**3GPP TSG RAN WG1 Meeting #110-bis R1-2210260**

**e-meeting, October 10th – 19th, 2022**

**Agenda Item: 9.11.4**

**Source: Moderator (MediaTek)**

**Title: Feature lead summary #1** **of AI 9.11.4 on improved GNSS operations**

**Document for: Discussion**

# 0 Introduction

[110bis-e-R18-NTN-04] Email discussion on improved GNSS operations – Wen (MediaTek)

* Check points: October 14, October 19

## 0.1 Background

In RAN#96e, the revised WID on IoT NTN enhancements has been endorsed for Release 18 [1].

The work item aims to specify further enhancements for E-UTRA (LTE-RAN) based NTN (non-terrestrial networks) according to the following assumptions:

- GEO and NGSO (LEO and MEO).

- Earth fixed Tracking area. Earth fixed & Earth moving cells for NGSO

- FDD mode

- UEs with GNSS capabilities

The detailed objectives are to specify enhanced NB-IoT NTN and eMTC NTN radio interfaces and E-UTRAN/NG-RAN as follows:

4.1.1 IoT-NTN Performance Enhancements in Rel-18 to address remaining issues from Rel-17

This work considers Rel-17 IoT-NTN as baseline as well as Rel-17 NR-NTN outcome and the further IoT-NTN performance enhancements objectives are listed below:

- Disabling of HARQ feedback to mitigate impact of HARQ stalling on UE data rates [RAN1,RAN2]

- Study and specify, if needed, improved GNSS operations for a new position fix for UE pre-compensation during long connection times and for reduced power consumption. Simultaneous GNSS and NTN NB-IoT/eMTC operation is not assumed. [RAN1]

* *NOTE: The need for RAN4 Core requirements for this objective will be identified after the conclusion on the need for improvements.*

In this meeting, company views on improved GNSS operations for IoT NTN are summarized proposals on identified issues are made.

## 0.2 Contact Information

Please help to fill in the contact information for the FL summary. (If any change, please revise.)

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# [Active] Issue #1: Closed Loop control and potential enhancements

**Agreement (RAN1 106e):**

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 (RAN1 109e):**

Closed loop time and frequency correction, with potential enhancements, for IoT-NTN is considered to reduce the need for UE to update GNSS position fix in long connection time

## Company contributing views

|  |  |
| --- | --- |
| Contribution | Observation/Proposals |
| MediaTek | Observation 1: The TA error due to the position error of a UE that is moving without GNSS measurements can be approximately 5.8 us and 11.6 us within 30 seconds and 60 seconds at UE velocity of 120 km/h in IoT NTN for LEO 600km.Observation 2: For UE velocity above 30 km/h, if no closed loop time correction exists, UE needs to do GNSS position fix within 60 seconds to make TA error due to the position error of a UE smaller than transmit time error 2.6 us in NB-IoT NTN for LEO 600km.Observation 3: TA error caused by UE velocity in TN is larger than that in NTN.Observation 4: The TA error caused by UE velocity in NTN can be taken care of by legacy closed loop time correction in Rel-18.Observation 5: The maximum Doppler shift error due to the position error of a UE that is moving without GNSS measurements at Nadir can be approximately 168.8Hz and 337.7Hz within 60 seconds and 120 seconds at UE velocity of 120 km/h for LEO 600km. At the lower elevation angle 30 degree, the frequency error is in the order of a few Hz for LEO 600km.Observation 6: Depending on UE velocity and time elapsed since UE last acquired GNSS location, the frequency error could become increasingly large and exceed the frequency error requirements without closed-loop frequency correction. Observation 7: Closed loop frequency correction is not used in legacy TN system, which will require specifications if it is found to be beneficial. |
| Huawei, HiSilicon | Observation 1: The update of GNSS validity duration can further take the closed loop TAC into consideration from UE side and the power consumption on GNSS position fix can be saved. |
| Spreadtrum | Proposal 3: Closed loop frequency correction should not be supported. |
| Nordic Semiconductor ASA | Proposal 1: In RRC connected mode, the closed loop time and frequency correction loops should be further studied. |
| CMCC | Proposal 6. For long connection, the power consumption of potential mechanisms that enable alternate GNSS measurement and data transmission needs to be evaluated. |
| InterDigital | Observation 3: Excessive acquisition and reporting of GNSS information can lead to unnecessary power consumption and lower throughput. Proposal 3: Introduce a new prohibit timer to prevent excessive acquisition and reporting of GNSS information. |
| Nokia | Proposal 1: the release 18 must ensure the UE can obtain a new GNSS position fix during the “long” connection and remain RRC Connected to minimize the impact on UE energy consumption, signaling overhead and latency.Observation 4: UE may not be aware that it is moving during a long connection (uplink repetitions), because it cannot use the GNSS simultaneously. The UE movement will result in misaligned transmission timing.Proposal 4: GNSS error caused by UE movement should be studied and solved.Proposal 5: RAN1 to discuss network detection of UE movement based on uplink transmission drift and subsequent network triggering of UE’s GNSS measurement.Observation 5: Network can attempt closed-loop correction of transmission errors, caused by inaccurate UE location information, but it is not feasible to correct frequency-domain errors. Furthermore, UE cannot receive network’s TA Commands during a long repetition period.Proposal 12: To save power consumption and latency, keeping RRC connection and new UL synchronization after re-acquiring GNSS should be considered for long term connection, instead of going back to IDLE mode. |
| Ericsson | Observation 1 The existing TAC mechanism is sufficient to address the timing error due to incorrect UE position in IoT NTN. Proposal 2 Network can optionally indicate service link timing drift parameters to an IoT NTN UE in connected mode. Proposal 3 Upon GNSS timer expiry in connected mode, an IoT NTN UE may use service link drift information (in addition to common TA parameters) to calculate TA values before receiving the next TA command. Proposal 4 Closed loop frequency correction mechanism should optionally be supported in IoT NTN. |
| Samsung | Proposal 1: Introduce closed loop pre-compensated frequency offset command signaling, e.g., using a MAC CE similar to current TA command. |
| Qualcomm | On power consumption due to GNSS fixes:Observation 1: Under the studied scenario of short, sporadic connections, a GNSS fix before every connection consumes approximately $34\%$ of the UE’s total available energy.Observation 2: Under the studied scenario of a long connection employing connected mode DRX (with a DRX cycle of $\~10s$), a GNSS fix before every uplink transmission consumes approximately $45\%$ of the UE’s total available energy without additional enhancements w.r.t uplink synchronization.* This is especially true for mobile UEs that cannot depend on a prior acquired GNSS fix

Observation 3: For long connections in eMTC and NB-IoT over NTN, NPRACH-driven closed-loop time and frequency corrections lowers the GNSS power penalty from $45\%$ to $17\%$ (with a GNSS relaxation factor of 4), w.r.t a baseline without closed-loop corrections.On specifying, and facilitating closed-loop time and frequency corrections to minimize the number of GNSS fixes required:Proposal 1: RAN1 to specify NPRACH-driven closed-loop time and frequency corrections, to mitigate UE power consumption on account of GNSS fixes.Observation 4: According to current specifications, any time a UE transmits a NPRACH, it uses a value of $N\_{TA}=0$ in calculating the TA for the NPRACH transmission.Observation 5: If a considerable amount of time has passed since the last GNSS position fix, e.g., for a mobile UE, the accuracy of $N\_{TA, adj}^{UE}$ becomes progressively worse over time, i.e., the error in $N\_{TA, adj}^{UE}$ increases over time.Observation 6: Although the eNB can progressively correct (by issuing TA commands) the timing error due to a stale UE location, this correction is not applied when transmitting NPRACH (which currently uses $N\_{TA}=0)$. This may cause the timing error to go beyond the NPRACH correction capability.Proposal 2: RAN1 to discuss solutions such that the residual TA that is to be corrected by a “closed loop” command (upon transmission of a NPRACH in connected mode), does not exceed the correction capability afforded by such a NPRACH transmission. Candidate solutions include:* Updating the $N\_{TA, adj}^{UE}$ term with every TA command received in response to transmitting a NPRACH in connected mode
* Accumulating prior TA commands into the $N\_{TA}$ term, as opposed to universally setting it to 0 for a NPRACH transmission

Proposal 3: Proposal 2—related to TA—shall also translate to an analogous solution for closed-loop residual (doppler) frequency correction.Observation 7: For mobile UEs, with a GNSS fix that is outdated by 2 minutes, there may be a residual doppler frequency error of 220 Hz, with LEO satellites at a 1200 km orbit operating in the S band.* This error may be outside the synchronization requirements set by RAN4.
* This may cause significant interference among UEs in the uplink when a 3.75 kHz subcarrier spacing is used for NB-IoT.
* This may be mitigated by introducing a closed-loop frequency correction mechanism, as proposed in this contribution.
* Requiring fresh GNSS fixes within such short intervals (e.g., 2 minutes) severely degrades battery life of the UE.

