e3GPP RAN WG2 Meeting #112e R2-200xxxx

November 2nd – 13th, 2020

Agenda Item: X.X.X.X

Source: InterDigital (email discussion Rapporteur)

Title: [DRAFT] [Post111-e][908][NTN] RACH and HARQ feedback aspects

Document for: Discussion, Decision

# Introduction

This discussion document is intended to enable continuation of user plane discussions from RAN2#111e, specifically relating to RACH and a subset of HARQ feedback-related aspects:

* [Post111-e][908][NTN] RACH and HARQ feedback aspects (Interdigital)

Scope: Continue the discussion on RACH aspects as well as on p1, p10, p11 in [R2-2008214](file:///C:\Data\3GPP\RAN2\Inbox\R2-2008214.zip)

Intended outcome: email discussion summary

Deadline: Long

Referring to the Rel-17 NTN WID [1], RACH scope continues to address the following aspects:

* *Random access:*
  + *Definition of an offset for the start of the ra-ResponseWindow for NTN.*
  + *Introduction of an offset for the start of the ra-ContentionResolutionTimer to resolve Random access contention*
  + *Solutions for resolving preamble ambiguity and extension of RAR window.*
  + *Adaptation for Msg-3 scheduling*
    - *Only for the case with pre-compensation of timing and frequency offset at UE side)*

And the following HARQ-related proposals from the previous user plane offline email discussion summary [2]:

*Proposal 1: Agreement 4 is clarified as follows:*

*From a RAN2 perspective, uplink HARQ feedback for downlink transmission at UE receiver and HARQ uplink retransmission at UE transmitter can be enabled/disabled in Rel-17 NTN, but HARQ processes remain configured. The criteria and decision to enable/disable HARQ feedback is under network control and is signalled to the UE via RRC in a semi-static manner.*

*Proposal 10: If HARQ feedback is enabled, an offset is applied to the start of drx-HARQ-RTT-TimerDL and drx-HARQ-RTT-TimerUL for both LEO and GEO scenarios.*

*Proposal 11: If HARQ feedback is disabled, drx-HARQ-RTT-TimerDL and drx-HARQ-RTT-TimerUL are not started for both LEO and GEO scenarios.*

Please note the final deadline for company feedback has been provided by the session and RAN2 chair. An interim deadline is further included to allow for company feedback on discussion summary and draft proposals:

* Initial deadline for companies' feedback to discussion document: **Friday October 9th 23:59 EDT**
* Final deadline company input to summary and draft proposals: **Thursday October 15th 23:59 EDT**

# Continuation of RACH discussion

## Offset and Extentions

### Ra-ResponseWindow and ra-ContentionResolutionTimer offset value

From RAN2#111e, the following agreements were made concerning the offset of the *ra-ResponseWindow* and the *ra-ContentionResolutionTimer* [3]:

Agreements via email - from offline 107

1. From RAN2 perspective, an offset is applied to the start of ra-ResponseWindow in NTN for both LEO and GEO scenarios.
2. An offset to the start of the ra-ContentionResolutionTimer is introduced for both LEO and GEO scenarios.

Introduction of an offset to the above timers was intended to accommodate the large propagation delay resulting from extension of NR to a non-terrestrial environment. Additional discussion focused on the value of delay compensation, where solution options can be generally categorized as compensating either:

* **Common Delay:** A delay value corresponding to a common reference point, experienced by all UEs served within the cell/beam.
* **UE-specific delay:** A delay value corresponding to the total delay between the UE and the gNB/reference point, where this value is specific to each UE within the cell/beam.

From the Phase 2 summary of offline [AT111][107] [2], although a majority of companies (17/23) responded that UE-specific delay compensation is always needed regardless of LEO or GEO deployment scenario, this discussion was ultimately inconclusive.

RAN1 is also discussing delay compensation aspects specifically in relation to time/frequency precompensation, where discussion summary from RAN1#102e can be found in [4]. This has led to the following RAN1 agreements [5]:

*Agreement:*

* *In Rel-17 NR NTN, at least support UE which can derive based on its GNSS implementation one or more of:*
  + *its position*
  + *a reference time and frequency*
* *And, based on one or more of these elements together with additional information (e.g., serving satellite ephemeris or timestamp) signalled by the network, can compute timing and frequency, and apply timing advance and frequency adjustment at least for UE in RRC idle/inactive mode.*
  + *FFS: Details on additional information signalled from network*

*Agreement:*

*In case of GNSS-assisted TA acquisition in RRC idle/inactive mode, the UE calculates its TA based on the following potential contributions:*

* *The User specific TA which is estimated by the UE:*
  + *Option 1: The User specific TA is estimated by the UE based on its GNSS acquired position together with the serving satellite ephemeris indicated by the network:*
    - *FFS: Details on serving satellite ephemeris indication*
  + *Option 2: The User specific TA  is estimated by the UE based on the GNSS acquired reference time at UE together with reference time as indicated by the networ*k
* *The Common TA if indicated by the network:*
  + *FFS: The need and details of Common TA indication*
* *FFS: The TA margin, if needed and indicated by the network (in order to account for the TA estimation uncertainty)*

From above agreements, it seems that although the method of calculation is FFS (e.g. timestamp-based solution or UE location-based solution), UE-specific delay for purposes of UE time/frequency pre-compensation\* is supported. This conclusions appears to be in-line with RAN2 majority understanding from [2] and [6].

*\*Note: This does not preclude further enhancement for UEs not capable of UE-specific precompensation (i.e. with only some form of common delay compensation) should RAN1 determine this solution also be necessary.*

