3GPP TSG RAN WG1 #110bis-e R1-220839x

e-Meeting, October 10th – 19th, 2022

Agenda Item: 9.11.2

Source: Moderator (Thales)

Title: FL Summary #1: Network verified UE location for NR NTN

Document for: Discussion

# Introduction

This feature lead summary document aims to collect and align on company views on the issues related Network verified UE location in NR NTN. It contains a summary of the contributions under 9.11.2 at TSG-RAN WG1 #110-bis. together with identified key issues. The goal of this document is also to provide recommendation on prioritization of discussion and whether any issues should be postponed.

The source contributions are cited in references [4]-[23]: A total of 20 TDocs have been submitted to current meeting for discussion. Please see the Appendix for the details, with all the proposals.

RAN1 agreements on Network verified UE location for NR NTN made at RAN1 Meeting #110 could be found in section 13.

Please note the following checkpoints for agreements:

|  |
| --- |
| [110bis-e-R18-NTN-02] Email discussion on network verified UE location for NR NTN by October 19 – Mohamed (THALES)   * Check points: October 14, October 19 |

# Topic#1 Evaluation of Multi-RTT positioning method for Network verified UE location with single satellite

## Background

The following sub-sections aim at summarizing the different observations made in the contributions submitted to the RAN1#110bis with respect to Multi-RTT positioning method for Network verified UE location in NTN and provide high level tracks for the summary of evaluation results as well as the main technical aspects discussed by different companies.

## Companies’ contributions summary

The following views/observations were expressed with respect to Multi-RTT positioning method for Network verified UE location in NTN :

|  |  |
| --- | --- |
| **Companies** | **Proposals** |
| THALES | Observation 4. With multi-RTT based positioning method in case of a single satellite in view, UE position uncertainty area below 10km could be obtained only with low RTT errors (e.g. 50ns to 100ns) and longer duration for RTT measurements collection (e.g. 508s or 624s).  Observation 5. The time period required to calculate uplink multi-RTT measurement is excessively long in case of multi-RTT based positioning method is used with single satellite in view which makes the feasibility of the method questionable. |
| Huawei, HiSilicon | **Observation 4:** Multi-RTT positioning outperforms DL-TDOA positioning, and its performance improves with increment of time interval between two measurements.  **Observation 5**: With Multi-RTT positioning, the positioning accuracy of less than 10km @90% UEs can be achieved by 3 RTT measurements with time intervals of 6s (which corresponds to a latency of 18seconds) or 4 RTT measurements with time interval of 4s (which corresponds to a latency of 16seconds). |
| ZTE | **Observation 3:** Multi-RTT has better performance than UL/DL-TDOA method.  **Observation 4:** When the ambiguity of single satellite positioning is not considered or can be resolved by other methods, and the measurement period is equal to or larger than 30s, the positioning error of multi-RTT method can be smaller than 10km with over 95% probability for LEO-600 set-1, rural LOS, S-band scenario, earth fixed beam.  **Observation 5:** When the ambiguity of single satellite positioning is not considered, and the measurement period is equal to 30s, the positioning error of multi-RTT method can be smaller than 10km with over 90% probability for LEO-600 set-1, rural LOS, S-band scenario, earth fixed beam.  **Proposal 2:** Single-satellite based multi-RTT positioning method can be used for UE location verification for earth fixed beam in LEO.  **Observation 6:** For earth moving beam case, single-satellite based multi-RTT/UL-TDOA/DL-TDOA with angular information at gNB side cannot achieve target performance.  **Proposal 3:** The earth moving beam case is deprioritized for single satellite based location verification. |
| OPPO | **Observation 2:** For multi-RTT method, when UE position approaches the orbit plane, there exists an estimation handicap zone, where the positioning accuracy is remarkably impacted and this issue cannot be resolved by increasing the satellite time instance interval.  **Observation 3:** For multi-RTT method, there exisits a compromise between the coverage and positioning accuracy. |
| CATT | **Observation 2**: For the Multi-RTT method, the influence of satellite motion on the RTT measurements should be considered, and the UL timing measurement is always worse than the one of DL.  **Proposal 1:** The DL-OTDOA method with perfect time synchronization should be treated as the baseline, due to the less impaction in satellite rapid motion and SNR deterioration in UL compared with Multi-RTT method. |
| Intel | **Proposal 3**:   * For Multi-RTT positioning with single satellite, RX-Tx Time difference reported by the UE shall consider the autonomous TA applied by the UE |
| Lenovo | **Proposal 4:** RAN1 to further study DL-TDoA/UL-TDoA and Multi-RTT timing-based positioning techniques and associated adaptations for NTN to verify UE reported location  **Proposal 5:** For NTN network, UE position is determined based on the propagation delay differences between satellite(s) and UE.  **Proposal 6:** For NTN network, satellite positions for different time instances are useful to determine the propagation delay difference between satellite and UE. |
| Apple | **Proposal 7:** In NGSO scenario with multi-RTT positioning method, consider that the distance between satellite and UE at the time of downlink transmission is different from the distance between satellite and UE at the time of uplink transmission.  **Proposal 8:** In NGSO scenario with multi-RTT positioning method, do not support the scheme that RTT is obtained as the sum of UE reported total TA and the timing error of the uplink reference signal |
| Samsung | **Observation 1:** The ambiguity of the mirror image position cannot be resolved using RTT or any other time based RAT dependent method.  **Proposal 1:** The ambiguity of the mirror image position is resolved by very low resolution DL-PRS beamforming or UL angle of arrival determination.  **Proposal 2:** Study low resolution DL-PRS and low resolution UL angle of arrival determination to decide which one offers a more efficient solution for the ambiguity of the mirror image position.  **Proposal 3:** Single-satellite multi-RTT positioning method can be used for UE location verification for LEO constellation. The RTT measurements are performed by the same satellite at different time instances. |
| NTT DOCOMO | **Proposal 5:**  For multi-RTT positioning method, using UE/gNB Rx-Tx time difference measurements is baseline. |
| Qualcomm | **Observation 1:** Single satellite can be used to verify the UE location only if the satellite moves fast enough, e.g., a LEO satellite.  **Observation 3:** It is feasible to achieve verification accuracy of 5 to 10 km with both single and multiple satellites.   * For single satellite with RTT measurements, a measurement window up to a few seconds may be required.   **Proposal 3**: For network verification of UE location, consider the following methods:   * Multi-RTT for single NGSO satellites * DL TDOA with possible RTT for the serving satellite for multi-satellite case. |
| Nokia, Nokia Shanghai Bell | **Observation 1:** Methods like multi-RTT, UL/DL-TDOA alone cannot distinguish between the mirror positions on either side of the orbital plane.  **Proposal 2:** RAN1 to consider other measurement approaches than current standardized methods (e.g., Multi-RTT and DL/UL-TDOA) to solve the network verified UE position problem.  **Observation 2:** UE neighboring cells measurements can be a good indicator of the UE location relative to the orbital line.  **Proposal 3:** RAN1 to consider to combine UE neighbor measurements to solve the ambiguity between mirror points. |
| Panasonic | **Observation 1:** Multi-RTT with a set of equations adjusted to the NTN-environment is a viable method to determine UE location with a verification accuracy of 5 to 10 km and with a single satellite.  **Proposal 1:** Adopt Multi-RTT as a method for network-based UE location verification.  **Observation 2:** A measurement window in the order of seconds may be required to achieve the required accuracy.  **Observation 3:** Multi-RTT can be modified such that three measurements (instead of four) are sufficient to determine UE location in three dimensions, but this requires a sufficiently large interval between subsequent RTT-measurement.  **Observation 4**: The interval between RTT-measurements has a stronger impact on the accuracy of UE location estimation than the number of RTT-measurements.  **Proposal 2**: RAN1 should carefully consider the number of required RTT-measurements for multi-RTT. |
| LG Electronics | **Proposal #3:** If multi-RTT is selected as a baseline scheme for NW verified UE location, study at least followings  • How to handle timing error/delay due to processing time in satellite and movement of satellite and/or UE  • Configuration of DL-PRS and SRS for the multiple measurement of UE Rx-Tx time difference |

