3GPP TSG RAN WG1 Meeting #106-e R1-2107069

e-Meeting, August 16th – 27th, 2021

Agenda Item: 8.15.1

Source: Moderator (MediaTek)

Title: Summary #1 of AI 8.15.1 Enhancements to time and frequency

synchronization

Document for: Discussion and Decision

# Introduction

At the RAN#92 meeting, a new Work Item was approved for IoT Non Terrestrial Network (NTN) [1]. 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.

# GNSS Measurements for sproradic short transmission

## Backround

In RAN#92e, the following objective was agreed in the Rel-17 IoT NTN WID [1]

*Specify the following time and frequency synchronization enhancements that are not covered by NR\_NTN\_Solutions WI agreements, according to Section 8 in TR 36.763:*

*- GNSS Measurements: Validity of a GNSS position fix and details of acquiring a GNSS position fix, duration of validity, in RRC CONNECTED mode for sporadic short transmission*

The following assumption is nade in the Rel-17 IoT NTN WID [1]

*Enhancements shall be specified as described hereafter with the following assumptions:*

*GNSS capability in the UE is taken as a working assumption 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.*

TR 36.763, Section 6.6.2 made the following recommendations on GNSS position fix for sporadic short transmission:

***For sporadic short transmission:***

***- The idle UE wakes up from idle DRX / PSM, access the network, perform uplink and/or downlink communications for a short duration of time and go back to idle.***

***- Before accessing the network, the UE acquires GNSS position fix and does not need to re-acquire a GNSS position fix for the transmission of the packets.***

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

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

*- TA error due to UE velocity satisfies the requirements defined in RAN4*

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

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

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

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

Moderator’s view is that given that the issue of GNSS measurements is discussed for first time in details in Work Item, it is necessary to align understanding of companies on following questions:

* How the acquisition of GNSS Position fix is done for sporadic short transmission
* What is the duration of the validity of GNSS position fix for some period of time X for sporadic short transmission
  + TA error due to UE velocity satisfies the requirements defined in RAN4
  + Doppler shift error due to UE velocity satisfies the requirement defined in RAN4
* What is the duration of the “short transmission” in sporadic short transmission.
  + This allows better understanding on whether GNSS measurement for long connection times (i.e. longer than in sporadic short transmission) are in scope of WID.

## Company views

### Acquisition of GNSS Position Fix

In idle:

* CATT proposed the UE triggers the GNSS measurement before DL synchronization when it is waken up by TAU T3412 timer expiration, and then enter IoT active state after GNSS measurement. GNSS measurement can be performed during the inactive state of eDRX.
* Nokia propose UE report / network configure GNSS measurement gap in paging procedure to validate GNSS and allocate sufficient time between paging message and when UE initiates random access procedure. GNSS measurement window for both initial access phace and in CONNECTED mode should be discussed. Overhead reduction should be considered for selection of GNSS measurement window and coordination between UE and eNB.
* ZTE proposed that the UE’s behavior for GNSS information acquisition should be explicitly specified at least before initiating UL transmission after the eDRX/PSM.



In connected:

* Spreadtrum proposed that if GNSS becomes outdated in connected mode, UE should go back to idle mode and re-acquire a GNSS position fix.
* CATT discussed that UE interrupts data transmission, makes GNSS measurement, then resynchronizes on DL.The TAU3412 timer would be one trigger to launch the GNSS signal reception.
* Nokia observed that for IoT UE with reduced cost/complexity, GNSS may be not available or not accurate. GNSS measurement may be needed in CONNECTED when GNSS information gets out of date. Multiple IoT UE with different capability and channel status may request different GNSS measurement window. Nokia preopose to evaluate whether GNSS based time frequency synchronization could be available or could be accurate with reduced number of receiver antenna, reduced power consumption, not covered by GNSS satellite.

***Moderator view****: Our understanding of recommendation in TR 36.763, Section 6.6.2 on GNSS position fix for sporadic short transmission , 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. Based on above company views,the details of acquiring a GNSS position fix for sporadic short transmissions can be further discussed.*

***Initial proposal – Section 2.2.1:***

***Companies are encouraged to further discuss and comment on acquisition of GNSS position fix for sporadic short transmission:***

* ***Q1: UE triggers the GNSS measurement before DL synchronization when it is waken up by TAU T3412 timer expiration.***
* ***Q2: UE report GNSS measurement gap / Network configure GNSS measurement gap in paging procedure to validate GNSS and allocate sufficient time between paging message and when UE initiates random access procedure.***
* ***Q3:*** ***UE’s behavior for GNSS information acquisition should be explicitly specified at least before initiating UL transmission after the eDRX/PSM.***
* ***Q4: if GNSS becomes outdated in connected mode, UE should go back to idle mode and re-acquire a GNSS position fix to be consistent with recommendation for sporadic short transmission (TR 36.763 Section 6.3.5)***

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| Companies | Comments |
| ZTE | Q1: In general, the intention for GNSS measurement is for potential UL transmission, then, it’s better to trigger it after DL synchronization and before UL transmission.  Q2: Since as the basic assumption for IoT-NTN, simultaneously operation with GNSS is not supported by UE. In this way, network configured GNSS measurement gap should be supported, e.g., explicit defiend in paging procedure. Otherwise, there will be ambiguity on the UE’s hehavior.  Q3: Agree. As mentioned in Q2.  Q4: Agree, it can be one possibility and unified mechanism can be defined with consideration on others factor, e.g., outdate of ephemeris or common TA. |
| MediaTek | Q1: The UE cannot use its GNSS receiver and NB-IoT/eMTC receiver simultaneously. Assuming GNSS measurements at least takes 1 second (hot fix), the UE will need to re-synchronize on DL if makes GNSS measurements after DL synchronization since it will need to switch off the cellular DL receiver module and hence cannot keep synchronized (for the same reason an UL Compensation Gap of 40 ms is specified to allow UE to re-synchronize on DL if it needs to transmit on UL for > 256 ms, since Half Duplex operations restrict simultaneoud DL and UL operations).  Q2: This way seems not workable. The GNSS measurement gap will depend on when the UE last used its GNSS receiver. It could be 1 second, 5 seconds, 30 seconds depending on hot / warm / cold start.   * To report the GNSS measuremet gap the UE already needs to have valid GNSS measurement and move to connected to transmit the report. Hence, there seems to be chicken-and-egg problem for the GNSS measurement gap configuration that cannot be based on the UE GNSS measurement gap and need for GNSS measurement gap report needs justification. * If the UE report 1 second when it is connected and move back to idle, then if it does not use its GNSS receiver for more than 2 hours, a GNSS measurement gap for warm start of 5 seconds would be needed and UE and network have ambiguous assumption for GNSS measuremets duration. * Likewise, if network configures GNSS measurement of 1 second, but UE can only do warm start then there is also GNSS measurement duration ambiguity.   For these reasons, the GNSS mesurement gap should be left to the UE, which can autonolouly decide how long it needs for the GNSS measurements. The network may assume worst case that the GNSS measurement gap can be up to 30 seconds, which corresponds to cold start. This should be fine for sporadic short transmission in Rel-17.  Q3: Agree. The simplest way is that UE get GNSS position fix just before leaving eDRX / PSM. Then, I can do cell search / DL synchronization, read ephemeris on SIB, determine amout of UE pre-compensation of delay and Doppler shift for UL transmission, transmit data and go back to idle. This way should work fine for sporadic short transmission.  Q4: Agree. It is not likely that GNSS becomes outdated in connected mode assuming sporadic short transmission. Outdate GNSS measurements is more likely in long connection, whch is not priority in Rel-17. |
| Intel | Q1: Such scenario is valid. Also, it is up to UE implementation, e.g. UE can do GNSS measurements after DL synch.  Q2: UE should transmit any UL signal only if valid GNSS measurements are available. Thus, if there is no valid GNSS meausrements after paging received UE shall do GNSS measurements.  In our view it can be left up to UE implementation how to update GNSS measurements, so the issue is more on the network side: how long network can wait until UE initiates RA procedure. So, in our view this issue is more on RAN2 side (network) rather than RAN1 (UE behaviour). We can discuss UE behaviour after details on network side are clear.  Q3: We disagree with this statement. In our view UE behaviour should be controlled using the following points.   * UE shall be constrained to transmit UL signal only with valid GNSS measurements * Enough time shall be given to UE to do GNSS measureemnts, if needed. E.g. not mandating the UE to initiate RA procedure before GNSS measurements are available   Q4: Agree |
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### Validity of GNSS Position Fix

MediaTek observed a UE may need a new GNSS position 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. GNSS receiver Time To First Fix (TTFF) can be 1 second for hot star, 5 seconds for warm start; up to 30 seconds for cold start. GNSS acquired position assumed to be valid for a period X=10 seconds with UE mobility of 60 km/h gives a TA error of 0.95 us and Doppler shift error of 6 Hz. At higher UE mobility, the UE position error can be reduced by application layer or UE implementation assuming dead-reckoning algorithms to extrapolate UE position. Hence, longer GNSS position fix assumed to be valid for a period X=20 s or 30 s may also be fine. The TA error due to UE mobility for NTN can be addressed by the PRACH CP for idle mode and the TA closed loop in connected mode.

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| **Validity of UE location** | 10 s | | 30 s | | 60 s | |
| **UE Velocity** | **UEpos,error** | **TAerror** | **UEpos,error** | **TAerror** | **UEpos,error** | **TAerror** |
| 3 km/h | 4.2 m | 0.02 us | 25 m | 0.14 us | 50 m | 0.29 us |
| 30 km/h | 83.3 m | 0.48 us | 250 m | 1.4 us | 500 m | 2.9 us |
| 60 km/s | 166.7 m | 0.95 us | 500 m | 2.9 us | 1000 m | 5.8 us |
| 120 km/h | 333.3 m | 1.92 us | 1000 m | 5.8 us | 2000 m | 11.6 us |

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| **Validity of UE location** | 30 s | | | 60 s | | |
| **UE Velocity** | **UEpos,error** | **θ** | **Fderror** | **UEpos,error** | **θ** | **Fderror** |
| 3 km/h | 25 m | 89.999 deg | 0.01 Hz | 50 m | 89.999 Hz | 0.61 Hz |
| 30 km/h | 250 m | 89.998 deg | 1.45 Hz | 500 m | 89.993 deg | 6.1 Hz |
| 60 km/s | 500 m | 89.993 deg | 6.1 Hz | 1000 m | 89.9 deg | 24.9 Hz |
| 120 km/h | 1000 m | 89.9 deg | 24.9 Hz | 2000 m | 89.87 deg | 97 Hz |

CATT, OPPO Intel, MediaTek observed that for short sporadic connections, no GNSS update needed in RRC\_CONNECTED for NB-IoT/eMTC.

Nokia propose validity timer of GNSS and ephemeris should be supported and coordinated between UE and eNB.