**Question 2.1: Do you agree that based on above RAN1 agreements and previous RAN2 discussion [2], RAN2 to assume UE can *at least* derive UE-specific delay based on its GNSS implementation in LEO/GEO deployments (with method FFS)?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Agree/Disagree** | **Additional comments** |
| MediaTek | Agree | UE can derive UE-specific delay based on its GNSS implementation in LEO/GEO deployments |
| APT | Agree |  |
| Nomor Research | Agree | UE can and shall derive UE-specific delay based on its GNSS implementation in NTN. UE-specific delay means total delay for UE-gNB-UE (NOT reference point). |
| Thales | Agree | The UE specific RTD (Round-Trip Delay) can be autonomously acquired by the UE based on its GNSS.  **But** for MAC timers extensions what is needed is the UE-gNB RTD. Not only the UE specific RTD. Indeed:   * If the GNSS assisted RTD acquisition is based on the satellite ephemeris (broadcasted satellite position and velcoity):   **UE-gNB RTD = UE specific RTD + Common RTD**:  UE specific RTD = Service link RTD = 2xT\_C  🡺 Autonomously acquired by the UE based on its GNSS acquired position and the serving satellite ephemeris.  Common RTD= gNB to satellite RTD = 2xT\_A + 2xT\_B 🡺 Network indication     * If the GNSS assisted RTD acquisition is based on time stamp:   UE-gNB RTD = UE specific RTD  UE specific RTD 🡺 Autonomously acquired by the UE based on its GNSS acquired reference time and the reference time indicated by the network |
| LG | Agree but | Above Rel-17, RAN2 should consider the UE without GNSS. Givne the UE without GNSS, RAN2 should discuss the solution for the UE with GNSS as well as the UE without GNSS. |
| CATT | Agree | We observed that all UEs will respond the SI change indication frequently if the common TA(e.g feeder-link delay) is broadcast via SI message, becuase the common TA(e.g feeder-link delay) changes frequently with the moving of satellite. The SI change indication will happen frequently accordingingly.  So we support the User specific TA which is estimated by the UE, but the Common TA(e.g feeder-link delay) not indicated via SI, or optionally indicatged by network. |
| Nokia | Tentatively Agree | Based on RAN1's agreements, R17 NTN at least support the UE to be able to compensate for timing offset and frequency offsets based on GNSS implementation. In current RAN1 agreements, there has been no agreement on excluding UEs that are not supporting pre-compensation capability, and the above agreement covers at least the RRC idle/inactive UE, so no explicit agreement on RRC connected mode UE. Further, in RAN1 there was an agreement to introduce k\_offset to enhance timing relationships (for instance in relation to transmission timing of RAR grant scheduled PUSCH). |
| Ericsson | Disagree | RAN2 shall wait for RAN1 conclusion on the TA estimation before going further.  We note that the last line of second RAN1 agreement is missing.  The Option 1 in second RAN1 agreement above seems to only compensate the service link and may need to be combined with the Common TA in same agreement to compensate for feeder link component. Alternatively the UE may need to know the gateway location and use satellite ephemeris to calculate the feeder link component. |

Should companies conclude that at least UE-specific delay is known at the UE and can used for time/frequency synchronization, a baseline definition of timer offset values may be determined.

**Question 2.2: If “Agree” to Question 2.1, do you agree that *ra-ContentioResolutionTimer* offset is defined using UE-specific delay as baseline in LEO/GEO?**

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| --- | --- | --- |
| **Company** | **Agree/Disagree** | **Additional comments** |
| MediaTek | Agree | *ra-ContentioResolutionTimer* offset should be defined using UE-specific delay as baseline in LEO/GEO |
| APT | Agree |  |
| Nomor Research | Agree | UE-specific delay saves UE power |
| Thales | Agree | **But** as already mentioned in our comment for question 2.1; UE-specific RTD is not enough. For ra-ContentioResolutionTimer offset we need to consider the whole RTD between UE and gNB:  **UE-gNB RTD = UE specific RTD + Common RTD**  The common RTD is equal to the RTD on the feeder link and the gNB to NTN GW RTD |
| LG | Disagree | Considering the UE without GNSS, RAN2 should discuss the solution for the UE with GNSS as well as the UE without GNSS. Thus, we prefer the common offset solution broadcasted by the network. |
| CATT | Agree |  |
| Nokia | Tentatively Agree | If UE has the pre-compensation capability,we think using the UE-specific delay based offset is reasonable. |
| Ericsson | Disagree | We propose to use the DL timing as reference for starting the CR window. This makes the TA, used to transmit Msg3, not affect the start of the CR window and avoid misalignment if TA estimation is not accurate. |

As noted in previous offline discussion [6] the start of the *ra-ResponseWindow* is captured by RAN1 in TS 38.213. However, referring to WID, definition of the offset is under RAN2 scope:

* *Definition of an offset for the start of the ra-ResponseWindow for NTN.*

**Question 2.3: If “Agree” to Question 2.1, do you agree that *ra-ResponseWindow* offset is defined using UE-specific delay as baseline in LEO/GEO? (Note: modification to start of *ra-ResponseWindow* to be captured by RAN1 in TS 38.213)**

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| --- | --- | --- |
| **Company** | **Agree/Disagree** | **Additional comments** |
| MediaTek | Agree | ra-ResponseWindow offset should be defined using UE-specific delay as baseline in LEO/GEO. Same is true for msgB-ResponseWindow. |
| APT | Agree |  |
| Nomor Research | Agree | Offset of UE-specific delay should also be applied for start of msgB-ResponseWindow |
| Thales | Agree | Similar to our comments in the prevous questions, For *ra-ResponseWindow* offset we need to consider the whole RTD between UE and gNB:  **UE-gNB RTD = UE specific RTD + Common RTD**  The common RTD is equal to the RTD on the feeder link and the gNB to NTN GW RTD  Also, we need such offset to delay the start of msgB-ResponseWindow to compensate the high RTD in 2-step RACH |
| LG | Disagree | Considering the UE without GNSS, RAN2 should discuss the solution for the UE with GNSS as well as the UE without GNSS. Thus, we prefer the common offset solution broadcasted by the network |
| CATT | Agree | ra-ResponseWindow offset is defined using UE-specific delay as baseline in LEO/GEO. |
| Nokia | Tentatively Agree | If UE has the pre-compensation capability,we think using the UE-specific delay based offset is reasonable. |
| Ericsson | Disagree | We propose using the DL timing as reference for starting the RAR window (or MsgB window). This makes the TA used (to transmit the preamble or MsgA) not affect the start of the RAR window (or MsgB window), and removes any uncertainty if the UE will be listening for RAR when the accuracy of TA used for the preamble transmission is uncertain. |

