3GPP TSG RAN WG1 Meeting #106bis-e R1-2111375

e-Meeting, November 11th – 19th, 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

## Backround

In RAN1#106-e, the following agreement was made:

Agreement:

For sporadic short transmission, UE in RRC\_CONNECTED should go back to idle mode and re-acquire a GNSS position fix if GNSS becomes outdated.

There was no further agreement during RAN1#106bis-e on this issue. Moderator made recommendation as follows

## Company views

### In RRC\_IDLE:

Paging timers:

CMCC discussed for sporadic DL traffic, UE may perform GNSS measurements after a paging occasion and only if it has been paged to reduce battery consumption. GNSS measurement duration can be up to 10 seconds, which implies that after MME requests the lower layer to start paging, it may receive paging response after a long time (e.g., 10 seconds). In current specification (TS 24.301), to initiate high level paging procedure initiated by the MME, the EMM (EPS Mobility Managed) entity in the network requests the lower layer to start paging and shall start the timer:

* T3415 for this paging procedure, if the network accepted to use eDRX for the UE and the UE does not have a PDN connection for emergency bearer services.
* Otherwise, T3413 for this paging procedure.

T3413/T3415 is a supervision timer for the paging procedure. The MME can re-attempt the paging procedure if T3413/T3415 expires before a response is received.

Note that the expiry time of T3413/T3415 is implementation dependent and is not specified in 3GPP, network operator may configure expiry time of T3413/T3415 considering GNSS measurement duration (e.g., 10 seconds) impact in NTN scenario. Thus, for sporadic DL traffic, the existing timers (e.g., T3413/T3415) can be configured large enough to ensure a sufficient gap to accommodate GNSS acquisition after decoding the paging message and before initiating UL transmission.

CMCC proposed conclusion: Acquisition of GNSS position fix during paging procedure is up to UE implementation and network configuration of paging timers considering GNSS measurement duration (e.g. GNSS Time To First Fix with cold start of typically 10 seconds) impact in NTN scenario. These paging timers are not specified in 3GPP in legacy paging procedure (i.e. T3413 / T3415).



**Figure 1: Paging procedure using S-TMSI. (CMCC 2111633)**

CATT proposed 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.



Figure 2 GNSS signal reception and IoT UE wakeup (CATT R1-2111236)

GNSS measurement report:

Nokia proposed UE shall report GNSS measurement gap at prior occasion such that network can allocate sufficient time between sending a paging message and when to expect random access procedure initialization from UE. Network shall not repeat the paging message for a UE during the UE’s GNSS measurement gap.



Figure 1 Illustration of GNSS start delay in a paging scenario. (Nokia R1-2111276)

Time gap for GNSS measurements:

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.



Figure 7 Illustration on Time gap for GNSS measurement. (ZTE R1-2111662)

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| **Assumption for GNSS TTFF** | **GNSS TTFF** |
| Cold start | No valid ephemeris, almanac | < 30 seconds (first TTFF of GNSS module) |
| Warm start | Valid almanac if used at least once within 180 days of last TTFF | < 5 seconds (at least a few TTFF within 180 days for optimised prediction algorithms)Up to 30 seconds (un-optimized algorithms)  |
| Hot start | Valid ephemeris if used within 4 hours of last TTFF | < 1 second |

***Moderator view:*** *This issue was discussed extensively in RAN1#106bis-e.*

*Commenting companies have indicated timer-based mechanisms for UE to acquire GNSS measurements during paging procedure. GNSS measurement duration can be up to 10 seconds. After MME requests the lower layer to start paging, it may receive paging response after a long time (e.g., 10 seconds). The MME can re-attempt the paging procedure if T3413/T3415 expires before a response is received. Several approachs were proposed with UE performs GNSS Measurement each time UE wakes up from IDLE mode, time gap for GNSS measurements, or UE shall report GNSS measurement gap at prior occasion. To the moderator understand, a warm start with a valid almanac if used at least once within 180 days of last TTFF would be 5 seconds (longer could be assumed like 10 seconds to be safe). Hot start 1s may only be valid for 4 hours, and may not be possible when next satellite comes by after 4 hours. A tyoical 10 seconds can be assumption for the network for UE and can be configuration optimization when the feature is tested in the network. Since there was no consensus on specifying enhancements, it seems reasonable to use legacy solution with paging timers as proposed by CMCC and CATT..*

***Initial proposal – Section 2.2.1: Companies are encouraged to further on the proposed conclusion, and whether enhancements are needed in Rel-17.***

***Conclusion***

* ***Acquisition of GNSS position fix during paging procedure is up to UE implementation and network configuration of paging timers considering GNSS measurement duration (e.g. GNSS Time To First Fix with cold start of typically 10 seconds) impact in NTN scenario. These paging timers are not specified in 3GPP in legacy paging procedure (i.e. T3413 / T3415).***

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### In RRC\_CONNECTED:

GNSS position fix error:

MediaTek provide some analysis suggesting GNSS position fix can be valid for up to 30 seconds assuming high-velocity UEs and UE implementation mechanisms to mitigate position errors in most challenging high velocity scenarios. This is more than sufficient for “short transmission”. A typical in-coverage LEO satellite time is in the order of two minutes (Eutelsat R1-2106776). Within that time the UE could go to idle a maximum of 3 times to re-acquire GNSS position fix with a typical hot fix of 1 second. Assuming Suspend and resume procedure to move UE in RRC\_IDLE and back to RRC\_CONNECTED would add some latency of a few 100 ms seconds (in suspend/resume procedure, the UE context is stored in UE memory and eNB memory, so the RRC messages are minimum size).

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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 |

***Table 1****: TA tracking error due to UE mobility for elevation angle 30 degrees (MediaTek R1-2111373)*

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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 |

***Table 2****: Doppler shift tracking error due to UE mobility at Nadir (MediaTek R1-211133)*

GNSS position fix validity report:

Ericsson observed that the short connection can be defined by considering the validity durations of GNSS position fix, common TA (if indicated) and satellite ephemeris.

Ericson proposed to send an LS to RAN4 on time and frequency error requirements for IoT NTN before discussing the details of validity duration for GNSS position.

Huawei, Nokia proposed UE report its GNSS position fix validity duration to the network.

NEC proposed an internal timer in the device is used by UE to set the GNSS validity duration autonomously.The UE could signal the network the length of time that GNSS position fix is valid, and the GNSS position fix validity duration is determined by the UE at the time it is reported by the UE. MAC CE can be used by the UE to report the remaining valid duration of GNSS position fix.

CATT suggest UE reports its valid duration of GNSS position fix to gNB.

Huawei, Nokia proposed based on the UE reported GNSS position fix validity duration, the network can configure a measurement gap for a new GNSS position fix if the UE does not support simultaneous GNSS and NTN NB-IoT/eMTC operation.

Qualcomm proposed a UE initiates a GNSS validity period when it acquires a fresh GNSS position fix to obtain its geolocation.

* The duration of this validity period is autonomously determined by the UE.
* The start of validity period and validity duration is reported to the network by the UE.

Xiaomi proposed the duration of the GNSS position fix validation is autonomously determined by the UE. The GNSS position fix duration and the time of last GNSS position fix is reported to the network. If UE can maintain its RRC connection when performing the GNSS measurement, UE can trigger RLF or re-acquire GNSS position fix without releasing connection. Otherwise, the UE should directly release the RRC connection

Apple proposed UE autonomously determines the validity of GNSS position fix, based on UE’s mobility patterns (e.g., UE speed). UE reports GNSS position fix validity duration to network via high layer signaling (e.g., MAC CE). UE reporting GNSS position fix validity duration is event-triggered, e.g., when the GNSS position fix validity timer is less than a threshold. UE expects to receive a scheduling gap window from network after reporting GNSS position fix validity duration. UE suspends uplink transmissions and re-acquires GNSS position fix during this scheduling gap window.

It was discussed in discussed in Rel-17 IoT NTN Study Item that UE to re-acquire GNSS is via connected DRX in RRC\_CONNECTED or in eDRX in RRC\_IDLE. This seems straightforward way as in connected DRX or idle eDRX, all IoT operations are stopped which would be consistent with the assumption in the Rel-17 Study Item and Rel-17 Work Item of no simulataneous GNSS and IoT operations. In idle mode, a maximum eDRX of 43.69 min for eMTC and 2.91 hours for NB-IoT can be configured, where eDRX cycle consist of an integral multiple of length of a single H-SFN. The minimum eDRX cycle is 5.12 s for eMTC and 20.48 s for NB-IoT [Table 10.5.5.32, 5]. In connected mode, a maximum DRX of 2.56 s and a maximum eDRX of 10.24s can be configured in *MAC-MainConfig* information element. Rel-12 Power Saving Mode (PSM) with a maximum of 12.1 days can be configured with T3412 configuration.

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| **Connected UE**  | **Max DRX=2.56 s / eDRX = 10.24 s** |
| **Idle UE** | **Min eDRX = 5.12 s (eMTC) Min eDRX = 20.48 s (NB-IoT)** |
| **Max eDRX = 43.69 min (eMTC) Max eDRX = 2.91 hours (NB-IoT) Max PSM = 12.1 days (NB-IoT)** |

***Table 2****: Connected DRX, Idle DRX, PSM durations (MediaTek R1-2104568)*

It was discussed in discussed in Rel-17 IoT NTN Study Item that during long connections, GNSS fixes by connected UE for UE pre-compensation can be avoided by using closed-loop time and frequency corrections issued by the base-station. Potentially periodic, or prior to each uplink transmission, dedicated/contention-free NPRACH transmission from the UE, followed by a timing and/or frequency correction command are issued by the network in a response message. NPRACH resources with alternate starting subcarriers for NPRACH transmissions *robust* to time and frequency synchronization errors are used for the dedicated/contention-free NPRACH transmission. Reduction in power consumption penalty from GNSS fixing during a long connection can be achieved by replacing a GNSS fix with an NPRACH followed by a closed loop correction as illustrated in Figures below.



Figure 1: Relaxed GNSS fixing using (N)PRACH-based closed loop corrections (Qualcomm R1-2104823)

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Figure 2: Example of "restrictions" on starting NPRACH subcarriers for CBRA. Alternate starting subcarriers may be selected for NPRACH transmission by a UE. (Qualcomm R1-2104823)

Mechanisms to move UE to RRC\_IDLE if GNSS position fix outdated:

ZTE proposed if GNSS becomes outdated, UE in RRC\_CONNECTED declares RLF and move to RRC\_IDLE. There is no need to specify link recovery mechanism specifically for GNSS expiration. Report of GNSS validity duration should be supported to ensure common understanding between BS and UE. The rest validity duration after reporting time is reported.

MediaTek proposed RAN1 send LS to RAN2 to specify mechanism where

* if GNSS position fix becomes outdated, UE in RRC\_CONNECTED declares RLF and move to RRC\_IDLE
* Before GNSS position fix becomes outdated, UE in RRC\_CONNECTED sends Rel-16 MAC CE Release Assistance Indication to request network to move into RRC\_IDLE.

OPPO proposed RAN2 can further discuss and decide the procedure for the UE to go back to idle for GNSS acquisition.