Qualcomm proposed a UE initiates a GNSS validity period when it acquires a fresh GNSS position fix to obtain its geolocation. Whether the duration of this validity period is autonomously determined by the UE is for further study. They proposed to introduce a mechanism that triggers RLF when the UE’s GNSS-based geolocation validity expires.

GNSS validity timer shall be justified (OPPO), may not be needed (FGI), validity of GNSS position fix is up to UE implementation and/or RAN4 requirements/conformance tests (Intel), RAN4 should discuss, send an LS to RAN4 on time and frequency error requirements for IoT NTN before discussing the details of validity duration for GNSS position (Ericsson), Consider the validity of GNSS position fix based on the supported maximum UE speed (Apple)

***Moderator view****: Our understanding of recommendation in TR 36.763, Section 6.6.2 on GNSS position fix for sporadic short transmission , the UE acquires GNSS position fix before moving to connected and there is no need for the UE to re-acquire GNSS position in connected. This means the GNSS position fix is valid for the duration of sporadic short transmission. Based on above company views,the details of validity of GNSS position fix for some period of time X for sporadic short transmissions can be further discussed. The value X may depend on understanding of duration of “short transmission” in sporadic short transmission. To the moderator understanding, UE velocity is not taken into account in UL frequency error requirement in cellular NB-IoT / eMTC, and was not taken into account in discussions for NTN NR on UL transmission frequency error requirement in RAN4. Frequency error for UE pre-compensation of satellite Doppler shift due to UE velocity was shown by some analysis to be not significant for NTN IoT (i.e. a few Hz). The TA error for UE pre-compensation of satellite delay due to UE velocity for NTN can be addressed by the PRACH CP for idle mode and the TA closed loop in connected mode. It would be helpful to have common understanding on these aspects related to UE velocity to help consensus on details of the duration of the short transmission, acquisition of the GNSS position and validity of the GNSS position can be discussed in normative phase.*

***Initial proposal – Section 2.2.2:***

***Companies are encouraged to further discuss and comment on acquisition of GNSS position fix for sporadic short transmission:***

* ***Q1: GNSS position fix is valid for the duration of sporadic short transmission***
* ***Q2: Frequency error for UE pre-compensation of satellite Doppler shift for sporadic short transmission due to UE velocity is not significant for NTN IoT.***
* ***Q3: The TA error for UE pre-compensation of satellite delay for sporadic short transmission due to UE velocity can be addressed by the PRACH CP for idle mode and the TA closed loop in connected mode.***

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| Companies | Comments |
| ZTE | Q1: Agree. GNSS position fix should be valid.  Q2: Agree. Frequency error caused by GNSS position error is not significant in short transmission.  Q3: 3.The UE enters idle mode between two sporadic transmission. The idle mode may last for a very long time and new GNSS position fix is needed. For connected mode, the closed loop TA mechanism may be enough. |
| MediaTek | Q1: Agree. GNSS position fix should be valid for the duration of sporadic short transmission.  Q2: Agree. Frequency error caused by GNSS position error is not significant in sporadic short transmission  Q3: Valid GNSS position fix is needed to start sporadic short transmissions. Then, the TA error due to UE velocity can be addressed by the PRACH CP for idle mode and the TA closed loop in connected mode |
| Intel | Agree with Q1, Q2, Q3 statements. |
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### Duration of short transmission

ZTE proposed gaps for GNSS position fix should be supported in RRC connected mode for long transmission.

CATT observed that for long connection, SIB reading and GNSS fixes should be applied and power assumption needs to be evaluated for this case. CATT proposed (i) to study the mechanism to trigger GNSS measurement when UE initiates the wakeup from PSM state or inactive state of eDRX; (ii) Power consumption should be evaluated for long connection, including SIB reading and repeated GNSS fixes in RRC\_CONNECTED.

***Moderator view****: The recommendation and objective in WID for GNSS Measurements are*

*Specify the following time and frequency synchronization enhancements that are not covered by NR\_NTN\_Solutions WI agreements: Validity of a GNSS position fix and details of acquiring a GNSS position fix, duration of validity, in RRC CONNECTED mode for sporadic short transmission.*

*To the moderator understanding, the long connection in RRC connected is not in scope of objective for GNSS measurement in Rel-17 WID as copied below:*

*Specify the following time and frequency synchronization enhancements that are not covered by NR\_NTN\_Solutions WI agreements, according to Section 8 in TR 36.763:*

*- GNSS Measurements: Validity of a GNSS position fix and details of acquiring a GNSS position fix, duration of validity, in RRC CONNECTED mode* ***for sporadic short transmission***

***Initial proposal – Section 2.2.3:***

***Companies are encouraged to further discuss and comment on duration of short transmission for sporadic short transmission, and further comments on whether GNSS measurement for long connection times is in scope of WID.***

* ***Q1: What is a typical duration of short transmission in sporadic short transmission?***
* ***Q2: Is it company understanding that aspects related to GNSS measurements in long connection in RRC connected are not in scope of Rel-17 WID?***

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| Companies | Comments |
| ZTE | Q1: It depends on the typical packet size and channel condition in short sporadic transmission, which need more clear definition.  Q2: Long transmission is not within Rel-17 WID. But in high mobility case, the problem in long transmission, e.g., aging of GNSS, may also happen in short transmission cases if the duration is not short enough. Therefore, definition of sporadic short transmission should be confirmed first and then we can exclude the concern on how long the transmission duration is. |
| MediaTek | Q1: It can be in the order of 10 seconds or so. If the channel coditions are good it can be a few seconds and if there are not good it could be longer than 10 seconds. It should not be assumption that the short transmission could be several 10 seconds or minutes.  Q2: Long transmission is not within Rel-17 WID. With assumption of short transmission in the order of 10 seconds or longer (i.e. 20 seconds or could be up to 30 seconds), the problem of GNSS aging is not significant based on analysis. |
| Intel | In our view it is not necessary to define short sporadic transmission explicetely. It is assumed by RAN1 that there is not need to update GNSS measurements during connection. |
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# Validity timer for UL synchronization

## Background

In RAN#92e, the following objective was agreed in the Rel-17 IoT NTN WID [1]

*Specify the following time and frequency synchronization enhancements that are not covered by NR\_NTN\_Solutions WI agreements, according to Section 8 in TR 36.763:*

* *Validity timer for UL synchronization: satellite ephemeris, and potentially other aspects*

The UE can use its GNSS-acquired location and satellite-assisted information for the ephemeris broadcast on NTN SIB for the prediction of the TA and Doppler shift to apply satellite delay and Doppler shift in pre-compensation over the service link for UL transmission. Analysis contributed by several companies in NTN NR showed that the prediction can be done with very high accuracy over 10 of seconds. To the moderator understading, this would suggest that for sporadic short transmission, the UE can read the ephemeris on NTN SIB at time *n* and use the prediction of TA and Doppler shift to apply for UL transmission at time *n+1, n+2, .., n+K* without need to read again the ephemeris on NTN SIB.



Similarly, the UE can use satellite-assisted information for the common TA parameters broadcast on NTN SIB for the prediction of the common TA to apply satellite delay pre-compensation over the feeder link for UL transmission. Analysis contributed by several companies in NTN NR showed that the prediction can be done with very high accuracy over 10 of seconds. To the moderator understading, this would suggest that for sporadic short transmission, the UE can read the common TA on NTN SIB at time *n* and use the prediction of common TA pre-compensation to apply for UL transmission at time *n+1, n+2, .., n+K* without need to read again the common TA parameters on NTN SIB.

## Company views

Configuration of validity timer for Common TA:

Huawei proposed network configures a validity timer for common TA and RLF will be triggered once the timer expires at the UE.

Lenovo proposed two individual timers are introduced to determine the validity of uplink synchronization – i.e. (i) Timer for satellite ephemeris; (ii) Timer for common TA and/or common drift rate.

Configuration of validity timer for ephemeris:

Qualcomm, SONY, NEC, Nordic Semi Conductor, Ericsson, Apple, ZTE, Lenovo, InterDigital proposed network configures a validity timer for ephemeris.

Huawei, CATT proposed that for sporadic short transmission, the UE acquires satellite ephemeris before accessing the network and does not need to re-acquire it for the transmission of the packets. FGI commented validity timer may not be needed.

Ericsson observed the validity timer is configured based on satellite constellation and re-acquisition of ephemeris depends on RAN1/RAN4 discussions on maximum tolerable timing and frequency errors due to inaccurate satellite position information for serving or neighbor cells, configuration may be for a single satellite or group of satellites.

ZTE proposed indication of valid time for assistance information broadcast from BS, e.g., ephemeris data, should be supported. The activation time instant of assistance information can be implicitly known as a reference time linked to DL subframe where the SIB carrying the assistance information is broadcast. The validity timer is started/restarted once new assistance information is activated. The valid time length can be broadcast along with assistance information. A coarse signaling granularity can be applied, e.g., a SIB period. If the residual duration of validity timer is shorter than the time duration of following UL transmission, UE will postpone the access to network until new assistance information is activated.

MediaTek proposed to postpone discussion on validity of satellite ephemeris until this issue under discussion in NR NTN WI has been resolved to avoid duplication of discussion.

Intel proposed that the need for validity timer depends on the signalling design for satellite ephemeris; support of validity timer should be discussed in RAN2.

Expiration / duration of validity timer:

Qualcomm, ZTE proposed RLF will be triggered once the ephemeris timer expires at the UE.

SONY, Nordic Semi Conductor, Apple, Interdigital proposed UE refreshes ephemeris when timer expires. Ericsson observed further discussions needed for the case where ephemeris validity timer expires during an ongoing connection

Qualcomm proposed the duration of valid ephemeris is counted starting from the first repetition of this SIB. A SIB can potentially have multiple repetitions (depending on coverage levels), the specifications need to be precise about when—during these SIB repetitions—the timer is started at the UE side.