## Summary of Multi-RTT positioning method evaluation

Seven companies commented on the suitability of Multi-RTT positioning method for Network verified UE location in NTN:

For network verified UE location with single satellite based on multi-RTT positioning method:

* 5 sources observed that multi-RTT positioning method can meet the NTN UE location verification accuracy requirement for LEO:
  + 3 sources observed that the positioning accuracy of less than 10km can be achieved with few seconds latency (less or equal to 10s).
  + One source observed that the positioning accuracy of less than 10km can be achieved with 18 seconds latency.
  + One source observed that the positioning accuracy of less than 10km can be achieved with 30 seconds latency for earth fixed beam.
* One source observed that the positioning accuracy of less than 10km can be achieved only with 508 seconds latency, especially for UE near the orbit plane
* One source observed that the Multi-RTT method is more suitable for UE location far from the orbit plane

A recap of multi-RTT positioning method evaluation results is provided within the following table:

|  |  |
| --- | --- |
|  | Latency (seconds) |
| **[Thales]:** UE position uncertainty area below 10km could be obtained only with low RTT errors (e.g. 50ns to 100ns) and longer duration for RTT measurements collection (e.g. 508s or 624s). | **508** |
| **[Huawei, HiSilicon]:** With Multi-RTT positioning, the positioning accuracy of less than 10km @90% UEs can be achieved | **18** |
| **[ZTE]:** Single-satellite based multi-RTT positioning method can be used for UE location verification for earth fixed beam in LEO: The positioning error of multi-RTT method can be smaller than 10km with over 95% probability for LEO-600 set-1, rural LOS, S-band scenario, earth fixed beam.  For earth moving beam case, single-satellite based multi-RTT/UL-TDOA/DL-TDOA with angular information at gNB side cannot achieve target performance | **30** (earth fixed beam) |
| **[Oppo]:** ForUEs close to the orbit plane, there may exist some positioning estimation handicap zone, where the estimation accuracy may be remarkably impacted. and this issue cannot be resolved by increasing the satellite time instance interval | Even with 30s the raised near-orbit-plane issue subsist |
| **[Samsung]:** The accuracy of the RTT method will be satisfactory for the network verified requirements demanded by TR 38.882, even for the windows of measurement as short as 10s, and measurement errors as large as 200ns. | 10s |
| **[Qualcomm]:** It is feasible to achieve verification accuracy of 5 to 10 km with both single and multiple satellites.  • For single satellite with RTT measurements, a measurement window up to a few seconds may be required. | 8s |
| **[Panasonic]:** Multi-RTT with a set of equations adjusted to the NTN-environment is a viable method to determine UE location with a verification accuracy of 5 to 10 km and with a single satellite. | order of seconds |

## Initial proposal 1

Based on the summary of Multi-RTT positioning method evaluation given in the section above it seems that there are two issues that might impact the feasibility of this method:

* The latency inherent to the method might be an issue (actually, it is an issue: to be discussed under Topic#4). Here, the latency is referring to the measurement window needed for RTT measurements collection.
* The second issue is related to measurement geometry which has an impact on location accuracy: indeed, The position error that results from RTT measurement errors depends on the relative geometry between the UE and the satellite positions. As observed by 4 sources multi-RTT method might not be appropriate for UE located near the orbit plane:
  + **Thales**: area near orbit plane has very high geometric dilution of precision (GDOP)
  + **Oppo**: Positioning estimation handicap zone; close to the orbit plane where the estimation accuracy may be remarkably impacted
  + **Qualcomm**: Figure 5 in [20]; black region corresponds to locations where max error is greater than 5km, which occur right below the satellite orbit.
  + **Nokia, Nokia Shanghai Bell**: one of the problems with triangulation methods is the general dilution of precision, which requires a relative large separation of the measurement point. With the approach of using only a single satellite, the measurement samples that are available will be located on a single line which is described by the satellite path during the fly-over. This reduction of the “space” when limiting to a single satellite monitoring will reduce the general accuracy.

Based on the above and from Moderator’s perspective, it is premature to conclude on the feasibility for this method and discuss design details (RTT determination, resolve ambiguity of the mirror image position etc…). We may first need more inputs on the acceptable latency for UE location verification (to be discussed in section 4). Further, companies may need more time to study the second issue related to **measurement geometry**.

Initial observation 1 is made as follows:

Initial proposed observation 1:

**For network verified UE location based on multi-RTT positioning method** **with single satellite:**

* **5 sources observed that multi-RTT positioning method can meet the NTN UE location verification accuracy requirement for LEO:**
  + **3 sources observed that the positioning accuracy of less than 10km can be achieved with few seconds latency (less or equal to 10s),**
  + **One source observed that the positioning accuracy of less than 10km can be achieved with 18 seconds latency,**
  + **One source observed that the positioning accuracy of less than 10km can be achieved with 30 seconds latency for earth fixed beam.**
* **One source observed that the positioning accuracy of less than 10km can be achieved only with 508 seconds latency, especially for UE near the orbit plane.**
* **One source observed that multi-RTT method is more suitable for UE location far from the orbit plane.**

Companies are encouraged to provide views within the following table:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| QC | We need to specify a confidence level, for instance, 90-percentile. |
| Apple | Fine with the proposed observation. One clarification is needed. These observations are based on LEO-600, not LEO-1200. In general, different orbits will have different latencies. |
| Xiaomi | One clarification question is what is the intention or what’s the follow-ups with the observations. Meanwhile, the results are quite diverse at least from the latency aspects as different parameters like timing error, UE distribution are assumed in the evaluation. |
| Samsung | We are fine with the first bullet. However, for the second and the third bullets, the terms “near the orbit plane” and “far from the orbit plane” are not clear to us. Such terms as “far” and near the orbital plane” should be clarified and defined quantitatively to make them clearer. |

# Topic#2 Evaluation of XL-TDOA method for Network verified UE location in NTN

## Background

The following sub-sections aim at summarizing the different observations made in the contributions submitted to the RAN1#110bis with respect to UL/DL-TDOA positioning method for Network verified UE location in NTN and provide high level tracks for the summary of evaluation results as well as the main technical aspects discussed by different companies.