**Question 2.4: If “Agree” to Question 2.3, should and LS be sent to RAN1?**

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| --- | --- | --- |
| **Company** | **Agree/Disagree** | **Additional comments** |
| MediaTek | Agree | An LS should be sent to RAN1 |
| APT | Agree | LS to RAN1 is needed because R1-1909479 shows RAN1’s consensus that enhancement for the RAR window/RA-RNTI related issues should be up to RAN2 discussion. It is better to clarify that the start of the RAR window shall be captured by RAN1. |
| Nomor Research | Agree | LS should be sent to RAN1 |
| Thales | Agree |  |
| LG | Disagree | RAN1 can refer the RAN2 decision. |
| CATT | Agree |  |
| Nokia | Disagree | It is up to the conclusion of Question2.1. If UE with GNSS capability but without pre-compensation of timing is still in the scope of R17 NTN, then common delay offset for the timer should be broadcasted to UE as well. No LS should be sent to RAN1 before conclusion reached on this case. |
| Ericsson | Disagree | An LS can be sent to ask for RAN1 opinion on starting RAR window, MsgB window, and CR window based on the DL timing instead of the UL timing. |

### Extention of the ra-ResponseWindow

In addition to introduction of an offset to the *ra-ResponseWindow*, extension to cover the maximum differential delay of an NTN cell/beam was discussed. In NTN GEO, two times the maximum differential delay (20.6 ms) exceeds the current maximum monitoring duration in a licensed spectrum for the *ra-ResponseWindow* (10 ms). Therefore, for UEs at cell edge, if the *ra-ResponseWindow* is started in the first PDCCH monitoring occasion after 2 times the minimum delay, the monitoring duration may expire before reception of the RA response.

From [AT111][107] Phase 1 offline summary [6], a large majority of companies (19/26) responded that an extension to the *ra-ReponseWindow* is not needed if an appropriate offset is applied, with a further (6/26) companies clarifying that if UE-specific delay (from gNB to UE) is compensated then an extension is not necessary. Therefore, if companies agree to Question 2.3 (the baseline offset defintition to the *ra-ResponseWindow* is via a UE-specific delay), from past discussion the following may also be agreeable:

**Question 2.5: If the start of the *ra-ResponseWindow* is compensated by a UE-specific delay-based offset, do you agree an extension of the *ra-ResponseWindow* is not needed in LEO/GEO?**

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| --- | --- | --- |
| **Company** | **Agree/Disagree** | **Additional comments** |
| MediaTek | Agree | Extension of the *ra-ResponseWindow* is not needed in LEO/GEO |
| APT | Agree | No need for this RAR window extension if each UE can calculate proper UE-specific offset for the start of the RAR window. |
| Nomor Research | Agree |  |
| Thales | Agree | There is no need to extend the ra-ResponseWindow and msgB-ResponseWindow |
| LG |  | If the common offset is used for LEO/GEO, the extension of the RAR window may be required. |
| CATT | Agree | Extension of the *ra-ResponseWindow* is not needed in LEO/GEO. |
| Nokia | Agree with comments | We want to clarify UE-specific delay in the proposal is from UE to gNB instead of from UE to reference point, because both of them are mentioned in Section2.1.1. Additionally, the offset applied to ra-ResponseWindow should be two times of UE-specific delay (from gNB to UE).  E.g. If the UE can estimate or get the total round-trip delay between UE and gNB and apply the exact total delay as offset to start ra-ResponseWindow, there is no need to extend the window, otherwise, the window may be extended to cover 2 times of maximum differential delay. |
| Ericsson | Agree | Extension of RAR window is not connected to how the RAR window is started, it is connected to if TA can be accurately estimated by the UE in which case there is no need to extend the RAR window.  If RAN1 decides that accurate TA compensation is not possible for all users, we may revisit this assumption. |

### Preamble Ambiguity

Given the large maximum differential delay possible in NTN, it is noted in section 7.2.1.1.1.2 of TR 38.821 [7] that certain RACH occasion periodicities configurable in Rel-16 NR may lead to overlaps in preamble receiving windows between successive RACH occasions. gNB may not know which RO the preamble is associated with in the overlap period, thus may not be able to accurately estimate the appropriate timing advance.

In [AT111][107] Phase 1 offline [6], a number of potential solutions to address this issue where examined. However, based on responses a majority of companies (14/26) commented that should UE-specific delay be compensated, RACH preamble ambiguity may not be an issue.

**Question 2.6: If UE-specific RTD is compensated, is preamble ambiguity still an issue in LEO/GEO? If ‘Yes’ please describe the remaining issue(s) to be addressed in the ‘Additional Comments’ section.**

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| --- | --- | --- |
| **Company** | **Yes/No** | **Additional comments** |
| MediaTek | No | With UE-specific RTD precompensation, preamble ambiguity will not be an issue. |
| APT | No |  |
| Nomor Research | No | With UE-specific RTD compensation, preamble ambiguity is not an issue. However, from our perspective this is an RAN1 issue in general. |
| Thales | No | With UE-based pre-compensation of RTD, the delay associated with msg1 transmission will be updated and there will be no preamble ambiguity |
| LG |  | The preamble ambiguity can be resolved by network implementation. |
| CATT | No | Preamble ambiguity is not an issue if UE-specific RTD is compensated. |
| Nokia | No with comments | Same comment as Q2.5. |
| Ericsson | No |  |

### Method of offset calculation

Referring to Section 2.1.1, RAN1 has agreed to further evaluate the following options regarding calculation of UE-specific delay: (Note Option 1 may additionally have a portion of common delay, e.g. feeder-link delay, to obtain the full RTD from the UE to land-based gNB. Companies are encourage to refer to [4] for detailed solution description)*:*

* *Option 1: The User specific TA is estimated by the UE based on its GNSS acquired position together with the serving satellite ephemeris indicated by the network:*
  + *FFS: Details on serving satellite ephemeris indication*
* *Option 2: The User specific TA  is estimated by the UE based on the GNSS acquired reference time at UE together with reference time as indicated by the network*

A similar discussion occured in RAN2#111e, where solutions were discussed and described as follows [6]:

* *Option 3: UE-specific offset calculated by UE based on UE-satellite location;*

*...*

* *Option 5: UE-specific offset calculated by UE based on UTC time (via IE in SIB9);*

The outcome of this discussion [6] resulted in (20/27) companies supporting Option 3 (i.e. RAN1 Option1) and (3/27) companies supporting option 5 (i.e. RAN1 option 2).

As the method of TA calculation/compensation may also impact RAN2 signalling and procedures (e.g. SIB acquisition), companies are invited to indicate a preference on RAN1 options *from a RAN2 perspective*, as well as any potential impacts to RAN2 work resulting from the adoption of either method, if identified.

