3GPP TSG RAN WG1 Meeting #105-e R1-2104572

e-Meeting, May 10th – 27th, 2021

Agenda Item: 8.15.2

Source: Moderator (MediaTek)

Title: Summary #1 of AI 8.15.2 Enhancements to time and frequency

synchronization

Document for: Discussion and Decision

# Introduction

At the RAN#86 meeting, a new Study Item was approved for IoT Non Terrestrial Network (NTN) and revised in RAN#91 [1]. There was an email discussion on [91E][42][NTN\_IoT\_Roadmap] In RAN#91 with moderator summary and final proposal for GTW input in [2].

In RAN#91-e GTW session, the Chairman endorsed a Way Forward Proposal in [3] on email discussion on [50][New\_proposals\_approval]. This included guidance from RAN Chairman for NTN NR and NTN IoT as follows

* *RAN#92E (June) to finalize the scope and project plan to deliver the essential minimum functionality of both NTN NR and NTN IoT (both NB-IoT and eMTC) within the existing TU allocations*
* *Detailed scoping exercise (NTN NR WID revision, NTN IoT WID approval) to be undertaken at RAN#92E (June)*

In this meeting, company views on UL synchronization for IoT NTN are summarized and observations/proposals on identified issues are made. Observations and proposals in Company’s TDoc contributions are listed in the Appendix.

# Initial Round Discussion

## GNSS measurements

In RAN1#104bis-e, the following Feature Lead recommendation was made:

* *Companies are encouraged to further discuss scenarios, motivation and solution to ensure there is a sufficient gap for GNSS measurements in idle UE or connected UE and to discuss offline to align on understanding of legacy procedures (i.e. configuration of paging, DRX timers). Further consider whether issue should first be discussed in RAN2.*

A note in the Rel-17 IoT NTN SID states that assumption of GNSS capability is that UE can estimate and pre-compensate timing and frequency offset with sufficient accuracy for UL transmission.

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

Since simultaneous GNSS and NTN NB-IoT/eMTC operation is not assumed, it seems reasonable to discuss need for GNSS measurement window when IoT module is switched off.

### GNSS measurement for sporadic short transmission

Spreadtrum proposed UE should perform GNSS measurements before moving to connected mode, no need to introduce measurement gaps for GNSS measurements.

CATT proposed UE triggers the GNSS measurement when it is waken up by T3412 timer expiration, and then enter IoT active state after GNSS measurement as illustrated in figure below [7]. GNSS measurement can also be performed during the inactive state of eDRX. GNSS TTFF will take a long time.



MediaTek observed a UE may only need a new GNSS position solely for UE pre-compensation for UL synchronization in corner case scenarios where (i) it is not fixed; (ii) reporting of the GNSS position is not needed by application layer and proposed to re-use legacy paging and DRX procedures for UE acquisition of GNSS position fix assuming simultaneous GNSS and NTN NB-IoT/eMTC operation is not used in the device

CMCC, OPPO, MediaTek proposed for “short, sporadic connection” case, UE would make GNSS measurements for initial access, and there is no need to do GNSS measurements in connected mode. Ericsson observed as GNSS-equipped UEs can perform timing/frequency pre-compensation before MSG1 transmission, the existing (N)PRACH formats for NB-IoT/eMTC in TN are also sufficient for NTN scenarios. UE should pre-compensate its timing and frequency before transmitting MSG1.

Ericsson observed the need and purpose of a new UL compensation gap should first be justified. For example, it is not clear if it is needed for re-acquiring satellite ephemeris, or getting a GNSS position fix, or calculating pre-compensation values, or adjusting transmit timing and frequency

Intel proposed it is assumed by RAN1 that a UE in has valid GNSS measurements available for UL synchronization. No need to discuss GNSS measurement window in RAN1

Nokia several proposals for normative phase: GNSS measurement gap corresponding to the time the UE requires to validate GNSS shall be configured in the paging procedure, where the position and duration of the gap can be decided in the normative phase. Network should know the validity of GNSS and ephemeris and have aligned understanding with UE. Consider UL random procedure in case GNSS based time frequency synchronization is not accurate enough or available for IoT cases, with baseline as NR over NTN solutions but power consumption and complexity/cost reduction should also be considered. Reporting UE location for determining UE-specific Timing Advance in half duplex deployments is one method, which can be used by eNB scheduler to avoid UL-DL collisions.

ZTE proposed the UE’s behavior for GNSS information acquisition should be explicitly specified at least before initiating UL transmission after the eDRX/PSM.

***Moderator view****: based on above for sporadic short transmissions, the UE can get GNSS position fix before moving to connected and there is no need for the UE to re-acquire GNSS position in connected. Assuming valid GNSS position fix, it is sufficient if the UE’s behavior for GNSS information acquisition is specified before initiating UL transmission after the eDRX/PSM. RAN2 may also discuss this issue.*

***Initial proposal – Section 2.1.1:***

***Companies are encouraged to further discuss and comment on GNSS measurement for sporadic short transmission***

* ***Q1: UE can get GNSS position fix before moving to connected and there is no need for the UE to re-acquire GNSS position in connected***
* ***Q2: Assuming valid GNSS position fix, is it sufficient if the idle UE’s behavior for GNSS information acquisition is specified before initiating UL transmission after the eDRX/PSM***

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| --- | --- |
| Companies | Comments |
| APT | Two concerns about Q1:   1. For eMTC over NTN, CHO may be introduced as shown in [Pre114-e][004][IoT NTN]. To support eMTC mobility, UE location may need an update in RRC\_CONNECTED. 2. “Before moving to connected” includes MSG2/3/4, but GNSS shall be ready before cell search or a PRACH transmission of the initial access procedure.   Initial proposal – Section 2.1.1 (APT)   * Q1: **NB-IoT** UE can get GNSS position fix before ~~moving to connected~~ **the MSG1 transmission during the initial access procedure** and there is no need for the **NB-IoT** UE to re-acquire GNSS position in connected. |
| ZTE | For these two Questions, following points are listed:   1. Q1: based on scope of this SI, two UE types with speed = 0 and 120 km/h are considered as below:  |  |  |  |  | | --- | --- | --- | --- | | C-IoT device motion on the earth | Min 0 km/s (stationary device), max 120 km/h | Min 0 km/s (stationary device), max 120 km/h | Min 0 km/s (stationary device), max 120 km/h |   But it seems only the stationary device is further considered for the evaluation with corresponding density as defined in RAN2. Then, **if the prioritization can be considered, it's clear that the UE is not required to update the position during the connected mode (e.g., after the initial access). W.r.t the case with UE’s speed as 120km/h (i.e., ~33m/s), whether the re-acquisition on the UE’s location is needed or not is up to the requirement defined in RAN4 for synchronization since even for the short, sporadic transmission, the long transmission may be needed in case of poor link budget**.   1. Q2: this is mainly related to how to specify the UE’s behavior on GNSS acquisition: we are supportive to clear specify the UE’s behavior for GNSS acquisition as mentioned in Q2. It should be noticed that clear restriction on eNB/UE’s behaviors is needed during the period for GNSS fix.   It will be sufficient if Q1 is concluded. |
| Apple | Q1: We agree that UE can get GNSS position fix before moving to connected state. For sporadic short transmission, there seems no need for the UE to re-acquire GNSS position in connected state.  Q2: It is sufficient if idle UE can acquires GNSS position before initiating UL transmission after eDRX/PSM. |
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#### FIRST ROUND – GNSS measurements for sporadic short transmission

TBA

### GNSS measurement for long connection times

Ericsson proposed RAN1 should discuss whether GNSS positioning in RRC\_CONNECTED state is to be supported by IoT NTN UE. RAN1 to wait for further RAN2 progress on GNSS measurement window.

CATT proposed Proposal 10: Power consumption should be evaluated for long connection, including SIB reading and repeated GNSS fixes in RRC\_CONNECTED.

MediaTek provided some analysis as shown in Tables and illustrated in figure below. The TA error due to UE mobility for NTN with a GNSS position fix up to every 60 seconds is similar to TA in legacy non-NTN system and can be addressed by the PRACH CP for idle mode and the TA closed loop in connected mode. Likewise the Doppler shift error with a GNSS position fix up to every 60 seconds is consistent with cellular IoT device (note that in cellular IoT there is no UE pre-compensation of Doppler shift due to UE velocity that actually exceeds the values in the table – i.e. at 120 km/h, in cellular IoT the Doppler shift experienced is in the order of 222 Hz) [8].