* As GNSS measurements in idle/connected state is an important case which requires detailed discussions to make meaningful progress, we have no objection if any remaining discussions are deferred until the start of Release 18.

Intel proposed to rely on UE implementation for GNSS validity

* Before commencing an UL transmission, the UE shall ensure it has a GNSS position fix that is valid for the duration of that UL transmission
* If UE GNSS measurements are not valid UE declares RLF

Qualcomm proposed to introduce a mechanism that declares RLF when the UE’s GNSS-based geolocation validity expires.

* Details to be specified by RAN2.

CMCC proposed if GNSS becomes outdated, UE in RRC\_CONNECTED declares RLF and move to RRC\_IDLE. UE reports GNSS position fix validity duration to be used by network to move UE to RRC\_IDLE can be considered as an enhancement functionality.

* The rest GNSS position fix validity duration after the reporting may be reported.
* The report may be triggered by the network before UL transmission is scheduled.

Lenovo popose the network can optionally configure the following options for UE to acquire GNSS position fix for sporadic short transmission:

* UE performs GNSS Measurement each time it wakes up from IDLE mode even if the GNSS position fix keeps valid
* When UE wakes up from IDLE mode, if the GNSS position fix is outdated, or if the GNSS validity duration is valid but the remaining GNSS validity duration is less than a threshold, it performs GNSS Measurements

 If GNSS becomes outdated, UE in RRC\_CONNECTED declares RLF and move to RRC\_IDLE.

***Moderator view:*** *Commenting companies have indicated a preference if GNSS becomes invalid to move to idle, stay in connect, or trigger RLF. It was proposed that Before commencing an UL transmission, the UE shall ensure it has a GNSS position fix that is valid for the duration of that UL transmission. The short connection could be defined by considering the validity durations of GNSS position fix, common TA (if indicated) and satellite ephemeris. This can be in the order of up to 30 seconds (and would likely have to be at least shorter than 2 minutes because anyway the satellite is in coverage for typically up to 2 minues in LEO). For transmitting a typical IoT packet with a few hundred bits, a short transmission duration or 10 seconds or less should be fine in most cases.*

*Companies also discussed reporting the GNSS position fix validity duration to allow network and UE to have common understanding for either*

1. *Moving UE to RRC\_IDLE;*
2. *Scheduling a gap to allow UE to refresh its GNSS position fix.*

*There were also other ways discussed in the Study Item phase and in offline discussions during Work Item:*

1. *UE re-acquire GNSS in connected DRX*
2. *UE closed-loop time and frequency corrections issued by the base-station*

*Interpretation (i) for the GNSS report usage is consistent with RAN1#106-e agreement “For sporadic short transmission, UE in RRC\_CONNECTED should go back to idle mode and re-acquire a GNSS position fix if GNSS becomes outdated.”.*

*Interpretation (ii) for an UL scheduling gap using GNSS position validity report to network was discussed without consensus in RAN1#106bis-e due to expected large impact on RAN1 specifications and no time in RAN1 to discuss and make agreements within Rel-17 timeframe as many design aspects for an UL scheduling gap will need to be discussed - i.e. when to start/end/duration of gap), how to configure / indicate the gap, UE behaviour before the gap starts (drop / suspend UL transmissions, Ack of DL packets), maintain DL synchronization during/after gap if no simultaneous GNSS and IoT operation, preference for not making new GNSS measurements and instead use combination of Closed-loop timing adjustments and CFRA with Closed-Loop frequency correction to save power consumption and so on. RAN2 cannot specify a scheduling gap which is RAN1 expertise and scope. Scheduling gap enhancements to re-acquire GNSS in RRC\_CONNECTED can be deferred to Rel-18 as part of broader discussions on improved GNSS operations for long connection and high-velocity UEs.*

*Interpretation (iii) UE re-acquire GNSS in connected DRX would be straightforward where eNB can configure connected DRX and restrict scheduling according to the GNSS position fix validity. A Max DRX=2.56 s / eDRX = 10.24 would be more than suffieint time to allow UE to make a GNSS position measurement with a typical hot fix of 1 second. It has minimum impact on specifications since it is a legacy mechanism with only minimum adjustments needs based on GNSS position fix validity.*

*Interpretation (iv) has the advantage that UE may not use its GNSS module to re-acquire GNSS position fix after moving to RRC\_CONNECTED for the time the UE is in coverage of LEO satellite (about 2 minutes in typical LEO constellation). This is optimum for power consumption. The impact on specifications may be relatively higher than interpretation iii, but may be simpler and more flexible than interpretation ii since it is not needed to have a scheduling gap and simply send CFRA on configured resources and receive closed-loop frequency compensation for Doppler and MAC CE TAC for timing corrections in RRC\_CONNECTED..*

***Initial proposal – Section 2.2.2: Companies are encouraged to comment RAN1 send LS to RAN2 to specify solution to move UE to RRC\_IDLE when GNSS becomes outdated***

* ***RAN1 has discussed the following aspects and leaves it up to RAN2 to specify UE behaviour related to GNSS position fix validity and determine which of the following aspects are to be specified:***
	+ ***A new clause of RLF for GNSS becomes outdated to move UE to RRC\_IDLE and re-acquire GNSS***
	+ ***UE signalling to indicate the GNSS position validity duration is about to expire***
* ***It is up to UE implementation to determine if GNSS position fix becomes outdated***
* ***Long connection and high-velocity UEs were not prioritized in RAN1 discussions in Rel-17 IoT NTN. These more challenging scenarios of IoT NTN can be deferred to Rel-18 IoT NTN.***

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

***Companies are also encouraged to comment on usage and role of GNSS position fix duration report, on the use case (e.g. long connection and high velocity UEs, duration of sporadic short transmission), pros and cons of each way, on scope of potential enhancements and impact on RAN1 / RAN2 specification effort for interpretations i, ii, iii, and iv to use the report, and deferring these potential enhancements to Rel-18 as part of broader discussions on improved GNSS operations for long connection and high-velocity UEs.***

1. ***Moving UE to RRC\_IDLE***
2. ***Scheduling a gap to allow UE to refresh its GNSS position fix***
3. ***UE re-acquire GNSS in connected DRX***
4. ***UE closed-loop time and frequency corrections issued by the base-station***

***Companies can also comment on sending an LS to RAN4 on time and frequency error requirements for IoT NTN before discussing the details of validity duration for GNSS position.***

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# Validity timer for UL synchronization

## Background

The following agreements were made in RAN1#106e.

Agreement:

* Satellite ephemeris read on SIB are valid for the duration of sporadic short transmission in RRC\_CONNECTED.
* Common TA parameters if indicated and read on SIB are valid for the duration of sporadic short transmission in RRC\_CONNECTED.
* Note: The duration of the short transmission is not longer than the “validity timer for UL synchronization” referred to in the WID objective (but which still needs further discussion for specifying further details)

Agreement:

The validity timer of UL synchronization is configured by the network

* FFS: Whether a single validity timer or separate validity timers are used for satellite ephemeris and common TA parameters

Agreement:

UE in RRC\_IDLE reads the satellite ephemeris on SIB and the common TA parameters if indicated on SIB and (re-)start the validity timer(s) for UL synchronization before moving to RRC\_CONNECTED.

* FFS: Details of the precise (re-)start time for the validity timer for UL synchronization to ensure a common understanding between gNB and UE.
* Other signaling details for validity timer are up to RAN2

RAN1#106bis-e made the following agreements

Agreement:

The validity timer for UL synchronization is started/restarted with configured timer validity duration at the epoch time of the assistance information (i.e. serving satellite ephemeris data).

* FFS: Precise definition of epoch time taking into account SIB repetitions

Agreement:

A single validity duration for both serving satellite ephemeris and common TA related parameters is defined at least if serving satellite ephemeris and common TA parameters are signalled in the same SIB message.

Agreement:

RAN1 has discussed the following aspects and leaves it up to RAN2 to specify UE behaviour related to expiry of UL synchronization validity timer and determine which of the following aspects are to be specified:

* Mechanisms for UE to declare loss of UL synchronization including mechanisms for UL synchronization recovery procedure when UL synchronization is lost if UL synchronization validity timer expires in RRC\_CONNECTED
	+ It is up to RAN2 to specify this new behaviour for connected UE within RLF set of procedures or a new procedure for re-acquiring satellite ephemeris
	+ Mechanism for UL synchronization includes re-acquiring the satellite ephemeris and common TA parameters if indicated on SIB
	+ A new clause of RLF for loss of UL synchronization if validity timer for UL synchronization expires assuming a new re-interpretation of RLF set of procedures is specified for recovery of UL synchronization with re-acquisition of satellite ephemeris and common TA parameters if indicated
	+ Potential additional RACH after re-acquisition of satellite ephemeris and common TA parameters if indicated for the UL synchronization recovery procedure in case of potential residual TA error.
* If validity timer for UL synchronization expires and no UL synchronization recovery mechanisms specified as above, UE behaviour shall declare RLF and go into idle mode autonomously to re-acquire ephemeris SIB. UE will then need to re-access the cell via Random Access procedure.

UE signalling to indicate the validity timer for UL synchronization is about to expire

## Company views

Epoch time:

Huwaei proposed the reference point for Epoch time is set at the serving satellite transmitter. The Epoch time for common TA and satellite ephemeris is defined as the ending time of the SI window carrying the common TA and satellite ephemeris.

Marvenir proposed the Epoch time of serving satellite ephemeris data is the time instance at which the corresponding ephemeris data has been captured. The epoch time of serving satellite ephemeris data is transmitted in the same SIB which contains the ephemeris data.

CATT proposed if SIBs are transmitted repeatedly, epoch time should be based on the transmitting time of the first SIB.

SONY proposed the epoch time of the current ephemeris information is defined as the time that the first physical layer repetition of the first RRC level repetition of the current ephemeris information is transmitted. The epoch time of the current ephemeris information is transmitted on SIB.

ZTE proposed the Epoch time of assistance information is set to be boundary of last DL subframe carrying the first transmission of SIB.

Samsung proposed Epoch time of assistance information (i.e., satellite ephemeris and common TA) can be defined as the starting time of the first repetition of the SIB received by UE to acquire the assistance information.

Ericsson proposed to adopt the same definition of epoch time for IoT NTN as for NR NTN.

Validity timer duration:

Ericsson proposed that separate validity timers are preferred if ephemeris and common TA are transmitted in different SIBs.

Qualcomm proposed that the duration of valid ephemeris (and common TA, if applicable) is counted starting from the first repetition of the SIB carrying satellite ephemeris (and, if applicable, common TA-related) information.

ZTE proposed validity timer for uplink synchronization (i.e., satellite ephemeris or common TA parameters) (re)starts at the starting time of system information window of system information carrying uplink synchronization parameters.

CMCC proposed RAN2 determine adoption of one of the following two approaches for updating the assistance information (i.e. serving satellite ephemeris data or Common TA parameters).