## Companies’ contributions summary

The following views/observations were expressed with respect to XL-TDOA positioning method for Network verified UE location in NTN :

|  |  |
| --- | --- |
| **Companies** | **Proposals** |
| Huawei | **Observation 1:** With DL-TDOA positioning, the horizontal error decreases with the increasing of the time interval and the number of measurements.  **Observation 2:** With DL-TDOA positioning, the positioning accuracy of less than 10km @90% UEs can be achieved under the time interval of 8s with 3 RSTDs (which corresponds to a latency of 32 seconds) or 6s with 4 RSTDs (which corresponds to a latency of 30 seconds).  **Observation 3:** UL-TDOA positioning is not suitable in verification of UE reported location due to the open-loop TA update on UE, meanwhile even if the pre-compensated TA is fixed on UE in order to enable UL-TDOA based location verification, the remaining TA of UE could exceed the CP length and lead to timing misalignment in uplink transmissions. |
| vivo | **Observation1:**   * The maximum timing measurement error allowed to meet the positioning accuracy requirement of 5-10km is about 100ns when the measurement gap is 30s.   **Observation2:**   * The maximum timing measurement error allowed to meet the positioning accuracy requirement of 5-10km is about 200ns when the measurement gap is 60s.   **Observation3:**   * The maximum timing measurement error allowed to meet the positioning accuracy requirement of 5-10km is about 300ns when the measurement gap is 120s.   **Observation4:**   * The larger the measurement gap is configured, the larger the additional timing measurement error can be allowed to meet the target positioning accuracy.   **Proposal 1:**   * Reuse existing DL-TDoA method already specified in TN which is enough for UE location verification in NTN. |
| Oppo | **Observation 4:** for DL-TDOA method, the issue for UE approaching the orbit plane also exists but this issue can be resolved by enlarging the satellite time instance interval.  **Observation 5:** DL-TDOA method can meet the NTN UE location verification accuracy requirement with agreed simulation assumptions.  **Proposal 2:** RAN1 to take DL-TDOA as a baseline method with higher priority. |
| CATT | **Proposal 1:** The DL-OTDOA method with perfect time synchronization should be treated as the baseline, due to the less impaction in satellite rapid motion and SNR deterioration in UL compared with Multi-RTT method.  **Observation 3:** Due to the impact of SNR, the higher elevation angles the UE begins measuring, the better performance can be achieved in horizontal position error.  **Proposal 5:** In LEO 600km scenario, the horizon position error can be achieved less than 10km above 97% by collecting 10 measurements in about 180s when the UE’s elevation angle is above 30º.  **Proposal 6:** In LEO 1200km scenario, the horizon position error can be achieved less than 7km above 100% by collecting 15 measurements in about 280s with the elevation angle beginning at 30º, meanwhile the total measuring time reduced to 120s with collecting 7 measurements to satisfy the accuracy when the elevation angle beginning with 60º. |
| Intel | **Proposal 1**:  The following enhancements are considered to enable UL-TDOA for single satellite-based positioning   * Reporting of the TA values applied for each SRS transmission * Reporting of the TA value applied for the 1st SRS transmission and fixed TA for other SRS transmissions.   **Proposal 2**:  The following enhancement is considered for DL-TDOA for single satellite-based positioning   * Reporting of RSTD values for multiple measurements of single PRS resource (periodic or semi-persistent) with a PRS transmission for the same PRS resource as a time reference |
| Xiaomi | **Observation:**   * The measurement interval, and the satellite orbit have significant impact on the positioning accuracy * The delay for verifying the location is at least 10s and 20s for LEO600 and LEO1200 cases respectively.   **Proposal 5:** The DL-TDOA solution is feasible to support the network verified location.  **Proposal 6:** The delay required for verifying the location needs to be further considered to avoid the impact to the service. |
| Apple | **Proposal 4:** For network verified UE location with DL TDOA positioning method, the LMF based scheme is used.  **Proposal 5:** For network verified UE location with DL TDOA positioning method, the time differences between multiple DL PRS transmission instances need to be reported from gNB to LMF.  **Proposal 6:** For network verified UE location with UL TDOA positioning method, the time differences between multiple UL SRS transmission instances need to be reported from UE to LMF. |
| Nokia, Nokia Shanghai Bell | **Observation 1:** Methods like multi-RTT, UL/DL-TDOA alone cannot distinguish between the mirror positions on either side of the orbital plane.  **Proposal 2:** RAN1 to consider other measurement approaches than current standardized methods (e.g., Multi-RTT and DL/UL-TDOA) to solve the network verified UE position problem |

## Summary of UL/DL-TDOA positioning method evaluation

Six companies provided inputs on the suitability of DL-TDOA positioning method for Network verified UE location in NTN:

For network verified UE location based on DL-TDOA positioning method with single satellite:

* Five sources observed that DL-TDOA positioning method can meet the NTN UE location verification accuracy requirement for LEO:
  + 2 sources observed that the positioning accuracy of less than 10km can be achieved with 20 seconds latency or less:
    - According to one of the two sources: the latency maybe reduced to 12s with 90% horizontal accuracy
    - For the other source: the latency is at least 10s and 20s for LEO600 and LEO1200 cases respectively.
  + One source observed that the positioning accuracy of less than 10km @90% UEs can be achieved with 32 seconds latency.
  + One source observed that the positioning accuracy of less than 10km can be achieved with 30, 60, 120 seconds latency with timing measurement errors of 100ns, 200ns and 300ns respectively.
  + One source observed that the positioning accuracy of less than 10km @97% UEs can be achieved with 180 (LEO600) and 280 (LEO1200) seconds latency.
* One source observed that DL-TDOA cannot meet the target requirement for both earth fixed beam and earth moving beam

A recap of DL-TDOA positioning method evaluation results is provided within the following table:

|  |  |
| --- | --- |
|  | Latency (seconds) |
| **[Huawei, HiSilicon]:** With DL-TDOA positioning, the positioning accuracy of less than 10km @90% UEs can be achieved | **32** |
| **[vivo]:** With proper measurement gap configuration, DL-TDoA method would be enough to meet the target positioning accuracy of 5 to 10km | **30** (with timing measurement error = 100ns), 60s (with timing measurement error = 200ns), 120s (with timing measurement error = 300ns), |
| **[ZTE]:** DL-TDOA cannot meet the target requirement **for both earth fixed beam and earth moving beam**  Positioning error performance for DL-TDOA without consideration of ambiguity issue = 29.93 km, CDF=95% | **60** (to achieve 29.93 km, CDF=95%) |
| **[OPPO]:** DL-TDOA method can meet the NTN UE location verification accuracy requirement with agreed simulation assumptions:  90% horizontal accuracy is below 8km and 95% horizontal accuracy is below 11.3km, with 12s latency  95% horizontal accuracy is below 5.6km, with 20s latency | **20** (maybereduced to 12s with 90%) |
| **[CATT]:** With DL-TDOA: in LEO 600km scenario, the horizon position error can be achieved less than 10km above 97% by collecting 10 measurements in about 180s when the UE’s elevation angle is above 30º. In LEO 1200km scenario, the horizon position error can be achieved less than 7km above 100% by collecting 15 measurements in about 280s with the elevation angle beginning at 30º | **180** (LEO600)  **280** (LEO1200) |
| **[Xiaomi]:** The DL-TDOA solution is feasible to support the network verified location  The delay for verifying the location is at least 10s and 20s for LEO600 and LEO1200 cases respectively | **10** (LEO600)  **20** (LEO1200) |

Two companies commented on the suitability of UL-TDOA positioning method for Network verified UE location in NTN:

For network verified UE location based on UL-TDOA positioning method with single satellite:

* One source observed that UL-TDOA cannot meet the target requirement due to the open-loop TA update on UE.
* The other source observed that UL-TDOA cannot meet the target requirement for both earth fixed beam and earth moving beam. This source highlighted that with 60s latency the positioning error performance that can be achieved is 43.46 km, CDF=90%.