* Maximum UE-specific TA tracking error a beam edge elevation for UE position error due to UE velocity
* *Maximum UE-specific Doppler shift error beam center elevation θ with UE position error due to UE velocity*

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| --- | --- | --- | --- | --- | --- | --- |
| **Validity of UE location** | 30 s | | | 60 s | | |
| **UE Velocity** | **UEpos,error** | **β** | **TAerror** | **UEpos,error** | **Elevation** | **TAerror** |
| 30 km/h | 333 m | 30 deg | 1.9 us | 666 m | 30 deg | 3.8 us |
| 120 km/h | 999 m | 30 deg | 5.8 us | 2000 m | 30 deg | 11.6 us |

*UE-specific TA tracking error at beam edge elevation β with UE position error due to UE velocity*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Validity of UE location** | 30 s | | | 60 s | | |
| **UE Velocity** | **UEpos,error** | **θ** | **Fderror** | **UEpos,error** | **θ** | **Fderror** |
| 30 km/h | 333 m | 89.96 | 6 Hz | 666 m | 89.93 | 10 Hz |
| 120 km/h | 999 m | 89.9 deg | 79 Hz | 2000 m | 89.8 deg | 158 Hz |

*UE-specific Doppler shift error beam center elevation θ with UE position error due to UE velocity*



*TA error for elevation at beam edge and at Nadir [8]*

***Moderator view****: based on above for long connection times, connected UE depending on UE mobility may acquire a new GNSS position fix. Assuming valid GNSS position fix, it is sufficient if the connected UE’s behavior for GNSS information acquisition is specified. With a GNSS position fix up to every 60 seconds, the TA error due to connected UE velocity can be addressed by the PRACH CP for idle mode and the TA closed loop in connected mode; the Doppler shift error is consistent with high-velocity cellular IoT device where Doppler shift due to UE velocity is not pre-compensated and, hence, can be tolerated at the gNB. RAN2 may also discuss this issue.*

***Initial proposal – Section 2.1.2:***

***Companies are encouraged to further discuss and comment on GNSS measurement for long connection times.***

* ***Q1: With a GNSS position fix up to every 60 seconds, can the TA error due to connected UE velocity be addressed by the PRACH CP for idle mode and the TA closed loop.***
* ***Q2: With a GNSS position fix up to every 60 seconds, can the Doppler shift error due to connected UE velocity be tolerated at the gNB.***
* ***Q3: Assuming valid GNSS position fix, is it sufficient if the connected UE’s behavior for GNSS position acquisition is specified for UL transmission***

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| --- | --- |
| Companies | Comments |
| APT | Q1: Yes  Q2: Yes  Q3: Not sure. Is it to propose a valid timer for a GNSS position fix applied to all UL transmission, e.g., every 60s? For RRC\_CONNECTED, UL timing and frequency adjustment can be done by the closed-loop TA and reference signal measurement. Also, the legacy TA timer shall be useful. |
| Apple | Overall, we agree with the direction of the proposal. But we may not specify the exact number of 60 seconds in the proposal at this stage.  Q1: TA error due to connected UE velocity can be addressed by PRACH CP for idle mode and the TA closed loop.  Q2: Doppler shift error due to connected UE velocity can be tolerated at the eNB  Q3: It can be depending on UE implementation. If a UE does not move, then the GNSS position fix period could be longer. |
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#### FIRST ROUND – GNSS measurements for long transmission

TBA

## PRACH Congestion

In RAN1#104bis-e, the following FL recommendation was made:

* *Proponents of PRACH congestion issue are encouraged to provide some analysis on scenarios and consider whether network configuration can mitigate issue of PRACH congestion.*

The PRACH congestion is illustrated in figure below [15]. Once the UEs have the satellite PVD information, all the UEs attempt to transmit at the same time, leading to a spike in PRACH activity and PRACH congestion. To avoid this issue, UEs can defer transmission of their PRACH following reception of SIB carrying satellite PVD information by a random amount, such that PRACHs arrive in a uniformly distributed fashion between SIB transmissions; or UEs can transmit PRACH when satellite is not shadowed to spread out the PRACH load in time.

SONY proposed RAN1 observes in TR36.763 that there may be PRACH congestion when IDLE mode UEs simultaneously transmit PRACH after receiving satellite PVD information.

CATT proposed enhanced mapping mechanism of PRACH occasion in the initial access to avoid PRACH congestion is needed.

CMCC observed for sporadic DL traffic, PRACH congestion issue can be alleviated by aligned configuration of DRX and SIB containing satellite location information and proposed it is further studied.

Interdigital observed the following and proposed it is up to gNB implementation how to handle PRACH congestion in Rel-17.

* Short RO period configuration could reduce PRACH congestion since the first RO after ephemeris SIB read could be different across the UEs due to different propagation delay;
* Frequent ephemeris SIB transmission also reduces PRACH congestion when its associated ROs configured appropriately.



The moderator view is that based on contributing companies the issue of RACH congestion could happen with some solutions possible depending on adequate RO configuration and ephemeris broadcast periodicity. The moderator would encourage companies to comment on whether the potential RACH congestion issue should be prioritized in Rel-17 normative phase or could be left to future releases.

***Initial Proposal – Section 2.2:***

***Companies are encouraged to comment on their understanding of potential PRACH congestion issue and also comment potential solution and whether these will require specifications or can be up to gNB implementation.***

* ***Q1: Capture in TR36.763 that there may be PRACH congestion when IDLE mode UEs simultaneously transmit PRACH after receiving satellite PVD information***
* ***Q2*: *Could short RO period configuration and frequent broadcast of SIB on ephemeris reduce PRACH congestion?***
* ***Q3: Could aligned configuration of DRX and SIB containing satellite location information reduce PRACH congestion?***
* ***Q4: Does potential issue of PRACH congestion need to be prioritized in Release-17 normative phase or could be left to future releases?***

|  |  |
| --- | --- |
| Companies | Comments |
| APT | Not sure. This issue is valid only if UE cannot obtain sufficient information from SIB1 for initial access, e.g., NTN cell indication, satellite ephemeris, K\_offset, or DL Doppler pre-compensation value cannot be provided in SIB1 but be provided in NTN-SIB.  Q1: Yes. This issue is valid if UE cannot have sufficient information from SIB1 to access an NTN cell.  Q2: Yes. No issue if SIB1 provides satellite location info and other NTN parameters for initial access.  Q3: Yes. but not sure how much gain it could achieve.  Q4: left to future releases, if a target satellite’s ephemeris is not provided via SIB1. |
| ZTE | This issue is not significant based on current assumption on the UE’s density for IoT over NTN, e.g., 400 per km^2. If the intention is to address the impacts on the high dense UE, the overall design/optimization on the system is needed. W.r.t to each Questions:  Q1: Highly level description can be added to describe the potential issue once supported by majority  Q2: Yes, it’s obvious that any solution/implementation to improve the supported density of this system is also useful to address this issue.  Q3: Yes, it’s only implementation based and configuration of eDRX is up to the traffic characteristic for each UE. It’s difficult to evaluate the performance gain.  Q4: As highlighted before, we need to address the density issue as whole picture instead of prioritizing the congestion issue firstly. It can be achieved once the major issue for density is resolved. This part can be postponed. |
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### FIRST ROUND – PRACH Congestion

TBA

## Long UL transmission on PUSH and PRACH

The following agreements were made in RAN1#104e

Agreement:

Study the UE pre-compensation of satellite delay during long UL transmission on (N)PUSCH in NB-IoT and eMTC.

Agreement:

Study the UE pre-compensation of satellite Doppler shift during long UL transmission on (N)PUSCH in NB-IoT and eMTC.

Agreement:

Study the UE pre-compensation of satellite delay and Doppler during long UL transmission on PRACH in NB-IoT and eMTC.

***Moderator comment****:*

*The issues of UE pre-compensation for long PUSH and long RACH can be considered together since the issues associated with long transmission such as Delay drift rate impact on TA error, Pre-calculation of TA and Doppler for UL transmission, and Delay drift rate impact on phase discontinuity are common.*

Delay drift rate impact on UE pre-compensation TA error:

The maximum TA drift rate including both feeder link and service link is 93 us/s in LEO-600, or about 25 us/s one way on service link and on feeder link as illustrated in figure below below [15].



The UCG=40 ms is scheduled every 256 ms in case of long UL transmission. The delay drift rate of 93 us/s can in time continuous transmission over 256 ms can give a maximum time drift of 93 us/s \* 256 ms/1000 ms = 23.8 us = 731\*Ts. The transmit timing error Te is 80\*Ts=2.6 us for NB-IoT and Te is 24\*Ts=0.78 us for eMTC is . Assuming maximum TA error should be less than transmit timing error Te, the segment duration should be less than 2.6 us / 93 us/s \* 1000 = 27.9 ms for NB-IoT and 0.7 us / 93 us/s \* 1000 = 7.5 ms for eMTC. The maximum TA error is for NB-IoT is illustrated in Figure below [16].



***TS 36.133 Table 7.20.2-1: Te Timing Error Limit***

|  |  |
| --- | --- |
| Downlink Bandwidth (MHz) | Te\_ |
| 0.18 | 80\*TS |
| Note 1: TS is the basic timing unit defined in TS 36.211 | |

***TS 36.133 Table 7.1.2-1: Te Timing Error Limit***

|  |  |
| --- | --- |
| Downlink Bandwidth (MHz) | Te\_ |
| 1.4 | 24\*TS |
| ≥3 | 12\*TS |
| Note: TS is the basic timing unit defined in TS 36.211 | |

Asia Pacific Telecom observed that in the specifications UE is not allowed to adjust timing advance in the duration of repetitions as specified in TS 36.133 V16.8.0, Clause 7.20.2.

[***3GPP TS 36.133 V16.8.0, Section 7.20.2] When a repetition period is configured on the uplink for which R>1, the UE shall not adjust the uplink transmission timing autonomously during an ongoing repetition period other than at initial transmission as defined above.***

Nokia proposed that after the time adjustment in the N time units, the transmission is still covered by the cyclic prefix without overlap with the next symbol when received by eNB. The segment length and TA adjustment gap based on elevation angle should be studied in normative phase.