***Moderator view****: based on the above, there are various views on the need and configuration for validity timer for UL synchronization: satellite ephemeris, and potentially other aspects. Moderator view is that companies can first align understanding on need for validity timer for UL synchronization for satellite ephemeris in sporadic short transmission. Details specific to configuration of validity timer can then be discussed. Aspects related to common TA are under discussion in NTN NR and discussion on validity timer for common TA can be postponed to next meeting. The recommendation on sporadic short transmission in TR 36.763 Section 6.3.5 is copied below to help understanding on this topic. Although this recommendation only explicitly mentioned re-acquisition of GNSS position fix is not needed in sporadic short transmission,to the moderator understanding the recommendation seems also relevant for the discussion on whether re-acquisition of ephemeris on NTN SIB is needed in sporadic short transmission since both the GNSS-acquired Position fix and the satellite ephemeris are needed for UE pre-compensation.*

*For sporadic short transmission (TR 36.763 Section 6.3.5):*

*- The idle UE wakes up from idle DRX / PSM, access the network, perform uplink and/or downlink communications for a short duration of time and go back to idle.*

*- Before accessing the network, the UE acquires GNSS position fix and does not need to re-acquire a GNSS position fix for the transmission of the packets.*

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

***Initial proposal – Section 2.5:***

***Companies are encouraged to further discuss and comment on validity timer for UL synchronization***

* ***Q1: What would be the need for UE to read again the satellite ephemeris on SIB in connected for sporadic short transmission assuming it has read the ephemeris / has a valid ephemeris before moving to connected***
* ***Q2:What would be the need to configure a validity timer for sporadic short transmission for the following***
  + ***Satellite ephemeris***
  + ***Common TA***
* ***Q3: Is it company understanding that configuration of validity timer for satellite ephemeris for long connection is not in scope of Rel-17***
* ***Q4: What happens when validity timer for satellite ephemeris expires***
  1. ***Should RLF be triggered?***
  2. ***Should UE read Ephemeris or common TA parameters on SIB again?***

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| Companies | Comments |
| ZTE | Q1: There is no need to read ephemeris on SIB in connected mode if UE is ensured to have a valid ephemeris and the residual valid time is long enough. The valid time for assistance information may be long enough for several successive short transmissions. In this case, by configuring a validity timer, there is no need to read new assistance information before each UL transmission.  Q2: Configuration on the valid duration for both parameters are needed as the backup restriction, e.g., if the timer is expired before the ending of transmission, additional behavior can be considered to keep the system work.  Q3: No. The validity timer is not specifically configured for long transmission. This configuration can reduce the times of SIB reading and also act as the backup solution to align the behavior between UE and BS.  Q4: Synchronization is thought lost and UE re-access network again. Reading SIB will be basic operation and whether reusing the legacy behavior as RLF can be further considerd along with other mechanisms, e.g., PDCCH order triggered RACH |
| MediaTek. | Q1: No need for sporadic short transmission. Several companies showed by analysis / simulations that prediction of TA and Doppler shift can be very accurate over 10s of seconds after reading assistance information on SIB.  Q2: This discussion could be postponed as it is also under discussion in NR NTN. It seems an optimization where the most likely justification being to configure validity timer for ephemeris and common TA long enough for several successive sporadic short transmissions. It should work if UE goes back to idle after each sporadic short transmission. This way seems better for power consumption as keeping UE in connected for several seconds between each sporadic short transmissions is not good way.  Q3: Validity timer specifically configured for long transmission is not in scope of Rel-17. This would require addressing different issues where the UE is in connected for a long time with GNSS measurements aging requiring UE to refresh GNSS position fix.  Q4: If in connected and validity timer is configured, RLF is triggered and UE goes back to idle. UE can read ephemeris on SIB before accessing the network. For sporadic short transmission this way is sufficient to make it work in Rel-17. |
| Intel | Q1: Satellite ephemeris update is not needed. However, if satellite ephemeris is transmitted in SIB and UE is indicated with SI modification, UE will need to update SI including satellite ephemeris.  Q2: In our view the need for validity timer depends on the indication design. E.g. if SIB indication is used, validity timer may not be needed.  Q3: Yes |
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# Long UL transmission on PUSH and PRACH

## Background

In RAN#92e, the following objective was agreed in the Rel-17 IoT NTN WID [1]

*Specify the following time and frequency synchronization enhancements that are not covered by NR\_NTN\_Solutions WI agreements, according to Section 8 in TR 36.763:*

*- Long PUSCH and PRACH Transmission enhancements: segmented UE pre-compensations, new UL gaps and/or implementation solutions, time units and duration of segments.*

TR 36.763, Section 6.6.2 made the following recommendations on Long PUSCH and PRACH Transmission enhancements:

* *A specification change is needed for UL transmission with repetitions R>1.*
* *Segmented UE pre-compensation done per N time units for long transmission on PUSCH and on PRACH, where the pre-compensation does not vary within a block of N time units.*
* *For segmented UE pre-compensation how the following is handled can be further discussed* 
  + *Phase discontinuity at subframe boundary when applying new pre-compensation*
  + *Coherence time limitation due to delay/frequency drift rate during segment*
  + *Signal overlapping between different TA segments*
* *It can be further studied during the normative phase (i) Need for more frequent new UL gaps during long transmission; (ii) Whether sampling frequency adjustment to avoid new UL gaps can be achieved by implementation; (iii) Value of N for the number of time units and what is the time unit for the segmented UE pre-compensation.*

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.***

The maximum TA drift rate including both feeder link and service link is up to 93 us/s in LEO-600, or about 25 us/s one way on service link and on feeder link depending on elevation angle as illustrated in figure below below. In GEO, the maximum TAdrift rate is much smaller.

The specified UL Compensation Gap, UCG==40 ms is scheduled every 256 ms in case of long UL transmission. This is used by device to interrupt long transmission to re-synchronized in DL. The delay drift rate 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. Even assuming a lower drift rate of 20 us/s, the TA drift can be about 5 us. This exceeds transmit timing error Te is 80\*Ts=2.6 us for NB-IoT and Te is 24\*Ts=0.78 us for eMTC specified in TS 36.133 Table 7.20.2-1 and Table 7.1.2-1 respectively. 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.





To avoid the issue with delay drift rate during the long UL transmission, the UE can read the satellite ephemeris on NTN SIB at time *n* and pre-calculate the timing and frequency pre-compensation values for each anticipated pre-compensation occasion *n+1, n+2, .., n+K* prior to the start of the long UL transmission. The UE could apply the pre-compensation with an adjusted TA and new Doppler shift continuously during the long UL transmission.



The application of the pre-compensation with an adjusted TA during the long UL transmission introduces a phase discontinuity at the subframe boundary and lead to overlapping of segments of one or several subframes, which is due to puncturing (i.e. sample are skipped) to advance the transmission timing. The phase discontinuity can be expressed as

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

Table below gives examples of phase discontinuity with TA appled every 1 ms for different numerologies in NB-IoT

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Δf** |  |  |  | **TRU** | **ΔTdrift** | **Δφ** |
| 15 kHz | 12 | 2 | 7 | 1 ms | 0.1 us | 3.36 deg |
| 15 kHz | 6 | 4 | 7 | 2 ms | 0.2 us | 6.72 deg |
| 15 kHz | 3 | 8 | 7 | 4 ms | 0.4 us | 13.44 deg |
| 15 kHz | 1 | 16 | 7 | 8 ms | 0.8 us | 26.88 deg |
| 3.75 kHz | 1 | 16 | 7 | 32 ms | 3.2 us | 103.68 deg |

For eMTC, the phase discontinuity can be even larger with TA applied every 1 ms – e.g. phase discontinuity = 0.1 us \* 1.4 MHz/2 \* 360 degrees = 25.2 degrees

The issue with the adjustment of TA accross repetitions of the overlapping of UL transmission segments is illustrated below, where a segment can be one or several subframes



***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.*

## Company views

### Phase discontinuity in segmented pre-compensation

Huawei observed that the phase discontinuity is predictable and can be compensated at the UE side via implementation. Implementing frequent sampling frequency adjustment at UE side with no UL gaps to avoid violating the transmit timing error Te will introduce extra complexity and power consumption that may not be able to be handled by UE due to the hardware limitations.

Ericsson, CMCC, ZTE mentioned impact of phase discontinuity due to large timing drift on PAPR needs to be determined. ZTE observed that the PAPR increment due to phase discontinuity in segmented pre-compensation is acceptable even if no further enhancement is introduced.



Figure 3 PAPR of segmented signal with 12 subcarriers [14]

|  |  |
| --- | --- |
| spectrum_1sc | spectrum_1sc_edge |
| 1. pi/2-BPSK, center subcarrier | 1. pi/2-BPSK, edge subcarrier |
| spectrum_1sc_pidiv4qpsk | spectrum_1sc_pidiv4qpsk_edge |
| 1. pi/4-QPSK, center subcarrier | 1. pi/4-QPSK, edge subcarrier |

Figure 4 Spectrum of segmented signal with 1 subcarrier [14]

|  |  |
| --- | --- |
| papr_1sc | papr_1sc_edge |
| 1. pi/2-BPSK, center subcarrier | 1. pi/2-BPSK, edge subcarrier |
| papr_1sc_pidiv4qpsk | papr_1sc_pidiv4qpsk_edge |
| 1. pi/4-QPSK, center subcarrier | 1. pi/4-QPSK, edge subcarrier |

Figure 5 PAPR of segmented signal with 1 subcarrier [14]

|  |  |
| --- | --- |
| papr_1sccomp | papr_1sccomp_edge |
| 1. pi/2-BPSK, center subcarrier | 1. pi/2-BPSK, edge subcarrier |
| papr_1sccomp_pidiv4qpsk | papr_1sccomp_pidiv4qpsk_edge |
| 1. pi/4-QPSK, center subcarrier | 1. pi/4-QPSK, edge subcarrier |

Figure 6 PAPR of segmented signal with 1 subcarrier with 100 us/s TA drift rate [14]

***Moderator view****: To the moderator understanding, based on analsysis from ZTE it seems the impact of segmented pre-compensation on PAPR is not significant. It would be helpful if companies can share their understanding and own analysis on this issue of phase discontinuity impact on PAPR.*

***Initial Proposal – Section 4.2.1:***

***Companies are encouraged to further discuss and comment on phase discontinuity potential impact on PAPR***

|  |  |
| --- | --- |
| Companies | Comments |
| ZTE | For single-tone modulation, the PAPR is mainly caused by windowing and filtering, which could cause overlap between adjacent symbols. Hence, even if the phase discontinuity seems large, the impact on PAPR may not be so significant once the overlap length is short. W.r.t to the impact of phase discontinuity on PAPR, the PAPR performance should be directly evaluated instead of only analyzing the phase discontinuity.  We think the phase discontinuity does have impact on PAPR but it is negligible. If as the group consensus that the increasing of PAPR not acceptable, new UL gaps can be inserted between segments to completely avoid the impact. |
| MediaTek | Based on ZTE analysis, the issue seem not to be significant. New UL gaps could be inserted to avoid issue of PAPR with UL transmission segment overlapping if seen to be significant. |
| Intel | Agree with ZTE and Moderator’s view. |
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### Duration of UL transmission segment

TR 36.763 recommendation is that “*segmented UE pre-compensation done per N time units for long transmission on PUSCH and on PRACH, where the pre-compensation does not vary within a block of N time units*”. Hence, it is needed to discuss the value of N and the time unit.

CMCC proposed alternatives for further study:

- Alt 1: adopt small block duration to reduce the phase discontinuity difference at each block boundary

- Alt 2: adopt large block duration to reduce the frequency when phase discontinuity effect occurs

- Alt 3: spec enhancement to keep phase continuity from TA correction action

Nokia showed some analysis showing the TA change as a function of elevation angle within 256 ms



|  |  |
| --- | --- |
| (a) Initial elevation angle is 10 degrees. | (b) Initial elevation angle is 30 degrees. |
| (c) Initial elevation angle is 50 degrees. | (d) Initial elevation angle is 70 degrees. |
| (e) Initial elevation angle is 90 degrees. | |

TA changes during a 256 ms transmission period at different elevation angles [16]

Samsung proposed for segmented UE pre-compensation per N time units, the value of N can be different for UL timing pre-compensation and UL frequency pre-compensation, e.g., separately configured by network. For segmented UE timing pre-compensation, if signal is overlapped between different TA segments, the last one is dropped.