A recap of UL-TDOA positioning method evaluation results is provided within the following table:

|  |  |
| --- | --- |
|  | Latency (seconds) |
| **[Huawei, HiSilicon]:** UL-TDOA positioning is not suitable in verification of UE reported location due to the open-loop TA update on UE |  |
| **[ZTE]:** UL-TDOA cannot meet the target requirement **for** **both earth fixed beam and earth moving beam**  Positioning error performance for UL-TDOA without consideration of ambiguity issue = 43.46 km, CDF=90% | **60s** (to achieve 43.46 km, CDF=90%) |

## Initial proposal 2

Based on the summary of DL-TDOA positioning method evaluation given in the section above it seems that the latency issue might impact the feasibility for this method. The measurement geometry may have also an impact on location accuracy. **Also, how RSTD measurements are performed with single satellite and w.r.t to which reference need further discussions**.

Thereby, from Moderator’s perspective, it is premature to conclude on the feasibility of this method. We may need more inputs on the acceptable latency for UE location verification (to be discussed under section 4). Details design of DL-TDOA (RSTD measurements etc..) and potential enhancements to be considered to enable DL-TDOA in NTN could be discussed when the group conclude on the feasibility of the method.

Initial proposed observation 2 is made as follows:

**Initial proposed observation 2:**

**Six companies provided inputs on the suitability of DL-TDOA positioning method for Network verified UE location with single satellite:**

* **Five sources observed that DL-TDOA positioning method can meet the NTN UE location verification accuracy requirement for LEO:**
  + **Two sources observed that the positioning accuracy of less than 10km can be achieved with 20 seconds or less:**
    - **According to one of the two sources: the latency maybe reduced to 12s with 90% horizontal accuracy**
    - **For the other source: the latency is at least 10s and 20s for LEO600 and LEO1200 cases respectively.**
  + **One source observed that the positioning accuracy of less than 10km @90% UEs can be achieved with 32 seconds latency.**
  + **One source observed that the positioning accuracy of less than 10km can be achieved with 30, 60, 120 seconds latency with timing measurement errors of 100ns, 200ns and 300ns respectively.**
  + **One source observed that the positioning accuracy of less than 10km @97% UEs can be achieved with 180 (LEO600) and 280 (LEO1200) seconds latency.**
* **One source observed that DL-TDOA cannot meet the target requirement for both earth fixed beam and earth moving beam.**

**Two companies commented on the suitability of UL-TDOA positioning method for Network verified UE location with single satellite:**

* **One source observed that UL-TDOA cannot meet the target requirement due to the open-loop TA update on UE**
* **Another source observed that UL-TDOA cannot meet the target requirement for both earth fixed beam and earth moving beam. With 60s latency positioning error performance that can be achieved is 43.46 km, CDF=90%.**

Companies are encouraged to provide views within the following table:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| QC | For DL-TDOA for single satellite, the biggest error would be UE clock accuracy. New simulations are needed by taking into account UE clock accuracy before any observation s can be made. |
| Apple | Fine with the proposed observation. |
| Xiaomi | One clarification question is what is the intention or what’s the follow-ups with the observations. Meanwhile, the results are quite diverse at least from the latency aspects as different parameters like timing error, UE distribution are assumed in the evaluation. |
| Samsung | We would like to suggest two main bullets as follows.  **For network verified UE location based on DL-TDOA positioning method** **with single satellite,**  …  **For network verified UE location based on UL-TDOA positioning method** **with single satellite,** |

# Topic #3 Timing measurement error in NTN

## Background

Timing measurement error has a significant impact on positioning error performance. The following sub-sections aim at summarizing the different observations made in the contributions submitted to the RAN1#110bis with respect to timing measurement error in NTN.

## Companies’ contributions summary

A recap of timing measurement error in NTN assumptions considered in different contributions is provided within the following table:

|  |  |
| --- | --- |
| **Companies** | **Proposals** |
| ZTE | **Observation 2:** The timing measurement error of SRS and PRS can be smaller than 24ns and 6ns respectively with 95% probability under 30 degree elevation angle for LEO-600 set-1, rural LOS S-band scenario. |
| Oppo | The measurement error range could be assumed to be [-256Tc, 256Tc] as suggested by RAN4 for NTN TA estimation error.  Simulated DL-PRS based measurement error: 6ns  one PRS symbol instead of multiple PRS symbols joint detection, PRS bandwidth is 100 RB and the subcarrier spacing is 15kHz |
| CATT | **Observation 1:** The timing measurement error could not be ignored in both Multi-RTT and OTDOA positioning methods.  Assumption of Maximum timing measurement: <-6: 98Tc, -3>SNR>=-6: 42Tc, 0>SNR>=-3: 20Tc, 3>SNR>=0: 10Tc, SNR>=3: 1Tc.  **Proposal 4:** The SNR is the major factor to impact the PRS timing measurement error in AWGN channel, and the evaluated results of accuracy of PRS measuring in NR RAT-dependent position methods can be reused in NTN scenarios. |
| Xiaomi | **Proposal 2:** The RTT estimation error due to the movement of the satellite should be taken into account.  **Proposal 3:** The RTT estimation error on the feeder-link can be handled the gNB.  **Proposal 4:** The RTT estimation error on the service-link can be reported by the UE. |
| Qualcomm | max RTT timing measurement errors of 100 ns and 200 ns are considered. For 10 MHz BW, 100 ns is achievable with PRS and SRS |

## Initial Proposal 3

Based on the above, the following Initial proposed observation is made:

Initial proposed observation 3:

Regarding Timing measurement error in NTN:

There is a consensus that the timing measurement error could not be ignored in time based positioning methods in NTN:

* One source observed that the timing measurement error of SRS and PRS can be smaller than 24ns and 6ns respectively with 95% probability under 30 degree elevation angle for LEO-600 set-1, rural LOS S-band scenario,
* One source observed that the measurement error range could be assumed to be [-256Tc, 256Tc] as suggested by RAN4 for NTN TA estimation error. And provided simulated DL-PRS based measurement error: 6ns,
* One source observed that the evaluated results of accuracy of PRS measuring in NR RAT-dependent position methods can be reused in NTN scenarios. Thereby, depending on the SNR maximum timing measurement error could be assumed to be: SNR <-6: 98Tc, -3>SNR>=-6: 42Tc, 0>SNR>=-3: 20Tc, 3>SNR>=0: 10Tc, SNR>=3: 1Tc,
* One source observed that max RTT timing measurement errors of 100 ns and 200 ns could be considered. For 10 MHz BW, 100 ns is achievable with PRS and SRS.