The moderator understanding is that segmented UE pre-compensation is needed to avoid breaking the transmit timing error Te. This requirement ensures the UL transmission is consistent with the cyclic prefix. We now further summarise discussions on how the segmented UE pre-compensation can be applied:

* Pre-calculation of TA and Doppler for UL transmission
* Delay drift rate impact on phase discontinuity
* Segmented UE pre-compensation via more frequent new UL gaps
* Segmented UE pre-compensation via UE implementation with sampling rate adjustment in device (and no new UL gaps)

Pre-calculation of TA and Doppler for UL transmission:

Ericsson, MediaTek, Samsung proposed UE pre-calculate the timing and frequency pre-compensation values for each anticipated pre-compensation occasion prior to the start of the UL transmission as illustrated below.

Xiaomi proposed UE-specific TA calculation based on the timing drift rate for UE pre-compensation during long UL transmission should be supported



Delay drift rate impact on phase discontinuity:

SONY provided some analysis for this potential issue of phase discontinuity. For single subcarrier NB-IoT, TS36.211 [3] section 10.1.5 defines the waveform in a way that ensures phase continuity between transmitted symbols and slots. The phase continuity between symbols reduces the PAPR of the waveform. Given that the timing can drift by up to ± 50 s/sec, in one 1ms slot the timing can drift by 50ns. A 50ns timing drift for the 12th subcarrier in NB-IoT (located at 180kHz) can lead to a phase discontinuity of 3 degrees. After 8ms, the phase discontinuity increases to 26 degrees.

The moderator understanding is that the phase discontinuity at subframe / slot boundary is due to the application of TA compensation at the subframe boundary, where the UL transmission is punctured to advance the transmission timing. The phase discontinuity can be expressed as

**Phase discontinuity [degree] = delay drift per subframe \* sampling frequency \* 360 degree**

Assuming total delay drift is 100 us/s , then in 1 ms subframe the delay drift is 0.1 us/ms. Then, for PUSCH we get

* NB-IoT SCS=15 kHz (2\*0.5 ms slot): phase discontinuity= 0.1 us/s \* 180 kHz/2 \* 360 degrees = 3.36 degree
* NB-IoT SCS=3.75 kHz (16\*2 ms slot): phase discontinuity = 16\*2 \* 0.1 us/s \* 180 kHz/2 \* 360 degrees = 103.68 degree
* eMTC: phase discontinuity = 0.1 us \* 1.4 MHz/2 \* 360 degrees = 25.2 degrees

It is the moderator understanding that assuming TA correction is applied every 1ms or several ms, the phase discontinuity at subframe boundary when repetition is used will be too large for NB-IoT SCS = 3.75 kHz and eMTC. A solution seems needed.

*S 36.211 Table 10.1.2.1-1: NB-IoT parameters.*

|  |  |  |
| --- | --- | --- |
| Subcarrier spacing |  |  |
|  |  |  |
|  |  |  |

*Table 10.1.2.3-1: Supported combinations of , , and  for frame structure type 1.*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| NPUSCH format |  |  |  |  |
| 1 | 3.75 kHz | 1 | 16 | 7 |
| 15 kHz | 1 | 16 |
| 3 | 8 |
| 6 | 4 |
| 12 | 2 |
| 2 | 3.75 kHz | 1 | 4 |
| 15 kHz | 1 | 4 |

A similar analysis for PRACH can be provided. ZTE mentioned while for PRACH, since slot is no longer the basic unit for transmission, the time length of RA symbol group can be the time unit for pre-compensation. For FDD NB-IoT, the time length of RA symbol group is 1.4 ms for preamble format 0, 1.6 ms for preamble format 1, and 3.2 ms for preamble format 2. That is, the pre-compensation can be done per 19 RA symbol groups for preamble format 0, 17 for format 1, and 8 for format 2.

***TS 36.211, Figure 10.1.6.1-1: Random access symbol group***



***TS 36.211, Table 10.1.6.1-1: Random access preamble parameters for frame structure type 1***

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Preamble format | G | P | N |  |  |
| 0 | 4 | 4 | 5 |  |  |
| 1 | 4 | 4 | 5 |  |  |
| 2 | 6 | 6 | 3 |  | 3 |

Segmented UE pre-compensation via more frequent new UL gaps:

ZTE proposed segmented UE pre-compensation with a length of segment of 8 slots for 3.75 kHz SCS and 32 slots for 15 kHz SCS. For NPRACH pre-compensation, the length of segment can be considered as 16 random access symbol groups for preamble format 0 and 1 and 8 random access symbol groups for preamble format 2. An applicable timing range, e.g., N in terms number of time units, can be indicated to UE to apply each TA value within the UL transmission where N is 8 or 16 slot for PUSCH. The frequency error in connected mode should be smaller than 0.1 ppm. Since the maximum Doppler shift variation is 0.27 ppm/s [TS 38.821], the length of each segment is at most 0.1/0.27\*1000 = 370 ms, which is longer than that for TA pre-compensation.

ZTE observed that for simplicity of implementation, the segment length for Doppler shift pre-compensation can be set same as for TA pre-compensation. When TA report is enabled, TA value of first or last segment of transmission delivering the TA report should be considered.



Segmented UE pre-compensation with more UL gaps inserted according to the maximum allowed time-continuous transmission for IoT over NTN is supported by Huawei, Vivo (configurable UL gaps), Spreadtrum, CATT, OPPO

Ericsson observed the need and purpose of a new UL compensation gap should first be justified. For example, it is not clear if it is needed for re-acquiring satellite ephemeris, or getting a GNSS position fix, or calculating pre-compensation values, or adjusting transmit timing and frequency. The value of N can be determined based on the maximum transmit timing error that needs to be tolerated for eMTC and NB-IoT.

Lenovo proposed UE pre-compensation done per N time units with inserting transmission gap or puncturing uplink transmission should be considered in UL transmission in IoT on NTN.

Segmented UE pre-compensation via UE implementation with sampling rate adjustment in device (and no new UL gaps):

Mediatek proposed to apply the UE pre-compensation with N=1 subframe (SCS=15 kHz) for adjustment of TA and Doppler shift correction, which can be supported in a typical NB-IoT device implementation.

Apple proposed in long PRACH or long PUSCH transmissions, UE applies the same time and frequency pre-compensation every N time units, where N is indicated by network.

Asia Pacific Telecom proposed the value of N shall be N = 1, and the unit shall be a subframe shall be considered to minimize the spec impact by reusing the current UE behavior for a transmission overlap due to TA adjustment. Wait for RAN4 progress in NR over NTN for whether timing adjustment during repetition (R>1) for long NPUSCH transmission shall be allowed.

One implementation method to avoid phase discontinuity is via sampling frequency adjustment to compensate the delay drift, instead of a TA being applied. The phase discontinuity at subframe / slot boundary is avoided, since the application of TA compensation at the subframe boundary is not done via puncturing of the UL transmission to advance the transmission timing. Instead, the sampling rate is adjusted at the subframe boundary. Take an example to illustrate the sampling frequency adjustment method for UE pre-compensation:

Assume the delay drift is -46ppm, the sampling rate will be +46ppm. In specification: One slot = 15360\*Ts , where Ts=0.5 ms / 15360 =~ 32.55208 ns. We denote Ts’ as the sample duration generated by the UE. Assuming the device changes the Ts value for NB-IoT implementation, then the number of Ts per OFDM symbol / slot / subframe also change.

* In one subframe, 46 ppm \* 1 ms = 0.046 us then Ts’ = (1000000 + 46)/(15360\*2)=32.55358 ns
* In 256 subframes, 46 ppm \* 256 = 11.776 us then Ts’ = 256\*(1000000 + 46)/ (15360\*2\*256)=32.55358 ns

A slot in UE implementation is then not 15360.Ts = 0.5 ms as in the spec, but it is now = 15360 \* Ts’ = 0.500023 ms

After transmission over the service + feeder links due to compression by negative delay drift, the received signal will be of duration 15360\*Ts=0.5 ms

If this is left to UE implementation, with sampling rate adjustment method there is no change in specifications. Since this is implementation method, there is no need to change the specifications beyond mentioning that the TA adjustment can be applied for each repetition.

The implementation method with sampling frequency adjustment to compensate the delay drift removes the need for new UL gaps in segmented UE pre-compensation.

The implementation method with sampling frequency adjustment can also be used to compensate the Doppler shift.