* If Approach 1 is adopted: the update period (e.g. 160 ms) as well as the validity duration (e.g. 10~30s) for the assistance information are much smaller than SI modification period (e.g. 1~3 hours), one of the following options can be supported. Changes of the assistance information should neither result in system information change notifications nor in a modification of systemInfoValueTag in SIB1.
	+ Option 1: Provide the epoch time as part of the assistance information by indicating the SFN and the sub-frame number that the information is valid for.
	+ Option 2: The epoch time is set to be boundary of last DL slot carrying the SIB.
* If Approach 2 is adopted: Set the SI modification period = The update period for the assistance information = the validity duration for the assistance information (about 10~30s), no spec impact is expected. In this case, UE expects the assistance information keep valid within the current SI modification period.

Nordic Semiconductor proposed if serving satellite ephemeris and common TA are signaled in separate SIB messages, a separate validity timer for serving satellite ephemeris and timer for common TA is configured by eNB with initial timer values X and Y. Validity timer for SIB ephemeris is reset at least upon UE reading SIB with ephemeris and validity timer for common TA is reset at least upon UE receiving SIB with common TA.

Validity timer duration report:

Nokia proposed there should be common understanding on start time and expire time of validity timer for GNSS and validity timer for ephemeris between UE and network, which should be specified in IoT NTN. TAT like validity timer could be used as a baseline, where UE should report to network so that both UE and network reset the validity timer and keep common understanding. To reduce overhead, UE reporting should be reduced, where e.g. only first report valid information and failure report. Network configured UL resource for report for validity of ephemeris should be specified. Validity report within the repetitions should be specified.

UL transmission duration:

CATT proposed to support validity duration along with satellite ephemeris and Common TA is broadcasted in SIB to simplify the signaling design. After UE has lost uplink synchronization caused by unavailable new or additional assistance information, IoT NTN UE will go back to IDLE state and resynchronize.

Ericsson observed that the short connection can be defined by considering the validity durations of GNSS position fix, common TA (if indicated) and satellite ephemeris. The need and purpose of a new UL compensation gap for long UL transmission is not well-justified. For example, it is not clear if it is needed for avoiding phase discontinuity, re-acquiring satellite ephemeris, getting a GNSS position fix, calculating pre-compensation values, or for reducing implementation complexity for transmit timing and frequency adjustment.

SONY proposed the UE estimates the time it will take to complete a short transmission based on the amount of data to transmit, measurements and scaling / correction information transmitted in SIB. SIB configures a scaling factor and time offset to allow the UE to calculate the time to complete its short transmission. The UE only commences a short transmission if its estimate of the duration of the short transmission is less than the remaining validity time of UL synchronisation. If an ongoing short transmission cannot be completed within the validity time of UL synchronization, the UE informs the network of imminent loss of UL synchronisation.

* Issue 1: How to ensure the UE only starts a short transmission if there is a reasonable prospect of it completing the transmission before the validity timer expires.
* Issue 2: There is a limited time in CONNECTED mode for the UE to complete its short transmission.
* Issue 3: The UE needs to calculate when the validity timer will expire.
* Issue 4: Definition and configuration of epoch time, where the epoch time is the start time of the validity of the ephemeris information.
* Issue 5: Any RLF procedure that may be specified by RAN2 is for exceptional situations. The UE should complete its short transmission before an RLF procedure is triggered.

The UE has to undertake the following procedure when data arrives in its UE buffers and it starts a short mobile-originated transmission (more details in R1-2111410):

* UE reads SIB containing ephemeris information
* UE determines value of validity timer from SIB
* UE determines the current age of the ephemeris information on SIB [issue 4]
* UE calculates the remaining time for which ephemeris information on SIB is valid [issue 3]
* UE decides whether it can complete a short transmission during the remaining validity time [issue 1]
* If the UE estimates that there is sufficient time to complete the short transmission:
	+ UE performs initial access
	+ UE moves to CONNECTED mode
	+ UE takes part in signalling exchange in order to communicate its short transmission
	+ RRC connection is released gracefully
* If the UE short transmission time exceeds the validity time of the ephemeris information, the UE undertakes a modified RLF procedure or moves to IDLE [issue 5]
	+ Note: this should be an exceptional situation that should be avoided



Issues to short transmissions while UL synchronisation is valid SONY R1-2111410

***Moderator view****: It was discussed that UL transmission duration is determined autonomously by the UE based on its validity timer duration and scheduled UL grant. Report of validity timer duration was also discussed. On Epoch time, several companies proposed it is based on the first transmission of SIB. NB-IoT has SIB scheduling based on SIB1. Adopting same definition of epoch time for IoT NTN as for NR NTN from NR is a good guiding principle. It seems reasonable to base the Epcoh time on the boundary of last DL subframe carrying the first transmission of SIB as it simplifies timing aspects of when the SIB is read within the window and latency due to processing. It gives some margin fo the validity of the ephemeris and common TA parameters. Then, it seems also logival that the validity timer for uplink synchronization (i.e., satellite ephemeris or common TA parameters) (re)starts at the starting time of system information window of system information carrying uplink synchronization parameters. The validity duration can be discussed in RRC parameter email discussion.*

*Companies are encouraged to comment the following two proposals below.*

***Initial proposal – Section 3.2-1:***

***Epoch time of assistance information is set to be boundary of last DL subframe carrying the first transmission of SIB***

***Initial proposal – Section 3.2-2:***

***Validity timer for uplink synchronization (i.e., satellite ephemeris or common TA parameters) (re)starts at the starting time of system information window of system information carrying uplink synchronization parameters.***

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# Long UL transmission on PUSCH and PRACH

## Background

The following issues are for discussions based on agreements were made during RAN1#106e.

* Configuration of UL transmission segment via SIB or dedicated RRC signalling
* Downscoping of values for NPRACH/RACH UL transmission segment duration
* Downscoping of values NPUSCH/PUCH UL transmission segment duration
* New UL gaps for long UL transmissions
* Phase discontinuity in segmented pre-compensation

During Rel-17 IoT NTN SI, it was clarified that there is impact on specification of applying TA adjustments during long UL transmission:

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

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

## Company views

Configuration of UL transmission segment duration / gap:

The following agreements were made during RAN1#106e and RAN1#106bis-e on configuration of UL transmission segment.

Agreement:

The UL transmission segment duration is configured by the network

* FFS: Details of the configuration signalling.

Agreement:

* The UL transmission segment duration is provided by UE-specific RRC signalling or by signalling in SIB.
* NOTE: the values of UL transmission segment duration for NB-IoT can be different to those for eMTC

In RAN1#106-e and RAN1#106bis-e , the following agreements on NPUSCH/PUSCH UL transmission segment were made

Agreement:

Duration of UL transmission segment for UE pre-compensation for PUSCH transmission is a number of PUSCH repetition units configured by the network

* For NB-IoT, repetition unit is $M\_{identical}^{NPUSCH}×N\_{slot}^{UL}×T\_{slot}$
* For eMTC, repetition unit is $N\_{slot}^{UL}×T\_{slot}$ for sub-PRB allocation, where Tslot = 0.5 ms. For full-PRB allocation, repetition unit is one subframe.
* NOTE1: $M\_{identical}^{NPUSCH}, N\_{slot}^{UL}, T\_{slot}$ are defined in TS 36.211 10.1.2.3 and 10.1.3.6 for NB-IoT
* NOTE2: $M\_{symb}^{UL}, M\_{slot}^{UL}$M\_^UL\_slot is defined in TS 36.211, 5.2.3A for eMTC
* FFS: RAN1 to further discuss valid and invalid subframes
* FFS: Configuration details

Agreement:

* For NB-IoT/eMTC NTN, the network configures one of K candidate values for the UL transmission segment duration of NPUSCH/PUSCH in a k-bit field.
	+ For NB-IoT, maximum 3-bit field with a maximum number of K=8 candidate values 2 ms, 4 ms, 8 ms, 16 ms, 32 ms, 64 ms, 128 ms, 256 ms
* FFS: Down scoping of K candidate values, size of k-bit field

***NOTE: the values of UL transmission segment duration for NB-IoT can be different to those for eMTC***

Agreement:

For NB-IoT, if a mapping to Nslots slots or a repetition of the mapping in an UL transmission segment for UE pre-compensation for NPUSCH transmission contains a resource element which overlaps with any configured NPRACH resource, the NPUSCH transmission in overlapped Nslots slots is postponed until the next Nslots slots not overlapping with any configured NPRACH resource.

* NOTE: Nslots is defined in TS 36.211, 10.1.3.6

Agreement:

Configuration of UL transmission segment is indicated on SIB at least for initial access

* FFS via UE-specific RRC signalling in RRC\_CONNECTED.

Agreement:

Configuration of UL transmission segment is indicated on SIB at least for initial access

* FFS via UE-specific RRC signalling in RRC\_CONNECTED.

Agreement:

For eMTC PUSCH, a 3-bit field to indicate K=8 values for the uplink transmission segment duration:

* Full-PRB allocation (unit: subframes): 2 4 8 16 32 64 128 256
* Sub-PRB allocation (unit: resource units): 1 2 4 8 16 32 64 128

In RAN1#106-e and RAN1#106bis-e, the following agreements on NPRACH/PRACH UL transmission segment were made

Agreement:

Duration of UL transmission segment for UE pre-compensation for PRACH transmission is a number of RACH repetition units configured by the network

* For NB-IoT, repetition unit is P symbol groups.
* For eMTC, repetition unit is one preamble including guard period.
* FFS: Configuration details

Agreement:

* For NB-IoT NTN, the network configures one of K values for the UL transmission segment duration of each PRACH preamble format in a k-bit field, where the size of the k-bit field and the number of K candidate values depend on the preamble format.
* Format 0 and format 1: 3-bit field, K=6 candidate values 2.4.(TCP+TSEQ), 4.4.(TCP+TSEQ), 8.4.(TCP+TSEQ), 16.4.(TCP+TSEQ), 32.4.(TCP+TSEQ), 64.4.(TCP+TSEQ)
* Format 2:  2-bit field, K=4 candidate values 2.6.(TCP+TSEQ), 4.6.(TCP+TSEQ), 8.6.(TCP+TSEQ), 16.6.(TCP+TSEQ)
* FFS: Down scoping of K candidate values, size of k-bit field
* FFS: Whether the same segment duration can be used for all preambles within a preamble format

Agreement:

For eMTC, the network configures one of K values for the UL transmission segment duration of PRACH in a k-bit field.

* FFS: K candidate values, size of k-bit field

Agreement:

For eMTC, a 3-bit field is defined in the SIB to indicate the following K=8 values for the uplink transmission segment duration of PRACH:

(TCP+TSEQ+TGP), 2\*(TCP+TSEQ+TGP), 4\*(TCP+TSEQ+TGP), 8\*(TCP+TSEQ+TGP), 16\*(TCP+TSEQ+TGP), 32\*(TCP+TSEQ+TGP), 64\*(TCP+TSEQ+TGP), 128\*(TCP+TSEQ+TGP)

Agreement:

For eMTC, the same value is used for segment durations for all PRACH preambles

Agreement:

For NB-IOT, the same value is used for segment durations for all NPRACH preambles for a particular NPRACH format

The main issue for the configuration of UL transmission segments is that the delay drift increases as elevation angle decreases. If indicated on SIB, this would ean that only the smaller UL transmission segments can be used for initial access. In RRC\_CONNECTED the UL transmission segments can be re-configured with larger UL transmission segment for higher elevation angles.

