer simulation methodology where the system access procedures are simulated, we suggest limiting the number of required cells. One approach is to reduce the number of simulated cells to 19 and then remove the outer layer to only collect statistics from the inner cells to avoid the effects of the outer cells not having any adjacent interferers. This can be seen in Figure 2.



Figure 2. 19-cell layout with only inner layers considered.

Regarding which type of access procedure is used, i.e., either RRC Resume or EDT should be simply stated.

A further evaluation option could be to include the time for the UE to perform its GNSS time-to-first-fix.

**Question 6: Do you agree that the methodologies described in 4.1 and 4.2. above can be considered as the baseline?** **Please comment especially if you think otherwise and/or different methodologies need to be used for NB-IoT or LTE-M.**

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| **Company** | **Yes/No** | **Comments** |
| OPPO |  | We think the same topology given in figure 1 above could be used in IoT over NTN, we wonder why to reduce the cell number. |
| Gatehouse | Yes | Agreed to minimize cells for simulation purposes |
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### 4.2.1 LEO scenario

For the LEO scenario, we suggest evaluating the connection density performance for IoT NTN under one of the scenarios from TR 38.821. Table 6.1.1.1-9 defines a set of cases from which *Case 9* appears to be the most relevant from the perspective of IoT NTN. *Case 9* is a LEO scenario at 600km altitude, S-band, 90-degree elevation angle with 1:1 frequency reuse. Furthermore, RAN1 has agreed a set of IoT NTN -specific link budget items in [4] for the UE characteristics. The combined parameters from TR 38.821 and [4] are shown in Annex A.

**Question 7: Do you agree that *Case 9* from TR 38.821 is used for the LEO scenario when evaluating the connection density performance for IoT NTN? Please comment especially if you think otherwise and/or different case(s) need to be used for NB-IoT or LTE-M.**

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| **Company** | **Yes/No** | **Comments** |
| OPPO | Yes |  |
| Gatehouse | Yes | Agree to use Case 9 based on set-1 in the TR38.821 document. In our understanding, this would represent a best-case scenario for a connection density perspective, compared to the other sets of parameters (set-2, set-3 and set-4) addressed in the IoT NTN SI. |
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### 4.2.2 GEO scenario

Similarly, for GEO scenario, we suggest evaluating the connection density performance for IoT NTN under one of the scenarios from TR 38.821. Table 6.1.1.1-9 defines a set of cases from which *Case 4* appears to be the most relevant from the perspective of IoT NTN. *Case 4* is a GEO scenario with 45-degree elevation angle at the central beam, S-band with 1:1 frequency reuse. Furthermore, RAN1 has agreed a set of IoT NTN -specific link budget items in [4] for the UE characteristics. The combined parameters from TR 38.821 and [4] are shown in Annex B.

**Question 8: Do you agree that *Case 4* from TR 38.821 is used for the GEO scenario when evaluating the connection density performance for IoT NTN? Please comment especially if you think otherwise and/or different case(s) need to be used for NB-IoT or LTE-M.**

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| **Company** | **Yes/No** | **Comments** |
| OPPO | Yes |  |
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**Question 9: Please comment if there are any other aspects/questions that would be good to discuss regarding the evaluation for connection density performance.**

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# 5 Other evaluations

In sections 3 and 4 evaluations for paging capacity and connection density performance are described.

**Question 10: Please comment if there are any other evaluations that would be good to consider for NB-IoT and LTE-M in IoT NTN.**

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| **Company** | **Comments** |
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# 6 Conclusion

In the previous sections we made the following observations:

[Observation 1 An Observation with automatic numbering. Assign this type by pressing Alt-O. A list of all Observations can be found in the Conclusion section.](#_Toc509923396)

Based on the discussion in the previous sections we propose the following:

[Proposal 1 A Proposal with automatic numbering. Assign this type by pressing Alt-P. A list of all Proposals can be found in the Conclusion section.](#_Toc509923397)