Huawei, Vivo, CATT, Sony, MediaTek, Spreadtrum, Samsung, Nokia, Ericsson, Apple, ZTE, Xiaomi, Lenovo discussed maximum UL transmission segment duration without applying adjusted TA for PUSCH or PRACH depends on the delay drift rate. Huawei, Vivo, CATT, Sony, MediaTek, Spreadtrum, FGI, Ericsson, ZTE discussed UL segment duration is based on maximum timing transmit error Te (80\*Ts=2.6 us for NB-IoT, and 24\*Ts=0.78 us for eMTC).

Qualcomm proposed the UL transmission segment duration is based the satellite orbit type, with longer segment duration for GEO than for LEO. For RACH, the number of coherent repetitions/preamble repetition units can be indicated on SIB. For PUSCH, the number of coherent repetitions for pre-compensation may be indicated via dedicated unicast signalling (UE may send assistance information to the network, e.g., indicating its mobility pattern and speed).

Huawei proposed that the maximum allowed time-continuous transmission is based on the common TA rate and the worst case of UE-specific TA rate in a cell, which can be indicated by the network.

Nokia proposed Segment length and transmission gap within the PUSCH transmission period is calculated by using equation below, where N is the segment length, Tunit is the time unit, Nsegment is the number of segments in X, and W is the adjustment gap.

Mediatek proposed UL transmission segment Tsegment defined below, where Time units is Tslot = 15360.Ts for Δf=15 kHz; 61440.Ts for Δf=3.75 kHz, and value of K, Tsegment,max are configured. In an example below, with SCS=15kHz, 12 sub-carriers, 2 RUs, 8 Repetitions, the repetition boundary is at the beginning of sf4/sf8/sf12 and UL transmission segment Tsegment can be chosen to be K \* 4ms = 8 ms which corresponds to a value of K equal to 2 – i.e. UL gap is inserted between end of SF7 and beginning of SF8. Tsegment can be configured differently based on the numerology as shown in Table below.



*Example of NPUSCH pattern with SCS=15 kHz, 12 subc, 2 RUs, 8 repetitions [6]*

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Δf [kHz]** |  |  |  | **TRU** |  |  | **Tslot** | **Tsegment** | **Tgap** |
| 15 | 12 | 2 | 7 | 1 ms | 8 | 4 | 0.5 ms | K\*4 ms | 1 ms |
| 15 | 6 | 4 | 7 | 2 ms | 8 | 4 | 0.5 ms | K\*8 ms | 1 ms |
| 15 | 3 | 8 | 7 | 4 ms | 8 | 4 | 0.5 ms | K\*16 ms | 1 ms |
| 15 | 1 | 16 | 7 | 8 ms | 8 | 1 | 0.5 ms | K\*8 ms | 1 ms |
| 3.75 | 1 | 16 | 7 | 32 ms | 8 | 1 | 2 ms | K\*32 ms | 1 ms |

*Numerology examples for the UL transmission segments Tsegment for NB-IoT NTN [6]*

CATT showed examples of duration of UL transmission segment of N time units based on numerology for NB-IoT as shown in Table below [5]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **NPUSCH format** |  |  |  | **RU duration(ms)** | **N（ms）** | **N（slot）** |
| 1 | 3.75 kHz | 1 | 16 | 32 | 32 | 16 |
| 15 kHz | 1 | 16 | 8 | 8、16 | 16、32 |
| 3 | 8 | 4 | 4、8、16 | 8、16、32 |
| 6 | 4 | 2 | 2、4、6、8、10、12、14、16 | 4、8、12、16、20、24、28、32 |
| 12 | 2 | 1 | 1、2、3、4、5、6、7、8、9、10、11、12、13、14、15、16 | 2、4、6、8、10  12、14、16、18、20、22、24、26、28、30、32 |
| 2 | 3.75 kHz | 1 | 4 | 8 | 8、16 | 4、8 |
| 15 kHz | 1 | 4 | 2 | 2、4、6、8、10、12、14、16 | 4、8、12、16、20、24、28、32 |

Time unit for duration of UL transmission segment of N time units for PUSCH

* Slot: Vivo, Samsung, CATT
* PUSCH repetition unit: Spreadtrum, MediaTek, NEC, CMCC
* 1 ms: CATT, SONY

Time unit for duration of UL transmission segment of N time units for PRACH

* preamble repetition unit: Huawei, Spreadtrum, Qualcomm, Samsung, CATT, NEC, MediaTek, CMCC

***Moderator view****: Based on company analysis, moderator understanding is that the duration of UL transmission segment depends on the delay drift and the numerology. Several companies proposed the time unit can be based on the PUSCH repetition unit or PRACH preamble repetition unit. The UL transmission segment duration can be configured and configuration may depend on the type of constellation (GEO or LEO)..*

The initial proposals 4.2.2-1 and 4.2.2-2 were revised as discussed in first GTW Session

***Revised Initial Proposal – Section 4.2.2-1:***

***Duration of UL transmission segment for UE pre-compensation for PRACH transmission is a number of preamble repetition units***

* ***FFS: Precise definition of repetition unit***

***Revised Initial Proposal – Section 4.2.2-2:***

***Duration of UL transmission segment for UE pre-compensation for PUSCH transmission is a number of PUSCH repetition units***

* ***FFS: Precise definition of repetition unit***

***Initial Proposal – Section 4.2.2-3:***

***Is it company understanding that***

* ***Q1: The duration of UL transmission segment of N time units depends on the delay drift, elevation, and the numerology?***
* ***Q2: The duration of UL transmission segment should be configured to be consistent with the transmit timing error Te for NB-IoT and eMTC?***
* ***Q3: The configuration of duration of UL transmission segment can be specified by***
  + ***Formulation for UL transmission segment duration and transmission gap can be provided in the specifications (e.g. Nokia, MediaTek formulas).***
  + ***Tables with UL transmission segment duration values (e.g. CATT, MediaTek).***

|  |  |
| --- | --- |
| Companies | Comments |
| ZTE | Firstly, w.r.t the definition of repetition unit, to ensure the performance for coherent processing, the repetition unit can be considered as the segement length by taking the definition in legacy specification, e.g., P symbol groups for NPRACH and RU(s) for NPUSCH. However, for eMTC case, different unit as subframe can be used.  Q1: Yes. In our view, the duration of segement can be scenario and configuration dependent. Otherwise, the requirement for BS performance can not be defined.  Q2: Yes. The tolerable range of timing error can be reference for segment length determination.  Q3: We are not supportive for both options. In our view, we only need to specify the simply signaling to configure the segment length along with potential new UL gap since in current specification, the determination of numerology and pusch/PRACH format is done from begining. |
| vivo | No matter what the time unit is, the duration (ms) of UL transmission segment for PUSCH cannot exceed 27.9ms for NB-IOT over NTN, and 7.5ms for eMTC over NTN.  Q1: Yes.  Q2: Yes.  Q3: The maximum duration of segment can also be calculated based on the transmit timing error T\_e. However, the suitable duration of segment could be calculated by the actual delay draft. Considering the flexibility, the duration value should be able to cover NTN scenarios.  Furthermore, due to closely connection between UL transmission segment and new UL gaps, we think the design of duration could be joint considered with the discussion of new UL gaps in 4.2.3. |
| MediaTek: | On definition of repetition Unit:  For RACH:   * For NB-IoT, Repetition unit is based on P symbol groups for NPRACH as specified in 36.211 Section 10.1.6.1. It is 5.6ms, 6.4ms and 19.2ms length for format 0, 1, 2 respectively;  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | Preamble format |  |  |  |  |  | | 0 | 4 | 4 | 5 |  |  | | 1 | 4 | 4 | 5 |  |  | | 2 | 6 | 6 | 3 |  | 3 |  * For eMTC, Repetition unit is based as specified in 36.211 Section 5.7.1. It is 0.9671 ms, 1.48 ms, 1.80 ms, 2.28 ms for format 0, 1, 2, 3 respectively  |  |  |  | | --- | --- | --- | | Preamble format |  |  | | 0 |  |  | | 1 |  |  | | 2 |  |  | | 3 |  |  | | 4 (see Note) |  |  | | NOTE: Frame structure type 2 and special subframe configurations with UpPTS lengths and only assuming that the number of additional SC-FDMA symbols in UpPTS X in Table 4.2-1 is 0. | | |   For PUSCH:  For NB-IoT, Repetition unit is based on RUs (TS 36.211 Section 10.1.2.3) and M\_identical^NPUSCH (TS 36.211 section 10.1.3.6). Values of RU depend on the numerology  **Resource units are used to describe the mapping of the NPUSCH to resource elements. A resource unit is defined as  SC-FDMA symbols in the time domain and consecutive subcarriers in the frequency domain, where  and  are given by Tables 10.1.2.3-1 and 10.1.2.3-2 for frame structure types 1 and 2, respectively.**   |  |  |  |  |  | | --- | --- | --- | --- | --- | | 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 |   After mapping to slots, the  slots shall be repeated  additional times, before continuing the mapping of  to the following slot, where    To our understanding, this mean the repetition unit is for NB-IoT  **For eMTC, repetition unit is based on RUs (TS 36.211 Section 5.2.3 and 5.2.3A)**  **A physical resource block is defined as consecutive SC-FDMA symbols in the time domain and consecutive subcarriers in the frequency domain, where  and  are given by Table 5.2.3-1.  A physical resource block in the uplink thus consists of  resource elements, corresponding to one slot in the time domain and 180 kHz in the frequency domain.**   |  |  |  | | --- | --- | --- | | Configuration |  |  | | Normal cyclic prefix | 12 | 7 | | Extended cyclic prefix | 12 | 6 |   **Resource units are used to describe the mapping of PUSCH using sub-PRB allocations to resource elements for BL/CE UEs. A resource unit is defined as SC-FDMA symbols in the time domain and consecutive subcarriers in the frequency domain, where and are given by Table 5.2.3A-1.**   |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | | **Physical channel** |  | **Modulation scheme** |  |  |  |  | **Comment** | | PUSCH | 15 kHz | π/2-BPSK | 12 | 3 | 16 | 7 | 2 out of 3 subcarriers used | | QPSK | 3 | 8 |  | | 6 | 4 |  |   To our understanding, this mean the repetition unit is for eMTC, where Tslot = 0.5 ms. For PRB allocation, there are 2 slots per subframe. |
| Intel | Q1: Yes  Q2: Yes  Q3: Duration of segment can be indicated by the gNB directly |
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### New UL gaps for long UL transmission

Huawei, Vivo, spreadtrum, NEC, Apple, ZTE, MediaTek, Lenovo support new UL gaps for long UL transmission.