The maximum total TA drift over service link and feeder link in 256 ms can be in the order of 24 µs for LEO-600 km as can be derived from TR 36.763 Section 6.1 Table 6.1-1: IoT NTN reference scenario parameters. At higher elevation angles it can be lower and even 0 µs.



Figure 3. TA changes during a 256 ms transmission period at different elevation angles from 10 degree to 90 degrees (Nokia R1-2109265)

Huawei, Vivo, Spreadtrum, Apple, Qualcomm, Nokia proposed NPUSCH segmentation duration can be configured via UE-specific signalling. Some down-scoping proposed:

* Huwaei: {16 ms, 32 ms, 64 ms, 128 ms, 256 ms}.
* Vivo: *{4ms, 8ms, 16ms, 32ms, 64ms, 128ms, 256ms}.*

Huawei, Vivo, Ericsson proposed add one value for NPRACH format 2 of *1\*6\*(TCP+TSEQ).*

Nokia proposed UE selects the segment duration that is applicable to the elevation angle and has the smallest number of gaps / TA adjustments. A set of applicable UL transmission segments is indicated in SIB. After UE selects a segment duration, the index of the selected segment duration should be sent to the network. When UE location is available to the network, eNB can indicate the transmission segment duration to UE via RRC signaling.

Qualcomm proposed the for PUSCH, the segment duration for uplink pre-compensation may be indicated/negotiated between the network and the UE via dedicated unicast (RRC) signalling. This may involve the UE sending assistance information to the network, e.g., indicating its mobility pattern and speed.

CMCC, ZTE, Nordic Semiconductor, MediaTek propose configuration of UL transmission segment is indicated (only) on SIB in RRC\_CONNECTED.

UL gap for NPUSCH (NB-IoT) / PUSCH / PUCCH (eMTC):

Huawei, ZTE, MediaTek proposed support 1ms of UL gap for NB-IoT over NTN.

Spreadtrum, Lenovo, Samsung proposed a gap of N time units (i.e. PUSCH repetitions is a number of Tslots or ms)

Vivo proposed to support gaps X ms or Y symbols configured or pre-determined

Nokia, CATT support gap of last symbol of slot

Ericsson, Qualcomm: no gap, skip / drop samples

CATT proposed that for small TAvariation, TA adjustment is implemented by dropping tail samples of a segment or delaying a few samples for UL transmission

CATT proposed for small TA variation, TA adjustment is implemented by dropping tail samples of a segment or delaying a few samples for UL transmission. For large TA variation, the gap can be configured with original GP is reused for (N)PRACH’s gap.

UL gap for NPRACH / PRACH for NB-IoT / eMTC:

CATT proposed skip/drop samples within Guard Period of RACH preamble (i.e. no new gap)

Postponment of NPUSCH with overlapped NRACH:

ZTE propose postponement of NPUSCH due to overlap with NPRACH is counted in segment duration. The portion of postponement which coincides with a UL gap is counted as part of the gap.

Phase noise:

NEC support gaps to avoid phase discontinuity

Nokia proposed RAN1 to study the impact of timing drift induced phase error for NB-IoT transmission in NTN. Timing-drift-induced phase error may exceed the phase error tolerance for demodulation at the receiver. The phase error increases as the elevation angle decreases since the TA drift rate is higher at a lower elevation angle. Accumulating phase error of SC-FDMA symbols occurs due to the TA drift in the IoT NTN scenarios. There can be two solution approaches:

* At the UE transmitter, UE scales up the phase difference across symbols based on TA drift rate:
* At eNB transmitter, the network estimate the UE-specific TA drift and pre-compensate the phase difference across symbols based on UE location:

***Moderator view:*** *To the moderator understanding, it is is needed to discuss UL segment duration and gap in initial access and in RRC\_CONNECTED:*

* *In initial access:*
	+ *A gap duration of 1 ms between UL transmission segments of duration [16 ms, (32 ms)] for NPUSCH for NB-IoT and PUSCH/PUCCH for eMTC is configured on SIB. UL transmission duration <=16 ms (without UL segmented transmission) can be scheduled without need to apply UE pre-compensation of TA at any elevation*
	+ *UEs in different locations without large beams up to 1700 km may experience different elevation angles in [30 degrees – 90 degrees]. Segment duration indicated on SIB must work for all UEs, which limits segment duration to 16 ms or 32 ms to avoid breaking CP.*
	+ *In initial access, eNB cannot be assumed to know UE capability to support UE pre-compensation between segments with a gap of 1 ms for LEO/MEO before UE moves to RRC\_CONNECTED*
* *In RRC\_CONNECTED*
	+ *UL transmission segment duration for NPUSCH for NB-IoT and PUSCH/PUCCH for eMTC may be configurable by dedicated RRC Signalling if eNB as knowledge of elevation angle / UE location (depends on SA3) for LEO / MEO.*

*On UL gap, companies have different views. Huawei, ZTE, MediaTek, Spreadtrum, Lenovo, Samsung support for 1 ms gap; Ericsson, Qualcomm, Nokia, CATT do not support gap (skip samles / puncture 1 OFDM).*

*Postponent of NPUSCH with overlapped NRACH was discussed in RAN1#106bis-e and had near consensus:*

*Phase noise issue at the subframe boundary was discussed extensively in RAN1#106-e, RAN1#106bis-e. There can be work around solution in UE and eNB, or a gap can be used.*

***Initial Proposal 4.2-1*** *For UL Segmented transmission in Initial Cell Access:*

1. *Segmented UL transmission NPUSCH / NPRACH for NB-IoT and PUSCH/PUCCH / PRACH for eMTC is not configured for GEO*
2. *UL transmission segment duration [16 ms, (32 ms)] for NPUSCH for NB-IoT and PUSCH/PUCCH for eMTC is indicated on SIB for LEO / MEO*
3. *UL transmission segment duration for NPRACH/RACH for NB-IoT / eMTC is indicated on SIB for LEO/MEO*
4. *UE applies UE-Pre-compensation between UL transmission segments by skip/drop samples in GP of NPRACH/PRACH*
5. *A gap duration of 1 ms between UL transmission segments of duration [16 ms, (32 ms)] for NPUSCH for NB-IoT and PUSCH/PUCCH for eMTC is configured on SIB. UL transmission duration <=16 ms (without UL segmented transmission) can be scheduled without need to apply UE pre-compensation of TA at any elevation*
* *NOTE 1: UEs in different locations without large beams up to 1700 km may experience different elevation angles in [30 degrees – 90 degrees]. Segment duration indicated on SIB must work for all UEs, which limits segment duration to 16 ms or 32 ms to avoid breaking CP.*
* *NOTE2: In initial access, eNB cannot be assumed to know UE capability to support UE pre-compensation between segments with a gap of 1 ms for LEO/MEO before UE moves to RRC\_CONNECTED*

***Initial Proposal 4.2-2*** *For UL Segmented transmission* during RRC\_CONNECTED:

1. *Segmented UL transmission NPUSCH / NPRACH for NB-IoT and PUSCH/PUCCH / PRACH for eMTC is not configured for GEO*
2. *UL transmission segment duration for NPUSCH for NB-IoT and PUSCH/PUCCH for eMTC may be configurable by dedicated RRC Signalling if eNB has knowledge of elevation angle / UE location (depending on SA3) for LEO / MEO*
3. *UE applies UE-Pre-compensation between UL transmission segments by skip/drop samples in GP of NPDCCH/PDCCH ordered NPRACH/PRACH for LEO/MEO*
4. *UE capability to support UE pre-compensation between segments for LEO/MEO*
	* *Option 1:*
		+ *UE capability to support UE-Pre-compensation between UL transmission segments by skip/drop samples/puncture last OFDM symbol of UL transmission segment duration [1 ms, 2 ms, 4 ms, 8 ms, 16 ms, 32 ms, 64 ms, 128 ms] for NPUSCH for NB-IoT and PUSCH/PUCCH for eMTC*
		+ *A gap duration of 1 ms between UL transmission segments of duration [16 ms, (32 ms), (64 ms), (128 ms)] for NPUSCH for NB-IoT and PUSCH/PUCCH for eMTC is specified*
	* *Option 2:*
		+ *UE applies UE-Pre-compensation between UL transmission segments by skip/drop samples/puncture last OFDM symbol of UL transmission segment duration [1 ms, 2 ms, 4 ms, 8 ms, 16 ms, 32 ms, 64 ms, 128 ms] for NPUSCH for NB-IoT and PUSCH/PUCCH for eMTC*
		+ *UE capability to support UE-Pre-compensation between UL transmission segments with a gap duration of 1 ms between UL transmission segments of duration [16 ms, (32 ms), (64 ms), (128 ms)] for NPUSCH for NB-IoT and PUSCH/PUCCH for eMTC*
	* *Option 3:*
		+ *UE does not support UL segmented transmission / only support up to 16 ms or (32 ms) UL transmission duration without UL segmented transmission / for longer UL transmission eNB will schedule several normal UL transmissions*

***Initial Proposal 4.2-3:*** *For NB-IoT, postponement of NPUSCH due to overlap with NPRACH is counted in segment duration. The portion of postponement which coincides with a UL gap is counted as part of the gap*

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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.*

The differential Doppler frequency can be up to +/-39.9 kHz with set-4 LEO-600. The max Doppler shift cann be +/-48 kHz. Wth 20 ppm oscillator error at UE, there can be additional frequency error term of +/-40 KHz. The total uncertainty on DL raster exceeds half of 100 kHz channel raster of terrestrial NB-IoT/eMTC. Synchronizing on the wrong raster could cause error in (N)Cell frequency selection.

## Company views

New channel raster:

MediaTek discussed this solution is specification is a RAN4 discussion and only considered for LEO. It is not needed for GEO or MEO since Doppler is only +/-0.93 ppm and +/-7.5 ppm respectively and Cell Search algorithms should synchronize on correct raster. Grid with new channel raster 200 kHz should align with NB-IoT carrier / Ncell deployment on satellite band. With channel raster 200 kHz, UE always synchronize to correct raster. The UE does not know the value and direction of change of feeder link delay drift (before reading common TA parameters on SIB). UE corrects / tracks feeder link delay spread contribution to Sampling Frequency Offset (SFO). Some analysis to show impact of feeder link delay drift on SFO was shown in R1-2119169. When UE first access cell, it does not know if cell is cellular or NTN GEO or LEO. Earliest this can be known is NTN SIB with NTN SIB or NTN fields in legacy SIBs.



***Figure 3: Illustration of channel raster with 100 kHz and 200 kHz grid and 3\*200 kHz allocation (MediaTek R1-2111373)***

Huawei, NEC, CATT, Nokia, OPPO, Xiaomi, ZTE, Apple, Lenovo proposed introducing the new channel raster with step size greater than 100 kHz for DL synchronization in IoT NTN (i.e. 200 kHz).

MediaTek, proposed RAN1#107-e further discuss pros and cons and select one solution for DL synchronization enhancements for LEO.

Ericsson discussed new channel ratser provides a clean approach to address the ambiguity in downlink synchronization. Since this is the last RAN1 meeting, RAN1 may agree on increasing the channel raster size as RAN4 work will not begin until 03/2022.