# References

1. 3GPP TR 38.821, Solutions for NR to support non-terrestrial networks (NTN), Release 16 (V16.0.0), 2019-12
2. 3GPP TR 38.811, Study on New Radio (NR) to support non-terrestrial networks, Release 15 (V15.2.0), 2019-09
3. 3GPP TR 37.910, Study on self-evaluation towards IMT-2020 submission, Release 16 (V16.1.0), 2019-09
4. R1-210xxxx, Draft Report of 3GPP TSG RAN WG1 #104-e v0.3.0, Online meeting, 25th January – 5th of February 2021, accessed March 2021.
5. RP-202689, Study on NB-IoT/eMTC support for Non-terrestrial Network, RAN#90, Dec 2020.
6. TR 38.821, Solutions for NR to support Non-terrestrial Networks (NTN), 3GPP, V16.0.0, Jan 2016.
7. 3GPP TR 38.913, “Study on scenarios and requirements for next generation access technologies,” version 16.0.0, July 2020.
8. ITU-R, Report ITU-R M.2412-0, “Guidelines for evaluation of radio interface technologies for IMT-2020”, October 2017.
9. R2-1901404, IoT Device Density Models for Various Environments, Vodafone, RAN2#105, Athens 2019.

Contact delegates

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# Annex

## A. LEO IoT NTN IMT-2020 connection density scenario

The combined satellite scenario for evaluating the IMT-2020 connection density under LEO scenario is as below.

Satellite characteristics:

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| --- | --- |
| Satellite orbit | LEO-600 |
| Satellite altitude | 600 km |
| Satellite antenna pattern | Section 6.4.1 in [2] |
| Payload characteristics for DL transmissions |  |
| Equivalent satellite antenna aperture (Note 1) | S-band(i.e. 2 GHz) | 2 m |
| Satellite EIRP density | 34 dBW/MHz |
| Satellite Tx max Gain | 30 dBi |
| 3dB beamwidth | 4.4127 deg |
| Satellite beam diameter (Note 2) | 50 km |
| Payload characteristics for UL transmissions |  |  |
| Equivalent satellite antenna aperture (Note1) | S-band (i.e. 2 GHz) | 2 m |
| G/T | 1.1 dB K-1 |
| Satellite Rx max Gain | 30 dBi |
| For Notes see [1]. |

The UE characteristics(based on [1] and RAN1 agreements in [4]):

|  |  |
| --- | --- |
| Characteristics | Handheld |
| Frequency band | S band (i.e. 2 GHz) |
| Antenna type and configuration | (1, 1, 1) with omni-directional antenna element |
| Polarisation Loss | 3 dB  |
| Rx Antenna gain  | 0 dBi per element |
| Antenna temperature | 290 K |
| Noise figure | 9 dB |
| Tx transmit power | (PC5) 100 mW (20 dBm) |
| Tx antenna gain | 0 dBi per element |

Beam layout characteristics:

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| --- | --- |
| Beam layout definition | Baseline: Hexagonal mapping of the beam bore sight directions on UV plane defined in the satellite reference frame.Only the 3dB beam width parameters should be used. The beam diameter and beam spacing values can be computed directly from the 3 dB beam width assumptions and should be considered as informative.  |
| Number of beams | Baseline: 19-beam layout |
| UV plane illustration (extracted from [19]) |  |
| UV plane convention | U axis is defined as the perpendicular line to the satellite-earth line on the orbital plane as illustrated here after :The straight line being orthogonal to UV plane is pointing towards the Earth centre.UV coordinates of the nadir of the reference satellite is (0,0) |
| Adjacent beam spacing on UV plane | Baseline: Adjacent beam spacing computation based on 3dB beam width of the satellite antenna pattern :ABS = sqrt(3) x sin(HPBW/2 [rad]) |
| Central beam bore sight direction definition | Central beam center is considered at nadir point |

Miscellaneous parameters:

|  |  |
| --- | --- |
| Frequency band | S-band (i.e. 2 GHz) |
| Maximum Bandwidth per beam (DL + UL) | To be stated for LTE-M/NB-IoT. |
| Satellite antenna pattern | See section 6.4.1 in [2]: Bessel function |
| Satellite polarization configuration | Circular |
| Beam layout definition | For singles satellite simulation : See Table 6.1.1.1-4 |
| Frequency re-use factor | 1:1 |
| Polarization re-use | Disabled |
| Channel model | Large scale model of [2] (Note 2) |
| Deployment scenarios | Base-line : Rural |
| Propagation conditions | Line of sight |
| UEs outdoor/indoor distribution | 100% outdoor distribution for UEs |
| UEs coverage distribution | Randomly uniform.  |
| UE configuration | Handheld (optional for scenario A) |
| UE orientation | Ideal Tracking serving beam; |
| Handover Margin | 0 dB |
| UE attachment | RSRP |
| For Notes see [1] |

## B. GEO IoT NTN IMT-2020 Connection density Scenario

The combined scenario for evaluating the IMT-2020 under GEO scenario.