ZTE observed additional complexity on the UE is needed to achieve the UE implementation with sampling rate adjustment in device to avoid phase discontinuity. If the phase discontinuity is needed to be handled, introduction of new UL gap is preferred.

Xiaomi proposed UE-specific TA calculation based on the timing drift rate for UE pre-compensation during long UL transmission should be supported. Use of valid UE-specific TA calculation based on GNSS-acquired UE position and serving satellite ephemeris can also be used. Segmented UE pre-compensation of satellite Doppler shift is not needed as assuming a transmission time of 1 second, max Doppler shift variation can be 0.54Hz in S band.

CATT mentioned the new UL gaps will cause slot misalignment for (N)PUSCH, if the length of new UL gaps is not the integer of a slot. If enforcing slot alignment, the new UL gaps will cost too much time resource. For small TA change, TA can be updated with implementation way, instead one gap insertion. For larger TA variation, small gap configuration should be considered, for example, reserving last symbol for one slot for TA gap.

***Moderator view****: There is partial consensus on need for new UL gaps with minimum UL transmission segment duration driven by the phase discontinuity issue and the maximum UL transmission segment duration driven by the satellite delay drift. Implementation solution to apply the UE pre-compensation during UL transmission segment may not be support by device hardware and may have high complexity.*

***Initial Proposal – Section 4.2.3:***

***Companies are encouraged to to align understanding on the need for new UL gaps for segmented UE pre-compensation. In particular, indicate whether introduction of new UL gaps should be supported / not supported in the specification.***

|  |  |
| --- | --- |
| Companies | Comments |
| ZTE | In general, we are supportive on the new UL gaps.  In our view, with this new gap, at least, the overlap of adjacent segments due to TA variance can be avoided and the potential impacts on the PAPR due to phase discontinuity can be fully alleviated. |
| vivo | If reuse the legacy UL gap mechanism in NTN, the accumulated error would easily exceed the transmit timing error T\_e after long continuous transmission. Hence, the legacy UL gap mechanism needs to be enhanced, or consider a new UL gaps mechanism. At least, more gaps should be configured for frequent timing synchronization during long continuous transmission.  With more gaps, as depicted in our contribution, the overlapping between two adjacent segments and the phase discontinuity issue can be easily handled. |
| MediaTek | New UL gaps are needed for issues of   1. satellite delay drift breaking timing transmit error Te (80\*Ts=2.6 us for NB-IoT, and 24\*Ts=0.78 us for eMTC); 2. phase discontinuity impact on demod performance if UE pre-compensation done within UL transmission segment, and also voiding segment overlapping with potential impact on PAPR. |
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# DL Synchronization

## Background

In RAN#92e, the following objective was agreed in the Rel-17 IoT NTN WID [1]

*Specify the following time and frequency synchronization enhancements that are not covered by NR\_NTN\_Solutions WI agreements, according to Section 8 in TR 36.763:*

* *DL synchronization enhancements: A single solution will be selected between: new channel raster, (part of) ARFCN-indication-in-MIB.*

## Company views

### Down-selection of solution for DL synchronization

Huawei, CATT, MediaTek, FGI, Intel, Apple, ZTE, Xiaomi, Lenovo support new channel raster with step size greater than 100 kHz for DL synchronization in IoT NTN.

Ericsson observed RAN4 input is needed before increasing the channel raster size. Multiple hypotheses testing may be needed if ARFCN-indication-in-MIB is used, It is proposed that RAN1 should (i) investigate DL synchronization performance for NB-IoT and eMTC NTN; (ii) compare the pros and cons of increasing the channel raster step size and introducing ARFCN-indication-in-MIB.

Qualcomm observed increasing the channel raster step size limits possible Ncell deployments for operators – e.g. if the raster step size is doubled, the number of Ncells that an operator can deploy within their allocated spectrum reduces by half. The MIB in NB-IoT already indicates a channel raster offset to aid the UE accurately determining the frequency of the Ncell.

Qualcomm proposed to indicate a portion (e.g., some of the least significant bits) of the ARFCN in the MIB for NB-IoT over NTN.

ZTE provided some analysis on DL synchronization with increased channel raster size, evaluations on the DL synchronization performance with pre-compensation of beam-level common frequency shift for all scenarios. The simulations show that robust DL synchronization performance including detection probability, synchronization latency and residual frequency offset can be achieved for all targeted scenarios.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Scenarios for all satellite parameters | | Set-1 | Set-2 | | Set-3 | |
| SNR (dB) | | 3 | -3.7 | | -2.1 | |
| Detection probability | | 100% | 100% | | 100% | |
| Synchronization Latency (50th percentile) | | 10ms | 20ms | | 20ms | |
| Synchronization Latency (90th percentile) | | 10ms | 90ms | | 20ms | |
| Synchronization Latency (95th percentile) | | 10ms | 105ms | | 60ms | |
| Synchronization Latency (100th percentile) | | 20ms | 220ms | | 200ms | |
| Residual frequency offset (95th percentile) | | -150Hz~150Hz | -235Hz~235Hz | | -240Hz~240Hz | |
| SNR and RFO for different satellite scenarios | BLER (no repetition) | | | BLER (8 repetitions of PDSCH) | |
| 3dB, 150Hz (Set-1) | 0.7% | | | 0.05% | |
| -3.7dB, 235Hz (Set-2) | 5.4% | | | 0.95% | |
| -2.1dB, 240Hz (Set-3) | 3.5% | | | 0.6% | |

BLER performance for NPDSCH with residual frequency offset [14]

***Moderator view: In order to obtain consensus on a single solution, the pros and cons of increasing the channel raster step size and introducing ARFCN-indication-in-MIB. To the moderator understanding, pros and cons in terms of RRM, cell measurement, cell deployment, detection latency and performance, power consumption, system robustness and simplicity, and so on could be discussed.***

***Initial Proposal – Section 5.2.1:***

* ***What are the pros and cons of increasing the channel raster step size and introducing ARFCN-indication-in-MIB***

|  |  |
| --- | --- |
| Companies | Comments |
| ZTE | In our view, enhancing the channel raster is straightforward way with benefits to enable the successful detection of synchronization signal and preliminary frequency offset estimation, which have been justified in our contribution. For ARFCH-indication-in-MIB method, with correct estiation on the frequency offset, the UE may not be able to detect the MIB for cell access. |
| Eutelsat | This response aims to set out some points to be considered from an operator perspective.  As we understand it, the legacy 100 kHz raster for NB-IoT was chosen to ensure that there are were a “sufficient number of cell frequencies” available for operators in their allocated (terrestrial) spectrum. A similar argument could apply to NTN. The number of centre frequencies available for deploymenmt would scale by: new raster in kHz/100 kHz – so for 200 kHz there are half the number of deployable frequencies.  Any NB-IoT device that supports NTN should also support operation on a terrestrial network (i.e., no need for two devices per asset NTN/ TN). A device may move between NTN and TN coverage so an initial search at 100 kHz may be required in any event.  Scaling with frequency – Doppler scales with frequency all else being equal. A raster based solution may therefore also need to scale? An ARFCN based solution could scale with frequency – 1 bit in the MIB for ‘odd’ or ‘even’ ARFCN number would suffice as an alternative to 200 kHz; more bits may be needed to support higher frequency.  Battery life and keeping the device low complexity are very important for NB-IoT. We would like to understand what impact the choice might have between the proposed options. |
| MediaTek | Channel raster is simple way and avoids issues with cell search / cell measurements for neighbour cells. NB-IoT channel bandwidth is 200 kHz. To our understanding, the new channel raster should not have any impact on capacity and cell deployment due to centre of frequencies being a multiplier of 200 kHz instead of 100 kHz. |
| Intel | We prefer increased channel raster solution for simplicity. |
| Sateliot | Agree with Eutelsat views.  While the channel raster solution may be simpler, it is important to understand if this comes with any limitations in terms of NB-IoT cell deployment flexibility, specially in scenarios with a reduced amout of continuous spectrum available for operating a single or a few NB-IoT carriers. |
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### DL frequency pre-compensation

CATT observed that for the reduction of total frequency error, one direction is to extend the requirement of the oscillator error, but it may cause higher cost of IoT device. Another direction is to reduce the residual Doppler shift. The Doppler shift experienced on the feeder links is perfectly compensated by the NTN GW, and one common Doppler shift of service link will be also compensated. The maximum residual Doppler shift is associated with the frequency offset between the reference point and beam edge. If the residual Doppler shift is still large, increasing the raster size would be one fall-back solution. In the initial access, in order to help UE to acquire frequency center point and avoid mis-judgement, increasing the raster size is necessary, which can improve the tolerance capability to frequency error.



Huawei observed that the differential Doppler frequency can be up to +/-39.9 kHz with set-4 LEO-600. Besides, with 20 ppm oscillator error at UE, there could be extra frequency offsets as +/-40 KHz. In addition, extra frequency offset due to gNB’s oscillator error will exist. The total uncertainty on DL raster exceeds half of 100 kHz channel raster of terrestrial NB-IoT/eMTC, which would cause error in (N)Cell frequency selection.

|  |  |  |  |
| --- | --- | --- | --- |
| **Satellite** | **Set 3** | **Set 3** | **Set 4** |
| **Satellite orbit** | LEO-1200 | LEO-600 | LEO-600 |
| **Satellite altitude** | 1200 km | 600 km | 600 km |
| **Central beam edge elevation** | 30 degree | 30 degree | 30 degree |
| **Central beam center elevation** | 46.05 degree | 43.8 degree | 90 degree |
| **Beam diameter size** | 1110.09Km | 610.8Km | 1701.8Km |
| **Differential Doppler** | +/-21.56KHz | +/-21.14KHz | +/-39.9KHz |

Differential Doppler of set3 and set4 with 2GHz central frequency [Huawei R1-2102344]

Huawei discussed DL frequency pre-compensation is needed for reducing the complexity and power consumption of IoT devices

Huawei, Xiaomi support DL frequency pre-compensation and indication of DL frequency pre-compensation normalized to the subcarrier spacing.