With regards to increasing the robustness of NPRACH and facilitating relaxations to GNSS measurements:Proposal 4: RAN1 to consider specifying (at least a subset of) NPRACH resources with increased robustness to time and frequency errors, to facilitate:* Accessing a cell from IDLE mode, while relaxing the requirement of an “immediately preceding” GNSS fix in all instances.
* Closed-loop corrections (e.g., after periods of UE inactivity), thereby reducing the number of GNSS fixes required during a connection.

Observation 8: Restricting alternate starting subcarriers for NPRACH transmissions allows to correct for potentially large initial uplink frequency synchronization errors (e.g., up to 1 kHz)* Such a scheme may facilitate UE power savings by relaxing the frequency and accuracy of GNSS fixes required.
* Such a scheme may also facilitate NPRACH-driven closed-loop corrections of time and frequency errors in connected mode, thereby reducing the power penalty from frequent GNSS fixes.
 |
| Lenovo | Proposal 2：Closed loop time and frequency correction can be studied as implementation solution for UL synchronization during long connection. |

Power consumption of GNSS position fix, TA and Doppler tracking error, Closed Loop control and potential enhancements are discussed by contributing companies.

**On power consumption of GNSS position fix:**

* CMCC proposed for long connection, the power consumption of potential mechanisms that enable alternate GNSS measurement and data transmission needs to be evaluated.
* Nokia proposed to save power consumption and latency, keeping RRC connection and new UL synchronization after re-acquiring GNSS should be considered for long term connection, instead of going back to IDLE mode.
* Qualcomm modelled a *short, sporadic connection* according to Fig. 1 below and a *long connection* according to Fig. 2 below in [R1-2210007](file:///C%3A%5CUsers%5Cyounsun%5CDocuments%5C3GPP%20documents%5CRAN1%20tdocs%5CTSGR1_110%5CDocs%5CR1-2207258.zip).



**Figure 1: Short, sporadic transmissions for IoT over NTN.**



**Figure 2: Long connection with connected mode DRX for IoT over NTN.**

And Qualcomm observed that Under the studied scenario of short, sporadic connections, a GNSS fix before every connection consumes approximately $34\%$ of the UE’s total available energy. Under the studied scenario of a long connection employing connected mode DRX (with a DRX cycle of $\~10s$), a GNSS fix before every uplink transmission consumes approximately $45\%$ of the UE’s total available energy without additional enhancements w.r.t uplink synchronization (This is especially true for mobile UEs that cannot depend on a prior acquired GNSS fix).

**On TA and Doppler tracking error of UE mobility:**

* MediaTek summarized Table 1-4 from R1-2206140 to show the TA error and frequency error due to the position error of a UE that is moving without GNSS measurements.

***Table 1****: TA tracking error due to UE velocity for elevation angle 30 degrees*

|  |  |  |
| --- | --- | --- |
| **Validity of UE location** |  30 s | 60 s |
| **UE Velocity** | **UEpos,error**  | **β** | **TAerror**  | **UEpos,error** | **β** | **TAerror** |
| 3 km/h | 25 m | 30 deg | 0.14 us | 50 m | 30 deg | 0.29 us |
| 30 km/h | 250 m | 30 deg | 1.4 us | 500 m | 30 deg | 2.9 us |
| 40 km/h | 333 m | 30 deg | 1.9 us | 666 m | 30 deg | 3.8 us |
| 60 km/h | 500 m | 30 deg | 2.9 us | 1000 m | 30 deg | 5.8 us |
| 120 km/h | 1000 m  | 30 deg | 5.8 us | 2000 m | 30 deg | 11.6 us |

***Table 2****: TA tracking error due to UE velocity for TN*

|  |  |  |
| --- | --- | --- |
| **Validity of UE location****UE Velocity** | 30 s | 60 s |
| **UEpos,error** | **TAerror** | **UEpos,error** | **TAerror** |
| 3 km/h | 25 m | 0.16 us | 50 m | 0.33 us |
| 30 km/h | 250 m | 1.6 us | 500 m | 3.3 us |
| 40 km/h | 333 m | 2.2 us | 666 m | 4.4 us |
| 60 km/h | 500 m | 3.3 us | 1000 m | 6.6 us |
| 120 km/h | 1000 m | 6.6 us | 2000 m | 13.3 us |

***Table 3****: Doppler shift tracking error due to UE velocity at Nadir*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Validity of UE location** |         10 s | 30 s | 60 s | 120 s |
| **UE Velocity** | **UEpos,error** | **θ** | **Fderror** | **UEpos,error** | **θ** | **Fderror** | **UEpos,error** | **θ** | **Fderror** | **UEpos,error** | **θ** | **Fderror** |
| 3 km/h | 8m | 89.999deg | 0.7Hz | 25m | 89.997 deg | 2.1Hz | 50 m | 89.99 deg | 4.2Hz | 100 m | 89.989deg | 8.4Hz |
| 30 km/h | 83m | 89.99deg | 7Hz | 250m | 89.97 deg | 21Hz | 500 m | 89.95 deg | 42Hz | 1000 m | 89.895deg | 84.1Hz |
| 40 km/h | 111m | 89.988deg | 9.3Hz | 333m | 89.96 deg | 28Hz | 666 m | 89.93 deg | 56.1Hz | 1333 m | 89.86deg | 112.2Hz |
| 60 km/h | 166m | 89.98deg | 14Hz | 500m | 89.95 deg | 42.1Hz | 1000 m | 89.9 deg | 84.2Hz | 2000 m | 89.79 deg  | 168.5Hz |
| 120 km/h | 333m | 89.96deg | 28.1Hz | 1000m | 89.9 deg | 84.4Hz | 2000 m | 89.79 deg | 168.8Hz | 4000 m | 89.58 deg  |  337.7Hz |

***Table 4****: Doppler shift tracking error due to UE velocity for TN*

|  |  |  |  |
| --- | --- | --- | --- |
| **Validity of UE location** |         10 s | 30 s | 60 s |
| **UE Velocity** | **UEpos,error**  | **θ** | **Fderror**  | **UEpos,error** | **θ** | **Fderror** | **UEpos,error** | **θ** | **Fderror** |
| 3 km/h | 8 m | 76.6deg | 1.2Hz | 25 m | 54.5deg | 3.2Hz | 50 m | 35deg | 4.5Hz |
| 30 km/h | 83m  | 22.7deg | 51.2Hz | 250 m  | 8deg | 55Hz | 500 m | 4deg | 55.4Hz |
| 40 km/h | 111m | 17.5deg | 70.6Hz | 333 m | 6deg | 73.7Hz | 666 m | 3deg | 73.9Hz |
| 60 km/h | 166m  | 11.8deg | 108.7Hz | 500 m  | 4deg | 110.8Hz | 1000 m | 2deg  | 111Hz |
| 120 km/h | 333m  | 6deg | 221Hz | 1000 m  |  2deg | 222.1Hz | 2000 m | 1deg  |  222.2Hz |
|  |  |  |  |  |  |  |  |  |  |  |

And MediaTek observed that TA error due to the position error of a UE that is moving without GNSS measurements can be approximately 5.8 us and 11.6 us within 30 seconds and 60 seconds at UE velocity of 120 km/h in IoT NTN for LEO 600km. For UE velocity above 30 km/h, if no closed loop time correction exists, UE needs to do GNSS position fix within 60 seconds to make TA error due to the position error of a UE smaller than transmit time error 2.6 us in NB-IoT NTN for LEO 600km. TA error caused by UE mobility in TN is larger than that in NTN. The TA error caused by UE mobility in NTN can be taken care of by legacy closed loop time correction in Rel-18. The maximum Doppler shift error due to the position error of a UE that is moving without GNSS measurements at Nadir can be approximately 168.8Hz and 337.7Hz within 60 seconds and 120 seconds at UE velocity of 120 km/h for LEO 600km. At the lower elevation angle 30 degree, the frequency error is in the order of a few Hz for LEO 600km. When GNSS validity duration is below 60 seconds, the frequency error from NTN is smaller than that of TN. RAN1 should first discuss on whether closed loop frequency correction is needed for NTN since there is no such mechanism in legacy TN system.