**Question 2.7: What is the preferred method of UE-specific delay timing pre-compensation *from a RAN2 perspective*? Companies are invited to list potential impacts on RAN2 work associated with each option (if identified) in the “Additional Comments” section.**

* **Option 1: The User specific TA is estimated by the UE based on its GNSS acquired position together with the serving satellite ephemeris indicated by the network**
* **Option 2: The User specific TA  is estimated by the UE based on the GNSS acquired reference time at UE together with reference time as indicated by the network**

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| --- | --- | --- |
| **Company** | **Preferred Option (1 or 2)** | **Additional comments** |
| MediaTek | Option 1 | The User specific TA should estimated by the UE based on its GNSS acquired position together with the serving satellite’s ephemeris information indicated by the network.  Knowing the satellite position and the UE position, the UE can calculate the propagation distance between satellite and UE and then calculate the TA. Hence, the knowledge of time (Option 2) is not needed. Option 1 is simpler as it does not require UE to use GNSS capability as often to acquire its position. On the other hand, Option 2 requires UE to use its GNSS capability very often to maintain its time reference accurately. |
| APT | Option 1 | Option 1 is better for LEO-based NTN. In this case, satellite ephemeris is crucial for UL frequency synchronization and mobility enhancement.  Option 2 is better for NTN ingeneral, including GEO, Air-to-Ground (ATG), and Unmanned Aircraft Systems (UAS). In these cases, whether providing satellite ephemeris does not matter. |
| Nomor Research | No strong view |  |
| Thales | Both options | It is true that autonomous TA acquisition based on GNSS and time stamp broadcast (e.g. ReferenceTimeInfo-r16) requires high-level integration of GNSS module and NR module in device and gNB.  Note that time stamp broadcast (e.g. ReferenceTimeInfo-r16) can already be supported using Rel-16 specifications.  On the other hand, for option 1 we need to discuss the implication of UL timing alignment requirements on the expected accuracy of :  The satellite position knowledge at UE side and the UE position knowledge at UE side.  Also, depending on UE motion on the earth, option 1 may also require UE to use its GNSS capability very often to derive its position, e.g. 1200 km/h (e.g. aircraft) and 500 km/h (e.g. high speed train) |
| LG |  | If the estmation of the user specific TA is required, option 1 can be a simple option. |
| CATT | Option 1 | We support the User specific TA which is estimated by the UE based on its GNSS acquired position.  If the reference time is indicated by the network in option 2, UE should get GNSS/UTC time accurately at first. Furthermore, option 1 can support the compensation of Doppler effect. |
| Nokia | Option 2 | From RAN2 perspective, to obtain the full RTD from the UE to land-based gNB, Option1 requires not only UE estimated delay for service link (from satellite to UE) but also the common delay for feeder link (from gNB to satellite), which means gNB need to broadcast common delay to UEs (e.g. it is challenging in LEO with moving satellite) to facilitate UE do full UE-specific TA compensation.  However, in Option2, the full RTD on the Uu interface (feeder and service link) can be estimated by the UE based on reference time IE in SIB9, which removes potential source of errors/inaccuracies when determining the UE-to-satellite distance/delays and also removes the requirement to broadcast exact common delay from gNB to UE for full TA compensation. Furthermore, Option2 is more future proof when thinking ISL in future release.  With Option 2, the potential error sources from GNSS system may be reduced, since it relies only on time stamps, while option 1 relies on accurate position combined with an associated estimate of time delay between UE and satellite, which is not representative of the entire gNB-to-UE delay. |
| Ericsson | Both are possible | RAN2 shall not waste time on this discussion until RAN1 decision is taken.  One of the options shall be selected, we shall not have both options in the spec. |

## Msg3 scheduling adaptation

Based on the outcome of the previous Phase 1 offline discussion [AT111][107] [6], a large majority of companies (23/26), supported the following option to address Msg3 scheduling adaptation for UE with UE-specific pre-compensation:

*Option 1: Network scheduling/implementation (i.e. no modification necessary)*

Leading to the following proposal for online discussion:

*From RAN2 perspective, for UE with UE-specific pre-compensation as a baseline it is up to gNB implementation to ensure a sufficient processing time on UE side for the Msg3 transmission*

However during RAN2#111e online discussion, concerns were raised about the terminology “UE processing time”. Email discussion rapporteur suggests a compromise proposal by removing the word “processing”, i.e.:

*From RAN2 perspective, for UE with UE-specific pre-compensation as a baseline it is up to gNB implementation to ensure a sufficient time on UE side for the Msg3 transmission.*

**Question 2.8: Do you agree with the proposed wording regarding Msg3 scheduling adaptation for UE with UE-specific delay pre-compensation?:**

* **From RAN2 perspective, for UE with UE-specific pre-compensation as a baseline it is up to gNB implementation to ensure a sufficient time on UE side for the Msg3 transmission.**

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| --- | --- | --- |
| **Company** | **Agree/Disagree** | **Additional comments** |
| MediaTek | Agree |  |
| APT | Agree | “sufficient processing time“ might be around 2 ms (PDSCH processing time plus MAC lay parsing time) based on UE capability, but “sufficient time” is more general and less confusing. |
| Nomor Research | Agree |  |
| Thales | Agree |  |
| LG |  | If the common TA and offset is used in NTN, this issue should be discussed futher. |
| CATT | Agree |  |
| Nokia | Agree |  |
| Ericsson | Agree with intent | We prefer a bit more specific:  From RAN2 perspective, for UE with UE-specific pre-compensation as a baseline it is up to gNB implementation to take into account UE processing capabilities to ensure a sufficient time on UE side for the Msg3 transmission. |

## RACH enhancements to accommodate the NTN environment

From RAN2#111e, the following was agreed regarding the inclusion of 2-step RACH in Rel-17 NTN [3]:

Agreements:

1. Both 2-step and 4-step RACH are supported in Rel-17 NTN. FFS enhancements to RACH to accommodate the NTN environment.

Companies are invited to provide initial enhancements to 2-step and 4-step RACH to accommodate the NTN environment (which are not otherwise covered in the other sections of this discussion document), or identify issues/enhancements specific to 2-step RACH.