***Moderator view****: To the moderator understanding, whether DL common frequency pre-compensation is applied by the network or not would still require a solution for DL synchronization due to the very large beam diameter sizes in IoT NTN. DL common Doppler precompensation and its indication by the network is under discussion in NTN NR WI. To avoid duplication of discussion, RAN1 should postpone discussion in IoT NTN WI and wait until this issue is resolved in NR NTN WI.*

***Initial Proposal – Section 5.2.2:***

***Companies are encouraged to to align understanding on the need for DL common frequency pre-compensation***

***Q1: A solution for DL synchronization is needed even if DL common frequency pre-compensation is applied by the network?***

***Q2: Should RAN1 postpone discussion in IoT NTN WI and wait until DL common frequency pre-compensation discussions have concluded in NR NTN WI?***

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| Companies | Comments |
| ZTE | It’s not clear what does the DL common frequency pre-compensation refer in this proposal. Is it similar as the solution proposed in NR, e.g., indicating DL frequency pre-compensation? If so, please find the replies below. Otherwise, more clarification is needed before discussion.  Q1: According to our intiail evaluation results (submitted in this meeting), with increased channel raster, the performance for initial access and following reception of DL PDSCH can be ensured. Then, it seems that no need to introduce new solution. For other purpose, e.g., to facilitate the beam switching, replies are listed in Q2.  Q2: No need. In NR-NTN, companies may try to optimize the performance for continuous transmission including fast beam switching. However, in IoT case, the needs for beam switching is still pending and corresponding justification is no longer valid. |
| MediaTek | DL common frequency pre-compensation is as in NR NTN discussion indicating DL frequency pre-compensation  Q1: DL synchronization solution would be needed anyway even if DL common frequency pre-compensation is done by the network (i.e. new channel raster, (Part-of) ARFCN-indication-in-MIB)  Q2: No need, RAN1 could conclude there is no need for DL common frequency pre-compensation on service link by the network in IoT NTN |
| Intel | Q1: Yes  Q2: In our view the main issue for pre-compensation of service link Doppler is RRM and handover, this issues can be discussed in parallel for IoT and NR. |
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# Synchronization aspects common to IoT NTN and NR NTN

## Background

In RAN#92e, the following objective was agreed in the Rel-17 IoT NTN WID [1]

*Specify the following time and frequency synchronization enhancements, using NR\_NTN\_solutions WI agreements as baseline, according to Section 8 in TR 36.763:*

*- UE pre-compensation including ephemeris format (orbital / Position -Velocity)*

*- UE pre-compensation for UL synchronization in RRC\_IDLE and RRC\_CONNECTED states based at least on its GNSS-acquired position and the serving satellite ephemeris*

*- Timing advance formula (granularity of the timing advance may be different)*

*- Combination of Open (i.e. UE autonomous TA estimation, and common TA estimation) and Closed TA (i.e., received TA commands) control loops in RRC\_CONNECTED state*

*Agreements on the above are up to the decision in NR\_NTN\_Solutions WI and will be used for IoT NTN with minimum changes, if any.*

## Company views

Spreadtrum, Qualcomm, MediaTek, FGI, CMCC, Intel, Xiaomi, Lenovo, InterDigital made proposals to re-use NR NTN agreements for IoT NTN.

***Moderator view****: the issues of time and frequency synchronization where NR NTN concluded discussions, the agreements can be re-used with minor adjustments if needed. We list below these agreements from NR NTN*

The following greement was made in frst GTW Session

Agreement:

The following agreements from NR NTN are re-used for IoT NTN as working assumption.

1. The Doppler shift over the feeder link and any transponder frequency error for both Downlink and Uplink is compensated by the GW and satellite-payload without any specification impacts in Release 17.
2. The orbital propagator model to be used at UE side can be left to implementation
3. Timing Advance formula can be transposed to IoT-NTN with Ts used instead of Tc

The Timing Advance applied by an NR NTN UE in RRC\_IDLE/INACTIVE and RRC\_CONNECTED is given by:

Where:

* is defined as 0 for PRACH and updated based on TA Command field in msg2/msgB and MAC CE TA command.
  + FFS: details of NTA update/accumulation.
* is UE self-estimated TA to pre-compensate for the service link delay.
* is network-controlled common TA, and may include any timing offset considered necessary by the network.
* with value of 0 is supported.
  + FFS:  details of signaling including granularity.
* is a fixed offset used to calculate the timing advance.

Note-1: Definition of  is different from that in RAN1#103-e agreement in NR NTN WI.

Note-2: UE might not assume that the RTT between UE and gNB is equal to the calculated TA for Msg1/Msg A.

Note-3:  is the common timing offset X as agreed in RAN1 #103-e in NR NTN WI.

1. Support the delivery of ephemeris information using both ephemeris formats, i.e., state vectors and orbital elements

* Set 1: Satellite position and velocity state vectors (position/velocity)
  + Position X,Y,Z in ECEF (m)
  + Velocity VX,VY,VZ in ECEF (m/s)
* Set 2: Parameters in orbital parameter ephemeris format
  + Semi-major axis α [m]
  + Eccentricity e
  + Argument of periapsis ω [rad]
  + Longitude of ascending node Ω [rad]
  + Inclination i [rad]
  + Mean anomaly M [rad] at epoch time to
  + FFS: Whether pre-provisioned ephemeris based on orbital elements can be used as reference. Thereby, only delta corrections can be broadcast in order to reduce the overhead

1. For TA update in RRC\_CONNECTED state, combination of both open (i.e. UE autonomous TA estimation, and common TA estimation) and closed (i.e., received TA commands) control loops shall be supported for IoT-NTN

The initial agreement 6.2.1 was revised following first GTW Session.

***Revised Initial Proposal – Section 6.2.1:***

***The following agreement from NR NTN is re-used for IoT NTN as working assumption.***

* ***In Rel-17 IoT-NTN, at least support UE which can compute timing and frequency based on its GNSS position and serving satellite ephemeris signalled by the network and apply timing advance and frequency adjustment in RRC\_IDLE, RRC\_INACTIVE and RRC\_CONNECTED modes***

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| Companies | Comments |
| ZTE | We are supportive of the intention for this proposal. In our view, the main purpose is to confirm that the location based solution will be used for pre-compensation in IoT-NTN. Then, following updates can be considered as conclusion:  Conclusion:  *In Rel-17 IoT-NTN, at least support UE which can compute timing advance and frequency adjustment for serving link based on its GNSS position and serving satellite ephemeris signalled by the network and apply corresponding timing advance and frequency adjustment in RRC\_IDLE~~, RRC\_INACTIVE~~ and RRC\_CONNECTED modes* |
| MediaTek | We agree with ZTE proposed wording |
| Intel | Support the proposal. Changes proposed by ZTE are OK except title: we prefer to make agreement instead of conclusion. |
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# Conclusions

TBA

# References

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20. R1-2105825, Asia Pacific Telecom, Time and frequency synchronization to NB-IoT in NTN, RAN1#105-e, May 2021