* Huawei, HiSilicon illustrated the TA error caused by the movement of UE in Figure 3 from R1-2208438. It is assumed that the UE is moving at opposite direction from satellite with the velocity of 5m/s. The elevation of satellite at t=0 is 30°. Suppose the timing error caused by GNSS measurement is 30Ts, the time error from UE’s GNSS position change will exceed the UE transmit timing error requirement (80Ts) after t=50s without closed loop TA adjustment. As UE does not know when and how frequently the Time Advanced Command will be indicated, gnss-validityDuration = 50s would be reported. The update of GNSS validity duration discussed above can further take the closed loop TAC into consideration from UE side (for example, the value of the received TAC) and the power consumption on GNSS position fix can be saved.



**Figure 3. Time error cause my UE movement with speed of 5m/s**

* Nokia mentioned according to TS 36.133, the UE initial transmission timing error shall be less than or equal to ±Te where the timing error limit value is 80\*Ts (2.6 µs) for NB-IoT and 24\*Ts (0.78 µs) for eMTC CE Mode A. TA error (left) and frequency error (right) caused by UE movement is illustrated in Figure 1 from R1-2209246, in the worst-case scenario (10⁰ elevation angle), the timing accuracy requirement corresponds to 126 meter and 38 meter UE location error respectively for NB-IoT (Te = 80 Ts) and eMTC (Te = 24 Ts). For a moving UE, it can easily move 126 m or 38 m in 10 seconds (the minimum GNSS validity duration according to RAN1 107-e agreement noted above). For example, if the UE is on a truck moving with 80 km/h (about 22 m/s) it would take less than 6 seconds to violate the requirement for NB-IoT and less than 2 seconds for eMTC. The requirements in TS 36.101 define the maximum error to be +/- 0.1 ppm i.e. 200 Hz at the 2 GHz S-band. As is evident from the figure, the frequency error will be below the limit.



Figure 1 TA error (left) and frequency error (right) caused by UE movement

And Nokia proposed GNSS error caused by UE movement should be studied and solved, and to discuss network detection of UE movement based on uplink transmission drift. Nokia also observed that UE may not be aware that it is moving during a long connection (uplink repetitions), because it cannot use the GNSS simultaneously, then the UE movement will result in misaligned transmission timing.

* Ericsson mentioned It is expected that an IoT NTN UE will apply segmented uplink pre-compensation to account for the timing drift due to satellite’s motion, and assume a worst-case TA error *due to satellite motion* of 0.39 $μs$ (i.e., 12\*Ts where Ts=32.55 ns) for an eMTC UE, the satellite contributes to a worst-case TA drift of 100 $μ$s/s. For NR NTN, RAN4 has relaxed the initial transmit timing error requirement from 12\*Ts to 29\*Ts to account for errors in the satellite/UE positions. Ericsson assume a similar relaxation for eMTC NTN (which has a minimum transmit timing error requirement of 12\*Ts in terrestrial networks), the net timing error due to satellite/UE motion needs to be within 17\*Ts for eMTC NTN. Assuming a worst-case TA error of 12\*Ts due to satellite motion at the end of a transmission segment, there remains 5\*Ts (0.16 $μ$s) to account for the TA error due to UE mobility. Without closed loop timing correction, Table 1 from R1-2209648 shows that for 3 km/h, the UE may need to correct its timing to account for TA error due to UE mobility either via a TA command (TAC) or by refreshing its GNSS after 34 s. At 120 km/h, such an intervention will be needed every 0.83 s. Ericsson assumed that the UE already corrects its timing every segment to account for the TA error due to satellite motion.

Table 1 Impact of UE mobility on timing error requirements for eMTC NTN.

|  |  |  |  |
| --- | --- | --- | --- |
| UE speed | TA error rate due to UE mobility only | TA error due to satellite’s motion only | Time to reach the timing error limit of 17\*Ts |
| 3 km/h | 0.00467 $μ$s/s | 0.39 $μ$s | 34.3 s |
| 60 km/h | 0.0967 $μ$s/s | 0.39 $μ$s | 1.65 s |
| 120 km/h | 0.193 $μ$s/s | 0.39 $μ$s | 0.83 s |

* Qualcomm observed that According to current specifications, any time a UE transmits a NPRACH, it uses a value of $N\_{TA}=0$ in calculating the TA for the NPRACH transmission, and if a considerable amount of time has passed since the last GNSS position fix, e.g., for a mobile UE, the accuracy of $N\_{TA, adj}^{UE}$ becomes progressively worse over time, i.e., the error in $N\_{TA, adj}^{UE}$ increases over time, and although the eNB can progressively correct (by issuing TA commands) the timing error due to a stale UE location, this correction is not applied when transmitting NPRACH (which currently uses $N\_{TA}=0)$. This may cause the timing error to go beyond the NPRACH correction capability.

**On Closed Loop control correction and potential enhancements:**

* Spreadtrum proposed closed loop frequency correction should not be supported considering the majority frequency error need to be corrected by updated GNSS fix.
* Nordic proposed the closed loop timing correction has already been supported since Rel-17 for IoT NTN. Likewise, the frequency error due to UE velocity could be tracked by a closed loop correction loop similar to closed loop timing correction mechanism.
* InterDigital observed that excessive acquisition and reporting of GNSS information can lead to unnecessary power consumption and lower throughput and proposed to introduce a new prohibit timer to prevent excessive acquisition and reporting of GNSS information.
* Nokia observed that Network can attempt closed-loop correction of transmission errors, caused by inaccurate UE location information, but it is not feasible to correct frequency-domain errors. Furthermore, UE cannot receive network’s TA Commands during a long repetition period.
* Ericsson mentioned if the network solely relies on TACs to correct UE’s timing before or after GNSS position expiry, the signalling overhead could be very high due to the large timing drift. Ericsson proposed Network can optionally indicate service link timing drift parameters to an IoT NTN UE in connected mode and upon GNSS timer expiry in connected mode, an IoT NTN UE may use service link drift information (in addition to common TA parameters) to calculate TA values before receiving the next TA command. And Ericsson proposed Closed loop frequency correction mechanism should optionally be supported in IoT NTN.
* Samsung proposed to introduce closed loop pre-compensated frequency offset command signaling, e.g., using a MAC CE similar to current TA command.
* Qualcomm proposed to discuss solutions such that the residual TA that is to be corrected by a “closed loop” command (upon transmission of a NPRACH in connected mode), does not exceed the correction capability afforded by such a NPRACH transmission. Candidate solutions include:
* Updating the $N\_{TA, adj}^{UE}$ term with every TA command received in response to transmitting a NPRACH in connected mode
* Accumulating prior TA commands into the $N\_{TA}$ term, as opposed to universally setting it to 0 for a NPRACH transmission

Qualcomm observed for long connections in eMTC and NB-IoT over NTN, NPRACH-driven closed-loop time and frequency corrections lowers the GNSS power penalty from 45% to 17% (with a GNSS relaxation factor of 4), w.r.t a baseline without closed-loop corrections. And proposed NPRACH-driven closed-loop time and frequency corrections, to mitigate UE power consumption on account of GNSS fixes, a strategy is (approximately) schematically depicted in Fig. 3 below and a robust NPRACH design in Fig. 4 in [R1-2210007.](file:///C%3A%5CUsers%5Cyounsun%5CDocuments%5C3GPP%20documents%5CRAN1%20tdocs%5CTSGR1_110%5CDocs%5CR1-2207258.zip)



**Figure 3: Relaxed GNSS fixing using NPRACH-based closed loop corrections.**

Figure 4: Example of "restrictions" on starting NPRACH subcarriers for CBRA. Alternate starting subcarriers may be selected for NPRACH transmission by a UE.

* Lenovo proposed Closed loop time and frequency correction can be studied as implementation solution for UL synchronization during long connection.

Companies contributed analysis on the impact of GNSS position error to TA error and Frequency error and power consumption issues of GNSS measurement. The motivation for closed-loop corrections is to improve power consumption with reduced use of GNSS module to re-acquire GNSS position fix as observed some contributing companies. RAN1 has agreed that Closed loop time and frequency correction, with potential enhancements, for IoT-NTN is considered to reduce the need for UE to update GNSS position fix in long connection time. Closed-loop time correction is aligned with previous RAN1 agreements. Closed-loop frequency correction is not supported in legacy IoT.