***Moderator view****: Based on analysis of delay drift rate impact on UE pre-compensation TA error above, segmented UE pre-compensation is needed. This means the UE should apply the pre-compensation of TA autonomously during an ongoing repetititon period. This would require a specification change in case repetitions with R>1 is used in UL transmission, where UE shall not adjust the uplink transmission timing autonomously during an ongoing repetition period . The segment length for UE pre-compensation is in the order of 27.9 ms for NB-IoT and 7.5 ms for eMTC. These segment length values to apply TA compensation in NB-IoT and eMTC are consistent with the specified transmit timing error Te of 80\*Ts for NB-IoT and 24\*Ts for eMTC. The moderator understanding is that it is needed to further discuss the following aspects on how the segmented UE pre-compensation can be applied:*

* *Pre-calculation of TA and Doppler for UL transmission*
* *Delay drift rate impact on phase discontinuity*
* *Segmented UE pre-compensation via more frequent new UL gaps*
* *Segmented UE pre-compensation via UE implementation with sampling rate adjustment (and no new UL gaps)*

*Assuming TA correction is applied every 1ms or several ms, the phase discontinuity at subframe boundary when repetition is used will be too large for NB-IoT SCS = 3.75 kHz and eMTC.*

*The segment duration for UE pre-compensation in long UL transmission is upper bounded by the impact of the delay drift and needs to be small to avoid issue with phase discontinuity depending on NB-IoT (i.e SCS=15 kHz or 3.75 kHz) or eMTC transmission parameters and specified UL transmission timing error Te (80\*Ts for NB-IOT and 24\*Ts for eMTC).*

***Initial Proposal – Section 2.3:***

***Companies are encouraged to comment on needs and ways UE can apply the segmented UE pre-compensation of delay and Doppler shift during long PUSCH transmission and long PRACH transmission:***

* ***Q1: Is segmented UE pre-compensation needed to avoid breaking the specified transmit timing error Te for NB-IoT and eMTC NTN due to delay drift rate during an on-going UL transmission?***
* ***Q2: Does segmented UE pre-compensation requires a specification change in case on UL transmission repetitions with R>1, since current specifications state that UE shall not adjust the uplink transmission timing autonomously during an ongoing repetition period.Ye***
* ***Q3: Is segmented UE pre-compensation with small segment duration and more frequent new UL gaps needed to avoid phase discontinuity issue and delay drift rate issue?***
* ***Q4: Can segmented UE pre-compensation with implementation method with sampling frequency adjustment in device be used with small segment duration without new UL gaps to avoid phase discontinuity issue and delay drift rate issue?***
* ***Q5: Based on the above, what is the value of N and what is the time unit for the segmented UE pre-compensation?***

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| Companies | Comments |
| APT | It might be better to use the OFDM-CP limit, e.g., 4.7us rather than using Te to calculate the UL timing requirement, e.g., 27.9ms. This is because 1) Te is to trigger the gradual timing adjustment that UE is required to adjust its timing, see TS 38.133 V15.10.0, Clause 7.1.2.1; and 2) RAN4 may have a new Te to support the combination of open and closed TA loop.  Q1: No, it is needed to avoid breaking the OFDM-CP limit  Q2: Yes, if no new UL gaps.  Q3: Yes, it prevents breaking RAN4 specs and prevents repetition overlap  Q4: Yes, but it must break RAN4 specs and handle repletion overlap  Q5: N = 1 subframe. This will break RAN4 specs, but it can reuse the current UE behavior for overlapping. See TS 36.213, Clause 4.2.3. |
| ZTE | It has already agreed to consider the enhancement on pre-compensation for long UL transmission, and the main bullet should be updated as below to encourage companies to focus on the detailed design:  ***Companies are encouraged to comment on ~~needs and~~ ways UE can apply the segmented UE pre-compensation of delay and Doppler shift during long PUSCH transmission and long PRACH transmission:***  Then, for each questions, views are shared as below:  Q1: It’s up to the requirement on the accuracy. In our views, it’s preferred to keep the existing limited as Te or half of CP as the upper bound to determine the value and time unit for segmented pre-compensation.  Q2: Yes, it’s needed to define the new UE’s behaviour to allow the pre-compensation on TA and Doppler.  Q3: Yes.  Q4: No, for the TA adjustment, additional gap to avoid the overlapping may be needed.  Q5: The time unit can be subframe or slot for PUSCH and symbol group for PRACH. According to our evaluation, there is no need to restrict the value as N=1, and 8 slots for 3.75 kHz SCS and 32 slots for 15 kHz SCS can be considered as example to mitigate the complexity for UE’s implementation and achieve the same understanding on TA adjustment between UE and eNB. |
| Apple | Q1: The transmit timing error Te is designed partly to allow the device oscillator error. In other words, not the whole Te should be used for compensating the delay and Doppler shift in NTN.  Q2: Yes  Q3: Yes  Q5: We think the value of N could be indicated by network. |
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### FIRST ROUND – Long UL transmission on PUSH and PRACH

TBA

## DL Synchronization

In RAN1#104bis-e, it was discussed that the UE can initial frequency error well exceeding 50KHz due to crystal error in device, satellite-based Doppler shift in S band and the following agreement was made:

Agreement:

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

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

Huawei proposed to indicate only the DL frequency pre-compensation is normalized to a predefine subcarrier spacing to reduce the signaling overhead and mentioned it is sufficient for UL frequency alignment.

CATT, ZTE, Xiaomi proposed increasing channel raster in IoT NTN is necessary

Ericsson and Asia Pacific Telecom observed RAN4 input is needed before increasing the channel raster size. Ericsson observed multiple hypotheses testing may be needed if ARFCN-indication-in-MIB is used. RAN1 should investigate DL synchronization performance for NB-IoT and eMTC NTN and compare the pros and cons of increasing the channel raster step size and introducing ARFCN-indication-in-MIB.

The moderator view is that the agreement is sufficient to include options for enhancements of DL synchronization in the Rel-17 timeframe and that RAN4 input would be needed at least for the new channel raster.

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

The company contributions have not advanced the analysis for either option and there isn’t sufficient consensus to down scope options.

Moderator conclusion:

The RAN1#104bis-e on DL synchronization is sufficient and can be captured in Section 8.1 RAN1 recommendations in TR 36.763.

## Validity of satellite ephemeris

The UE could acquire, store in its memory, and apply the satellite-assisted information for the ephemeris broadcast on NTN SIB. The stored ephemeris could be refreshed every time the UE acquires the NTN SIB, i.e. the UE considers the stored ephemeris as invalid, as soon as it acquires the NTN SIB, and overrides it with the ephemeris. Prediction over 60 seconds without having acquired new ephemeris data for UE specific TA calculation and Doppler shift calculation has an accuracy within 0.076 us and 4.8 Hz respectively as illustrated in Figure below [MediaTek R1-2104565]. Longer prediction time can be considered without significant impact on UL synchronization accuracy [8].



*UE pre-compensation on TA and Doppler shift over service link*

MediaTek proposed NTN UE time alignment timer for re-acquisition of the satellite ephemeris on NTN SIB is configured by the network.

Qualcomm proposed to define synchronization validity during which the ephemeris and/or GNSS information is (are) accurate based on timer(s) that are (re-)set autonomously by the UE after acquiring necessary location information. Such (re-)setting events may be indicated to the network to facilitate efficient scheduling. A mechanism that triggers RLF when the GNSS and/or ephemeris information at the UE is (are) outdated can be introduced.

Nokia proposed network should know the validity of GNSS and ephemeris and have aligned understanding with UE.

***Moderator view****: based on the above for validity of satellite ephemeris, the behavior of idle UE or connected UE for satellite ephemeris acquisition can be specified via validity timer. This issue to discuss is whether the timer is set autonomously by the UE or set by the network. This would ensure that the network should know the validity of ephemeris and have aligned understanding with UE. The aspects of validity related to GNSS was addressed in Section 2.1.*

***Initial proposal – Section 2.5:***

***Companies are encouraged to further discuss and comment on validity of satellite ephemeris in idle UE or connected UE***

* ***Q1: Can a validity timer for satellite ephemeris acquired on SIB be used in the device?***
* ***Q2: if answer to question 1 is yes, is the validity timer configure by the network or autonomously set by the UE?***
* ***Q3: if the answer is no, can the behaviour of UE for validity of satellite ephemeris be explicitly written in the specifications***

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| Companies | Comments |
| APT | Q1: No, satellite ephemeris can be broadcasted periodically, e.g., every 80ms.  Q2: No  Q3: Like SIB validity, we may have a new UE behavior, e.g., delete any stored version of satellite emperies after 60s from the moment it was successfully confirmed as valid. |
| ZTE | The validity of satellite ephemeris is up to the decision on the detailed configuration in NR-NTN. More specifically, w.r.t each question, views are shared as below:  Q1: Yes, regardless of the signalling mechanism for satellite ephemeris, e.g., periodically in SIB, the dedicated validity timer should be configured for this information to ensure the usage.  Q2: It should be configured by network. |
| Apple | Q1: Yes  Q2: Configured by network |
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### FIRST ROUND -Validity of satellite ephemeris

TBA

## Guiding principles and observations for future work in future releases

**Moderator comment**: In this section, it is considered to capture observations and proposals from contributing companies on the studied topics additionally (to the essential proposals) in the TR as guiding principles and observations for future work in future releases.

### Closed-loop (N)PRACH-driven time-frequency corrections with alternate starting subcarriers for NPRACH transmissions for long connection

Qualcomm proposed Closed-loop (N)PRACH-driven time-frequency corrections with alternate starting subcarriers for NPRACH transmissions for long connection. Moderator summary is given below:

Moderator summary: Closed-loop (N)PRACH-driven time-frequency corrections with alternate starting subcarriers for NPRACH transmissions for long connection:

During long connections, GNSS fixes by connected UE for UE pre-compensation can be avoided by using closed-loop time and frequency corrections issued by the base-station. Potentially periodic, or prior to each uplink transmission, dedicated/contention-free NPRACH transmission from the UE, followed by a timing and/or frequency correction command are issued by the network in a response message. NPRACH resources with alternate starting subcarriers for NPRACH transmissions *robust* to time and frequency synchronization errors are used for the dedicated/contention-free NPRACH transmission. Reduction in power consumption penalty from GNSS fixing during a long connection can be achieved by replacing a GNSS fix with an NPRACH followed by a closed loop correction as illustrated in Figure below [12].