# Appendix

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| Contribution | Observation/Proposals |
| Huawei (R1-2106485) | ***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***: *The phase discontinuity is predictable and can be compensated at the UE side.*  ***Observation 4***: *TA pre-compensation by sampling frequency adjustment at UE side will introduce extra complexity and power consumption at UE side.*  ***Observation 5:*** *The variation of sampling frequency adjustment for TA compensation may not be able to be handled by UE due to the hardware limitations.*  ***Observation 6:*** *RAN1 clarifies whether GNSS measurement has any specification impact for IoT-NTN UEs in RRC CONNECTED mode for sporadic short transmission.*  ***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****: The maximum allowed time-continuous transmission is based on the common TA rate and the worst case of UE-specific TA rate in a cell.*  ***Proposal 4:*** *Indicate* *time-continuous repetition number for preamble and time-continuous duration for UL data transmission in the system information for NB-IoT over NTN.*  ***Proposal 5:*** *Support indicating common TA drift rate in addition to common TA for UL TA adjustment in case of UL transmission with long duration.*  ***Proposal 6:*** *Sampling frequency adjustment at UE side with no UL gaps is not supported due to complexity and UE hardware limitations.*  ***Proposal 7****: For sporadic short transmission, the UE acquires satellite ephemeris before accessing the network and does not need to re-acquire it for the transmission of the packets.*  ***Proposal 8:*** *A validity timer for common TA can be indicated by the NW and RLF will be triggered once the timer expires at the UE.*  ***Proposal 9***: *Support introducing the new channel raster with step size greater than 100 kHz for DL synchronization in IoT NTN.*  ***Proposal 10:*** *DL frequency pre-compensation is needed for reducing the complexity and power consumption of IoT devices.*  ***Proposal 11:*** *The indication of DL frequency pre-compensation is normalized to the subcarrier spacing.* |
| VIVO (R1-2106633) | ***Observation 1****: The legacy mechanism that an UL gap is added after long UL transmission exceeding 256ms cannot be applied to IOT over NTN.*  ***Observation 2****: In order to not exceed the transmit timing error , timing re-synchronization is always needed once the continuous transmission exceeding 27.9ms for NB-IOT over NTN, and 7.5ms for eMTC over NTN.*  ***Proposal 1****: Support UE segmented pre-compensation of satellite delay and doppler shift per N time units.*   * *Indicate the value of N by network, and the time unit is slot.*   ***Proposal 2****: Support the enhanced UL gaps mechanism for timing and frequency segmented pre-compensation during UL transmission.* |
| Spreadtrum (R1-2104448) | ***Proposal 1****: UL timing compensation mechansim in RRC\_IDLE and RRC\_INACTIVE states of NTN WI can be reused in IoT NTN.*  ***Proposal 2****: UL timing compensation mechansim for RRC\_ CONNECED states UEs of NTN WI can be reused in IoT NTN.*  ***Proposal 3****: Reference point for autonomous acquisition of the TA at UE is located at the satellite in IOT NTN.*  ***Proposal 4****: In IOT NTN, the value of common TA defaults to 0.*  ***Proposal 5****: Both open and closed control loops are supported in connected mode for IOT NTN.*  ***Proposal 6****: Frequency compensation mechanism of NTN WI can be reused in IoT NTN.*  ***Proposal 7****: The Doppler shift over the feeder link and any transponder frequency error for both Downlink and Uplink is compensated by the GW and satellite-payload without any specification impacts in Release 17.*  ***Proposal*** *8: Close control loop for UL frequency alignment is not needed in IOT NTN.*  ***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.*  ***Proposal 13****: If GNSS becomes outdated in connected mode, UE should go back to idle mode and re-acquire a GNSS position fix.* |
| Qualcomm (R1-2106760) | ***Proposal 1****: The duration of the ephemeris validity timer is configured by the network.*  ***Proposal 2****: A UE starts the ephemeris validity timer upon reading the SIB carrying satellite ephemeris. The duration of valid ephemeris is counted starting from the first repetition of this SIB.*  ***Proposal 3****: Introduce a mechanism that triggers RLF when the ephemeris validity timer expires while in RRC\_CONNECTED mode.*  ***Proposal 4****: A UE initiates a GNSS validity period when it acquires a fresh GNSS position fix to obtain its geolocation.*  *- FFS whether the duration of this validity period is autonomously determined by the UE.*  ***Proposal 5****: Introduce a mechanism that triggers RLF when the UE’s GNSS-based geolocation validity expires.*  ***Proposal 6****: The duration of time for which the same pre-compensation value(s) for time and frequency is (are) are maintained depend on the satellite orbit type, with GEO satellites supporting longer durations of time than LEO satellites.*  ***Proposal 7****: Indicate in SIB, the number of coherent repetitions/preamble repetition units (i.e., the number of repetitions for which the UE may use the same pre-compensation values for time and frequency) associated with each PRACH preamble.*  ***Proposal 8****: For PUSCH, the number of coherent repetitions for pre-compensation may be indicated/negotiated between the network and the UE via dedicated unicast signalling. This may involve the UE sending assistance information to the network, e.g., indicating its mobility pattern and speed.*  ***Observation 1****: Increasing the channel raster step size limits possible Ncell deployments for operators. For example, if the raster step size is doubled, the number of Ncells that an operator can deploy within their allocated spectrum reduces by half.*  ***Observation*** *2: The MIB in NB-IoT already indicates a channel raster offset to aid the UE accurately determining the frequency of the Ncell.*  ***Proposal 9****: Indicate a portion (e.g., some of the least significant bits) of the ARFCN in the MIB for NB-IoT over NTN.*  ***Proposal 10****: Among aspects that depend on NR-NTN agreements, thus far, only the Timing Advance formula can be transposed to IoT-NTN; other aspects need further convergence in NR-NTN.* |
| SONY (R1-2106823) | ***Observation 1****: Closed loop TA commands can be sent in IoT-NTN for a “sporadic short transmission” traffic model.*  ***Observation 2****: The maximum rate of change of flight time between UE and eNodeB is ± 50s / sec.*  ***Observation 3****: The cyclic prefix budget for time misalignment can be exceeded within 9.4ms.*  ***Observation 4****: Timing misalignment during long PUSCH transmissions leads to phase discontinuity for single subcarrier transmissions.*  ***Observation 5****: From the perspective of phase continuity, the timing of UL transmissions needs to be corrected at least every 8 subframes.*  ***Proposal 1****: 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 2****: IoT-NTN supports segmented UL transmissions for long PUSCH and PRACH transmissions. Each segment of the UL transmission may have a different timing advance value applied.*  ***Proposal 3****: The UE updates the timing of its PUSCH transmissions every ‘N’ ms, where ‘N’ is less than or equal to 8ms.*  ***Proposal 4****: The validity time of the ephemeris information is signalled in system information.*  ***Proposal 5****: Once the validity timer for satellite ephemeris information has expired, it should be possible for the UE to refresh its ephemeris information without dropping the connection.* |
| Samsung (R1-2106920) | ***Proposal 1****: Common TA should be indicated to cover the roundtrip delay between Satellite and Gateway at least for position based TA estimation.*  ***Proposal 2****: Reporting of UE’s estimated TA should be supported at least during initial access.*  ***Proposal 3****: For segmented UE pre-compensation per N time units, the value of N is configured by network or determined according to delay/frequency drift.*  ***Proposal 4****: For segmented UE pre-compensation per N time units, the value of N can be different for UL timing pre-compensation and UL frequency pre-compensation, e.g., separately configured by network.*  ***Proposal 5****: For segmented UE timing pre-compensation, if signal is overlapped between different TA segments, the last one is dropped.* |
| CATT (R1-2107018) | ***Observation 1****: The new UL gap for long UL transmission will cause slot misalignment for (N)PUSCH, if the length of new UL gap is not the integer of a slot.*  ***Observation 2****: UE don't need validity timer for reading the SIB for short, sporadic connections, but validity timer may be useful for long connection state and for high-speed mobile terminals.*  ***Observation 3****: UE may have the maximum initial frequency error more than 50KHz contributed by oscillator, Doppler shift and anchor carrier offset in S band.*  ***Proposal 1****: Segment based compensation configuration should consider timing misalignment error, UE complexity and gNB receiver performance.*  ***Proposal 2****: Time unit of N can be ms or slot for (N)PUSCH and can be preamble symbol group for (N)PRACH.*  ***Proposal 3****: The maximum value of N is 4ms or 8ms for PUSCH of eMTC, and the value of N is 1ms, 2ms and 3ms corresponding to Format 0, Format1&2 and Format3 for PRACH of eMTC.*  ***Proposal 4****: The maximum value of N is 32ms or 16slot at NPUSCH format1 of 3.75kHz SCS and single-tone, and the maximum value of N is 16ms in other formats. The value of N for NPRACH may be 5.6ms, 6.4ms and 19.2ms or 1.4ms, 1.6ms and 4.8ms.*  ***Proposal 5****: For small TA variation, TA adjustment is implemented by dropping tail samples of a segment or delaying a few samples for UL transmission.*  ***Proposal 6****: For large TA variation, the gap can be configured with*   * *Last symbol of a slot can be reserved for (N)PUSCH’s gap* * *Original GP is reused for (N)PRACH’s gap.*   ***Proposal 7****: Increasing channel raster in IoT NTN is supported.*  ***Proposal 8****: The UE triggers the GNSS measurement when it is waken up due to T3412 timer expiration, and then enter IoT active state after GNSS measurement.* |
| NEC (R1-2107047) | ***Proposal 1:*** *Support UL gaps during long transmission to avoid phase discontinuity between segments.*  ***Proposal 2:*** *Length of segment and gap between pre-compensation segments is configured by the network. Time unit is the same as the PUSCH/PRACH preamble repetition unit.*  ***Proposal 3:*** *Validity timer is set/reset upon acquiring information required for uplink synchronization.* |
| Nordic SC (R1-2107047) | ***Proposal-1:*** *Define up to [3] gap patterns, for up to [3] orbit height intervals.*  ***Proposal-2:*** *Increase the maximum step size for MAC-CE TA adjustment by factor being multiple of ratio between maximum terrestrial and non-terrestrial RTT.*  ***Proposal-3:*** *Validity timer for SIB ephemeris is configured by eNB with initial timer value X and timer is reset at least upon UE reading SIB with ephemeris*   * *a UE is not allowed to access network if value of validity timer x<Y, where Y is configured by eNB and x is real time timer value.* |
| MediaTek (R1-2107068) | GNSS measurements for sporadic short transmissions:  ***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.*  ***Observation 3****: GNSS acquired position with UE mobility up to 120 km/h is not significant factor for satellite TA tracking accuracy.*  ***Observation 4****: GNSS acquired position with UE mobility up to 120 km/h is not significant factor for satellite Doppler shift tracking accuracy.*  ***Proposal 1****: GNSS position fix is acquired by device before moving to RRC\_CONNECTED and is assumed to be valid for the duration of sporadic short transmission.*  ***Proposal 2****: Postpone discussion on validity of satellite ephemeris until this issue under discussion in NR NTN WI has been resolved.*  Long UL Transmission on PUSH:  ***Observation 5****: UL transmission segment must be in the order or smaller than 26 ms to be consistent with specified transmit timing error Te = 80\*Ts= 2.6us in TS 36.133 Table 7.20.2-1.*  ***Observation 6****: Assuming a UL transmission segment of several ms or 10 ms, the phase discontinuity could be in the order of several 10s of degrees, which would likely have significant impact on demodulation performance.*  ***Proposal 3****: UE pre-compensation of satellite delay is not applied during UL transmission segment.*  ***Proposal 4****: After transmissions of NPUSCH continuously of N time units in IoT NTN, a gap of NUL gap shall be inserted at a repetition boundary of PUSCH, Brep, where the PUSCH transmission is postponed.*   * *FFS value of – e.g. NUL gap = 1ms*   ***Proposal 5****: The pre-compensation for NPUSCH does not vary within an UL transmission segment Tsegment defined as*  *Time units is Tslot = 15360.Ts for Δf=15 kHz; 61440.Ts for Δf=3.75 kHz*  FFS configuration and value of K, *Tsegment,max*  ***Proposal 6:*** *After postponements due to RACH of time units in IoT NTN, a gap NUL gap shall not be inserted before continuing transmission of NPUSCH.*  Long UL Transmission on PRACH:  **Proposal 7**: *A gap of NUL gap ms* shall be inserted at a repetition boundary of PRACH determined by t*he minimum duration of PRACH equals to 5.6ms for format 0 and 6.4ms for format 1*.   * FFS value of *NUL gap* – e.g. *NUL gap* =1 ms   ***Proposal 8****: The pre-compensation for NPRACH does not vary within a block of N time units in IoT NTN, where N is an integer multiplier K of the minimum duration of PRACH equals to 5.6ms for format 0 and 6.4ms for format 1.*  • FFS configuration and value of K for NPRACH format 0 and format 1  DL Synchronization:  ***Proposal 9****: New channel raster of 200 kHz is supported.* |