Moderator View: Specific solutions 1) closed loop pre-compensated frequency offset command signaling 2) NPRACH-driven closed-loop time and frequency corrections, 3) service link drift information (in addition to common TA parameters) to calculate TA values before receiving the next TA command 4) a new prohibit timer to prevent excessive acquisition and reporting of GNSS information can be further discussed to align company understanding. The main motivation is to reduce the use of the GNSS module after the GNSS validity duration expires to save power consumption.

## First Round Discussion

***Initial Proposal 1:***

***Companies are encouraged to comment on potential enhancements for closed-loop corrections in Rel-18 to avoid using GNSS module after GNSS validity duration expires to save power consumption:***

* ***Closed loop pre-compensated frequency offset command signaling - e.g., using a MAC CE similar to current TA command***
* ***NPRACH-driven closed-loop time and frequency corrections including not setting NTA to zero for NPRACH transmission***
* ***Service link drift information (in addition to common TA parameters) to calculate TA values before receiving the next TA command***

Companies are encouraged to provide comments within the following table:

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| Companies | Comments |
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# [Active] Issue #2: GNSS measurement triggering mechanisms

**Agreement (RAN1 109e)**

Further study on whether there is a need for potential enhancements on the following for long connection time

* UE triggered GNSS measurement.
* Network triggered GNSS measurement.

**Conclusion(RAN1 109e)**

IoT NTN UE may need to re-acquire a valid GNSS position fix in long connection time.

FFS: Whether and how to update or reduce the need to update GNSS position fix in long connection time

**Agreement (RAN1 110)**

When eNB triggers UE to make GNSS measurements, UE re-acquires GNSS position fix

* FFS details of signalling
* FFS how UE reports GNSS assistance information after eNB trigger and the detailed content
* Note: further discuss whether a UE is expected to handle all eNB triggers

## Company contributing views

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| --- | --- |
| Contribution | Observation/Proposals |
| MediaTek | Proposal 1: Based on UE reported GNSS assistance information and residual transmit timing error measurements at the eNB, the eNB can trigger UE to do GNSS measurement by RRC signalling.Observation 8: RAN1 should further discuss how the UE can be kept in connected after GNSS validity expiration if residual transmit timing error after closed-loop timing correction is within the transmit timing error requirements.Proposal 5: eNB can trigger UE to make GNSS measurements:* if transmit timing error / frequency error above some eNB receiver measurement threshold even after MAC TAC and maybe MAC CE frequency compensation indication sent to UE.
* when GNSS validity duration expires, and Timing Alignment Timer (TAT) has expired
 |
| Huawei, HiSilicon | Proposal 2: Aperiodic triggering by network can be applied to allow flexible and efficient configuration of GNSS measurement.Proposal 3: For network triggered GNSS measurement, support eNB to trigger GNSS measurement gap by MAC CE.Proposal 5: UE can skip GNSS position fix triggered by eNB, when its GNSS information is still valid.  |
| Spreadtrum | Proposal 2: The network can trigger the UE to perform GNSS measurements through PDCCH order. |
| ZTE | Proposal 3: The GNSS acquisition will start only after the expiration of GNSS validity duration even with reception of trigger information from gNB. |
| OPPO | Proposal 1: dynamic eNB triggering GNSS measurement should be supported. |
| CATT | Proposal 1: Support UE triggering and network triggering both for GNSS measurement. Proposal 2: For UE triggering, the triggering indication and measurement duration can be reported by the RRC signalling. Proposal 3: MAC CE can be applied for network trigger signalling. |
| Nordic Semiconductor ASA | Proposal 2: It should be considered if some signalling mechanism is needed for the network to dynamically allocate GNSS measurement gap to the UE in RRC connected mode. |
| Nokia | Proposal 9: RAN1 to discuss network configuring periodic/aperiodic GNSS measurement gap for the UE via RRC signaling. Proposal 11: RAN1 to discuss the possibility of network extending a UE’s GNSS validity timer. |
| Xiaomi | Proposal 2: Both network and UE triggered GNSS measurement can be supported. |
| Apple | Proposal 1: RAN1 considers network schedules new periodic GNSS measurement gap for UE to re-acquire GNSS position for long connection times.Proposal 3: MAC CE is used for triggering aperiodic GNSS measurement. |
| Ericsson | Proposal 1 Network can potentially indicate to an IoT NTN UE in connected mode if it can continue its uplink transmission after GNSS validity timer expiry.Observation 3 The network can use GNSS assistance information (which the UE will have to report anyways if configured by the network) to trigger a GNSS measurement by scheduling a gap.Observation 4 UE-triggered GNSS measurement may be useful when UE needs to make a GNSS measurement earlier than what is indicated by its GNSS validity timer, e.g., due to a sudden change in the UE’s mobility pattern.Proposal 6 Support network-triggered GNSS measurements in connected mode for IoT NTN. |
| Samsung | Proposal 2: Specify the condition of UE triggered GNSS measurement, e.g., GNSS validity timer is expired, there are UL data to transmit, and the UL synchronization is lost. Proposal 3: Specify the condition of eNB triggered GNSS measurement, e.g., GNSS validity timer is expired, there are DL data to transmit and the UL synchronization is lost.Proposal 5: Reserved bit in the DCI indicating PDCCH order RACH can be used to trigger a new GNSS measurement. |
| Lenovo | Proposal 3: eNB configures the GNSS position fix gap periodically and UE report the update of GNSS validity duration X and GNSS position fix measurement time instead of directly trigger a GNSS measurement to eNB |

Contributing companies discussed on details of signalling and the triggering conditions for GNSS measurement triggering.

**On how eNB to start a GNSS measurement, several options are proposed:**

*Option 1: RRC signaling*

* MediaTek proposed Based on UE reported GNSS assistance information and residual transmit timing error measurements at the eNB, the eNB can trigger UE to do GNSS measurement by RRC signalling
* Nokia proposed RAN1 to discuss network configuring periodic/aperiodic GNSS measurement gap for the UE via RRC signaling.

*Option 2: MAC CE*

* Huawei, HiSilicon, CATT, Apple proposed for network triggered GNSS measurement by MAC CE.

*Option 3: PDCCH order/DCI*

* Spreadtrum proposed the network can trigger the UE to perform GNSS measurements through PDCCH order.
* Samsung proposed reserved bit in the DCI indicating PDCCH order RACH can be used to trigger a new GNSS measurement.

*Option 4: eNB/Network periodically trigger GNSS measurement*

* Apple and Lenovo proposed periodic GNSS measurement gap for UE to re-acquire GNSS positio.

*Option 5: eNB/Network aperiodically trigger GNSS measurement*

* Huawei, HiSilicon, Apple proposed aperiodic triggering by network. Huawei, HiSilicon mentioned aperiodic triggering by network can be applied to allow flexible and efficient configuration of GNSS measurement.
* Nordic proposed it should be considered if some signalling mechanism is needed for the network to dynamically allocate GNSS measurement gap to the UE in RRC connected mode.
* OPPO proposed dynamic eNB triggering GNSS measurement should be supported.

**On triggering conditions and UE behaviours for GNSS measurement:**

* MediaTek observed RAN1 should further discuss how the UE can be kept in connected after GNSS validity expiration if residual transmit timing error after closed-loop timing correction is within the transmit timing error requirements. And proposed eNB can trigger UE to make GNSS measurements
	+ if transmit timing error / frequency error above some eNB receiver measurement threshold even after MAC TAC and maybe MAC CE frequency compensation indication sent to UE
	+ when GNSS validity duration expires, and Timing Alignment Timer (TAT) has expired
* Huawei, HiSilicon proposed UE can skip GNSS position fix triggered by eNB, when its GNSS information is still valid.
* ZTE proposed the GNSS acquisition will start only after the expiration of GNSS validity duration even with reception of trigger information from eNB
* CATT and Xiaomi proposed to support UE triggering and network triggering both for GNSS measurement. CATT proposed further For UE triggering, the triggering indication and measurement duration can be reported by the RRC signalling.
* Ericsson observed that UE-triggered GNSS measurement may be useful when UE needs to make a GNSS measurement earlier than what is indicated by its GNSS validity timer, e.g., due to a sudden change in the UE’s mobility pattern. And Network can potentially indicate to an IoT NTN UE in connected mode if it can continue its uplink transmission after GNSS validity timer expiry
* Nokia proposed RAN1 to discuss the possibility of network extending a UE’s GNSS validity timer.
* Samsung proposed to specify the condition of UE triggered GNSS measurement, e.g., GNSS validity timer is expired, there are UL data to transmit, and the UL synchronization is lost and specify the condition of eNB triggered GNSS measurement, e.g., GNSS validity timer is expired, there are DL data to transmit and the UL synchronization is lost.