Companies are encouraged to provide views within the following table:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| Xiaomi | We are fine with the main bullet. |
| Samsung | We think that “There is a consensus that the timing measurement error could not be ignored in time based positioning methods in NTN:” is not needed.  Also, this is related to what measurement error values should be assumed for evaluation. Thus, we don’t think observation is not needed. Instead, we need to directly discuss which measurement error values are needed for evaluation purpose. |

# Topic#4 Latency of UE location verification

## Background

The following was recommended in TR 38.882: The solution should not impact significantly the latency of the targeted services nor infringe privacy requirements that apply to the UE location. Further, the required latency for different regulated services are captured in the appendixes in TR 38.882 and recopied hereafter:

|  |
| --- |
| A.1 Emergency calls  Latency  The delay to determine the UE location should be minimised to ensure timely assistance or rescue,  While a typical call set-up is less than a second, the delay for UE location determination should not impact significantly this communication set-up time.  A.2 Lawful intercept (LI):  Latency  No regulatory requirement have been identified for this. Despite this, NTN location determination should not significantly impact the LI service as provided by an TN network.  A.2 Lawful intercept (LI):  Latency  No regulatory requirement have been identified for this. Despite this, NTN location determination should not significantly impact the LI service as provided by an TN network.  A.3 Public warning Service (PWS):  Latency  No regulatory requirement have been identified for this. Despite this, NTN location determination should not impact significantly the PWS service as provided by an TN network.  A.4 Charging and Tariff notifications:  Latency  No regulatory requirement have been identified for this. Despite this, NTN location determination should not significantly impact the charging/tariff service as provided by an TN network. |

## Companies’ contributions summary

The following was proposed in the Tdocs submitted to RAN1#110-bis w.r.t the latency of UE location verification:

|  |  |
| --- | --- |
| **Companies** | **Proposals** |
| Thales | 1. The time period required to calculate uplink multi-RTT measurement is excessively long in case of multi-RTT based positioning method is used with single satellite in view which makes the feasibility of the method questionable.   Proposal 2: RAN1 to send LS to RAN2/SA1 requesting inputs on the acceptable maximum latency to carry out the UE location verification procedure |
| Xiaomi | Observation:   * The measurement interval, and the satellite orbit have significant impact on the positioning accuracy * The delay for verifying the location is at least 10s and 20s for LEO600 and LEO1200 cases respectively.   **Proposal 6:** The delay required for verifying the location needs to be further considered to avoid the impact to the service. |
| Ericsson | Observation 1 Only the UE reporting an incorrect UE location will experience a potential delay in service.  Proposal 2 Send LS to RAN plenary to seek a clarification on the interpretation of latency requirements and trust in UE RRC measurements (and if it is actually the RRM measurements that is meant instead of the RRC measurements). What measurements can be trusted? When and how often does the network need to verify the UE reported location? In case UEs shall be denied service until the UE reported location is verified by the network, what is an acceptable delay for the network verification procedure? |
| PANASONIC | **Observation 2:** A measurement window in the order of seconds may be required to achieve the required accuracy.  **Observation 4**: The interval between RTT-measurements has a stronger impact on the accuracy of UE location estimation than the number of RTT-measurements. |

## Initial proposal 4

As discussed within section 1 and 2, and as raised by some companies, the latency of UE location verification needs to be further considered to avoid the impact to the service.

Based on the above, the following initial proposal is made:

Initial Proposal 4:

RAN1 to send LS to SA1 (Cc RAN2) requesting inputs on the acceptable maximum latency to carry out the UE location verification procedure.

Companies are encouraged to provide views within the following table:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| Apple | Fine with the proposal. |
| Samsung | We are open to discuss on sending LS. If possible, it might be better to include potential (agreed) RAN1 observations about performance results in order to provide that other working group understand for the range that the current specification can support. |

# Topic#5 Network verified UE location based on UE TA reporting

## Background

In the TR 38.882 it was observed that at least some of the information the UE supplies to the network will have to be considered as trusted, to avoid extreme conclusions (at least RRC measurements cannot be faked).

Also, it was recommended in TR 38.882 that the verification should be performed independently from the location information reported by UE.

## Companies’ contributions summary

The following views were expressed with respect to TA report based verification method:

|  |  |
| --- | --- |
| **Companies** | **Proposals** |
| MediaTek | **Proposal 2**: RAN1 study finer than 1 ms granularity for UE-specific TA report via MAC CE.  **Proposal 3**: RAN1 study configuration of time interval between each UE-specific TA report to allow sufficient accuracy of the verification of the UE position in single satellite scenario. |
| ZTE | **Observation 7:** TA report supported in Rel-17 NTN can be used for RTT estimation.  **Observation 8:** TA report accuracy is not affected by SNR.  **Observation 9:** TA reported by UE can be considered to have similar reliability as other RAT dependent parameters since it is related to UL synchronization.  **Proposal 4:** TA report based location verification method can be investigated as alternative to legacy multi-RTT positioning method.  **Proposal 5:** TA report with higher granularity can be investigated to improve the location verification performance. |
| OPPO | **Observation 1:** whether a TA reported by a non-trustful UE is considered to be trustful is a key question for multi-RTT method based on UE reported TA.  **Proposal 1:** RAN1 to send an LS to SA3 to ask for the confirmation on whether a TA reported by a non-trustful UE is considered to be trustful for positioning purpose. |
| Sony | **Observation 1:** A malicious UE intent on reporting a fake location can also report fake location verification measurements commensurate with its fake location.  **Proposal 3:** RAN1 shall define network location verification methods that are immune to spoofing by malicious UEs intent on reporting a fake location. |
| Apple | **Proposal 8:** In NGSO scenario with multi-RTT positioning method, do not support the scheme that RTT is obtained as the sum of UE reported total TA and the timing error of the uplink reference signal |
| Ericsson | **Proposal 1** UE reporting of timing advance cannot be trusted for the purpose of network-verified UE location in NTN.  **Observation 2** Existing RRM measurements for intra-RAT neighbours, inter-RAT neighbours, etc. can be trusted for location verification with the required location accuracy. They may, however, not be available on all locations on earth.  **Proposal 2** Send LS to RAN plenary to seek a clarification on the interpretation of latency requirements and trust in UE RRC measurements (and if it is actually the RRM measurements that is meant instead of the RRC measurements). What measurements can be trusted? When and how often does the network need to verify the UE reported location? In case UEs shall be denied service until the UE reported location is verified by the network, what is an acceptable delay for the network verification procedure? |
| Qualcomm | **Proposal 1**: Support TA report of an SRS transmission for network verification of UE location. |
| LG Electronics | **Proposal #2:** For RTT determination, option 1 is supported.  - Option 1: The multi-RTT positioning method makes use of the UE Rx-Tx time difference measurements of downlink signals (i.e. PRS) received from the satellite, measured by the UE and reported to the gNB and the measured gNB Rx-Tx time difference measurements, of uplink signals transmitted from UE (i.e. UL-SRS). |

The summary of views expressed by companies in their contribution is as follows:

**[MediaTek, ZTE, Qualcomm]** Support TA report for network verification of UE location and proposed to further study TA reporting with finer granularity which can be used for RTT estimation (ZTE, Qualcomm) or for the verification of UE location based on multiple RTT with prediction as proposed by MediaTek in [5].