Intel proposed channel raster with a step size increased to be greater than 100 kHz for NB-IoT NTN should be supported if no issues identified with the number of NB-IoT carriers.

Qualcomm observed increasing the channel raster step size limits possible Ncell deployments for operators. For example, if the raster step size is doubled, entire chunks of spectrum up to 200 kHz that do not contain a raster point cannot be used to deploy an Ncell.

Part-of ARFCN indication on MIB:

MediaTek discussed this solution is only considered for LEO. It is not needed for GEO or MEO since Doppler is only +/-0.93 ppm and +/-7.5 ppm respectively and Cell Search algorithms should synchronize on correct raster. With 100 channel raster, 9 bits will be needed to indicate all the possible ARFCNs – i.e. 30 MHz/100 kHz=300 = 9 bits. The ARFCN index with 2 spare LSBs allows to save 7 bits for S band.

* ARFCN 2 GHz + 0 kHz 000000000
* ARFCN 2 GHz + 100 kHz 000000001
* ARFCN 2 GHz + 200 kHz 000000010
* ARFCN 2 GHz + 300 kHz 000000011

Between synchronization on NPSSS/NSSS and PBCH/MIB CRC check, if UE synchronized to the wrong raster it will assume a wrong DL carrier to derive the Sampling Frequency Offset (SFO) for its sampling rate. The SFO is +/-100 kHz/2 GHz = +/-50 ppm at carrier frequency Fc= 2GHz. To avoid loss in performance in LEO, UE makes 3 hypothesis for channel raster per synchronization attempt , without trying SFO steps of 2 ppm sweep to detect MIB on wrong raster if it fails first time (this may depend on the averaging window size and experienced SNR conditions – i.e. at high SNR and small window, the MIB detection may succeed even if on wrong raster then 2 LSBs can be read to correct the impact of SFO on sampling rate).



***Figure 4: Illustration of channel raster with 100 kHz and 3\*200 kHz allocation (MediaTek R1-2111373)***

ZTE, MediaTek provided simulations to show the loss of NPBCH demodulation performance with 640 ms averaging window.They show good agreement (ZTE used the TDL-D channel profile, which is better). The SFO impact if UE is on wrong raster with SFO=+/-50 ppm is very severe resulting in complete loss of NPBCH detection. ZTE assume the UE attemps to decode the MIB even if on wrong raster and make multiple hypothesis trying SFO steps of 2 ppm sweep to detect MIB. This way has very high complexity but seems reasonable strategy as the purpose of the MIB is to indicate when UE is on the wrong raster, so it must be read. The other strategy was assumed by MediaTek, where the UE attempts to read the MIB on first try on raster without trying SFO steps of 2 ppm sweep to detect MIB.



Figure 1 Detection complexity for option 1 and option 2 (ZTE R1-2111662)



Ericsson comented that with part-of ARFCN solution, there is an implicit assumption that the UE successfully acquires the MIB. However, the UE may not be aware of the amount of frequency uncertainty prior to reading MIB. As a result, it may need to test multiple hypotheses to acquire (N)PBCH and MIB. RAN1 to compare the pros and cons of increasing the channel raster step size and introducing ARFCN-indication-in-MIB.

Qualcomm observed the MIB in NB-IoT already indicates a channel raster offset to aid the UE accurately determining the frequency of the Ncell. Proposed to indicate two LSBs of the ARFCN in the MIB for NB-IoT over NTN. The NB-MIB currently has 9 spare bits, facilitating this indication seamlessly.

DL frequency pre-compensation on service link:

Huawei proposed to support DL frequency pre-compensation in IoT NTN and use 12-bit to indicate the value of DL frequency pre-compensation with range [0,…, 4095] and granularity of 0.01ppm.

Intel proposed indication of Common Doppler pre-compensation should follow design agreed for NR NTN

***Moderator view: The two solutions with channel raster and Part-of ARFCN indication on MIB are serious contenders with pros and cons. These solutions were extensively discussed during the Rel-17 IoT NTN Study Item and Rel-17 IoT NTN Work Item. RAN1 can discuss further and select one solution in this RAN1#107-e. Satellite companies input is needed to ensure the right solution is selected for RAN4 specification. Based on offline discussions with companies***

* ***Part-of ARFCN indication on MIB allows UE to know early if on wrong raster in better SNR conditions and re-use legacy 100 kHz channel raster for easier cell deployment, small spectrum chunk deployment.***
* ***Channel raster allows simpler device implementation, but has cell deployment limitation, small spectrum chunk allocation concern, require specify one raster > 100 kHz specified for GEO/MEO/LEO only per satellite band.***

***Part-of ARFCN indication on MIB has advantage over no DL synchronization enhancements at good / medium SNR. For example with smaller NPBCH window, UE on wrong raster may still decode the MIB / pass CRC check if timing drift to SFO is relatively small compare to larger NPBCH window of 640 ms. UE can use 2 LSBs to know correct raster / ARFCN, and determine sampling rate without SFO issue. Without 2 LSBs, the UE cannot know it is on wrong raster and the timing drift due to SFO will increase in time until UE loses DL synchronization. At low SNR, the Part-of ARFCN indication on MIB cannot help compare to no indication as UE will need to update raster anyway if it cannot read the MIB.***

***It is needed to discuss whether the new channel raster or (Part-of) ARFCN indication on MIB are useful optimizations but not specified in Rel-17 if there cannot be consensus on selecting a single solution. If there is no enhancements, if the UE is on the wrong raster the DL link will break when UE loses its DL timing sunchronization because of SFO. The UE will need to update raster and attempt to synchronize and pass the MIB CRC check, then receive the NTN SIB with ephemeris. It can then calculate the satellite Doppler shift and determine whether it is on the correct raster and absolute ARFCN to use for its sampling rate. The SFO issue due to wrong raster is then resolved, and the UE can proceed with initial cell access.***

***Without a decision on select a single solution for specification in RAN4 in RAN1#107-e, the default is to re-use the legacy channel ratser 100 kHz for LEO/MEO/GEO constellations.***

***Initial Proposal – Section 5.2:*** *Companies are encouraged to comment on the pros and cons and take into account the respective views. It will be helpful if companies can show flexibility on implementation Versus cell deployment tradeoff. It is essential that a solution is selected in this RAN1#107-e.*

* *Discuss and summarize pros and cons for each DL synchronization solution for LEO – e.g.*
	+ *Cell deployment in small spectrum chunks*
	+ *What is to be specified in RAN1 specifications*
	+ *Expected RAN4 specification effort*
	+ *Firmware change / HW change / complexity in device*
* *RAN1 select a single solution for specification in RAN4 in RAN1#107-e*
	+ *If no conclusion on select single solution, RAN1 can conclude on the pros and cons, and feasibility of each solution without selection of a single solution. From RAN1 viewpoint, there will be no optimization with DL synchronization enhancements in Rel-17 IoT NTN. It is up to UE implementation.*

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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.*

In RAN1#106-e and RAN1#106bis-e, the following agreements were made

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:

$$T\_{TA}=\left(N\_{TA}+N\_{TA,UE-specific}+N\_{TA,common}+N\_{TA,offset}\right)×T\_{s}$$

Where:

* $N\_{TA}$  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.
* $N\_{TA,UE-specific}$  is UE self-estimated TA to pre-compensate for the service link delay.
* $N\_{TA,common}$ is network-controlled common TA, and may include any timing offset considered necessary by the network.
* $N\_{TA,common}$ with value of 0 is supported.
	+ FFS:  details of signaling including granularity.
* $N\_{TA,offset}$ is a fixed offset used to calculate the timing advance.

Note-1: Definition of $N\_{TA}$ 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: $N\_{TA,common}$ 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

Agreement:

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

1. 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 and RRC\_CONNECTED modes
2. Serving satellite ephemeris Epoch time is implicitly known as a reference time defined by the starting time of a DL slot and/or frame.

FFS: Whether this starting time is given by predefined rule or it is indicated by the Network

Agreement:

In eMTC/NB-IoT, NTA update based on TA Command field in msg2 and MAC CE TA command is used for UL timing alignment correction as follows:

* No extension on TAC 11-bit field in Random Access Response
* When TAC (TA) in Msg2 is received, UE first adjustment and NTA is adjusted as follows: NTA,new = TA ×16, where TA is the timing advance command in msg2.
* When TACs ($T\_{A})$ provided within the MAC CE is received, $N\_{TA}$ is updated as follows:
	+ $N\_{TA\\_new}=N\_{TA\\_old}+\left(T\_{A}-31\right).16$ ,
* Where TA is the TAC field received in MAC CE command.

## Company views

MediaTek proposed for the following Rel-17 NR NTN WI agreements are used for Rel-17 IoT NTN. These are included directly as moderator initial proposal

***Initial Proposal – Section 6.2-1:*** *The following agreements from NR NTN are re-used for IoT NTN*

*Common TA may include parameter(s) indicating timing drift.*

* *The UE will apply common TA according to the parameters provided by the network (if any). No offset between the common TA according to the parameters provided by the network and the actual feeder link RTT is considered when defining UE UL timing error requirements.*

*Common TA Epoch time is implicitly known as a reference time defined by the starting time of a DL slot and/or frame.*

* *FFS: Whether this starting time is given by predefined rule or it is indicated by the Network*
	+ *Note: “implicitly known” means that UTC is not provided to define the Common TA epoch time.*

*In NTN, the Network may optionally indicate one or more of the following parameters:*

* *Common TA , Common TA drift rate and Common TA drift rate variation.*
* *FFS: Common TA third order derivative.*
* *FFS: Details of combination of Common TA parameters*

***Initial Proposal – Section 6.2-2:*** *The following agreements from NR NTN are re-used for IoT NTN*

* *The granularity of Common TA is set to be 1.Ts*

***Initial Proposal – Section 6.2-3:*** *The following agreements from NR NTN are re-used for IoT NTN*

* *Conclusion: Do not define a TA margin.*

***Initial Proposal – Section 6.2-4:*** *The following agreements from NR NTN are re-used for IoT NTN*

*Support serving satellite ephemeris format bit allocations for LEO/MEO/GEO based non-terrestrial access network.:*

* *Position and velocity state vector ephemeris format [17 bytes payload].*
	+ *The field size for position [m]  is [78 bits]*
		- *Position range is driven by GEO : +/- 42 200 km*
		- *The quantization step is [1.3m] for position*
	+ *The field size for velocity [m/s] is [54 bits]*
		- *Velocity range is driven by LEO@600 km: +/- 8000 m/s*
		- *The quantization step is [0.06 m/s] for Velocity*
* *Orbital parameter ephemeris format [18 byte payload]*
	+ *Semi-major axis α [m] is [33 bits]*
		- *Range: [6500, 43000]km*
	+ *Eccentricity e is [19 bits]*
		- *Range: ≤ 0.015*
	+ *Argument of periapsis ω [rad] is [24 bits]*
		- *Range: [0, 2π]*
	+ *Longitude of ascending node Ω [rad] is [21 bits]*
		- *Range: [-180o , +180o]*
	+ *Inclination i [rad] is [20 bits]*
		- *Range: [-90o  , +90o ]*
	+ *Mean anomaly M [rad] at epoch time to is [24 bits]*
		- *Range: [0, 2π]*