Moderator View: The issue for discussion is to align understanding on when and how to start a GNSS measurement in connected. Several ways are mentioned for how eNB can trigger GNSS measurement – i.e. via RRC signaling, MAC CE, or PDCCH order/DCI. Whether trigger is periodically or aperiodically can also be discussed. For GNSS measurement triggered by eNB, RAN1 can discuss details of signalling for triggering mechanisms. For aspects of validity extension for GNSS measurements, the moderator understanding that it is related to discussions on the closed-loop correction and the new gap or a timer-based mechanism in the next section. The UE by itself cannot know whether the timing error as measured at the eNB receiver is acceptable after closed-loop correction is applied. For UE trigger for GNSS measurements, one potential mechanism would be based on a timer mechanism as discussed in the next section.

## First Round Discussion

***Initial Proposal 2-1:***

***Companies are encouraged to comment on signalling of eNB trigger UE to make GNSS measurement via***

* ***Option 1 (RRC signaling)***
* ***Option 2 (MAC CE)***
* ***Option 3 (PDCCH order/DCI)***

***Initial Proposal 2-2:***

***Companies are encouraged to comment on periodicity assumption for eNB trigger UE to make GNSS measurement***

* ***Option A (periodically)***
* ***Option B (aperiodically)***

Companies are encouraged to provide comments within the following table:

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# [Active] Issue #3: GNSS measurement in connected

**RAN2-116bis**

UE need to have a valid GNSS fix before going to connected. RAN2 assumes that the UE may need to re-acquire the GNSS fix right before establishing the connection (regardless if previously valid or not), if needed to avoid interruption during the connection.

When the GNSS fix becomes outdated in RRC\_CONNECTED mode, the UE goes to IDLE mode.

**Agreement (RAN1** **109e)**

At least the following options can be considered on GNSS measurement in connected for potential enhancements for improved GNSS operations:

* Option 1: UE re-acquires GNSS position fix during RLF procedure
* Option 2: UE re-acquires GNSS position fix with a new gap

Note: this does not imply that a Rel-18 IoT NTN UE is mandated to support one or both of the options.

## Company contributing views

|  |  |
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| Contribution | Observation/Proposals |
| MediaTek | Observation 9: UE can re-acquire GNSS position fix based on when it is triggered to make GNSS measurements utilizing:* A new GNSS timer
* A new scheduling gap

Observation 10: “UE can re-acquire GNSS position fix based on a new GNSS measurement timer” has lower impact on specifications. Proposal 6: “UE can re-acquire GNSS position fix based on a new GNSS measurement timer” is baseline for improved GNSS operations. |
| Huawei, HiSilicon | Proposal 1: Support to define measurement gap for UE to re-acquire GNSS position fix in long connection (option 2). |
| Spreadtrum | Proposal 1: UE re-acquires GNSS position fix with a new gap should be supported on GNSS measurement in connected. |
| ZTE | Proposal 4: The start time of GNSS measurement gap should be set to the expiration time of GNSS validity duration. Proposal 5: No scheduling and reception of any signaling is expected by UE during the GNSS measurement gap. |
| OPPO | Proposal 2: additionally, semi-static GNSS measurement gap configured can be considered to reduce the system signaling overhead. Proposal 3: If UE cannot complete the GNSS measurement, the UE should go back to idle. |
| Nordic | Proposal 2: It should be considered if some signalling mechanism is needed for the network to dynamically allocate GNSS measurement gap to the UE in RRC connected mode. |
| Nokia | Observation 1: Common understanding on GNSS measurement gap in time domain between UE and network is needed.Proposal 2: GNSS measurement gap in CONNECTED mode should be specified for a new GNSS measurement before the GNSS position is outdated.Observation 3: Multiple IoT UEs with different capability, mobility state and channel status may request different GNSS measurement gaps.Proposal 3: Overhead reduction should be considered for selection of GNSS measurement gap and coordination between UE and eNB.Observation 6: UE may be aware of its own movement based on RRC Idle mobility state or GNSS positions changing.Proposal 6: RAN1 to discuss how the network can handle UEs, which are aware they will need a GNSS measurement gap in an upcoming long RRC Connection.Observation 7: network can provide common GNSS measurement gap configurations for different UE mobility states.Proposal 7: RAN1 to discuss use of common GNSS measurement gap configurations to effectively support many moving UEs.Proposal 13: Enabling a GNSS measurement gap during a long repetition period for IoT should be studied |
| Xiaomi | Proposal 3: The IoT UE can be configured with measurement gap to perform GNSS measurement depending on the UE’s capability. |
| CMCC | Proposal 1. During long connection times, the GNSS measurement gaps can be applied to update the GNSS position fix in case the GNSS becomes outdated.Proposal 2. If GNSS measurement gap is applied to enable a new GNSS position fix during long connection times, the common understanding between UE and eNB that UE may automatically perform GNSS operation and NTN NB-IoT/eMTC operation on non-overlapping slot/frame should be achieved.Proposal 3. The GNSS measurement gaps can be configured individually per UE level.Proposal 4. Considering the mechanisms to support UE perform GNSS operation and NTN NB-IoT/eMTC operation on non-overlapping slot/frame, the following configuration can be further studied:* Option 1. GNSS measurement gap can be configured periodically by network and indicated by RRC signalling.
* Option 2. Indicate the GNSS measurement gap by DCI format.
* Option 3. Signal the GNSS measurement gap by MAC CE command.
 |
| Apple | Proposal 1: RAN1 considers network schedules new periodic GNSS measurement gap for UE to re-acquire GNSS position for long connection times.Proposal 2: For periodic GNSS measurement, UE derives the starting subframe for GNSS measurement by configured GNSS measurement gap, GNSS measurement periodicity and subframe offset. |
| Ericsson | Observation 2 GNSS acquisition during RLF procedure will only be needed if a UE fails to acquire it during a GNSS measurement gap.Proposal 5 Support GNSS measurement gaps for IoT NTN UEs in connected mode. |
| Samsung | Proposal 4: For eNB triggered GNSS measurement, a GNSS measurement window needs to be defined. |
| Qualcomm | With regards to GNSS measurements in connected mode:Observation 9: GNSS measurement in connected mode should be considered a fallback procedure (as opposed to a routine, expected occurrence), e.g., when closed-loop time and frequency commands fail to maintain uplink synchronization in time and frequency within stipulated requirements.Proposal 5: A UE may re-acquire GNSS as part of a “recovery” procedure before the declaration of an eventual RLF (if the recovery fails within a certain time), in a similar fashion to Release 17 recovery procedures for ephemeris and common TA parameters upon validity expiry.Proposal 6: The network shall indicate whether it supports UE behavior associated with connected mode GNSS measurements, as part of a recovery procedure upon expiry of GNSS validity.* This avoids backwards compatibility issues w.r.t a Rel 17 base-station, that always expects UEs to go to IDLE mode upon GNSS validity expiry.
 |
| Lenovo | Proposal 1: Scheduling new gap solution can be supported for UE with long uplink transmission and solution of scheduling new gap to allow UE to refresh its GNSS position fix needs further study. |

In RAN1#109 it was agreed

**Agreement**

At least the following options can be considered on GNSS measurement in connected for potential enhancements for improved GNSS operations:

Option 1: UE re-acquires GNSS position fix during RLF procedure

Option 2: UE re-acquires GNSS position fix with a new gap

Note: this does not imply that a Rel-18 IoT NTN UE is mandated to support one or both of the options.

The moderator understanding is that in RAN1#110 it was clarified that the Rel-17 solution to re-acquire the SIB in RRC\_CONNECTED based on a new timer is not part of the RLF procedure. A similar approach based on a new GNSS measurement timer can be used with a new timer for re-acquisition of GNSS measurements in RRC\_CONNECTED without change to RLF procedure.

Two options are mentioned in RAN1 109e and RAN1 110 meeting on GNSS measurement schemes in connected.