**[OPPO]** observed that whether reported TA is considered to be trustful is a key question for multi-RTT method based on UE reported TA.

**[Sony]** observed that a malicious UE intent on reporting a fake location can also report fake location verification measurements commensurate with its fake location.

**[Apple, Ericsson]** observed thatUE reporting of timing advance cannot be trusted.

Companies **[OPPO**, **Ericsson**] proposed for RAN1 to send an LS to SA3.

From Moderator’s perspective and based on the TR 38.882 recommendations, it is clear that the UE location verification should be performed independently from the location information reported by UE. But, it is not yet clear whether it can be performed based on information which is derived/calculated by the UE based on its GNSS e.g. UE specific TA. As stated in the TR 38.882, the UE reported location information (for example determined with its GNSS receiver), could be erroneous due to intentional (e.g. maliciously tampering by user or by 3rd party) or unintentional (e.g. interference) causes, hence it cannot be considered trusted see S3i200056.

In Moderator view, information reported by the UE such as UE specific TA which is in essence computed by the UE using its GNSS-acquired position and the serving satellite ephemeris might be also untrusted. Therefore, more discussion is needed. And possibly an LS to SA3 in this regards might be necessary.

## Initial proposal 5

Based on the discussion is previous section, the following Initial Proposal is made:

Initial Proposal 5:

RAN1 to send LS to SA3 asking whether the UE location verification could be performed based on information the UE supplies to the network which is derived by the UE based on its GNSS (e.g. UE Specific TA, Doppler shift, Radial satellite velocity etc..).

**Note: SA3#108-Ad Hoc-e – Meeting is scheduled from 10th to 14th of October. Hence, the LS should be sent as soon as possible during the RAN1 meeting.**

Companies are encouraged to provide views within the following table:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| QC | OK |
| Apple | We do not think the LS to SA3 is necessary. If UE reported location information based on GNSS measurement is not considered as trusted, it does not make sense that the TA reporting which is also based on GNSS measurement is considered as trusted.  It is clearly recommended in TR38.882 that “The verification should be performed independently from the location information reported by UE”. The TA reporting is NOT independent of the location reporting from the UE, since both are derived from GNSS.  Furthermore, the TA reporting is an optional UE feature. In other words, not every UE supports this feature. It is improper to explore UE’ TA reporting feature for UE location verification purpose.  Overall, this kind of discussions should be deprioritized. |
| Xiaomi | Fine |
| Samsung | We tend to agree with moderator’s view and it needs more investigation on the feasibility of using UE specific TA value. |

# Topic#6 TP for LS on network verified UE location based on UE TA reporting

## Background

Refer to section 5.1

## Companies’ contributions summary

Refer to section 5.2

## Initial proposal 6

Based on the Initial Proposal 5 (if agreed), a draft LS hereafter is proposed as follows:

**Initial proposal 6**

**Companies are encouraged to comment on the following draft LS** **about network verified UE location based on UE TA reporting:**

|  |
| --- |
| 3GPP TSG RAN WG1 #110bis-e R1-22xxxxx  e-Meeting, October 10th – 19th, 2022  **Title:**[Draft] LS on network verified UE location based on UE TA reporting  **Release:**                  Rel-18  **Work Items:**          NR\_NTN\_enh  **Source:**                   Thales ( to be RAN WG1)  **To:**                           SA3  **CC:** -  **Contact Person:**  **Name:**                 Mohamed EL JAAFARI  **E-mail Address:** [mohamed.el-jaafari@thalesaleniaspace.com](mailto:mohamed.el-jaafari@thalesaleniaspace.com)  **Send any reply LS to: 3GPP Liaisons Coordinator:** [**mailto:3GPPLiaison@etsi.org**](mailto:3GPPLiaison@etsi.org)  **Attachments:**          -  **1. Overall Description:**  As part of Release 18, a new work item is proposed to define enhancements for NG-RAN based Non-Terrestrial Networks in order to address requirements which mandate the network to cross check the UE location reported by the UE, which needs to be carried out in order to fulfil the regulatory requirements (e.g., Lawful intercept, emergency call, Public Warning System, …).  At RAN1#110, RAN1 started the study and the evaluation of potential solutions for the network to verify UE reported location information.  Relying only on the GNSS based location information reported by the UE is not considered reliable by SA3-LI [3GPP S3i200056].  Further, as stated in the TR 38.882, the UE reported location information  (for example determined with its GNSS receiver), could be erroneous due to intentional (e.g. maliciously tampering by user or by 3rd party) or unintentional (e.g. interference) causes, hence it cannot be considered trusted by network operators.  Also, as observed in the TR 38.882, at least some of the information the UE supplies to the network will have to be considered as trusted, to avoid extreme conclusions (at least RRC measurements cannot be faked). However,  some of the information reported by the UE may be derived by the UE based on its GNSS (e.g. UE Specific Timing Advance (TA) which calculated by the UE using its GNSS-acquired position and the serving satellite ephemeris)  RAN1 identified the following question that need clarification from RAN4:  **Question**: Whether the UE location verification could be performed based on information the UE supplies to the network which is derived by the UE based on its GNSS (e.g. UE Specific TA, Doppler shift, Radial satellite velocity etc..)?  **2. Actions**  **To SA3**  **ACTION**:         RAN1 respectfully asks SA3 to provide feedback on the above question  **3. Date of Next TSG-RAN WG1 Meetings:**  TSG-RAN1 Meeting #111,Toulouse      14 Nov - 18 Nov 2022 |

Companies are encouraged to provide views/edits within the following table:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| Apple | As we commented in Proposal 5, the LS is not needed at all. |
| Samsung | We are fine with the LS. But, the following should be changed to SA3.  RAN1 identified the following question that need clarification from RAN4. |

# Topic#7 Evaluation of UL-AoA based positioning techniques in NTN

## Background

It was agreed in last RAN1 meeting to evaluate Multi RTT and DL/UL-TDOA as starting point and it was noted that other methods such as AoA based techniques are not precluded.