**Question 2.9: Companies are invited to propose additional enhancements to RACH to accommodated the NTN environment, or issues/enhancements specific to 2-step RACH not already discussed in other sections.**

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| --- | --- |
| **Company** | **Description** |
| MediaTek | Include a TA report to the network in msg3 so that NW is aware of UE specific pre-compensation value for the service link. |
| APT | Currently, UE initials 2-step RACH based on a configured threshold of RSRP measurement. However, this may have some issues due to no near-far effect in NTN. Some enhancement might be considered for measurement-based 2-step RACH. |
| Nomor Research | As indicated in our answer to Question 2.3: Introduce an offset of UE-specific delay for the start of msgB-ResponseWindow.  NTN cells/beams are large in comparison to TN and therefore could cover a significantly larger number of UEs attempting to access the network. This could raise an issue regarding limited RACH capacity. It should be evaluated, if there are enhancements necessary to limit 2-step RA. |
| Thales | Introduce K\_offset to enhance the transmission timing of RAR grant scheduled PUSCH. For Koffset used in initial access, the information of Koffset is carried in system information.  Also, in case of autonomous acquisition of the TA at UE, only the UE knows the full TA, therefore, UE needs to report its autonomous TA in msg3. |
| LG | The legacy 2-step RACH can be used for NTN except for the introduction of the offset for MsgB. |
| CATT | UE may report the TA value via MsgA in 2-step RACH. |
| Nokia | If both 2-step and 4-step RACH are supported in one NTN cell, how to select RA type should be further studied on top of legacy RSRP threshold. |
| Ericsson | RAN1 decided the timing K\_offset to be used in initial access must be provided to the UEs in SI broadcasting.  It is beneficial for the system if the TA used by the UE is reported to the gNB as soon as possible, possibly in Msg3 of 4-step or MsgA of 2-step RA. If used TA is not include in the MsgA, the gNB scheduling of MsgB must, in same way as for Msg3, assume a worst case for the TA used. We may not require the TA to be include in Msg3/MsgB as that may decrease the coverage.  The start of *msgB-ResponseWindow* is specified in RAN1 spec, but the same method as for the start of the RAR window can be used.  RACH less handover is beneficial for connected mode UEs in NTN, as we avoid one RTT when the UEs can estimate the required TA in a new cell. It may decrease the RACH load and thereby decrease the RA collisions, and it may also be more resource efficient that relying on 2-step RA (which have a similar delay). |

## Other RACH aspects

**Question 2.10: Are there any other identified issues and potential enhancements for RACH in NTN for Rel-17? Companies are invited to describe the issue/enhancement in the “Description” section.**

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| --- | --- |
| **Company** | **Description** |
| APT | Current RACH resources are independently configured into 2-step and 4-step RA types, either based on different RACH occasions or PRACH preamble indexes. However, since no near-far effect in NTN, all UEs in an NTN cell may have a similar RSRP level, therefore either 2-step RA type or 4-step RA type resources will run out easily when NW configures both and UE determines based on its RSRP measurement. |
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# HARQ Aspects

## Disabling uplink HARQ retransmission

From discussion in RAN2#111e, the following proposal was discussed:

*From a RAN2 perspective, uplink HARQ feedback for downlink transmission at UE receiver and HARQ uplink retransmission at UE transmitter can be enabled/disabled in Rel-17 NTN, but HARQ processes remain configured. The criteria and decision to enable/disable HARQ feedback is under network control and is signalled to the UE via RRC in a semi-static manner.*

Although agreement was reached in both RAN1 [5] and RAN2 [3] regarding the enabling/disabling of uplink HARQ feedback for downlink retransmission, discussion regarding the inclusion of uplink HARQ retransmission (i.e. the portion in red above) was inconclusive. Reference to SI discussion on enabling/disabling uplink HARQ retransmission can be found in TR 38.821 section 7.2.1.4 (included below for convenience):

*For NTN the network could disable HARQ uplink retransmission at the UE transmitter. Even if HARQ uplink retransmissions are disabled, the HARQ processes are still configured. The enabling / disabling of HARQ uplink retransmission could be configurable on a per UE, per HARQ process and per LCH basis. Details can be decided in a normative phase. And the LCP impact caused by disabling the HARQ uplink retransmission configuration can be discussed in the WI phase.*

And is again referenced (in a slightly modified form) in section 9.2 Recommendations from RAN2 in SI conclusions:

*enabling / disabling of HARQ uplink retransmission should be configurable per UE or per HARQ process. The LCP impact caused by disabling the HARQ uplink retransmission configuration and its impact on UE's uplink transmission should be discussed in the work item phase.*