| Nokia (R1-2107173) | ***Observation 1****: For IoT UE with reduced cost/complexity, GNSS may be not available or not accurate.*  ***Observation 2****: 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 3****: 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 4****: The history acquired GNSS/ephemeris will be out-of-date after some time because of e.g. UE movement or satellite perturbation.*  ***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****: GNSS measurement may be needed in CONNECTED mode, when GNSS information may get out of date.*  ***Observation 7****: Multiple IoT UE with different capability and channel status may request different GNSS measurement window.*  ***Observation 8****: The amount of TA value change during the 256 ms NPUSCH transmission period exceeds the maximum tolerance.*  ***Observation 9****: The size of segment “N time units” and the corresponding TA are related to the elevation angle.*  ***Observation 10****: Using TimeReferenceInfo-r15 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 eNB).*  ***Observation 11****: The phase error increases as the elevation angle decreases since the TA drift rate is higher at a lower elevation angle.*  ***Observation 12****: Accumulating phase error of SC-FDMA symbols occurs due to the TA drift in the IoT NTN scenarios.*  ***Proposal 1****: 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 2****: Considering non-simultaneous operation and power consumption for IoT UE, utilization of GNSS operation should be managed as less as possible in IoT NTN.*  ***Proposal 3****: 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-automatic pre-compensation, network assisted pre-compensation, and other possible solution, to avoid sync error.*  ***Proposal 4****: for T/F synchronization, the UE automatic pre-compensation and network assisted pre-compensatioin should be compared and further discussed to provide complete solution.*  ***Proposal 5****: 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 6****: 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 7****: Combination of UE automatic precompensation and network assisted precompensation should be added as one option in specification, to provide effective UL synchronization in all IoT NTN scenario, avoid GNSS issue on inaccuracy/interruption on IoT operation and to provide fast convergance of UL synchronization.*  ***Proposal 8****: Validity timer of GNSS and ephemeris should be supported and coordinated between UE and eNB.*  ***Proposal 9****: 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 10****: 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 and supported in Rel 17.*  ***Proposal 11****: GNSS measurement window for both initial access phace and in CONNECTED mode should be discussed.*  ***Proposal 12****: Overhead reduction should be considered for selection of GNSS measurement window and coordination between UE and eNB.*  ***Proposal 13****: 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 14****: 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 one option.*  ***Proposal 15****: TA change within the NPUSCH transmission period at different elevation angles should be considered to determine the segment length and TA adjustment gap.*  ***Proposal 16****: Segment length and transmission gap within the PUSCH transmission period is calculated by using equation below, where N is the segment length, Tunit is the time unit, Nsegment is the number of segments in X, and W is the adjustment gap.*  *N× T\_unit× N\_segment +  W × (N\_segment -1) = X*  ***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 TimeReferenceInfo-r15 is a feasible solution and should be standardized as well.*  ***Proposal 20****: Phase error in SC-FDMA should be compensated in the IoT NTN scenarios.*  ***Proposal 21****: UE should reduce the phase error by compensating the timing-drift-induced phase error in its modulation process based on the TA drift rate.*  ***Proposal 22****: alternatively, eNB receiver can modify the reference phase for demodulation to match the received symbol phase.* |
| OPPO (R1-2107247) | ***Proposal 1****: the NTN-NR timing advance formula can be reused with a change of the sampling interval.*  ***Proposal 2****: the common TA can be estimated by the UE based on a virtual reference point position.*  ***Proposal 3****: Doppler shift over service link is pre-compensated by the UE and Doppler shift over feeder link is handled by Gateway.*  ***Proposal 4****: for NTN-IoT release 17, open-loop TA updating seems enough.*  ***Proposal 5****: RAN1 does not consider GNSS measurement for UE in connected mode.*  ***Proposal 6****: the need for a GNSS validity timer shall be justified.* |
| FGI (R1-2107291) | ***Proposal 1****: Support the delivery of ephemeris information using both ephemeris formats, i.e., state vectors and orbital elements, where the format of state vectors shall be mandatorily provided.*  ***Proposal 2****: Reuse UE-specific TA to allow UE adjusting UL timing for long PUSCH and PRACH transmission.*  ***Proposal 3****: UE-specific TA is done per N time units for long PUSCH and PRACH transmission, where UE-specific TA does not vary within a block of N time units. FFS on N time units.*  ***Proposal 4****: UE is allowed to perform UE-specific TA when the initial transmission timing error per N time units is larger than Te\_NTN. FFS whether to reuse the legacy Te or introduce a new Te\_NTN.*  ***Proposal 5****: A validity timer for UL synchronization may not be needed.*  ***Proposal 6****: New channel raster with a step size increased to be greater than 100 kHz.*  ***Proposal 7****: RAN1 shall discuss whether a common frequency pre-compensation offset on the DL service link is needed.*  ***Proposal 8****: Validity of GNSS Measurements, e.g., a timer for GNSS measurement, may not be needed.* |
| CMCC (R1-2107430) | ***Proposal 1****: Support delivery of ephemeris information using both ephemeris formats, i.e., state vectors and orbital elements.*  ***Proposal 2****: Support serving-satellite ephemeris broadcast based on satellite position and velocity state vectors with high accuracy for a short-term.*  ***Proposal 3****: Support whole satellite constellation ephemeris broadcast based on orbital parameter ephemeris format with low accuracy for a long-term.*  ***Proposal 4****: Regarding phase discontinuity issue when applying segmented UE TA correction, there following can be further studied.*   * *Alt 1: adopt small block duration to reduce the phase discontinuity difference at each block boundary* * *Alt 2: adopt large block duration to reduce the frequency when phase discontinuity effect occurs* * *Alt 3: spec enhancement to keep phase continuity from TA correction action* |
| Intel (R1-2107619) | ***Proposal 1****: In Rel-17 IoT-NTN, at least support UE which can compute timing and frequency based on its GNSS position and serving satellite ephemeris signalled by the network and apply timing advance and frequency adjustment in RRC\_IDLE, RRC\_INACTIVE and RRC\_CONNECTED modes*   * *FFS: UE which can derive timing and frequency based on a reference time and frequency from GNSS and timestamp indication and reference signal transmission from a eNB*   ***Proposal 2****:*   * *Support Common TA indication by the network*    + *FFS: granularity of Common TA* * *Consider features for Common TA update overhead reduction to enable deployment with aligned DL/UL timing at the eNB*   + *Indication of Common TA drift rate*   + *Indication of reference point for Common TA calculation at the UE*   ***Proposal 3****: Support serving-satellite ephemeris broadcast based on the following*   * *Set 1: Satellite position and velocity state vectors (position/velocity)*   + *Position X,Y,Z in ECEF (m)*   + *Velocity VX,VY,VZ in ECEF (m/s)* * *Set 2: Parameters in orbital parameter ephemeris format*   + *Semi-major axis α [m]*   + *Eccentricity e*   + *Argument of periapsis ω [rad]*   + *Longitude of ascending node Ω [rad]*   + *Inclination i [rad]*   + *Mean anomaly M [rad] at epoch time to*   + *FFS: Whether pre-provisioned ephemeris based on orbital elements can be used as reference. Thereby, only delta corrections can be broadcast in order to reduce the overhead*   ***Proposal 4****: The following is assumed for IoT-NTN unless additional relevant agreements are made*   * *The orbital propagator model to be used at UE side can be left to implementation* * *The Doppler shift over the feeder link and any transponder frequency error for both Downlink and Uplink is compensated by the GW and satellite-payload without any specification impacts in Rel. 17*   ***Proposal 5****: For TA update in RRC\_CONNECTED state, combination of both open (i.e. UE autonomous TA estimation, and common TA estimation) and closed (i.e., received TA commands) control loops shall be supported for IoT-NTN*  ***Proposal 6****: Support new Channel raster with a step size increased to be greater than 100 kHz for NB-IoT NTN*  ***Proposal 7****: It is assumed that UE can predict the Doppler/Delay variation during long UL transmission with sufficient accuracy*   * *GNSS measurements and/or satellite ephemeris updates are not needed during the time of transmission*   ***Proposal 8****:*   * *The need for validity timer depends on the signalling design for satellite ephemeris; support of validity timer should be discussed in RAN2* * *Validity of GNSS position fix is up to UE implementation and/or RAN4 requirements/conformance tests* |
| Ericsson (R1-2107659) | ***Observation 1****: 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 2****: Before addressing the issue of phase discontinuity due to large timing drift, the severity of its adverse impacts such as high PAPR first needs to be determined.*  ***Observation 3****: 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 4****: RAN1/RAN4 need to discuss the maximum tolerable timing and frequency errors due to inaccurate satellite position information.*  ***Observation 5****: The accuracy requirements for satellite position information may vary depending on whether it is a serving or a neighbouring satellite.*  ***Observation 6****: The duration of validity timer needs to be configured depending on the specific satellite constellations.*  ***Observation 7****: An ephemeris validity timer can be defined for each individual satellite or for a group of satellites.*  ***Observation 8****: Further discussions are needed for the case where ephemeris validity timer expires during an ongoing connection.*  ***Observation 9****: RAN4 input is needed before increasing the channel raster size.*  ***Observation 10****: Multiple hypotheses testing may be needed if ARFCN-indication-in-MIB is used.*  ***Proposal 1****: 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 2****: RAN1 should discuss whether GNSS positioning in RRC\_CONNECTED state is to be supported by IoT NTN UE.*  ***Proposal 3****: RAN1 to use the agreed values of delay and Doppler shift drifts for the IoT NTN reference scenarios as a baseline for discussing the pre-compensation segment duration defined by N.*  ***Proposal 4****: RAN4 input is needed on the maximum transmit timing error requirements for IoT NTN.*  ***Proposal 5****: 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 6****: RAN1 should investigate DL synchronization performance for NB-IoT and eMTC NTN.*  ***Proposal 7****: RAN1 to compare the pros and cons of increasing the channel raster step size and introducing ARFCN-indication-in-MIB.*  ***Proposal 8****: Send an LS to RAN4 on time and frequency error requirements for IoT NTN before discussing the details of validity duration for GNSS position.* |
| Apple (R1-2107772) | ***Proposal 1****: In long PRACH or long PUSCH transmissions, introduce more frequent uplink gaps.*  ***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****: Support network to configure and indicate the validity timer of satellite ephemeris.*  ***Proposal 4****: UE needs to re-acquire satellite ephemeris when its validity timer expires.*  ***Proposal 5****: Consider increasing the channel raster step size in IoT NTN.*  ***Proposal 6****: Consider the validity of GNSS position fix based on the supported maximum UE speed.* |
| ZTE (R1-2107779) | ***Observation 1:*** *Increasing the channel raster up to 200 kHz is sufficient to provide robust performance for DL synchronization.*  ***Observation 2:*** *The PAPR increment due to phase discontinuity in segmented pre-compensation is acceptable even if no further enhancement is introduced.*  ***Observation 3:*** *Further improvement on the PAPR with proper configuration of segment length can be achieved.*  ***Observation 4:*** *Additional complexity on the UE is needed to achieve the UE implementation with sampling rate adjustment in device.*  ***Proposal 1:*** *Increasing the channel raster is preferred for DL synchronization.*  ***Proposal 2:*** *The configurable segment length should be supported to enable the segmented UL pre-compensation with applying one TA value per segment.*  ***Proposal 3:*** *The time unit of segmented pre-compensation should be slot for PUSCH and random access symbol group for PRACH.*  ***Proposal 4:*** *If the phase discontinuity is needed to be handled, new UL gaps is preferred.*  ***Proposal 5:*** *No extra enhancement for closed loop TA maintenance mechanism is needed in long connection.*  ***Proposal 6:*** *Gaps for GNSS position fix should be supported in RRC connected mode for long transmission.*  ***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:*** *Indication of valid time for assistance information broadcast from BS, e.g., ephemeris data, should be supported.*  ***Proposal 9:*** *The activation time instant of assistance information can be implicitly known as a reference time linked to DL subframe where the SIB carrying the assistance information is broadcast.*  ***Proposal 10:*** *The valid time length can be broadcast along with assistance information. A coarse signaling granularity can be applied, e.g., a SIB period.*  ***Proposal 11:*** *A validity timer should be supported for assistance information, and the followings apply for UE*   * *The validity timer is started/restarted once new assistance information is activated.* * *The time duration of validity timer is set according to indicated valid time from BS.* * *Upon expiry of the validity timer, the synchronization is thought lost and UE will re-access the network.* * *If the residual duration of validity timer is shorter than the time duration of following UL transmission, UE will postpone the access to network until new assistance information is activated.* |
| Xiaomi (R1-2107909) | ***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:*** *The value of N expressing validity period of TA should be configured by network.*  ***Proposal 4****: UE-specific TA calculation based on the timing drift rate for UE pre-compensation during long UL transmission should be supported.*  ***Proposal 5****: 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 (R1-2107942) | ***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 N\_TA based on closed loop and N\_(TA,UE-specific)+N\_(TA,common) 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.*  ***Proposal 5****: Two individual timers are introduced to determine the validity of uplink synchronization.*  ***Proposal 6****: For DL synchronization enhancement, new channel raster with a step size greater than 100 kHz (e.g., 300kHz) is introduced.* |
| InterDigital (R1-2108038) | ***Proposal-1****: Support N=1 subframe and no new UL gap for segmented UL transmission.*  ***Proposal-2****: Validity timer for satellite ephemeris is configured by network and UE needs to re-acquire the satellite ephemeris before the timer expires.*  ***Proposal-3****: Ephemeris format indication mechanism used for NR NTN is reused for IoT-NTN.* |