*Option 1: UE re-acquires GNSS position fix with a new measurement timer*

* MediaTek proposed Option 1 is baseline for improved GNSS operations and Option 1 has lower impact on specifications. And mentioned the UE will stay in connected and start the new timer when GNSS validity duration expires and eNB doesn’t trigger GNSS measurements for UE in connected after legacy Timing Alignment Timer expires. On starting the new timer, UE re-acquire GNSS position fix and re-synchronize on DL, then it can reset the new timer. Assuming a hot fix of 1-2 seconds and re-synchronization time in the order of several hundred ms, the total time will be consistent with connected DRX of 2.56 s. The above procedure is similar to the procedure for re-acquiring SIB31 with a new timer specified by RAN2 in Rel-17 when UL ephemeris validity expired.
* Qualcomm proposed a UE may re-acquire GNSS as part of a “recovery” procedure before the declaration of an eventual RLF (if the recovery fails within a certain time), in a similar fashion to Release 17 recovery procedures for ephemeris and common TA parameters upon validity expiry and network shall indicate whether it supports UE behavior associated with connected mode GNSS measurements, as part of a recovery procedure upon expiry of GNSS validity (This avoids backwards compatibility issues w.r.t a Rel 17 base-station, that always expects UEs to go to IDLE mode upon GNSS validity expiry.) And clarified that GNSS measurement in connected mode should be considered a fallback procedure (as opposed to a routine, expected occurrence), e.g., when closed-loop time and frequency commands fail to maintain uplink synchronization in time and frequency within stipulated requirements.

*Option 2: UE re-acquires GNSS position fix with a new gap*

Huawei, HiSilicon, Spreadtrum, ZTE, OPPO, Nokia, xiaomi, CMCC, Apple, Ericsson, Samsung, Lenovo proposed proposals for GNSS measurement gap.

* ZTE mentioned no scheduling and reception of any signaling is expected by UE during the GNSS measurement gap.
* OPPO mentioned additionally, semi-static GNSS measurement gap configured can be considered to reduce the system signaling overhead. And if UE cannot complete the GNSS measurement, the UE should go back to idle.
* Nokia proposed GNSS measurement gap in CONNECTED mode should be specified for a new GNSS measurement when GNSS position is about to outdated. And mentioned Common understanding on GNSS measurement gap in time domain between UE and network is needed, where multiple IoT UEs with different capability, mobility state and channel status may request different GNSS measurement gaps. UE may be aware of its own movement based on RRC Idle mobility state or GNSS positions changing, and network can provide common GNSS measurement gap configurations for different UE mobility states. Nokia proposed RAN1 to discuss how the network can handle UEs, which are aware they will need a GNSS measurement gap in an upcoming long RRC Connection, use of common GNSS measurement gap configurations to effectively support many moving UEs, overhead reduction should be considered for selection of GNSS measurement gap and coordination between UE and eNB
* Xiaomi proposed IoT UE can be configured with measurement gap to perform GNSS measurement depending on the UE’s capability.
* CMCC proposed if GNSS measurement gap is applied to enable a new GNSS position fix during long connection times, the common understanding between UE and eNB that UE may automatically perform GNSS operation and NTN NB-IoT/eMTC operation on non-overlapping slot/frame should be achieved. And the GNSS measurement gaps can be configured individually per UE level with the following configuration can be further studied: Option 1. Semi-static indication of GNSS measurement gap period through RRC configuration; Option 2. Indicate the GNSS measurement gap by DCI format; Option 3. Signal the GNSS measurement by MAC CE command.
* Apple proposed periodic GNSS measurement gap for UE to re-acquire GNSS position for long connection times. And for periodic GNSS measurement, UE derives the starting subframe for GNSS measurement by configured GNSS measurement gap, GNSS measurement periodicity and subframe offset
* Ericsson mentioned GNSS acquisition during RLF procedure will only be needed if a UE fails to acquire it during a GNSS measurement gap
* Lenovo proposed scheduling new gap solution can be supported for UE with long uplink transmission and solution of scheduling new gap to allow UE to refresh its GNSS position fix needs further study.

Moderator View: UE re-acquires GNSS position fix with a new measurement timer is close to recovery procedures for ephemeris and common TA parameters upon validity expire in Rel-17, where the UE is kept in RRC\_CONNECTED based on a new configured timer (note that this recovery procedure is not part of RLF procedure). RAN1 could further discuss when the new timer could be started. UE re-acquires GNSS position fix with a new gap when triggered by eNB could also be considered.

## First Round Discussion

***Initial Proposal 3:***

***Companies are encouraged to comment on the following mechanisms:***

* ***If eNB triggers connected UE to make GNSS measurement, UE can re-acquire GNSS position fix with a new gap***
* ***UE can re-acquire GNSS position fix based on a new GNSS measurement timer configured by the network***
	+ ***FFS details of configuration, when to start the timer***

Companies are encouraged to provide comments within the following table:

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# [Active] Issue #4: Report GNSS assistance information

The moderator recalls the agreements for GNSS assistance information.

**Agreement (RAN1 107-e):**

The UE autonomously determines its GNSS validity duration X and reports information associated with this valid duration to the network via RRC signalling.

* X = {10s, 20s, 30s, 40s, 50s, 60s, 5 min, 10 min, 15 min, 20 min, 25 min, 30 min, 60 min, 90 min, 120 min, infinity}

Send LS to RAN2 to take the following RAN1 agreements into consideration to specify the aspects related to GNSS position validity:

* 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
* The UE autonomously determines its GNSS validity duration X and reports information associated with this valid duration to the network via RRC signalling.
	+ X = {10s, 20s, 30s, 40s, 50s, 60s, 5 min, 10 min, 15 min, 20 min, 25 min, 30 min, 60 min, 90 min, 120 min, infinity}
* 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 (RAN1 109-e):**

UE reports additional GNSS assistance information and further study the detailed GNSS assistance information, including e.g. GNSS position fix measurement time

* Note: Since RAN1 agreed that GNSS validity duration is reported by UE in Rel-17, it is already included in GNSS assistance information.

**Agreement (RAN1 110):**

GNSS assistance information that UE reports to eNB at least consists of:

* GNSS position fix time duration for measurement
* GNSS validity duration

**RAN2-118**

* A new parameter for remaining GNSS validity duration is introduced in Msg5, e*.g. RRCConnectionResumeComplete*, *RRCConnectionSetupComplete* and RRCreestablishmentComplete messages, and the parameter refers to the time of message transmission.
* Can discuss offline whether to expand the granularity of the value range, but if no convergence will implement the R1 proposal from the LS.
* P1: The value range of the remaining GNSS validity duration should include the values proposed by RAN1 , i.e. {10s, 20s, 30s, 40s, 50s, 60s, 5 min, 10 min, 15 min, 20 min, 25 min, 30 min, 60 min, 90 min, 120 min, infinity}.
* P3: The new parameter for remaining GNSS validity duration is introduced in the following Msg5 messages: RRCConnectionResumeComplete, RRCConnectionSetupComplete, RRCreestablishmentComplete RRCConnectionResumeComplete-NB, RRCConnectionSetupComplete-NB, RRCreestablishmentComplete-NB.
* P4: The new parameter for remaining GNSS validity duration is introduced in *RRCConnectionReconfigurationComplete* for MTC Handover.
* P5: No new RRC release cause “GNSS invalidity” is introduced in RRC Release.
* This mechanism is not configurable, and the UE always reports.