**Question 3.1: From a RAN2 perspective, do you agree that HARQ uplink retransmission at the UE transmitter can be enabled/disabled in Rel-17 NTN as per RAN2 recommendations in SI conclusion? If ‘Disagree’ please justify why SI conclusion is no longer valid.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Agree/Disagree** | **Additional comments** |
| MediaTek | Agree | Uplink retransmission at the UE transmitter can be enabled/disabled in Rel-17 NTN as per RAN2 recommendations in SI conclusion |
| APT | Agree |  |
| Nomor Research | Agree, but | In UL, HARQ retransmission usually depend on gNB’s PUSCH decoding result of initial transmission. These retransmissions can be enabled/disabled in Rel-17 NTN. However, UL HARQ retransmissions as retransmissions of a TB in a bundle or retransmissions based on blind scheduling are still supported. |
| Thales | Agree | We need to discuss LCP impact caused by disabling the HARQ uplink retransmission configuration and its impact on UE's uplink transmission |
| LG | Agree |  |
| CATT | Agree |  |
| Nokia | Agree with comments | We think the SI conclusion is to avoid UL HARQ stalling by disabling HARQ uplink retransmissions which always rely on previous PUSCH transmission decoding result of the same HARQ (i.e. long RTT to wait). So, we prefer to update it as below:  “HARQ uplink retransmission relying on the decoding result of previous PUSCH transmission at the UE transmitter can be enabled/disabled in Rel-17 NTN”  We are also fine to current proposal if majority view is that, disable HARQ uplink retransmission means disable all types of retransmission including slot aggregation as well as blind retransmissions |
| Ericsson | Disagree | The benefit for NTNs is to enable the gNB and UE to reuse one HARQ process ID before a full HARQ RTT has passed. This enables peak throughput even when the number of HARQ processes is less than needed to fill the HARQ RTT, and the cost is that there can be no HARQ retransmissions on the reused HARQ process.  Obviously the HARQ feedback sent in UL for DL transmissions becomes useless for HARQ processes that are intended to be reused, but for UL transmissions no such feedback exist today (besides in NR-U). The UE shall always follow the grants/assignments that the gNB sends to it, be it with or without the NDI toggled.  Today one HP ID can not be reused while a drx-HARQ-RTT is running (MAC spec issue, a timer value of zero is already available in the spec):  -    *drx-HARQ-RTT-TimerDL* (per DL HARQ process except for the broadcast process): the minimum duration before a DL assignment for HARQ retransmission is expected by the MAC entity;  -    *drx-HARQ-RTT-TimerUL* (per UL HARQ process): the minimum duration before a UL HARQ retransmission grant is expected by the MAC entity;  Also RAN1 specifies requirements on not reusing a HARQ process ID in 38.214 clause 5.1 and 6.1:  The UE is not expected to receive another PDSCH for a given HARQ process until after the end of the expected transmission of HARQ-ACK for that HARQ process, where the timing is given by Clause 9.2.3 of [6]  …  Thus for DL, the gNB cannot send a new DL assignment for a given HARQ process ID until after (about a) half a RTT has passed since last use of the HPID.  …  The UE is not expected to be scheduled to transmit another PUSCH by DCI format 0\_0, 0\_1 or 0\_2 scrambled by C-RNTI or MCS-C-RNTI for a given HARQ process until after the end of the expected transmission of the last PUSCH for that HARQ process.  The meaning of last sentence for UL may be discussed, but the conservative interpretation (in Rel 15) is that the UE cannot receive a new grant for same HP ID before the end of the PUSCH transmission. Thus at least one or two slots (depending on CORSET, timing advance and Tproc2 and SCS) has to pass before gNB may reuse the same HP ID in an UL grant.  Thus “HARQ disabling” means 1) UE do not send HARQ feedback in UL for the DL transmissions, 2) gNB may schedule the same HARQ process ID in consecutive PDSCH/PUSCH allocations (using the same or toggled NDI).  Note that for UL we only need to allow a HP ID in consecutive PUSCH allocations, no need to signal this to the UE by RRC for specific HARQ process IDs.  Note that UEs already in Rel 15 had optional features pdsch-RepetitionMultiSlots/pusch-RepetitionMultiSlots where UEs receive/transmit on one HP ID in consecutive PDSCH/PUSCH allocations, though that is after receiving one assignment/grant for the first allocation only.  We propose modified the agreements from last meeting as follows:  **Proposal: From a RAN2 perspective, when a downlink HARQ process is disabled, the UE do not send uplink HARQ feedback for downlink transmissions scheduled on the disabled HARQ process.**  **Proposal: Enabling/disabling uplink HARQ feedback for downlink transmissions is under network control and is signalled to the UE via RRC in a semi-static manner.**  **Proposal: From a RAN2 perspective, when a DL HARQ process is disabled, the given DL HARQ process can be used in consecutive PDSCH allocations for new transmissions or retransmissions (pending RAN1 input on feasibility).**  **Proposal: From a RAN2 perspective, a given UL HARQ process can be used in consecutive PUSCH allocations for new transmissions or retransmissions (pending RAN1 input on feasibility).**  **Proposal: Send LS to RAN1 about the feasibility of these proposals.** |

RAN2 recommendations in the SI conclusion further mention that the granularity for disabling HARQ uplink retransmission can be configurable ‘*per UE or per HARQ process.*’

**Question 3.2: If ‘Agree’ to Question 3.1, what is the preferred granularity for enabling/disabling HARQ uplink retransmission from a RAN2 perspective?**

* **Option 1: configurable per HARQ process;**
* **Option 2: configurable per UE.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Preferred Option** | **Additional comments** |
| MediaTek | Option 1 | Granularity for enabling/disabling HARQ uplink retransmission could be configured per HARQ process basis. |
| APT | Option 1 |  |
| Nomor Research | Option 1 | UE can request for different services. |
| Thales | Option 1 | Same as for HARQ feedback for downlink transmission, enabling/disabling HARQ uplink retransmission should be at least configurable per HARQ process |
| LG | Option 1,  Option 2 |  |
| CATT | Option 1 | Per HARQ process is more flexible. |
| Nokia | Option 1 | It could be left transparent to the UE, as this is controllable through the NDI on the scheduling DCI, but if LCP is to be impacted by pre-knowledge at the UE side, this should be indicated on per HARQ process. |
| Ericsson | Option 1 |  |

The TR additionally mentions other aspects regarding the enabling/disabling of HARQ specifically referring to HARQ feedback (i.e. HARQ processes remain configured, criteria to enable/disable is under network control, and signalled to the UE via RRC in a semi-static manner) which was agreed in RAN2#111e [3]. Companies are invited to comment whether these agreements are also valid for uplink HARQ retransmission (if agreed).

**Question 3.3: From a RAN2 perspective, which of the following statements agreed for UL HARQ feedback for downlink transmission are applicable to HARQ uplink retransmission?**

1. **HARQ uplink retransmission at the UE transmitter can be enabled/disable, but HARQ processes remain configured;**
2. **The criteria to enable/disable HARQ uplink retransmission is under network control;**
3. **Enabling/disabling HARQ uplink retransmission is signalled to UE via RRC in a semi-static manner;**

|  |  |  |  |
| --- | --- | --- | --- |
| **Company** | **Statements** | | **Additional comments** |
| **Agree** | **Disagree** |
| MediaTek | Option 1  Option 2  Option 3 | None |  |
| APT | Option 1  Option 2  Option 3 |  |  |
| Nomor Research | Statements 1, 2 and 3 |  | Regarding statement 1, we would prefer to precise to “HARQ uplink retransmission at the UE transmitter **based on PUSCH decoding results** can be enabled/disable**d**, but HARQ processes remain configured; |
| Thales | Options 1, 2 and 3 |  |  |
| LG | Option 2,  Option 3 | Option 1 | For Option 1, it would be used to solve the HARQ stalling. However, the HARQ stalling problem would not hanppen by the network implementation. |
| CATT | Options 2 and 3 |  |  |
| Nokia | Option1/2/3 |  | As a complete suggestions in TR, we think the LCP impact should be capatured for UL as well. E.g. The LCP impact caused by disabling the HARQ uplink retransmission configuration and its impact on UE's uplink transmission should be discussed. |
| Ericsson |  | 1, 2, 3 | It is NOT about disabling HARQ retransmissions, it is about reusing the HARQ process IDs before a HARQ RTT has passed. This shall obviously be under network control. |