Relaxed GNSS fixing using (N)PRACH-based closed loop corrections.

NPRACH starting subcarriers (e.g., over a subset of all available starting subcarriers) that a UE can use for contention-based random access (CBRA) are restricted as illustrated in Figure below [12], where “alternate starting subcarriers” can be selected by UEs. The robustness of NPRACH to time and frequency errors up to 1 kHz improves significantly due to the increased resiliency to ICI among preambles as shown on CDFs of residual timing and frequency errors after base-station processing of the NPRACH preamble below. With alternate preambles, the performance is close to single preamble transmitted.

**Chart, treemap chart

Description automatically generated**

Figure 2: Example of "restrictions" on starting NPRACH subcarriers for CBRA. Alternate starting subcarriers may be selected for NPRACH transmission by a UE.

Chart, line chart

Description automatically generated

***Figure: Cumulative distribution functions (CDFs) of residual timing error after base-station processing of NPRACH preambles transmitted by UE(s). In this setting, initial frequency errors can be up to +/- 1 kHz, and the power levels of different UEs are within +/- 10 dB of each other.***

**Initial Proposal – Section 2.6.1:**

**Companies are encouraged to comment on their understanding, need, and workability of Closed-loop (N)PRACH-driven time-frequency corrections with alternate starting subcarriers for NPRACH transmissions in long connection**

* **Q1: During long connections, can GNSS fixes for UE pre-compensation by connected UE be avoided by using closed-loop (N)PRACH-driven time and frequency corrections issued by the base-station?**
* **Q2: Can moderator summary on Closed-loop (N)PRACH-driven time-frequency corrections with alternate starting subcarriers for NPRACH transmissions be included in TR 36.763 as guiding principles and obse*rvations for future work in future releases.***

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| Companies | Comments |
| APT | Q1: frequency corrections need more discussion.  Q2: Yes |
| ZTE | It’s up to the discussion on the pre-compensation for long PRACH and based on the design principle of pre-compensation, it should be assumed that accurate improvement on both TA and Doppler can be achieved with corresponding design. Then, for each question:  Q1: For the long connection, we need to introduce the GNSS fix to enable the pre-compensation for both TA and Doppler and the closed-loop mechanism can be considered to address the TA as discussed in NR-NTN.  Q2: No, the needs should be further justified. |
| Apple | Q1: Not sure if the closed-loop NPRACH-driven time and frequency corrections could fully achieve the time and frequency synchronization, due to the limitation on the current NPRACH design. |
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#### FIRST ROUND - Closed-loop (N)PRACH-driven time-frequency corrections with alternate starting subcarriers for NPRACH transmissions for long connection

TBA

### Synchronization failure and recovery

Qualcomm proposed UE behaviour when synchronization failure (e.g., ephemeris and/or GNSS are outdated) occurs. Moderator summary is given below:

Moderator summary: Triggering of RLF by connected UE when the GNSS and/or ephemeris information at the UE is (are) outdated:

Assuming a timer-based approach for synchronization validity where a validity timer for ephemeris is used, a synchronization failure may be indicated by the expiry of such timer and GNSS position fix is outdated. A simple UE behaviour upon a detecting synchronization failure is to trigger radio link failure (RLF), go back to IDLE, and re-establish connection from scratch. This solution would have minimal specification impact.

**Initial Proposal – Section 2.6.2:**

**Companies are encouraged to comment on their understanding, need, and workability of a mechanism where connected UE triggers RLF when the GNSS and/or ephemeris information at the UE is (are) outdated in long connection**

* **Q1: If validity timer for satellite ephemeris is expired and GNSS position fix is not valid during long connections, can UE trigger RLF?**
* **Q2: Can moderator summary on Triggering of RLF by connected UE when the GNSS and/or ephemeris information at the UE is (are) outdated be included in TR 36.763 as guiding principles and obse*rvations for future work in future releases?***

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| Companies | Comments |
| APT | Q1: No. After initial access, satellite ephemeris and GNSS are non-essential to maintain UL timing and frequency.  Q2: Yes. This is like the conditional RLF. |
| ZTE | Q1: No, if the intention is to support the long connection, the overall design as other solutions should also be considered, e.g., SIS acquisition.  Q2: No, |
| Apple | Q1: No. Timing synchronization may also be maintained by MAC CE TA command.  Q2: No. |
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#### Synchronization failure and recovery

## Useful optimizations

In this section, proposals from contributing companies for useful optimizations are considered.

### Network based pre-compensation

Nokia proposed in case UE GNSS is unavailable/faulty/inaccurate and solution with only UE GNSS based auto-precompensation can not work well and assuming GNSS based measurement can provide UE a good reference for adjustement on oscillator, then based on a correct oscillator, one possible way is UE can adjust time based on network assistance as TimeReferenceInfo-r15 from eNB without impact from satellite location derivation, while measure DL RS for UL frequency adjustment without impact by UE location derivation and satellite location derivation [18, Section 2.3.2.2]. The later solution, i.e. time reference configured from eNB and DL RS based UL synchronization is more stable while not impacted by GNSS issue, with regular DL measurement and configuration supported by specification of IoT over TN.

**Moderator view**: more discussions on the understanding and workability of the proposed solution where UE adjust timing based on network assistance as TimeReferenceInfo-r15 seems needed. In particular, whether device and eNB can use common GNSS-timing reference for their respective internal clocks, when UE GNSS is unavailable / faulty / inaccurate.

***Initial Proposal – Section 2.8:***

***Companies are encouraged to comment on network based pre-compensation***

* ***Q1: In case UE GNSS is unavailable/faulty/inaccurate and solution with only UE GNSS based auto-precompensation can not work well, can GNSS based measurement provide UE a good reference for adjustement on oscillator in device?***
* ***Q2: In case GNSS is unavailable/faulty/inaccurate in device, can device keep accurate GNSS-referenced internal timing to measure gNB-satellite-UE delay from reception of TimeReferenceInfo-r15 broadcast by eNB with also GNSS-reference internal timing?***

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| Companies | Comments |
| APT | Q1: No. This could be a conner case that UE could sync with GNSS satellites but not obtain enough GNSS data.  Q2: Not sure but maybe No. |
| ZTE | This part is to introduce a new assumption for the discussion and not aligned with the basic scope for this SI. We share the views that there are case that UE’s GNSS may not be available or accurate, but the corresponding solution should be discussed in further release or by revising the scope of this SI. |
| Apple | The similar discussions occurred in NR NTN, where the scheme may be based on UE implementation. |
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#### FIRST ROUND – Other