## Company contribution views

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| Contribution | Observation/Proposals |
| MediaTek | Proposal 2: After eNB triggers UE to re-acquire GNSS position fix in connected, UE can report GNSS related information with MAC CE.Proposal 3: Add the following fields to GNSS assistance information that UE reports to eNB:* Differential GNSS validity duration
* Fixed UE indication

Proposal 4: When one or more fields of GNSS assistance information are not reported by UE, the eNB behaviour is to assume that the information remains same as the latest reported one. |
| Huawei, HiSilicon | Proposal 6: After GNSS position fix, UE can either update GNSS validity duration (if changed from previous report) or indicate success of GNSS position fix. UE is not required to report if GNSS position fails in the measurement gap.Proposal 7: UE should report GNSS position fix time duration for measurement before eNB trigger GNSS measurement gap. The minimum value of measurement gap reported by UE can be zero, implying the capability of simultaneous cellular and GNSS operation. Proposal 8: UE needs to notify the eNB before the start of a GNSS measurement gap if it determines to skip the GNSS position fix during the gap and the remaining validity duration |
| ZTE | Proposal 1: For the GNSS validity duration, the legacy procedure in Rel-17 can be reused for reporting.Observation 1: Frequent update is not expected for GNSS position fix time duration for measurement.Proposal 2: The report of GNSS measurement time duration can be carried by Msg5 only before the first GNSS position fix measurement. |
| CATT | Proposal 4: GNSS measurement duration can be treated as one type of UE capability to report. Proposal 5: UE should send the UL PRACH signal to indicate network when the GNSS measurement is completed. |
| Nokia | Proposal 10: RAN1 to further discuss UE providing updated assistance information and/or indication to reset the GNSS validity duration timer after a successful GNSS measurement. |
| Xiaomi | Proposal 1: UE reports the capability related to the non-simultaneously GNSS and NTN NB-IoT/eMTC operation. |
| CMCC | Proposal 5. GNSS assistance information reported by UE to eNB may consist of the following information:* If GNSS measurement gap is periodically configured by network, the maximum GNSS validity duration and GNSS measurement time duration can be reported to eNB to determine the period of GNSS measurement gap and GNSS measurement gap length.
* If the GNSS measurement is triggered aperiodically, UE can directly report the required duration of GNSS measurement gap to assist the network in determining the GNSS measurement gap length.
 |
| InterDigital | Observation 1: Unlike GNSS location information, GNSS assistance information (i.e., position fix time duration and validity duration) does not require AS security since it provides no indication of the UE’s actual position.Observation 2: Semi-static signaling (e.g. RRC) may not be suitable to report GNSS assistance information since position fix time duration and validity duration can vary dynamically based on UE characteristics (e.g. surroundings, UE speed). Proposal 1: Introduce a new GNSS assistance information MAC CE, which contains at least GNSS position fix time and validity duration.Proposal 2: GNSS assistance information is at least reported upon NW request. FFS other reporting trigger conditions. |
| Ericsson | Observation 5 NTN UEs are required to have a valid GNSS position before accessing the network.Proposal 7 UE should report the GNSS assistance information during connection establishment phase.Proposal 8 Upon GNSS timer expiry, a UE in connected mode should report the GNSS assistance information after GNSS reacquisition using RRC signalling if configured by the network.Proposal 9 If a UE in connected mode has already reported its GNSS assistance information to the network, the UE may not to be required to report it again during the same connection provided that the GNSS assistance information is expected to remain unchanged.Proposal 10 Network should configure the type of GNSS assistance information to be included in the UE report. |
| Lenovo | Proposal 3: eNB configures the GNSS position fix gap periodically and UE report the update of GNSS validity duration X and GNSS position fix measurement time instead of directly trigger a GNSS measurement to eNB |

It has been agreed that GNSS assistance information that UE reports to eNB at least consists of: GNSS position fix time duration for measurement and GNSS validity duration. On detailed/other information of UE reported GNSS assistance information and when/ how to report, several options are proposed by contributing companies.

**On detailed/other information of UE reported GNSS assistance information**

*Option 1: Differential GNSS validity duration*

* MediaTek proposed UE to report Differential GNSS validity duration.

*Option 2:* *Fixed UE indication*

* MediaTek proposed UE to report Fixed UE indication.

*Option 3: UE capability of simultaneous cellular and GNSS operation*

* Huawei, HiSilicon proposed UE to imply the capability of simultaneous cellular and GNSS operation with the minimum value of measurement gap reported by UE be zero.
* Xiaomi proposed UE reports the capability related to the non-simultaneously GNSS and NTN NB-IoT/eMTC operation.

*Option 4: Indicate success/complete of GNSS measurement.*

* Huawei, HiSilicon proposed After GNSS position fix, UE can either update GNSS validity duration (if changed from previous report) or indicate success of GNSS position fix.
* CATT proposed UE should send the UL PRACH signal to indicate network when the GNSS measurement is completed.

*Option 5: Indicate same information as the latest reported one.*

* MediaTek proposed when one or more fields of GNSS assistance information are not reported by UE, the eNB behaviour is to assume that the information remains same as the latest reported one.
* Ericsson proposed if a UE in connected mode has already reported its GNSS assistance information to the network, the UE may not to be required to report it again during the same connection provided that the GNSS assistance information is expected to remain unchanged.

**On when/how UE should report the GNSS assistance information:**

* MediaTek and InterDigital proposed a UE can report GNSS related information with MAC CE. InterDigital further proposed a new GNSS assistance information MAC CE, which contains at least GNSS position fix time and validity duration and GNSS assistance information is at least reported upon NW request, FFS other reporting trigger conditions
* Huawei, HiSilicon proposed After GNSS position fix, UE can either update GNSS validity duration (if changed from previous report) or indicate success of GNSS position fix. UE is not required to report if GNSS position fails in the measurement gap. And proposed UE should report GNSS position fix time duration for measurement before eNB trigger GNSS measurement gap.
* ZTE proposed for the GNSS validity duration, the legacy procedure in Rel-17 can be reused for reporting, the report of GNSS measurement time duration can be carried by Msg5 only before the first GNSS position fix measurement.
* CATT proposed GNSS measurement duration can be treated as one type of UE capability to report.
* CMCC proposed if GNSS measurement gap is periodically configured by network, the maximum GNSS validity duration and GNSS measurement time duration can be reported to eNB to determine the period of GNSS measurement gap and GNSS measurement gap length and if the GNSS measurement is triggered aperiodically, UE can directly report the required duration of GNSS measurement gap to assist the network in determining the GNSS measurement gap length.
* Ericsson proposed UE should report the GNSS assistance information during connection establishment phase and upon GNSS timer expiry, a UE in connected mode should report the GNSS assistance information after GNSS reacquisition using RRC signalling if configured by the network. Besides, Ericsson proposed Network should configure the type of GNSS assistance information to be included in the UE report.

Moderator View: On detailed/other information of UE reported GNSS assistance information, for Option 1 (Differential GNSS validity duration) and Option 5 (Indicate same information as the latest reported one), they may help save signaling overhead, for Option 2 (Fixed UE indication), Option 3 (UE capability of simultaneous cellular and GNSS operation) and Option 4 (Indicate success/complete of GNSS measurement), they may help on network scheduling. On when/how UE should report the GNSS assistance information, whether UE should report by MAC CE and where UE should report can be further discussed. To the moderator understanding RAN2 specified report of GNSS validity duration in Msg5 in Rel-17. Then the GNSS position fix time duration for measurement should also be reported in Msg5.

## First Round Discussion

***Initial Proposal 4-1:***

***During connection establishment phase, GNSS assistance information in Msg5 includes at least the following:***

* ***GNSS validity duration***
* ***GNSS position fix time duration for measurement***

***Initial Proposal 4-2:***

***In connected, GNSS assistance information UE report with MAC CE includes at least:***

* ***GNSS validity duration***
* ***GNSS position fix time duration for measurement***

Companies are encouraged to provide comments within the following table:

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# [Active] Issue #5: GNSS measurement and C-DRX

## 5.1 Company contributing views

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| Contribution | Observation/Proposals |
| Huawei, HiSilicon | Proposal 4: Support UE autonomously perform GNSS position fix during the inactive state of UE’s C-DRX. UE could report the successful GNSS position fix and validity duration update, if applicable based on the measurement not triggered by network. |
| Nokia | Observation 2: GNSS measurement outside Active Time of DRX is not feasible, because it requires long DRX cycles and results in too frequent GNSS measurement opportunities.Proposal 8: RAN1 to discuss whether GNSS reacquisition is always needed for short RRC Idle periods during a long data transmission duration. |
| Apple | Proposal 4: RAN1 is to consider the interaction between GNSS measurement and C-DRX.  |

Huawei, HiSilicon proposed to support UE autonomously perform GNSS position fix during the inactive state of UE’s C-DRX. UE could report the successful GNSS position fix and validity duration update, if applicable based on the measurement not triggered by network. UE can perform GNSS position fix autonomously and ensure the GNSS position fix end before UE enters into active state, as illustrated in Figure 2 from R1-2208438. With this scheme, the resources for GNSS position fix can be saved especially when the duration of inactive state is longer than the validity of GNSS position fix. It should be noted that the timing of GNSS position fix during inactive state is by UE’s implementation. After UE autonomously performs GNSS position fix during the inactive state and enter into active state, the GNSS position fix and updated validity duration should be indicated to eNB as assistant information to postpone the following GNSS measurement accordingly.