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| Companies | Comments |
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# Conclusions

We list the RAN1#106-e agreements here.TBA

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# Appendix

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| Contribution | Observation/Proposals |
| Huawei (R1-2110808) | In this contribution, we discuss the time/frequency adjustment, RACH enhancement and power consumption introduced by GNSS and NTN related SIB reading in IoT NTN. The following observations and proposals are presented.***Observation:*** *Without DL frequency pre-compensation, UE initial cell search complexity and latency will introduce large power consumption.****Proposal******1****:* *UE in RRC\_CONNECTED can report its GNSS position fix validity duration to the network.****Proposal 2:*** *Based on the UE reported GNSS position fix validity duration, the network can configure a measurement gap for a new GNSS position fix if the UE does not support simultaneous GNSS and NTN NB-IoT/eMTC operation.****Proposal 3***: *For all satellite orbits, network configures one of 5 candidate values for the UL transmission segmentation duration of NPUSCH in a 3-bit field, where the 5 candidate values are* * *{16 ms, 32 ms, 64 ms, 128 ms, 256 ms}*

***Proposal 4****: The NPUSCH segmentation duration can be configured via UE-specific signaling.****Proposal 5****: Network configures one of K values for the UL transmission segment duration of each PRACH preamble format in a k-bit field in the system information where the size of k and K values are:** *Format 0 and format 1: 3-bit field, K=6 candidate values 2\*4\*(TCP+TSEQ), 4\*4\*(TCP+TSEQ), 8\*4\*(TCP+TSEQ), 16\*4\*(TCP+TSEQ), 32\*4\*(TCP+TSEQ), 64\*4\*(TCP+TSEQ)*
* *Format 2: 3-bit field, K=5 candidate values 1\*6\*(TCP+TSEQ), 2\*6\*(TCP+TSEQ), 4\*6\*(TCP+TSEQ), 8\*6\*(TCP+TSEQ), 16\*6\*(TCP+TSEQ)*

***Proposal 6****:**The reference point for epoch time is set at the serving satellite transmitter.****Propose 7:*** *The epoch time for common TA and satellite ephemeris is defined as the ending time of the SI window carrying the common TA and satellite ephemeris.****Proposal 8****: Support 1ms of UL gap for NB-IoT over NTN.****Proposal 9***: *Support introducing the new channel raster with step size greater than 100 kHz for DL synchronization in IoT NTN.****Proposal 10:*** *Support DL frequency pre-compensation in IoT NTN and use 12-bit to indicate the value of DL frequency pre-compensation with range [0,…, 4095] and granularity of 0.01ppm.* ***Proposal 11****: Update the RRC parameters according to the Table provided in the Appendix.* |
| VIVO (R1-2111048) | ***Observation 1:*** *Time gaps are needed to operate timing and frequency pre- compensation between two adjacent segments.****Proposal 1:*** *For PUSCH transmission segment duration of NB-IoT, use 3-bit field with 7 candidate values {4ms, 8ms, 16ms, 32ms, 64ms, 128ms, 256ms} for various satellite orbits.****Proposal 2:*** *For PRACH transmission segment duration of NB-IoT, use**3-bit field with 5 candidate values {2\*4\*(TCP + TSEQ), 4\*4\*(TCP + TSEQ), 8\*4\*(TCP + TSEQ), 16\*4\*(TCP + TSEQ), 32\*4\*(TCP + TSEQ)} for format 0 and 1,* *2-bit field with 4 candidate values {1\*6\*(TCP + TSEQ), 2\*6\*(TCP + TSEQ), 4\*6\*(TCP + TSEQ), 8\*6\*(TCP + TSEQ)} for format 2.****Proposal 3:*** *Support to indicate configuration of UL transmission segment via UE-specific RRC signalling****.******Proposal 4:*** *Support to configure time gaps for timing and frequency pre-compensation during UL transmission.* |
| Spreadtrum (R1-2111117) | ***Proposal 1:*** *The segment duration can be configured by UE-specific RRC signaling in RRC\_CONNECTED state.****Proposal 2:*** *Inserting a gap between adjacent segments (N time units) to avoid the overlap of segments for long PUSCH should be supported.* |
| Mavenir (R1-2111172) | ***Proposal 1:*** *UE shall read SIB in RRC\_CONNECTED state for non-“short sporadic transmission”.****Observation 1:*** *SIB repetition does not impact the start time of the validity timer for UL synchronization.****Proposal 2:***  *The epoch time of serving satellite ephemeris data is the time instance at which the corresponding ephemeris data has been captured.****Proposal 3:*** *The epoch time of serving satellite ephemeris data is transmitted in the same SIB which contains the ephemeris data.* |
| NEC (R1-2111182) | ***Proposal 1****. An internal timer in the device is used by UE to set the GNSS validity duration autonomously.****Proposal 2****. The UE could signal the network the length of time that GNSS position fix is valid, and the GNSS position fix validity duration is determined by the UE at the time it is reported by the UE.* ***Proposal 3****. MAC CE can be used by the UE to report the remaining valid duration of GNSS position fix.****Proposal 4****. Support UL gaps during long transmission to avoid phase discontinuity between segments.****Proposal 5****. Support increased channel raster size in IoT NTN.* |
| CATT (R1-2111236) | ***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 may have the maximum initial frequency error more than 50KHz contributed by oscillator, Doppler shift and anchor carrier offset in S band.****Proposal 1****: UL transmission segment duration can be provided to UE by dedicated RRC signaling in handover command.****Proposal 2****: For small TA variation, TA adjustment is implemented by dropping tail samples of a segment or delaying a few samples for UL transmission.****Proposal 3****: 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 4****: If SIBs are transmitted repeatedly, epoch time should be based on the transmitting time of the first SIB.* ***Proposal 5****: Support validity duration along with satellite ephemeris and Common TA is broadcasted in SIB to simplify the signaling design.****Proposal 6****: After UE has lost uplink synchronization caused by unavailable new or additional assistance information, IoT NTN UE will go back to IDLE state and resynchronize.****Proposal 7****: Suggest UE reports its valid duration of GNSS position fix to gNB.****Proposal 8****: Increasing channel raster in IoT NTN is supported.****Proposal 9****: 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.****Proposal 10:*** *Network activates UE to perform the GNSS position fix through the configuration of T3413/T3415.* |
| Nokia, Nokia Shanghai Bell (R1-2111276) | ***Observation 1****: The acquired GNSS/ephemeris will be out-of-date after some time because of e.g. UE movement or satellite perturbation. UE need to keep valid GNSS/ephemeris before any UL transmission.****Observation 2****: there would be unexpected/uncontrolled operation of UE for eNB scheduling if there is no common understanding on validity timer of GNSS and ephemeris, causing that network can not schedule as no information on when UE can/will transmit or receive.****Observation 3****: 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 4****: Basing paging repetition/escalation on GNSS cold start time value significantly delays the paging procedure.****Observation 5****: If UE validates GNSS before every paging occasion it will waste energy due to low paging probability.****Observation 6****: Common understanding on GNSS measurement window between UE and network is needed.****Observation 7****: Multiple IoT UE with different capability and channel status may request different GNSS measurement window.****Observation 8****: The TA error in a transmission segment duaration is related to the elevation angle.****Observation 9****: Long segment duration can be used by the UE at a high elevation angle to keep the TA change within the timing error tolerance.****Observation 10****: NB-IoT UE can use equivalent or longer segments than eMTC UE for a given elevation angle, due to the high timing error tolerance of NB-IoT.* ***Observation 11****: When multiple segment durations satisfy the timing error tolerance, UE can use the longest segment for efficient utilization of uplink resources.* ***Observation 12****: An indexed table can be used to indicate the relationship between elevation angle range and segment duration.* ***Observation 13****: When the applicable segment durations are known, UE can decide the most suitable segment length depending on the UE’s elevation angle.* ***Observation 14****: The network should be aware of the UE’s selection in order to know when an UL transmission period ends and how many repetitions are scheduled.* ***Observation 15****: If UE is in RRC CONNECTED mode, the network can select a new segment duration based on the UE’s elevation angle, which can be derived from the UE’s location and satellite ephemeris.* ***Observation 16****: Operation of closed loop and open loop TA control in RRC connected state needs careful design to avoid instability due to erroneous calculation of the UE-specific TA value by the UE.****Observation 17****: If TAC is generated to fix a temporary deviation in the UE transmission timing, when UE updates their autonomous components on the timing advance formula, there may be an overcompensation of the timing advance, generating a similar deviation on the opposite direction (Figure 5).****Observation 18****: If TAC is generated to introduce an offset in UE timing due to eNB internal optimizations, the TAC should be applied regardless of UE accuracy for timing estimation.* ***Observation 19****: In order to guarantee TA update loop stability, two operation modes for TAC update are needed.****Observation 20****: Timing-drift-induced phase error may exceed the phase error tolerance for demodulation at the receiver.* ***Observation 21****: The phase error increases as the elevation angle decreases since the TA drift rate is higher at a lower elevation angle.****Observation 22****: Accumulating phase error of SC-FDMA symbols occurs due to the TA drift in the IoT NTN scenarios.****Proposal 1****: there should be common understanding on start time and expire time of validity timer for GNSS and validity timer for ephemeris between UE and network, which should be specified in IoT NTN.****Proposal 2:*** *TAT like validity timer could be used as a baseline, where UE should report to network so that both UE and network reset the validity timer and keep common understanding.****Proposal 3****: To reduce overhead, UE reporting should be reduced, where e.g. only first report valid information and failure report.****Proposal 4****: To save power consumption and latency, one possible way is only to perform a new UL synchronization by CFRA instead of CBRA or going back to IDLE mode.****Proposal 5****: Network configured UL resource for report for validity of ephemeris should be specified.****Proposal 6****: Validity report within the repetitions should be specified.****Proposal 7****: UE shall report GNSS measurement capability such that network can allocate sufficient time between sending a paging message and when to expect random access procedure initialization from UE.* ***Proposal 8****: Network shall not repeat the paging message for a UE during the UE’s GNSS measurement gap.****Proposal 9****: 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 10****: GNSS measurement window in CONNECTED mode should be specified for a new GNSS measurement when GNSS is about to outdated.****Proposal 11****: Overhead reduction should be considered for selection of GNSS measurement window and coordination between UE and eNB.****Proposal 12****: UE report the GNSS measurement gap should be the specified, to keep a low overhead.****Proposal 13****: Within the segment duration, the accumulated timing error due to TA drift should not exceed the tolerance provided by the cyclic prefix.****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****: A TA adjustment gap between adjacent segments should be no longer than one SC-FDMA symbol length.****Proposal 16****: UE selects the segment duration that is applicable to the elevation angle and has the smallest number of gaps / TA adjustments.****Proposal 17****: A set of applicable UL transmission segments is indicated in SIB.****Proposal 18****: After UE selects a segment duration, the index of the selected segment duration should be sent to the network.* ***Proposal 19****: When UE location is available to the network, eNB can indicate the transmission segment duration to UE via RRC signaling.****Proposal 20****: The update rate that the UE applies for both the UE-specific TA and Common TA should be such that the applied TA fulfilles the RAN4 time synchronization requirements.****Proposal 21****: The Common TA should be calculated in a deterministic way and applied at the same time for all UEs.****Proposal 22****: For UE in RRC connected mode, in case closed loop TA control is used, open loop TA control should be applied only in a way that does not impact the stability and accuracy as provided by closed loop TA control.****Proposal 23****: The eNB should be able to use the closed-loop solution (Timing Advance Commands over DL MAC-CE) at any time.* ***Proposal 24****: The TAC should operate in two different states to allow both differential and absolute indication of the TAC updates.****Proposal 25****: RAN1 to study the impact of timing drift induced phase error for NB-IoT transmission in NTN.* |
| OPPO (R1-2111319) | ***Proposal 1****: RAN2 can further discuss and decide the procedure for the UE to go back to idle for GNSS acquisition.* ***Proposal 2****: for DL synchronization, RAN1 to adopt the solution with channel raster grid increase to 200kHz.* |
| MediaTek (R1-2111373) | GNSS measurements for sporadic short transmissions:***Proposal 1:*** *RAN1 send LS to RAN2 to specify mechanism where* * *if GNSS position fix becomes outdated, UE in RRC\_CONNECTED declares RLF and move to RRC\_IDLE*
* *Before GNSS position fix becomes outdated, UE in RRC\_CONNECTED sends Rel-16 MAC CE Release Assistance Indication to request network to move into RRC\_IDLE.*