TBA

# Conclusions

TBA

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# Appendix A

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| Contribution | Observation/Proposals |
| Huawei (R1-2104259) | ***Observation 1:*** *There will be a large timing drift in case of large number of repetitions for preamble transmission.*  ***Observation 2:*** *There will be**a large timing drift in case of 256ms time-contiguous transmission for NPUSCH.*  ***Observation 3:*** *Decoding system information or receiving closed loop TAC command for TA adjustment during UL repetition will introduce extra power consumption for IoT devices.*  ***Observation 4:*** *RACH failure may happen for an NB-IoT UE since it may stay in the cell for a short time, which leads to* *increased power consumption.*  ***Proposal 1:*** *UE autonomous TA adjustment should be applied during the long preamble transmission duration to compensate the large timing drift.*  ***Proposal 2:*** *More UL gaps should be inserted according to the maximum allowed time-continuous transmission for IoT over NTN.*  ***Proposal 3:*** *Indicate* *time-continuous repetition number for preamble and time-continuous duration for UL data transmission in the system information for IoT NTN*  ***Proposal 4:*** *Using TA drift rate to calculate and compensate the TA drift for UL transmission with long duration.*  ***Proposal 5:*** *The indication of DL frequency pre-compensation is normalized to a predefine subcarrier spacing.*  ***Proposal 6:*** *To reduce the signaling overhead, only DL pre-compensation indication is needed and sufficient for UL frequency alignment.*  ***Proposal 7:*** *Introduce time offset for adjacent NPRACH subcarriers to avoid inter-carrier interference.* |
| VIVO (R1-2104399) | ***Observation 1****: Legacy mechanism of UL gap needs to be enhanced in IoT over NTN.*  ***Proposal 1****: Support to report UE-specific TA value and to network.*  ***Proposal 2****: Configurable UL gap are needed for UE pre-compensation operation during long PUSCH.* |
| Spreadtrum (R1-2104448) | ***Proposal 1****: R17 does not need to introduce measurement gaps for CNSS measurements.*  ***Proposal 2****: UE should perform GNSS measurements before moving to connected mode.*  ***Proposal 3****: UL timing compensation mechansim in RRC\_IDLE and RRC\_INACTIVE states of NTN WI can be reused in IoT NTN.*  ***Proposal 4****: UL timing compensation mechansim for RRC\_ CONNECED states UEs of NTN WI can be reused in IoT NTN.*  ***Proposal 5****: Reference point for autonomous acquisition of the TA at UE is located at the satellite in IOT NTN.*  ***Proposal 6****: Both open and closed control loops are supported in connected mode for IOT NTN.*  ***Proposal 7****: Frequency compensation mechanism of NTN WI can be reused in IoT NTN.*  ***Proposal 8****: In IOT NTN, the reference point for frequency synchronization is located at the satellite.*  ***Proposal 9****: PUSCH repetition unit is used as the granularity of N for long PUSCH should be supported.*  ***Proposal 10****: Inserting a gap between adjacent segments (N time units) to avoid the overlap of segments for long PUSCH should be supported.*  ***Proposal 11****: Preamble repetition unit (i.e. P symbol groups) is used as the granularity of N for long PRACH is should be supported.*  ***Proposal 12****: Inserting a gap between adjacent segments (N time units) to avoid the overlap of segments for long PRACH should be supported.* |
| CATT (R1-2104504) | ***Observation 1****: UE may have the maximum initial frequency error more than 50KHz contributed by oscillator, Doppler shift and anchor carrier offset in S band.*  ***Observation 2****: There may have collision of GAP and PUSCH/PRACH signal after GAP because of different UE\_specific TA adopted.*  ***Observation 3****: A large amount of UEs are linked to same PRACH occasion after reading SIB1, which probably causes PRACH congestion.*  ***Proposal 1****: Increasing channel raster in IoT NTN is necessary.*  ***Proposal 2****: Reuse timing and frequency compensation mechanism of NR NTN to IoT NTN by taking into account UE power assumption.*  ***Proposal 3****: Defining specific requirement on synchronization accuracy for IoT NTN is needed.*  ***Proposal 4****: Consider resource isolation for different users in UL signal transmission to guarantee UL transmission performance of NTN NB-IoT.*  ***Proposal 5****: For UE pre-compensation per N time units for long PUSCH/PRACH, the value of N can be 4ms for eMTC and the value of N for NB-IoT can be 16ms.*  ***Proposal 6****: Consider dropping tail samples of a slot or inserting a gap before signal transmission for TA variation during long (N)PUSCH repetition transmission.*  ***Proposal 7****: Add a small GP or take advantage of a small period of 40ms in GAP as reserved time should be considered to solve transmission collision.*  ***Proposal 8****: Study suitable interval for frequency compensation updating during long PRACH and (N)PUSCH repetition transmission.*  ***Proposal 9****: Study the mechanism to trigger GNSS measurement when UE initiates the wakeup from PSM state or inactive state of eDRX.*  ***Proposal 10****: Power consumption should be evaluated for long connection, including SIB reading and repeated GNSS fixes in RRC\_CONNECTED.*  ***Proposal 11****: Need to enhance mapping mechanism of PRACH occasion in the initial access to avoid PRACH congestion.* |
| MediaTek (R1-2104568) | GNSS measurements  ***Observation 1****: A UE may only need a new GNSS position solely for UE pre-compensation for UL synchronization in corner case scenarios where (i) it is not fixed; (ii) reporting of the GNSS position is not needed by application layer.*  ***Observation 2****: GNSS measurement duration depends on assumption for GNSS receiver for Time To First Fix (TTFF) – hot start can be 1 second; warm start can be 5 seconds; cold start can be 30 seconds.*  ***Proposal 1****: Re-use legacy paging and DRX procedures for UE acquisition of GNSS position fix assuming simultaneous GNSS and NTN NB-IoT/eMTC operation is not used in the device*   * *Re-use legacy paging timer configuration in paging procedure to allow time for a GNSS TTFF with hot start or warm start for mobile-terminated calls* * *If needed, idle UE can do a GNSS TTFF with hot start or warm start in idle DRX / eDRX / PSM before moving to connected for mobile-originated calls* * *If needed, connected UE can do a GNSS TTFF with hot start in connected DRX / eDRX.*   Prediction accuracy on UE-specific tracking of TA and Doppler shift  ***Observation 3****: Prediction over 60 seconds without having acquired new ephemeris data for UE specific TA calculation and Doppler shift calculation has an accuracy within 0.076 us and 4.8 Hz respectively. Longer prediction time of 120 seconds or longer can be considered without significant impact on UL synchronization accuracy.*  GNSS position accuracy  ***Observation 4****: In cellular NR, there is no UE pre-compensation of delay error or Doppler shift error due to UE mobility by idle UE. The UE may apply pre-compensation of delay error based on MAC CE in connected.*  Impact of UE velocity on UE-specific tracking of TA  ***Observation 5****: An accuracy of approximately 5.8 us and 11.6 us can be achieved within 30 seconds and 60 seconds for the UE specific TA tracking at UE velocity of 120 km/h. The TA error due to UE mobility for NTN is similar to TA in legacy non-NTN system and can be addressed by the PRACH CP for idle mode and the TA closed loop in connected mode.*  Impact of UE velocity on UE-specific tracking of Doppler shift  ***Observation 6****: An accuracy of approximately 79 Hz and 158 Hz respectively can be achieved within 30 seconds and 60 seconds for the UE-specific Doppler shift tracking at UE velocity of 120 km/h.*  Validity of satellite ephemeris  ***Proposal 2****: NTN UE time alignment timer for re-acquisition of the satellite ephemeris on NTN SIB is configured by the network.*  Long UL Transmission on PUSH and PRACH  ***Proposal 3****: UE pre-compensation done per N time units for long PUSCH and long PRACH is the baseline solution.*   * *The pre-compensation does not vary within a block of N time units* * *N=1 subframe*   Satellite ephemeris format for UE wake up  ***Proposal 4****: Satellite ephemeris orbital is used for long-term prediction of satellite position for UE wake up from idle DRX for next satellite fly-by*  ***Proposal 5:*** *The lowest level of knowledge in network of when a UE will be in coverage of a satellite is the time when the UE last accessed the satellite cell.*  ***Observation 7****: The impact of UE wake up on power consumption is in the order of 1% battery life reduction per year.*  ***Observation 8****: The behaviour of the UE and the network can be different w.r.t. to Idle DRX / PSM.*   * *The UE can choose to leave idle DRX / PSM at any time. This is normal way for mobile-originated calls.* * *The network will not page a UE when it is in Idle DRX / PSM.*   ***Proposal 6****: The network should page the UE at the right time when*   1. *UE enters active period of idle DRX / PSM;* 2. *UE is within coverage.* |
| CMCC (R1-2104637) | ***Observation 1****: Prior to UL transmission the UE may have to perform GNSS measurements to aid UL synchronization if its previous GNSS measurement is no longer valid.*  ***Observation 2****: Focus on the “short, sporadic connection” case, UE would make GNSS measurements for initial access, and there is no need to do GNSS measurements in connected mode.*  ***Observation 3****: For sporadic UL traffic, UE may make GNSS measurements up to UE implementation before sending Msg 1/Msg A.*  ***Observation 4****: For sporadic DL traffic, UE may perform GNSS measurements after a paging occasion and only if it has been paged to reduce battery consumption. The existing timers (e.g., T3413/T3415) can be configured large enough to ensure a sufficient gap to accommodate GNSS acquisition after decoding the paging message and before initiating UL transmission.*  ***Observation 5****: For sporadic DL traffic, PRACH congestion issue can be alleviated by aligned configuration of DRX and SIB containing satellite location information.*  ***Observation 6****: The time-domain granularity for UE pre-compensation for long PUSCH transmission should be no larger than 65 ms for NB-IoT and 19.5 ms for eMTC.*  ***Observation 7****: The time-domain granularity for UE pre-compensation for long PRACH transmission should be no larger than 65 ms for NB-IoT and 19.5 ms for eMTC.*  ***Proposal 1****: There is no need to specify GNSS measurements windows.*  ***Proposal 2****: PRACH congestion issue for sporadic UL traffic needs further study.*  ***Proposal 3****: New or extended PUSCH UL Compensation Gap (UCG) is no need for SIB read to update satellite position.*  ***Proposal 4****: The time unit for UE pre-compensation for long PUSCH transmission is ms or subframe.*  ***Proposal 5****: The value N for UE pre-compensation for long PUSCH transmission is selected from 1..64.*  ***Proposal 6****: The time unit for UE pre-compensation for long PRACH transmission is ms or subframe.*  ***Proposal 7****: The value N for UE pre-compensation for long PRACH transmission is selected from 1..64.* |