**Figure 2 GNSS measurement during DL/UL idle period**

Nokia proposed to discuss whether GNSS reacquisition is always needed for short RRC Idle periods during a long data transmission duration.

Apple proposed to consider the interaction between GNSS measurement and C-DRX.

Moderator View: Long connections also imply that there may be “periods of inactivity”, after which the UE reconnects to the cell. For such cases, RAN1 can further discuss on whether UE can re-use a previously acquired GNSS position fix or UE can re-acquire GNSS position fix by UE implementation.

## 5.2 First Round Discussion

***Initial Proposal 5:***

***Companies are encouraged to comment on whether UE can re-acquire GNSS position fix during inactive state of Connected DRX.***

Companies are encouraged to provide comments within the following table:

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| Companies | Comments |
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# 6 [Low Priority] MISC

The WID objective is copied below for reminder

Study and specify, if needed, improved GNSS operations for a new position fix for UE pre-compensation during long connection times and for reduced power consumption. Simultaneous GNSS and NTN NB-IoT/eMTC operation is not assumed. [RAN1]

Based on the moderator understanding of the Rel-18 IoT NTN WID objectives and conclusions / agreements in Rel-17 IoT NTN Work Item, the following FL recommendations are made for sub-sections 6.1, 6.2, 6.3.

## 6.1 Acquisition of assistance information in Connected

The moderator recalls the RAN1 and RAN2 agreements for acquisition of assistance information for UL time/frequency synchronization in Connected.

**Agreement (RAN1 107-e):**

The serving satellite ephemeris and common TA related parameters are signalled in the same SIB message and have the same epoch time.

**Agreement (RAN1 107-e):**

A single validity duration for both serving satellite ephemeris and common TA related parameters is broadcast on the SIB.

**Agreement (RAN1 107-e):**

NTN validity duration is configured per cell and indicated to the UE in X bits with:

* Value range { 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 120, 180, 240~~, Infinity~~}
* Unit is second
* FFS (to be resolved in current meeting): Additional values for GEO

**Agreement (RAN1 108-e):**

First discuss for additional values of validity timer for GEO in NR NTN AI 8.4.2. For IoT NTN, adopt the NR NTN agreement without modification for additional values of validity timer for GEO.

**Agreement (RAN1 NR NTN 108-e):**

Add one additional NTN validity duration value for GEO i.e. 900 seconds. X = 4 bits.

**RAN2-116bis**

* When SI used for UL synch (pre-compensation) is no longer valid, the UE autonomously tunes away and re-aquires the required SI, and then comes back. FFS whether anything additional is needed.

**RAN2-117**

* FFS if we Will have a guard timer to handle the case where the UE takes ‘forever’ reacquire the SIB. At timer expiry UE triggers RLF handling. (Note that it is expected that the timer will not expire in the normal case, and the UE can just come back acc to previous decision).
* RAN2 assumes Upon recovery from loss of precomp synch while TAT has not expired, UE resumes UL operation, no RACH is needed.
* When the UE tunes away, it is assumed that the UE may not receive DL dedicated transmissions, actions in the DL can be left to UE implementation.
* There is some support for enhancements for long data transmissions, which could be Rel-18.
* Introduce a guard timer TXXXX for SIBXX acquisition in connected mode. At TXXX expiry, UE triggers RLF (if it can be shown in Q2 that UE will loose RLM when UE tunes away, it can be discussed to skip this timer)
* Upon timer expiry (or UE tune away), UE stops all UL transmissions, flushes all HARQ buffers and maintains all UL resources.

#### 6.1.1 Company contributing views

|  |  |
| --- | --- |
| Contribution | Observation/Proposals |
| xiaomi | Proposal 4: The IoT UE can acquire the assistant information from SIBx in connected mode. |
| Nokia | Observation 10: The satellite assistance information validity timer may expire during a UE’s uplink transmission using repetitions.Proposal 15: How the UE can acquire satellite assistance information during an uplink repetition period should be studied. |

Xiaomi proposed the IoT UE can acquire the assistant information from SIBx in connected mode.

Nokia proposed to study how to acquire ephemeris and update TA during a long sequence of repetitions, considering the ephemeris validity timer may expire during a UE’s uplink transmission using repetitions.

Moderator View: This issue was discussed in RAN1 109e and RAN1 110, there was FL recommendation “Companies can further align understanding on whether and how re-acquiring the NTN SIB with ephemeris and common TA parameters could improve GNSS operations, and whether there is need and gains for further potential enhancements for re-acquiring NTN SIB in addition to Rel-17.” Proponents of further enhancements on the topic are encouraged to further discuss offline with companies to get more support.

#### 6.1.2 First Round Discussion

***FL recommendation – 6.1:***

***Proponents of further potential enhancements for re-acquiring NTN SIB in addition to Rel-17 are encouraged to further discuss offline with companies to get more support.***

Companies are encouraged to provide comments on the FL recommendation within the following table:

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## 6.2 Enhanced UL segmented transmission

#### 6.2.1 Company contributing views

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| Contribution | Observation/Proposals |
| Nokia | Observation 8: Over a long uplink transmission the elevation angle change will cause large variation of TA drift rate.Observation 9: Different segment sizes may be needed depending on the TA drift rate, which changes with satellite movement. Proposal 14: RAN1 to discuss how to configure multiple segment sizes for an uplink transmission. |

Nokia proposed to discuss how to configure multiple segment sizes for an uplink transmission. Over a long uplink transmission, the elevation angle change will cause large variation of TA drift rate and different segment sizes may be needed depending on the TA drift rate.

Moderator View: FL recommendation in RAN1#109 and RAN1 110 was “UL segmented transmission has been discussed in Rel-17. RAN1 are specifying UL segmented transmission in Rel-17. Enhancements to UL segmented transmissions are not in scope of Rel-18 IoT NTN WID. It can be de-prioritized in Rel-18.” Proponents of further enhancements on the topic are encouraged to further discuss offline with companies to get more support.

#### 6.2.2 First Round Discussion

***FL recommendation- 6.2:***

***Proponents of further UL segmented transmission enhancements are encouraged to further discuss offline with companies to get more support.***

Companies are encouraged to provide comments on the FL recommendation within the following table:

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## 6.3 Repetition continuation between two NTN cells

#### 6.3.1 Company contributing views

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| Contribution | Observation/Proposals |
| Nokia | Proposal 16: RAN1 should discuss the issue of repetition continuation between two NTN cells |

Nokia proposed discussing the issue of repetition continuation between two NTN cells. The transmission times of 10s and 40s, can be larger than the time the UE is served by a single cell in the LEO scenarios. For example, the maximum coverage time of one cell may be 50 km / 7.56 km/s =6.6 s based on the assumption of 50km satellite beam diameter for set 1, or 234 km /7.56 km/s = 31s for set 3 with 234km satellite beam diameter. When considering the transparent scenario, at least intra-satellite mobility would entail the two cells most likely originate from the same eNB and thus transfer of received bits would be an eNB-internal process. The target would be to enable the data transfer to continue after a cell reselection instead of restarting. Likewise, the procedure could be for handovers in eMTC and should support both uplink and downlink data transfer. Thus, it is suggested that RAN1 can consider if such continuation is feasible on the PHY layer in terms of keeping soft bits/repetition data, while solutions on higher layer RLC can also be envisioned. This is required to support the long connection times, which are envisioned by the objective in release 18

Moderator View: FL recommendation in RAN1#109 and RAN1 110 was “de-prioritize repetition continuation between two NTN cells as it is not in scope of Rel-18 IoT NTN WID. RAN2 has made agreements “No enhancement to R16 CHO are introduced in R17.” in RAN2 116e. It needs to be clarified that in Rel-17 IoT NTN, HO is only for eMTC. In NB-IoT, there is no HO. Further, when there is HO the HARQ buffers are flushed (for eMTC). Repetition continuation between two NTN cells is not in scope of Rel-18 in moderator view. Impact on RAN1/RAN2 specs is likely to be significant.” Proponents of further enhancements on the topic are encouraged to further discuss offline with companies to get more support

#### 6.3.2 First Round Discussion

***FL Recommendation – 6.3:***

***Proponents of further repetition continuation between two NTN cells enhancements are encouraged to further discuss offline with companies to get more support.***

Companies are encouraged to provide comments on the FL recommendation within the following table:

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# 7 Proposals for GTW

# 8 Conclusion

# 9 References

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