**Question 3.4: If RAN2 agrees that HARQ uplink retransmission at the UE transmitter can be enabled/disabled in Rel-17 NTN, should an LS be sent to RAN1?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Send LS to RAN1? Agree/Disagree** | **Additional comments** |
| MediaTek | Agree | Send an LS to RAN1 corresponding to enabling/disabling of HARQ uplink retransmissions at the UE transmitter. |
| APT | Agree |  |
| Nomor Research | Agree | HARQ uplink retransmissions based on PUSCH decoding results can be enabled/disabled in Rel-17 NTN. |
| Thales | Agree |  |
| LG | Disagree | RAN1 can refer the RAN2 decision |
| CATT | Agree |  |
| Nokia | Disagree | Enable/Disable HARQ uplink retransmission at the UE transmitter is gNB’s scheduling behaviour which is up to NW implementation. We don’t see any RAN1 impact which should be metioned. |
| Ericsson | Disagree | We shall send an LS to RAN1 but we shall ask for feasibility for the UE receive grants and assignments for a specific HARQ process ID for consecutive PUSCH/PDSCH allocations. |

## drx-HARQ-RTT-Timers

### drx-HARQ-RTT-Timers behaviour when HARQ feedback is enabled

From RAN2#111e, the following proposal had large majority (25/27) support [2,6]:

* *If HARQ feedback is enabled, an offset is applied to the start of drx-HARQ-RTT-TimerDL and drx-HARQ-RTT-TimerUL for both LEO and GEO scenarios.*

Based on company feedback in RAN2#111e, there seems to be a general understanding that the timers require adaptation via an offset as per SI conclusion (and as captured in the WID). However based on further discussion it was was suggested that the offset may not need to apply to the start of the timers (as mentioned in the proposal), but instead used to extend the value range of the timers. Companies are therefore invited to provide additional clarification to the above proposal.

**Question 3.4: What is the preferred method to extend *drx-HARQ-RTT-TimerDL* and *drx-HARQ-RTT-TimerUL*?**

* **Option 1: offset is applied to the start of the timers;**
* **Option 2: offset is applied to the timer value range (i.e. existing values within value range increased by offset);**
* **Option 3: the timer value range is extended (i.e. additional values added to value range);**

|  |  |  |
| --- | --- | --- |
| **Company** | **Preferred Option** | **Additional comments** |
| MediaTek | Option 2 | These timers represent the minimum duration before a DL assignment for HARQ retransmission or a UL HARQ retransmission grant is expected by the MAC entity. In NTN, this duration needs to be extended by the UE specific RTD, i.e. the pre-compensation offset. Option 3 should not be supported as in that case the UE might be forced to monitor the DL for longer periods, thereby resulting in higher power consumption. |
| APT | Option1 | Less spec impact and easy to implement |
| Nomor Research | Option 2 | Current specification [3GPP TS 38.321] states: “*drx-HARQ-RTT-TimerDL*: the minimum duration before a DL assignment for HARQ retransmission is expected by the MAC entity” or “*drx-HARQ-RTT-TimerUL*: the minimum duration before a UL HARQ retransmission grant is expected by the MAC entity” AND “start the *drx-HARQ-RTT-TimerDL* for the corresponding HARQ process in the first symbol after the end of the corresponding transmission carrying the DL HARQ feedback” or “start the *drx-HARQ-RTT-TimerUL* for the corresponding HARQ process in the first symbol after the end of the first repetition of the corresponding PUSCH transmission”.  So Option 2, existing values increased by offset of size UE specific RTD, is preferred. Option 3 should not be supported as there are too many scenarios with different delays meaning Option 3 would result in a unclearly large set of values or in a waste of UE power consumption. |
| Thales | Option 2 | An offset of size of UE specific RTD is added for drx-HARQ-RTT-TimerDL and drx-HARQ-RTT-TimerUL |
| LG | Option 3 | The puspose of the offset for drx-HARQ-RTT-TimerDL/UL is to delay a time to start of the drx-HARQ-RTT-TimerDL/UL. In other words, the UE does not monitor the PDCCH before starting the drx-HARQ-RTT-TimerDL/UL.  Considering that the purpose of the drx-HARQ-RTT-TimerDL/UL is that the UE does not monitor the PDCCH while running the drx-HARQ-RTT-TimerDL/UL, the UE behaviour is same even if the drx-HARQ-RTT-TimerDL/UL is extended instend of the introduction of the offset for the drx-HARQ-RTT-TimerDL/UL.  Thus, RAN2 should discuss firstly whether the offset for drx-HARQ-RTT-TimerDL/UL should be introduced or the drx-HARQ-RTT-TimerDL/UL should be extended. |
| CATT | Option 3 | The drx-HARQ-RTT-TimerDL is the minimum duration before a downlink assignment for HARQ retransmission is expected by the MAC entity. HARQ-RTT-TimerUL for the uplink is samilar with drx-HARQ-RTT-TimerDL.  drx-HARQ-RTT-TimerDL and drx-HARQ-RTT-TimerUL may be extended to support NTN, for example:  drx-HARQ-RTT-TimerDLExt INTEGER (0.. 106848),  drx-HARQ-RTT-TimerULExt INTEGER (0.. 106848),  It’s up to network to config the value via drx-HARQ-RTT-TimerDLExt or drx-HARQ-RTT-TimerDL. |
| Nokia | Option 1 | We think both Option1 and Option2 can work efficiently in a simple way. However, as mentioned by SI recommendation: *Offset based solutions for timer adaptations are preferred to support all NTN scenarios*, we think Option1 is more aligned with the recommendation (e.g. similar to offset to start Ra-ResponseWindow and ra-ContentionResolutionTimer). |
| Ericsson | Option 2 | We shall keep the zero value, that is if drx-HARQ-RTT is zero we shall not add an offset to that value. Option 1 and 2 are the same as there is no use of monitoring for retransmission until the drx-RetransmissionTimer is started. |

As in Section 2, should companies conclude that at least UE-specific delay is known at the UE and is to used for time/frequency synchronization, a baseline definition of timer offset values may be determined.