Long UL Transmission on PUSCH:***Observation 2:*** *The new gap avoids issue of overlapping of UL transmission segments and allows less complex UE implementation to apply UE pre-compensation for UL synchronization. eNB schedule gaps between UL transmission segments for UL transmission based on UE capability. Before the UE capability is reported by UE, eNB schedules gaps between UL transmission segments for the UE.****Proposal 2:*** *UE capability for LEO, to support updating time and frequency pre-compensation between segments during UL repetition of NPUSCH for NB-IoT and PUSCH/PUCCH for eMTC** *with a gap of one 1 ms duration between segments with duration less than 256 ms*
* *without a gap between segments*

***Proposal 3:*** *For LEO, eNB may schedule a gap of 1 ms between UL transmission segments based on UE capability to support UE-pre-compensation between UL transmission segments with a gap****Observation 3:*** *The delay drift and Doppler shift are much smaller in GEO and MEO. UE does not need to update time and frequency pre-compensation between segments during UL repetition of PUSCH/PUCCH for eMTC and NPUSCH for NB-IoT****Proposal 4:*** *For GEO and MEO, UL transmission segments of PUSCH/PUCCH for eMTC and NPUSCH for NB-IoT are not configured by the network.*Long UL Transmission on PRACH:***Observation 4:*** *The delay drift within maximum UL transmission segment of NPRACH l is smaller than NPRACH Cyclic Prefix. The Doppler shift is within the transmit frequency error of +/-0.1 ppm. New gaps are not needed for NPRACH. For GSO and NGSO, UE may not update time and frequency pre-compensation between segments during UL repetition of PRACH/NPRACH for eMTC/NB-IoT. The legacy UL compensation gap of 40 ms to re-sync on DL can be used to apply UE pre-compensation for UL synchronization.****Proposal 5:*** *For GEO and MEO, UL transmission segments of NPRACH/PRACH for eMTC and NB-IoT are not configured by the network.*DL Synchronization:***Observation 5:*** *DL synchronization enhancements are not needed for GEO or MEO since Doppler is only +/-0.93 ppm and +/-7.5 ppm respectively and Cell Search receiver algorithms should synchronize on correct raster****.******Observation 6:*** *New channel raster of 200 kHz has minimum impact on complexity in device to support DL synchronization in LEO. Spectrum waste can be avoided by alignment of 3GPP raster grid and spectrum allocation by regulator. Perfect alignment may not be possible in case of allocation of small spectrum chunks.****Proposal 6:*** *DL synchronization enhancements with new channel raster or (Part-of) ARFCN indication on MIB are not specified for GEO and MEO.****Proposal 7: In*** *RAN1#107-e, further discuss and select one solution for DL synchronization enhancements for LEO.* * *New channel raster 200 kHz with less flexibility for spectrum deployment*
* *(Part-of) ARFCH indication on MIB impact on complexity with re-use of 100 kHz channel raster and up to 3 channel raster hypothesis for NPBCH detection*

Synchronization aspects common to IoT NTN and NR NTN:***Proposal 8:*** *Common TA may include parameter(s) indicating timing drift.** *The UE will apply common TA according to the parameters provided by the network (if any). No offset between the common TA according to the parameters provided by the network and the actual feeder link RTT is considered when defining UE UL timing error requirements.*

***Proposal 9:*** *Common TA Epoch time is implicitly known as a reference time defined by the starting time of a DL slot and/or frame.** *FFS: Whether this starting time is given by predefined rule or it is indicated by the Network*
	+ *Note: “implicitly known” means that UTC is not provided to define the Common TA epoch time.*

***Proposal 10:*** *In NTN, the Network may optionally indicate one or more of the following parameters:** *Common TA, Common TA drift rate and Common TA drift rate variation.*
* *FFS: Common TA third order derivative.*
* *FFS: Details of combination of Common TA parameters*

***Proposal 11:**** *The granularity of Common TA is set to be 1.Ts*

***Proposal 12:**** *Conclusion: Do not define a TA margin.*

***Proposal 13:*** *Support serving satellite ephemeris format bit allocations for LEO/MEO/GEO based non-terrestrial access network:** *Position and velocity state vector ephemeris format [17 bytes payload].*
	+ *The field size for position [m]  is [78 bits]*
		- *Position range is driven by GEO : +/- 42 200 km*
		- *The quantization step is [1.3m] for position*
	+ *The field size for velocity [m/s] is [54 bits]*
		- *Velocity range is driven by LEO@600 km: +/- 8000 m/s*
		- *The quantization step is [0.06 m/s] for Velocity*
* *Orbital parameter ephemeris format [18 byte payload]*
	+ *Semi-major axis α [m] is [33 bits]*
		- *Range: [6500, 43000]km*
	+ *Eccentricity e is [19 bits]*
		- *Range: ≤ 0.015*
	+ *Argument of periapsis ω [rad] is [24 bits]*
		- *Range: [0, 2π]*
	+ *Longitude of ascending node Ω [rad] is [21 bits]*
		- *Range: [-180o , +180o]*
	+ *Inclination i [rad] is [20 bits]*
		- *Range: [-90o  , +90o ]*
	+ *Mean anomaly M [rad] at epoch time to is [24 bits]*
		- *Range: [0, 2π]*
 |
| SONY (R1-2111410) | ***Proposal 1****: The epoch time of the current ephemeris information is defined as the time that the first physical layer repetition of the first RRC level repetition of the current ephemeris information is transmitted.****Proposal 2****: The epoch time of the current ephemeris information is transmitted on SIB.****Proposal 3****: The UE estimates the time it will take to complete a short transmission based on the amount of data to transmit, measurements and scaling / correction information transmitted in SIB.****Proposal 4****: SIB configures a scaling factor and time offset to allow the UE to calculate the time to complete its short transmission.****Proposal 5****: The UE only commences a short transmission if its estimate of the duration of the short transmission is less than the remaining validity time of UL synchronisation.****Proposal 6****: If an ongoing short transmission cannot be completed within the validity time of UL synchronization, the UE informs the network of imminent loss of UL synchronisation.* |
| Ericsson (R1-2111420) | ***Observation 1*** *For NB-IoT NPRACH format 2, the TA error after 1 preamble repetition unit spanning 19.2 ms is 1.92 μs assuming a 100 μs/s TA drift. This TA error is 3.84 μs for 2 preamble repetition units.****Observation 2*** *For NB-IoT NPRACH format 2, the network should be able to configure a transmission segment duration spanning 1 preamble repetition unit. For NPRACH format 0/1, it is not necessary to configure a transmission segment duration spanning 1 preamble repetition unit.****Observation 3*** *The agreed sets of values for transmission segment duration of PUSCH/NPUSCH are flexible enough to enable operation in both LEO and GEO scenarios.****Observation 4*** *For GEO scenario, the network may choose not to configure the transmission segment duration parameter for eMTC/NB-IoT.****Observation 5*** *A new UL compensation gap is not needed to address the phase discontinuity’s impact on the uplink demodulation performance.****Observation 6*** *The need and purpose of a new UL compensation gap for long UL transmission is not well-justified. For example, it is not clear if it is needed for avoiding phase discontinuity, re-acquiring satellite ephemeris, getting a GNSS position fix, calculating pre-compensation values, or for reducing implementation complexity for transmit timing and frequency adjustment.****Observation 7*** *Introducing a new UL compensation gap will complicate scheduling.****Observation 8*** *The short connection can be defined by considering the validity durations of GNSS position fix, common TA (if indicated) and satellite ephemeris.**Based on the discussion in the previous sections we propose the following:****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*** *The network should be able to configure UL transmission segment duration for PUSCH/NPUSCH via UE-specific RRC signalling.****Proposal 3*** *For NB-IoT PRACH format 2, the network configures one of the K values for the uplink transmission segment duration of each PRACH preamble format using a k-bit field. We propose using a 3-bit field to indicate the following set of values for the uplink transmission segment duration:**- Format 2: 3-bit field, K=5 candidate values 1.6.(TCP+TSEQ), 2.6.(TCP+TSEQ), 4.6.(TCP+TSEQ), 8.6.(TCP+TSEQ), 16.6.(TCP+TSEQ)****Proposal 4*** *Further down-scoping of the agreed values for the transmission segment duration is not needed.****Proposal 5*** *A new UL compensation gap for long UL transmission need not be introduced unless it is essential.****Proposal 6*** *If segmented pre-compensation is implemented by sample dropping or puncturing, the details should be specified.****Proposal 7*** *Separate validity timers are preferred if ephemeris and common TA are transmitted in different SIBs.****Proposal 8*** *Adopt the same definition of epoch time for IoT NTN as for NR NTN.****Proposal 9*** *RAN1 to compare the pros and cons of increasing the channel raster step size and introducing ARFCN-indication-in-MIB.****Proposal 10*** *Send an LS to RAN4 on time and frequency error requirements for IoT NTN before discussing the details of validity duration for GNSS position.* |
| Qualcomm (R1-2111451) | ***Proposal 1*: The duration of valid ephemeris (and common TA, if applicable) is counted starting from the first repetition of the SIB carrying satellite ephemeris (and, if applicable, common TA-related) information.*****Proposal 2*: A UE initiates a GNSS validity period when it acquires a fresh GNSS position fix to obtain its geolocation.*** **The duration of this validity period is autonomously determined by the UE.**
* **The start of validity period and validity duration is reported to the network by the UE.**

***Proposal 3*: Introduce a mechanism that declares RLF when the UE’s GNSS-based geolocation validity expires.*** **Details to be specified by RAN2.**