## Companies’ contributions summary

The following views were expressed with respect to UL-AoA based positioning techniques in NTN for Network verified UE location in NTN :

|  |  |
| --- | --- |
| **Companies** | **Proposals** |
| Thales | Observation 6. Different techniques for angle-based positioning can be used to estimate UE location depending on satellite antenna architecture and whether digital, analog or hybrid beamforming are used.  Observation 7. The result of the UL-AoA based positioning is a point on Earth, with a certain angular accuracy. Different defects may affect the angle estimation such as satellite beam pointing error, phase noise and defects due to all transformations (or operations) applied on the signals, from AE on board to the receiving base station on the ground.  Observation 8. The main advantage of UL-AoA positioning method is the low latency and its applicability for the GEO based NTN deployment  Observation 9: The characteristics of the SRS signal transmitted by the UE should be static over the time period required to calculate uplink AoA measurements. NTN environment impact (e.g. timing drift) on SRS should be further studied.  Proposal 4: RAN1 should study angle-based positioning techniques in NR NTN  Proposal 5: RAN1 to discuss the achievable location accuracy with the uplink angle of arrival techniques in NGSO and GSO based NTN deployment  Proposal 6: RAN1 should evaluate SRS coverage for UL-AoA and study NTN environment impact (e.g. timing drift) on SRS. For evaluation purposes, NR NTN SRS for Positioning reuses the Rel-16 NR sequence design and resource mapping as baseline.  Proposal 7: To enhance UL-AoA based positioning performance in NTN, consider auto-calibration process to compensate for satellite beam pointing error, this includes:   * Use of beacon uplink signals to adjust satellite beam pointing, * Zadoff-Chu sequence used for the SRS maybe beacon specifically configured as a potential solution to introduce such beacon signals in NR NTN with a minimum specification impact. |
| Lenovo | **Proposal 8:** RAN1 to further study DL/UL angle-based and NR ECID positioning techniques and associated adaptations for NTN to verify the UE reported location. |
| Ericsson | **Observation 4** It may be feasible to use the angle of arrival method in combination with other methods for network verified UE location depending on the achievable angle resolution at the satellite.  **Proposal 3** RAN1 to discuss the achievable accuracy with the angle of arrival method, and with the E-CID method based on measurements on the same satellite as well as hybrid combinations. |

## Initial proposal 7

Based on the views expressed within the contributions submitted to RAN1#110bis with respect to UL-AoA based positioning techniques, the following proposal is made:

Initial Proposal 7:

RAN1 to further study DL/UL angle-based positioning techniques in NR NTN:

* Discuss the achievable location accuracy with the uplink angle of arrival techniques in NGSO and GSO based NTN deployment
* Evaluate SRS coverage for UL-AoA and study NTN environment impact (e.g. timing drift) on SRS
* Discuss whether enhancements are necessary to meet Network verified UE location requirements

Companies are encouraged to provide views within the following table:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| QC | The AOA accuracy is limited by satellite antenna. To achieve reasonable positioning accuracy, the required AoA as shown by some companies is orders of magnitude less than the beam angular BW. We don’t see the feasibility and don’t think we should spend more time on it. |
| Apple | We prefer to focus on timing-based positioning techniques. The angle-based positioning techniques can be deprioritized.  It is unclear why uplink AoA techniques works for GSO based NTN deployment, considering the single satellite case. |

# Topic #8 Evaluation of NR NTN ECID positioning techniques

## Background

As per TR 38.882 recommendations, when considering solutions based on positioning methods, existing 3GPP defined RAT dependent positioning methods shall be considered as baseline. Other methods are not precluded.

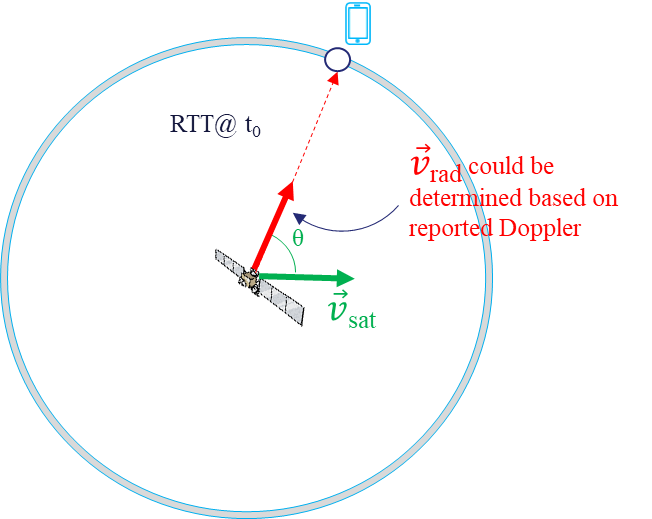
## Companies’ contributions summary

On the evaluation of NR NTN ECID positioning techniques, the following proposals were made by some companies :

|  |  |
| --- | --- |
| **Companies** | **Proposals** |
| Ericsson | Proposal 3 RAN1 to discuss the achievable accuracy with the angle of arrival method, and with the E-CID method based on measurements on the same satellite as well as hybrid combinations. |
| Nokia, Nokia Shanghai Bell | **Observation 2:** UE neighboring cells measurements can be a good indicator of the UE location relative to the orbital line.  **Proposal 2**: RAN1 to consider other measurement approaches than current standardized methods (e.g., Multi-RTT and DL/UL-TDOA) to solve the network verified UE position problem.. |
| Thales | Proposal 8: NR NTN UE should report the Doppler calculated on the service link.  Proposal 9: a VSAT UE beam pointing in respect to satellite beam line of sight  Proposal 10: RAN1 to discuss whether NR NTN Enhanced cell ID positioning methods could be used for UE location verification in NTN by considering appropriate NR E-CID measurements.  Proposal 11: RAN1 to determine the appropriate NR E-CID measurements that could be used to verify the location of the UE. These may include:   * UE reported measurements:   + UE specific Timing Advance   + Doppler calculated on the service link,   + SS-RSRP, SS-RSRQ, CSI-RSRP and CSI-RSRQ.   + For a VSAT UE beam pointing in respect to satellite beam line of sight. * gNB measurements:   + UL Angle of Arrival (azimuth and elevation) * RTT calculation:   + UE Rx-Tx time difference measurements of downlink signals   + gNB Rx-Tx time difference measurements, of uplink signals transmitted from UE |

## Initial proposal 8

The feasibility of time based positioning methods (i.e. Multi-RTT and XL-TDOA) in case of single satellite is still under investigation. It is Moderator recommendation to investigate other potential techniques such as Angle of Arrival or **a combination of different methods e.g. UE Location verification based on RTT calculation (one RTT measurement)** and radial velocity reported by the UE as illustrated in the figure below:



Based on the above, the following proposal is made:

Initial Proposal 8:

RAN1 to discuss whether NR NTN Enhanced cell ID positioning methods could be used for UE location verification in NTN by considering appropriate NR E-CID measurements.

Note: NR NTN ECID positioning allows combination of different methods e.g. UE Location verification based on RTT calculation (one RTT measurement) and radial velocity reported by the UE.

Companies are encouraged to provide views within the following table:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| QC | Companies can propose the specific methods. No need of the above agreement. |
| Apple | We prefer to focus on timing-based positioning techniques. |
| Xiaomi | We also suggest to focus on the timing-based positioning techniques unless there are problems that cannot be resolved. |

# Topic#9 UE Location verification during Initial access

## Background

As stated in the TR 38 882, clause 4.4 [2] most UE positioning functionality is typically UE-associated, i.e., it assumes that a UE context is present for the UE being positioned. This means that the UE itself has already completed the initial access procedures. Further, it is assumed that UE can only report GNSS location report after NAS security is established based on SA3 guidance. It is therefore assumed that UE is in RRC connected state in the procedure of network verifying UE’s reported location information.

During RAN1#110 there was no enough time to duly discuss this issue.