Satellite characteristics:

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| --- | --- |
| Satellite orbit | GEO |
| Satellite altitude | 35786 km |
| Satellite antenna pattern | Section 6.4.1 in [2] |
| Payload characteristics for DL transmissions |  |
| Equivalent satellite antenna aperture (Note 1) | S-band(i.e. 2 GHz) | 22 m |
| Satellite EIRP density | 59 dBW/MHz |
| Satellite Tx max Gain | 51 dBi |
| 3dB beamwidth | 0.4011 deg |
| Satellite beam diameter (Note 2) | 250 km |
| Payload characteristics for UL transmissions |  |  |
| Equivalent satellite antenna aperture (Note1) | S-band (i.e. 2 GHz) | 22 m |
| G/T | 19 dB K-1 |
| Satellite Rx max Gain | 51 dBi |
| For notes see [1]. |

The UE characteristics(based on [1] and agreements [4]):

|  |  |
| --- | --- |
| Characteristics | Handheld |
| Frequency band | S band (i.e. 2 GHz) |
| Antenna type and configuration | (1, 1, 1) with omni-directional antenna element |
| Polarisation Loss | 3 dB |
| Rx Antenna gain  | 0 dBi per element |
| Antenna temperature | 290 K |
| Noise figure | 9 dB |
| Tx transmit power | 100 mW (23 dBm) |
| Tx antenna gain | 0 dBi per element |

Beam layout characteristics:

|  |  |
| --- | --- |
| Beam layout definition | Baseline: Hexagonal mapping of the beam bore sight directions on UV plane defined in the satellite reference frame.Only the 3dB beam width parameters should be used. The beam diameter and beam spacing values can be computed directly from the 3 dB beam width assumptions and should be considered as informative.  |
| Number of beams | Baseline: 19-beam layout considering wrap-around mechanism (i.e. 18 beams surrounding the central beam and allocated on 2 distinct “tiers”) |
| UV plane illustration (extracted from [19]) |  |
| UV plane convention | U axis is defined as the perpendicular line to the satellite-earth line on the orbital plane as illustrated here after :The straight line being orthogonal to UV plane is pointing towards the Earth centre.UV coordinates of the nadir of the reference satellite is (0,0) |
| Adjacent beam spacing on UV plane | Baseline: Adjacent beam spacing computation based on 3dB beam width of the satellite antenna pattern :ABS = sqrt(3) x sin(HPBW/2 [rad]) |
| Central beam bore sight direction definition | Case 2 : Central beam boresight direction computed based on elevation angle target |

Miscellaneous parameters:

|  |  |
| --- | --- |
| Frequency band | S-band (i.e. 2 GHz)  |
| Maximum Bandwidth per beam (DL + UL) | To be stated for LTE-M/NB-IoT. |
| Satellite antenna pattern | See section 6.4.1 in [2]: Bessel function |
| Satellite polarization configuration | Circular |
| Beam layout definition | For singles satellite simulation : See Table 6.1.1.1-4 |
| Frequency re-use factor | 1:1 |
| Polarization re-use | Disabled  |
| Channel model | Large scale model of [2] (Note 2) |
| Deployment scenarios | Base-line : RuralAdditional deployment scenario results can be provided |
| Propagation conditions | Line of sight |
| UEs outdoor/indoor distribution | 100% outdoor distribution for UEs |
| UEs coverage distribution | Randomly uniform |
| UE configuration | Handheld  |
| UE orientation | VSAT and Others: Ideal Tracking serving beam;Handheld: Random |
| Handover Margin | 0 dB |
| UE attachment | RSRP |
| For Notes see [1]. |