***Proposal 4*: No gaps are specified between successive segments with different (constant within a segment) uplink pre-compensation values.*****Proposal 5*: The segment duration value(s) for uplink pre-compensation of time and frequency depend on the satellite orbit type, with GEO satellites supporting longer durations of time than LEO satellites.*** **For GEO, the smaller values of segment durations may not be required, leading to a smaller (or non-existent) bit-field size in the SIB/RRC configuration for GEO.**

***Proposal 6*: For eMTC when frequency hopping is configured:*** **When the hopping interval is less than the configured segment duration for uplink synchronization, the UE shall use the hopping interval as the segment duration for uplink synchronization**
* **When the hopping interval is greater than or equal to the configured segment duration for uplink synchronization, the UE shall use** $HI×\left⌊\frac{N\_{configured}}{HI}\right⌋$ **as the segment duration for uplink synchronization, where** $HI$ **denotes the hopping interval, and** $N\_{configured}$ **is the configured segment duration.**

***Proposal 7*: For PUSCH, the segment duration for uplink pre-compensation may be indicated/negotiated between the network and the UE via dedicated unicast (RRC) 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, entire chunks of spectrum up to 200 kHz that do not contain a raster point cannot be used to deploy an Ncell.*****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 8*: Indicate two LSBs of the ARFCN in the MIB for NB-IoT over NTN.*** **The NB-MIB currently has 9 spare bits, facilitating this indication seamlessly.**
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| Intel (R1-2111523) | ***Proposal 1****:* * *For eMTC and NB-IoT NTN, the Network may optionally indicate one or more of the following parameters*
	+ *Common TA, Common TA drift rate and Common TA drift rate variation*

***Proposal 2:*** * *Solution based on channel raster with a step size increased to be greater than 100 kHz for NB-IoT NTN should be supported if no issues identified with the number of NB-IoT carriers*

***Proposal 3****:* * *Support Common Doppler pre-compensation for DL*
	+ *Indication of Common Doppler pre-compensation should follow design agreed for NR NTN*

***Proposal 4****:* * *Rely on UE implementation for GNSS validity*
	+ *Before commencing an UL transmission, the UE shall ensure it has a GNSS position fix that is valid for the duration of that UL transmission*
	+ *If UE GNSS measurements are not valid UE declares RLF*
 |
| Xiaomi (R1-2111517) | ***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.****Proposal 1****: New Channel raster with a step size increased to 200 kHz should be supported.****Proposal 2****: The duration of the GNSS position fix validation is autonomously determined by the UE.****Proposal 3****: The GNSS position fix duration and the time of last GNSS position fix is reported to the network.****Proposal 4****: If UE can maintain its RRC connection when performing the GNSS measurement, UE can trigger RLF or re-acquire GNSS position fix without releasing connection. Otherwise, the UE should directly release the RRC connection* |
| CMCC (R1-2111633) | ***Observation 1:*** For sporadic DL traffic, UE may perform GNSS measurements after a paging occasion and only if it has been paged to reduce battery consumption. The existing timers (e.g., T3413/T3415) can be configured large enough to ensure a sufficient gap to accommodate GNSS acquisition after decoding the paging message and before initiating UL transmission.***Observation 2:*** Two approaches can be considered to update the assistance information (i.e. serving satellite ephemeris data or Common TA parameters).* Approach 1: The update period (e.g., 160ms) as well as the validity duration (e.g., 10~30s) for the assistance information are much smaller than SI modification period (e.g., 1~3 hours). Changes of the assistance information should neither result in system information change notifications nor in a modification of systemInfoValueTag in SIB1, just like “timeInfoUTC” field acts in SIB16.
* Approach 2: Set the SI modification period = The update period for the assistance information = the validity duration for the assistance information (about 10~30s).

***Proposal 1:*** Support the following conclusion.* Acquisition of GNSS position fix during paging procedure is up to UE implementation and network configuration of paging timers considering GNSS measurement duration (e.g. GNSS Time To First Fix with cold start of typically 10 seconds) impact in NTN scenario. These paging timers are not specified in 3GPP in legacy paging procedure (i.e. T3413 / T3415).

***Proposal 2:*** If GNSS becomes outdated, UE in RRC\_CONNECTED declares RLF and move to RRC\_IDLE.***Proposal 3:*** UE reports GNSS position fix validity duration to be used by network to move UE to RRC\_IDLE can be considered as an enhancement functionality.* The rest GNSS position fix validity duration after the reporting may be reported.
* The report may be triggered by the network before UL transmission is scheduled.

***Proposal 4:*** If Approach 1 (i.e., the update period as well as the validity duration for the assistance information are much smaller than SI modification period) is adopted, one of the following options can be supported.* Option 1: Provide the epoch time as part of the assistance information by indicating the SFN and the sub-frame number that the information is valid for.
* Option 3: The epoch time is set to be boundary of last DL slot carrying the SIB.

***Proposal 5:*** If Approach 2 (i.e., Set the SI modification period = The update period for the assistance information = the validity duration for the assistance information) is adopted, no spec impact is expected. In this case, UE expects the assistance information keep valid within the current SI modification period.***Proposal 6:*** It is up to RAN2 to determine which approach is adopted for updating the assistance information.* Approach 1: The update period (e.g., 160ms) as well as the validity duration (e.g., 10~30s) for the assistance information are much smaller than SI modification period (e.g., 1~3 hours). Changes of the assistance information should neither result in system information change notifications nor in a modification of systemInfoValueTag in SIB1.
* Approach 2: Set the SI modification period = The update period for the assistance information = the validity duration for the assistance information (about 10~30s).

***Proposal 7:*** Configuration of UL transmission segment is indicated on SIB in RRC\_CONNECTED. |
| ZTE (R1-2111662) | ***Observation 1:*** *The PAPR increment due to phase discontinuity in segmented pre-compensation is acceptable even if no further enhancement is introduced.****Observation 2:*** *Further improvement on the PAPR with proper configuration of segment length can be achieved.****Proposal 1:*** *Increasing the channel raster is preferred for detection complexity and NPBCH demodulation performance.****Proposal 2:*** *For NB-IoT, a 3-bit field is defined to indicate the following K=8 candidate values for UL transmission segment duration of NPUSCH:** *2ms, 4ms, 8ms, 16ms, 32ms, 64ms, 128ms, 256ms*

***Proposal 3:*** *For NB-IoT, a 3-bit field is defined to indicate the following K candidate values for UL transmission segment duration of NPRACH:** *Format 0 and format 1, K=7: 4\*(TCP+TSEQ), 2\*4\*(TCP+TSEQ), 4\*4\*(TCP+TSEQ), 8\*4\*(TCP+TSEQ), 16\*4\*(TCP+TSEQ), 32\*4\*(TCP+TSEQ), 64\*4\*(TCP+TSEQ)*
* *Format 2, K=5: 6\*(TCP+TSEQ), 2\*6\*(TCP+TSEQ), 4\*6\*(TCP+TSEQ), 8\*6\*(TCP+TSEQ), 16\*6\*(TCP+TSEQ)*

***Proposal 4:*** *The updating of TA and frequency used for pre-compensated UL transmission should be supported at UE side per segment if corresponding segment length is configured.****Proposal 5:*** *Configuration of UL transmission segment is indicated only via SIB for both (N)PRACH in initial access and (N)PUSCH in RRC\_CONNECTED****Proposal 6:*** *For enabling the updates of TA and frequency used for pre-compensated UL transmission, new UL gaps (i.e., 1ms) should be supported between segments to avoid segment overlap and phase discontinuity caused by segmented pre-compensation.****Proposal 7:*** *The postponement of NPUSCH due to overlap with NPRACH is counted in segment duration. The portion of postponement which coincides with a UL gap is counted as part of the gap.****Proposal 8:*** *The epoch time of assistance information is set to be boundary of last DL subframe carrying the first transmission of SIB.****Proposal 9:*** *The UE’s behavior for GNSS information acquisition should be explicitly specified at least before initiating UL transmission after the eDRX/PSM.****Proposal 10:*** *If GNSS becomes outdated, UE in RRC\_CONNECTED declares RLF and move to RRC\_IDLE.****Proposal 11:*** *There is no need to specify link recovery mechanism specifically for GNSS expiration.****Proposal 12:*** *Report of GNSS validity duration should be supported to ensure common understanding between BS and UE. The rest validity duration after reporting time is reported.* |
| Samsung (R1-2111767) | ***Proposal 1****: Frequent new gap is supported during long UL transmission, and the details of the new gap can be further discussed.****Proposal 2****: For sporadic short transmission, UE specific TA is reported only once, e.g., reporting UE specific TA in Msg3 or Msg5 via MAC CE.****Proposal 3****: Epoch time of assistance information (i.e., satellite ephemeris and common TA) can be defined as the starting time of the first repetition of the SIB received by UE to acquire the assistance information.* ***Proposal 4****: For segmented UE pre-compensation per N time units, the value of N can be separately configured for UL timing pre-compensation and UL frequency pre-compensation.* ***Proposal 5****: For segmented UE timing pre-compensation, if transmission signal is overlapped between two adjacent segments, overlapped samples of the last segment can be dropped.* |
| Apple (R1-2111904) | ***Proposal 1:*** *UE autonomously determines the validity of GNSS position fix, based on UE’s mobility patterns (e.g., UE speed).* ***Proposal 2:*** *UE reports GNSS position fix validity duration to network via high layer signaling (e.g., MAC CE).****Proposal 3:*** *UE reporting GNSS position fix validity duration is event-triggered, e.g., when the GNSS position fix validity timer is less than a threshold.* ***Proposal 4:*** *UE expects to receive a scheduling gap window from network after reporting GNSS position fix validity duration. UE suspends uplink transmissions and re-acquires GNSS position fix during this scheduling gap window.* ***Proposal 5:*** *Validity timer for uplink synchronization (i.e., satellite ephemeris or common TA parameters) (re)starts at the starting time of system information window of system information carrying uplink synchronization parameters.****Proposal 6:*** *Support the configuration of uplink transmission segment via UE-specific RRC signaling.* ***Proposal 7:*** *Consider increasing the channel raster step size in IoT NTN.*  |
| Lenovo, Motorola Mobility (R1-2122002) | ***Proposal 1：****The network can optionally configure the option A and B for UE to acquire GNSS position fix for sporadic short transmission.****Proposal 2:*** *If GNSS becomes outdated, UE in RRC\_CONNECTED declares RLF and move to RRC\_IDLE.****Proposal 3:*** *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 4:*** *For DL synchronization enhancement, new channel raster with a step size greater than 100 kHz (e.g., 300kHz) is introduced.* |
| Nordic Semiconductor ASA (R1-2112329) | ***Proposal-1:*** *No new gaps are introduced for long UL transmissions.****Proposal-2:*** *The configuration of UE pre-compensation segment should be signaled in SIB during initial access and after initial access.****Proposal-3:*** *If serving satellite ephemeris and common TA are signaled in separate SIB messages, a separate validity timer for serving satellite ephemeris and timer for common TA is configured by eNB with initial timer values X and Y. Validity timer for SIB ephemeris is reset at least upon UE reading SIB with ephemeris and validity timer for common TA is reset at least upon UE receiving SIB with common TA.* |