**Question 3.5: Do you agree that *drx-HARQ-RTT-TimerUL* and *drx-HARQ-RTT-TimerDL* offset is defined using UE-specific delay as baseline in LEO/GEO?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Agree/Disagree** | **Additional comments** |
| MediaTek | Agree |  |
| APT | Agree |  |
| Nomor Research | Agree | Applying UE-specific delay minimizes UE power consumption. |
| Thales | Agree | Need to consider UE-gNB RTD = UE specific RTD + Common RTD |
| LG | Disagree | We prefer the common offset broadcasted by network |
| CATT | Agree | drx-HARQ-RTT-TimerUL and drx-HARQ-RTT-TimerDL offset is defined using UE-specific delay as baseline in LEO/GEO. But there may be different ways of implementaion of offset. |
| Nokia | Tentatively Agree | If UE has the pre-compensation capability,we think using the UE-specific delay based offset is reasonable.  Same comments as Q2.5, we want to clarify UE-specific delay in the proposal is from UE to gNB instead of from UE to reference point, because both of them are mentioned in Section2.1.1. Additionally, the offset applied to RTT timers should be two times of UE-specific delay (from gNB to UE). |
| Ericsson | Agree | If the UE autonomously adjust the ***drx-HARQ-RTT-TimerUL* and *drx-HARQ-RTT-TimerDL*** offset, there is a great risk that there will be misalignment between the gNB and the UE. It may be hard for UE implementation if different HARQ processes are using a different offsets.  If the offset is in the order of the RTT, 25.77 ms for 600 km LEO, then there is no real use to have a resolution of a 0 to 56 symbols after that delay. These timers only influence the PDCCH monitoring when HARQ is used and the last TB have been transmitted. |

### drx-HARQ-RTT-Timers behaviour when HARQ feedback is enabled

In addition to the method of drx-HARQ-RTT-Timer offset (if HARQ feedback is enabled), should HARQ feedback be *disabled,* the following was proposed based on Phase 1 outcome [6]:

* *If HARQ feedback is disabled, drx-HARQ-RTT-TimerDL and drx-HARQ-RTT-TimerUL are not started for both LEO and GEO scenarios.*

Via feedback provided in Phase 2 [2], several companies mention *drx-RetransmissionTimerUL(DL)* may be useful to enable blind retransmission for improved reliability should UL HARQ feedback/HARQ UL retransmission be disabled. However, under current MAC specification [8], expiry of *drx-HARQ-RTT-TimerUL(DL)* is used as the trigger condition for the start of *drx-RetransmissionTimerUL(DL)* respectively (with the added DL condition that data of the corresponding HARQ process was not successfully decoded).

Therefore, should the drx-HARQ-RTT-Timers not be started as per the above proposal, under current specification the drx-Retransmission timers will also not be started. This may introduce limitations on blind retransmission unless further modification is adopted (e.g. introduction of additional start criteria for the drx-RetransmissionTimers).

Given the significant support for this proposal in previous discussion (23/27), and that discussion regarding blind retransmission is out of scope of this email discussion, rapporteur suggests the following compromise to avoid placing limitations on future solution options for blind retransmission:

* *If HARQ feedback is disabled, drx-HARQ-RTT-TimerDL and drx-HARQ-RTT-TimerUL are not started for both LEO and GEO scenarios. FFS modification of drx-RetransmissionTimerDL and drx-RetransmissionTimerUL to support blind retransmission, if agreed.*

**Question 3.6: Do you agree with the following proposal?**

* **If HARQ feedback is disabled, *drx-HARQ-RTT-TimerDL* and *drx-HARQ-RTT-TimerUL* are not started for both LEO and GEO scenarios. FFS modification of *drx-RetransmissionTimerDL* and *drx-RetransmissionTimerUL* to support blind retransmission, if agreed.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Agree/Disagree** | **Additional comments** |
| MediaTek | Agree | There is no need to start drx-HARQ-RTT-TimerDL and drx-HARQ-RTT-TimerUL is HARQ feedback is disabled.  If blind retransmission is needed, repetitions can already be configured by the network. For this first release of NTN, further enhancements are not needed |
| APT | Agree |  |
| Nomor Research | Agree | Support of blind retransmission in NTN should not be precluded. We wonder, whether it is not possible to start drxRetransmissionTimerDL/ UL directly for blind retransmissions. |
| Thales | Agree | Need to guarantee that neither drx-HARQ-RTT-TimerDL nor drx-HARQ-RTT-TimerUL will start, if HARQ feedback is disabled for the corresponding HARQ process; otherwise UE might monitor the PDCCH for retransmission opportunities that never will happen |
| LG | Agree | For the reception of the blind retransmission, the drx-RetransmissionTimerDL should be started even if the drx-HARQ-RTT-TimerDL is not started for disabling HARQ feedback. |
| CATT | Agree | If HARQ feedback is disabled, drx-HARQ-RTT-TimerDL and drx-HARQ-RTT-TimerUL are not started for both LEO and GEO scenarios. |
| Nokia | Agree with comments | We think blind retransmission is needed to lower the residual BLER as capatured in RAN2 recommenstion in TR.  *• Multiple transmission of the same TB to lower residual BLER should also be configured.*  How to enable UE power saving during blind retransmission phase can be discussed further.  Furthermore, any particular reason why the ‘for both LEO and GEO scenarios’ is explicitly stated, instead of just ‘NTN’? It just reads like HAPS are excluded. |
| Ericsson | Disagree | We agree to first part “**If HARQ feedback is disabled, *drx-HARQ-RTT-TimerDL* and *drx-HARQ-RTT-TimerUL* are not started for both LEO and GEO scenarios.**”  The second part is not needed, we may discuss that and come to an agreement later. |

# Summary

<To be generated pending company input>

# Conclusions

<To be generated pending company input>

# References

1. RP-201256 – “*Solutions for NR to support non-terrestrial networks (NTN)*” – Thales
2. R2-2008214 – “*Summary of [AT111][107][NTN] Pre-compensation and other MAC issues Phase 2*” – InterDigital
3. R2-2008122 – “*Report from Break-out session on R16 eMIMO, CLI, PRN, RACS and R17 NTN and REDCAP*” – RAN2 Vice Chairman (ZTE Corperation)
4. R1-2007290 – “*Feature lead Summary on enhancements on UL time and frequency synchronization for NR NTN*” – Thales
5. Chairman’s Notes RAN1#102-e 8.4 v004 – RAN1 Vice Chair
6. R2-2008188 – “*Summary of [AT111][107][NTN] Pre-compensation and other MAC issues* ” – InterDigital
7. TR 38.821 - Solutions for NR to support non-terrestrial networks (NTN) v16.0.0
8. TS 38.321 – Medium Access Control (MAC) protocol specification v16.1.0