| OPPO (R1-2104778) | ***Observation 1****: when N time unit gets longer, the CP length will be compromised to avoid the sample conflicting between two consecutive N units.*  ***Proposal 1****: For idle UE, if the DL synchronization before paging monitoring relies on an updated GNSS position fix, a GNSS measurement window is needed; otherwise, it may be left for UE implementation to update the GNSS position fix.*  ***Proposal 2****: For devices targeting low velocity and short sporadic transmission, GNSS measurement may not be needed in connected phase.*  ***Proposal 3****: The duration of N time units should be carefully analyzed to avoid performance degradation.*  ***Proposal 4****: a gap may be considered between two groups of N time units to avoid performance degradation, when N time unit has a long duration.*  ***Proposal 5****: For TA pre-compensation for long PRACH transmission, a gap is needed between consecutive N time units to avoid imbalanced achievable coverage.*  ***Proposal 6****: For TA pre-compensation for long PRACH transmission, N time units may be 1 symbol group or 1 repetition unit.* |
| Ericsson (R1-2104815) | ***Observation 1****: As GNSS-equipped UEs can perform timing/frequency pre-compensation before MSG1 transmission, the existing (N)PRACH formats for NB-IoT/eMTC in TN are also sufficient for NTN scenarios.*  ***Observation 2****: The need and purpose of a new UL compensation gap should first be justified. For example, it is not clear if it is needed for re-acquiring satellite ephemeris, or getting a GNSS position fix, or calculating pre-compensation values, or adjusting transmit timing and frequency.*  ***Observation 3****: The value of N can be determined based on the maximum transmit timing error that needs to be tolerated for eMTC and NB-IoT.*  ***Observation 4****: RAN4 input is needed before increasing the channel raster size.*  ***Observation 5****: Multiple hypotheses testing may be needed if ARFCN-indication-in-MIB is used.*  ***Proposal 1****: UE should pre-compensate its timing and frequency before transmitting MSG1.*  ***Proposal 2****: As a baseline, the time and frequency synchronization for eMTC and NB-IoT should follow the same principles as outlined in the NR NTN WI.*  ***Proposal 3****: RAN1 should discuss whether GNSS positioning in RRC\_CONNECTED state is to be supported by IoT NTN UE.*  ***Proposal 4****: RAN1 to wait for further RAN2 progress on GNSS measurement window.*  ***Proposal 5****: RAN1 to use the agreed values of delay and Doppler shift drifts for the IoT NTN reference scenarios as a baseline for discussing the UE pre-compensation frequency defined by N.*  ***Proposal 6****: RAN4 input is needed on the maximum transmit timing error for IoT NTN.*  ***Proposal 7****: UE may pre-calculate the timing and frequency pre-compensation values for each anticipated pre-compensation occasion prior to the start of the UL transmission.*  ***Proposal 8****: RAN1 should investigate DL synchronization performance for NB-IoT and eMTC NTN.*  ***Proposal 9****: RAN1 to compare the pros and cons of increasing the channel raster step size and introducing ARFCN-indication-in-MIB.* |
| Qualcomm (R1-2104823) | *Essential for Release 17:*  ***Observation E-1***: An implicit way to limit connection length for eMTC/NB-IoT over NTN is via the definition of synchronization validity.  ***Proposal E-1*: Define the notion of synchronization validity during which the ephemeris and/or GNSS information is (are) accurate.**   * **This validity is based on timer(s) that are (re-)set autonomously by the UE after acquiring necessary location information.** * **Such (re-)setting events may be indicated to the network to facilitate efficient scheduling.**   ***Proposal E-2*: Introduce a mechanism that triggers RLF when the GNSS and/or ephemeris information at the UE is (are) outdated:**  **- FFS details**  *Recommended for inclusion in TR 36.763:*  ***Observation R-1*:** For long connections in eMTC and NB-IoT over NTN, (N)PRACH-driven closed-loop time and frequency corrections lowers the GNSS power penalty from  **to**  (with a GNSS relaxation factor of 4), w.r.t a baseline without closed-loop corrections.   * Such an (N)PRACH-driven closed loop correction may be facilitated by a periodic or semi-persistent CFRA transmission from the UE, followed by a response message from the network. * An NPRACH design that is robust to time and frequency errors (e.g., the one based on restricted preambles in Section 4 of this contribution) is especially suitable for this.   ***Proposal R-1*: Include Observation R-1 in the TR, in the context of current or future study and support of long connections for eMTC and NB-IoT over NTN, as it relates to uplink synchronization aspects.**  ***Proposal R-2*: RAN1 to consider potential enhancements to (N)PRACH design, depending on the requirements for satellite location accuracy and UE’s own geolocation accuracy at the UE.**   * **The design should also consider facilitating closed-loop time and/or frequency corrections.**   ***Observation R-2*:** Restricting alternate starting subcarriers for NPRACH transmissions allows to correct for potentially large initial uplink frequency synchronization errors (e.g., up to 1 kHz)   * Such a scheme may facilitate UE power savings by relaxing the frequency and accuracy of GNSS fixes and/or satellite ephemeris reads required. * Such a scheme may also facilitate NPRACH-driven closed-loop corrections of time and frequency errors in connected mode, thereby reducing the power penalty from frequent GNSS fixes.   ***Proposal R-3*: Include Observation R-2 in the TR, in the context of current or future study for eMTC and NB-IoT over NTN, as it relates to uplink synchronization aspects.** |
| Intel (R1-2104937) | ***Proposal 1***:   * *Time and frequency offset introduced in service link is pre-compensated by the UE for UL transmission based on UE location (from GNSS) and satellite ephemeris (broadcasted by the eNB)* * *The following options are considered for compensation of time offset introduced in feeder link for UL transmission*   + *Post-compensation at the eNB side*   + *Pre-compensation at the UE side* * *Compensation at the gateway side should be used for frequency offset introduced in feeder link for UL and DL transmission*   ***Proposal 2***:   * *If pre-compensation of time offset introduced in feeder link for UL is used, at least one of the following options should be supported*   + *Broadcasting of common TA and common TA drift rate*   + *Broadcasting of reference point for common TA calculation*   ***Proposal 3***:   * *Enhancements for non-GEO satellite deployment with moving beams and frequency reuse should be discussed assuming existing features of eMTC and NB-IoT (e.g. multi-carrier operation and mobility)*   + *Increased number of anchor carriers for NB-IoT multi-carrier operation* *can be considered*   ***Proposal 4***:   * *It is assumed by RAN1 that a UE in has valid GNSS measurements available for UL synchronization*   *No need to discuss GNSS measurement window in RAN1* |
| Apple (R1-2105139) | ***Proposal 1:*** *In IoT over NTN, consider that UE pre-compensates a timing advance in PRACH transmission, which is composed of network indicated common timing offset and self-estimated UE specific TA based on its GNSS location and serving satellite ephemeris.*  ***Proposal 2:*** *In long PRACH or long PUSCH transmissions, UE applies the same time and frequency pre-compensation every N time units, where N is indicated by network.*  ***Proposal 3:*** *UE calculates and pre-compensates the Doppler shift on service link based on its GNSS location and serving satellite ephemeris in PRACH transmission.*  ***Proposal 4:*** *Support network pre-compensates the frequency offset in downlink transmissions.* |
| SONY (R1-2105183) | ***Observation 1****: The maximum rate of change of flight time between UE and eNodeB is ± 50ms / sec.*  ***Observation 2****: The cyclic prefix budget for time misalignment can be exceeded within 9.4ms.*  ***Observation 3****: Timing misalignment during long PUSCH transmissions leads to phase discontinuity for single subcarrier transmissions.*  ***Observation 4****: From the perspective of phase continuity, the timing of UL transmissions needs to be corrected at least every 8 subframes.*  ***Proposal 1****: The UE updates the timing of its PUSCH transmissions every ‘N’ ms, where ‘N’ is less than or equal to 8ms.*  ***Proposal 2****: A timing advance command is associated with a reference location. The reference location indicates which node (UE, eNodeB or satellite) the timing advance command refers to.*  ***Proposal 3****: A timing advance command is associated with a reference time. The reference time indicates the time at which the timing advance is valid. The reference time of the timing advance command can be signaled to the UE either in MAC CE or PDCCH.*  ***Proposal 4****: Satellite ephemeris information is signaled to the UE to allow the UE to wake up at the appropriate time.*  ***Proposal 5****: The motion of the NTN aerial platform is signaled to the UE using position and velocity information and the drift rate of the timing on the feeder link.*  ***Proposal 6****: The position / velocity / drift rate (PVD) information is signaled using SIB signalling.*  ***Proposal 7****: RAN1 observes in TR36.763 that there may be PRACH congestion when IDLE mode UEs simultaneously transmit PRACH after receiving satellite PVD information.* |
| ZTE (R1-2105194) | ***Observation 1:*** *Increasing the channel raster up to 200 KHz is sufficient to provide robust performance for DL synchronization.*  ***Proposal 1:*** *Increasing the channel raster should be supported for DL synchronization.*  ***Proposal 2:*** *Segmented pre-compensation for long PUSCH and PRACH should be supported.*  ***Proposal 3:*** *For PUSCH pre-compensation, the length of segment can be considered as 8 slots for 3.75 kHz SCS and 32 slots for 15 kHz SCS.*  ***Proposal 4:*** *For NPRACH pre-compensation, the length of segment can be considered as 16 random access symbol groups for preamble format 0 and 1 and 8 random access symbol groups for preamble format 2.*  ***Proposal 5:*** *An applicable timing range, e.g., N in terms number of time units, can be indicated to UE to apply each TA value within the UL transmission.*  ***Proposal 6:*** *When TA report is enabled, TA value of first or last segment of transmission delivering the TA report should be considered.*  ***Proposal 7:*** *The UE’s behavior for GNSS information acquisition should be explicitly specified at least before initiating UL transmission after the eDRX/PSM.*  ***Proposal 8:*** *Enhancement on the PRACH format to improve UE density should be considered.* |
| Samsung (R1-2105346) | ***Proposal 1****: TA estimation should be supported for GNSS-capable UE at least for initial access.*  ***Proposal 2****: Common TA should be indicated to cover the roundtrip delay between Satellite and Gateway at least for position based TA estimation.*  ***Proposal 3****: Reporting of UE’s estimated TA should be supported.*  ***Proposal 4****: Pre-compensated TA value can be updated based on UE specific TA estimation and/or TA drift rate during long UL transmission.*  ***Proposal 5****: Frequency offset estimation should be supported by GNSS-capable UE for pre-compensation.* |
| Nokia (R1-2105405) | ***Observation 1****: For IoT UE with reduced cost/complexity, GNSS may be not available or not accurate.*  ***Observation 2****: The maximum doppler shift supported by current LTE NB-IoT/eMTC design is much lower than expected doppler shift in NTN scenario.*  ***Observation 3****: If only consider UE automatic pre-compensation, there will be*  *• UL synchronization error for IoT UE in NTN scenario*  *• The syncrhnizaiton error may last for long time with repeeitions and error propagation,*  *• Mis-alignement between UE and eNB and ineffective for UL sync adjustment.*  ***Observation 4****: If GNSS based time synchronization is used for IoT over NTN, the entire cyclic prefix of the random access preamble should be able to cover multipath propagation delay as well as the inaccuracy imposed by the compensation algorithm based on the GNSS information.*  ***Observation 5****: If the network is not aware that a UE requires time to obtain valid GNSS information the network may trigger additional paging before the UE has a chance to initiate the pre-compensated random access procedure.*  ***Observation 6****: Using referenceTimeInfo-R16 and UE based understanding of GNSS time will suffer less from the satellite movement in terms of timing advance as the reference point is at a static location (the gNB).*  ***Observation 7****: Reporting each Timing Advance change leads to high uplink signalling load.*  ***Observation 8****: Limiting Timing Advance reporting to events where the TA has changed reduces the signalling, but due to moving satellites the signalling is not completely minimized.*  ***Observation 9****: Defining a TA reference, based on UE location, can minimize signalling overhead compared to TA change reporting, because network and UE can both predict TA. UE only needs to report if it has moved.*  ***Observation 10****: The amount of TA value change during the 256 ms NPUSCH transmission period exceeds the maximum tolerance.*  ***Observation 11****: The size of segment “N time units” and the corresponding TA are related to the elevation angle.*  ***Observation 12****: The history acquired GNSS/ephemeris will be out-of-date after some time because of e.g. UE movement or satellite perturbation.*  ***Proposal 1****: DL synchronization performance in NTN scenario based on LTE NPBCH/NPSS/NSSS and LTE PBCH/PSS/SSS in NTN scenario should be evaluated before any further study on DL synchronization, like for SSB in Rel-15.*  ***Proposal 2****: performance of GNSS for IoT UE in NTN should be evaluated.*  ***Proposal 3****: It should be evaluated whether GNSS based time frequency synchronization could be available or could be accurate for following IoT cases*  *· With reduced number of receiver antenna*  *· With reduced power consumption*  *· Not covered by GNSS satellite*  ***Proposal 4****: How to compensate large doppler shift for IoT UE should be solved, where simplification of IoT UE processing could be considered.*  ***Proposal 5****: RAN1 and RAN4 should select one alternative of reference point to be working assumption and it is preferred that the selection should be also base line for IoT NTN scenario, where eNB as reference point is more closer to existing eNB implementation and standard.*  ***Proposal 6****: In case GNSS accuracy is not accurate enough or not always available, solution for UL random access procedure should be conducted in normative phase, with baseline as NR over NTN solutions but power consumption and complexity/cost reduction should also be considered.*  ***Proposal 7****: In normative phase, it should be evaluated whether GNSS based time frequency synchronization could be accurate for IoT cases.*  ***Proposal 8****: it should be added in TR and solved in normative phase for the issue as, considering all issues on GNSS accuracy and GNSS fault for IoT UE with reduced antenna number, second synchronization solution should be studied, not based on GNSS or with less dependence on GNSS.*  ***Proposal 9****: considering reduced UE capability and issue for IoT UE, it is important to provide more chances for IoT UE on T/F synchronization, e.g. UE-auto matic pre-compensation, network assisted pre-compensation, and other possible solution, to avoid sync error.*  ***Proposal 10****: for T/F synchronization, the UE automatic pre-compensation and network assisted pre-compensatioin should be compared and further discussed in normative phase to provide complete solution, which should be addd in TR 36.763.*  ***Proposal 11****: If GNSS based time synchronization is used for IoT over NTN, the aggregate contribution of all sources of inaccuracy must not violate the limits imposed by the cyclic prefix of the random access preamble.*  ***Proposal 12****: The GNSS-assisted pre-compensation solution used by the UE shall meet the demands of the preamble format chosen by the operator, i.e., UE must be prepared to fulfil all preamble format requirements.*  ***Proposal 13****: Combination of UE automatic precompensation and network assisted precompensation should be added as one option in specification, to provide effective UL synchronization for all type of UE in all IoT NTN scenario, and to provide fast convergance of UL synchronization.*  ***Proposal 14****: RAN1 to recommend inclusion of power consumption considerations into the normative phase of the work*  ***Proposal 15****: UE shall report GNSS measurement gap such that network can allocate sufficient time between sending a paging message and when to expect random access procedure initialization from UE.*  ***Proposal 16****: A GNSS measurement gap, corresponding to the time the UE requires to validate GNSS, shall be configured in the paging procedure. The position and duration of the gap can be decided in the normative phase.*  ***Proposal 17****: Network should be in control of the timing advance updates applied at the UE.*  ***Proposal 18****: If UE is performing autonomous update of timing advance during RRC\_CONNECTED mode, the network should know the details of such adjustments in advance.*  ***Proposal 19****: Self adjustement by the UE based on GNSS time and the time provided by referenceTimeInfo-R16 is a feasible solution and should be standardized as well.*  ***Proposal 20****: Reporting UE location for determining UE-specific Timing Advance in half duplex deployments is one method, which can be used by eNB scheduler to avoid UL-DL collisions. The method can be considered to be added to the TR 36.763.*  ***Proposal 21****: when deciding “N time units”, the principle is it should guarantee that after the time adjustment in the N time units, the transmission is still covered by the cyclic prefix while not enter into the next symbol when received by eNB.*  ***Proposal 22****: For TA value changing during the repetitions of PUSCH, a simple configuration of a bundle of TA and corresponding time to utilize from Node B to UE, should be considered as an option to be added in TR 36.763.*  ***Proposal 23****: TA change within the NPUSCH transmission period at different elevation angles should be captured in the TR.*  ***Proposal 24****: How to set the segment length and TA adjustment gap based on elevation angle should be studied in normative phase.*  ***Proposal 25****: Network should know the validity of GNSS and ephemeris and have aligned understanding with UE. Candidate solution should be discussed in normative phase.* |
| Xiaomi (R1-2105551) | ***Observation 1****: 100 kHz channel raster may not be large enough to avoid ambiguity in DL synchronization of IoT over NTN when multiple cells from different satellites could cover same UE.*  ***Observation 2****: Existing NB-IoT/eMTC PRACH formats and preamble sequences can be reused with the assumption UE having GNSS capability.*  ***Observation 3****: Segmented UE pre-compensation of satellite Doppler shift is not needed.*  ***Proposal 1****: Pre-compensation on the Doppler shift for DL transmission should be supported.*  ***Proposal 2****: Larger channel raster should be supported in IoT NTN for the scenarios with co-covered cells from different LEO satellites.*  ***Proposal 3****: UE-specific TA calculation based on the timing drift rate for UE pre-compensation during long UL transmission should be supported.*  ***Proposal 4****: IoT NTN should reuse the UL time and frequency synchronization mechanism for NR NTN in short UL transmission while taking into account the UE power consumption.* |
| Lenovo (R1-2105624) | ***Proposal 1****: A common timing offset (TO) and a TO drift rate for the propogation delay of feeder-link are broadcast in SIB.*  ***Proposal 2****: UE can calculate distance/delay for service link and update the distance/delay based on the satellite velocity.*  ***Proposal 3****： For TA maintenance, the UE needs to update based on closed loop and based on open loop mechanism.*  ***Observation 1****: For NPUSCH transmission with large number repetition, the TA adopted in the beginning is not suitable in the middle/end of the TB transmission.*  ***Proposal 4****: UE pre-compensation done per N time units with inserting transmission gap or puncturing uplink transmission should be considered in UL transmission in IoT on NTN.* |
| InterDigital (R1-2105676) | ***Observation-1****: Short RO period configuration could reduce PRACH congestion since the first RO after ephemeris SIB read could be different across the UEs due to different propagation delay.*  ***Observation-2****: frequent ephemeris SIB transmission also reduces PRACH congestion when its associated ROs configured appropriately.*  ***Proposal-1****: it is up to gNB implementation how to handle PRACH congestion in Rel-17.* |
| Asia Pacific Telecom (R1-2105825) | ***Observation 1****: For long NPUSCH transmission due to a long repetition period (R>1), a UE is not allowed to adjust the uplink transmission timing autonomously based on TS 36.133 V16.8.0, Clause 7.20.2.*  ***Observation 2****: If timing adjustment during UCG is allowed, then no spec impact is needed for a long NPRACH transmission of more than 256ms.*  ***Proposal 1****: Timing adjustment during the UCG of 40ms for long NPUSCH transmission shall be supported.*  ***Proposal 2****: The value of N shall be N = 1, and the unit shall be a subframe shall be considered to minimize the spec impact by reusing the current UE behavior for a transmission overlap due to TA adjustment.*  ***Proposal 3****: Wait for RAN4 progress in NR over NTN for whether timing adjustment during repetition (R>1) for long NPUSCH transmission shall be allowed.*  ***Proposal 4****: Timing adjustment during the UCG of 40ms for long NPRACH transmission shall be supported.*  ***Proposal 5****: Support to capture new channel raster with a step size increased to be greater than 100 kHz in TR, but details shall be determined by RAN4.* |