## Companies’ contributions summary

On Topic#9 the following proposals were submitted to RAN1#110bis.

|  |  |
| --- | --- |
| **Companies** | **Proposals** |
| Apple | **Proposal 1:** The network verifying UE location only occurs in UE’s RRC connected state. |
| InterDigital, Inc. | **Proposal 1:** Study achievable accuracy of IDLE mode positioning for NTN  **Proposal 2:** Study feasibility of IDLE mode positioning methods using SRS for positioning and/or PRACH  **Proposal 3:** Send an LS to RAN2 to prioritize IDLE mode positioning in RAN2 positioning and consider NTN based scenario (e.g., moving TRP) |
| NTT DOCOMO | **Proposal 6:**  Deprioritize the discussion on UE location verification during initial access. |

## Initial proposal 9

From moderator’s perspective, it might be beneficial for the NG RAN to have information about verified UE location during call setup and before transmitting the NGAP Initial UE message containing User Location Information (ULI). This may be needed e.g. for AMF selection. Therefore, UE Location verification during Initial access might be discussed otherwise, it would be necessary to handle the initial access from the UE, without the availability of the location verification. And consider a delayed action once the verification verdict is available to the network.

However, it seems that other WGs (RAN2 and RAN3) are considering the re-use of the LCS framework of the LMF for the network verification of UE reported location information in NTN. Which de facto means that UE location verification may be performed only at RRC connected state.

Therefore, it seem reasonable to deprioritize for now the discussion on UE location verification during initial access.

Based the above discussion, the following proposal is made:

Initial Proposal 9:

Deprioritize the discussion on UE location verification during initial access.

Companies are encouraged to provide views within the following table:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| QC | OK |
| Apple | Agree |
| Xiaomi | Support |
| Samsung | Agree |

# Topic#10 Network node responsible for the location verification

## Background

This issue is discussed for the first time in RAN1 in current meeting.

## Companies’ contributions summary

The following views were expressed with respect to Topic#10 :

|  |  |
| --- | --- |
| **Companies** | **Proposals** |
| Xiaomi | Proposal 1: Both the gNB and the AMF could be responsible for the location verification |
| Lenovo | Proposal 10: The network entity performing the UE location verification may be up to RAN2 and SA2 decision depending on the type of location service request. |
| Apple | **Proposal 4:** For network verified UE location with DL TDOA positioning method, the LMF based scheme is used.  **Proposal 3:** For network verifying UE location in NGSO scenario, gNB reports satellite ephemeris information to LMF.  **Proposal 5:** For network verified UE location with DL TDOA positioning method, the time differences between multiple DL PRS transmission instances need to be reported from gNB to LMF.  **Proposal 6:** For network verified UE location with UL TDOA positioning method, the time differences between multiple UL SRS transmission instances need to be reported from UE to LMF. |

## Initial proposal 10

[**Apple**] is considering the re-use of the LCS framework of the LMF for the network verification of UE reported location information in NTN. [**Xiaomi**] considers both the gNB and the AMF could be responsible for the location verification. For [**Lenovo**] this is not RAN1 discussions.

Moderator’s view: Network-verified UE location has been discussed at RAN3 #117-e meeting, it was agreed that [RAN3 #117-e Chair’s Notes]:

• The verification is performed in the CN.

• If the reported UE location is not correct, the CN will take necessary action and Rel-17 behavior can be kept as baseline.

To the Moderator understanding, the RAN3 agreements are fully consistent with the current LCS architecture and protocol flow recalled in Figure 1 below. Once the UE is connected, the AMF triggers the location services request toward the LMF, which processes it and returns the result to the AMF. The AMF can then take the necessary action.



Figure Location service support by NG-RAN

Based on the above, initial Proposal 10 is made as follows:

Initial Proposal 10:

RAN1 assumes that the verification for UE location in NTN is performed in the core network (5GC). Details on how the 5GC verifies the UE location is up to SA2.

NTN specific assistance data and information elements to be reported by UE and/or gNB for Network verified UE location will be identified by RAN1.

Companies are encouraged to provide views within the following table:

|  |  |
| --- | --- |
| **Companies** | **Comments and Views** |
| QC | Agree |
| Apple | Agree |
| Xiaomi | For the first sentence, although we think gNB verification can have some benefits from the latency point of view. This is not RAN1’s work scope so don’t know whether we need to make an agreement on this. |
| Samsung | We think that the first bullet is not necessary because this is not RAN1 scope and doesn’t help for RAN1 progress. For second bullet, we think that it is premature since we don’t know yet on whether any assistance data and information is needed or not on top of the positioning scheme TN provides. |

# Conclusion

TBC

# Appendix: Summary of proposals

|  |  |  |
| --- | --- | --- |
| **TDoc** | **Source** | **Proposals** |
| [**R1-2208389**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2208389.zip) | THALES | Proposal 1: RAN1 to investigate whether TN positioning methods (e.g. OTDOA, Multi-RTT, DL-AoD, UL-AoA DL-TDOA and CID/NR E CID) could be adapted and used for the verification of UE location in case of only a single satellite is in view.  Proposal 2: RAN1 to send LS to RAN2/SA1 requesting inputs on the acceptable maximum latency to carry out the UE location verification procedure.  Proposal 3: RAN1 to discuss whether the UE location determination/verification could involve only a single cell or multiple cells within the same gNB.  Proposal 4: RAN1 should study angle-based positioning techniques in NR NTN:  Proposal 5: RAN1 to discuss the achievable location accuracy with the uplink angle of arrival techniques in NGSO and GSO based NTN deployment  Proposal 6: RAN1 should evaluate SRS coverage for UL-AoA and study NTN environment impact (e.g. timing drift) on SRS. For evaluation purposes, NR NTN SRS for Positioning reuses the Rel-16 NR sequence design and resource mapping as baseline.  Proposal 7: To enhance UL-AoA based positioning performance in NTN, consider auto-calibration process to compensate for satellite beam pointing error, this includes:   * Use of beacon uplink signals to adjust satellite beam pointing, * Zadoff-Chu sequence used for the SRS maybe beacon specifically configured as a potential solution to introduce such beacon signals in NR NTN with a minimum specification impact.   Proposal 8: NR NTN UE should report the Doppler calculated on the service link.  Proposal 9: a VSAT UE beam pointing in respect to satellite beam line of sight  Proposal 10: RAN1 to discuss whether NR NTN Enhanced cell ID positioning methods could be used for UE location verification in NTN by considering appropriate NR E-CID measurements.  Proposal 11: RAN1 to determine the appropriate NR E-CID measurements that could be used to verify the location of the UE. These may include:   * UE reported measurements:   + UE specific Timing Advance   + Doppler calculated on the service link,   + SS-RSRP, SS-RSRQ, CSI-RSRP and CSI-RSRQ.   + For a VSAT UE beam pointing in respect to satellite beam line of sight. * gNB measurements:   + UL Angle of Arrival (azimuth and elevation * RTT calculation:   + UE Rx-Tx time difference measurements of downlink signals   + gNB Rx-Tx time difference measurements, of uplink signals transmitted from UE |
| [**R1-2208396**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2208396.zip) | MediaTek Inc. | **Proposal 1**: Support network-based UE location verification with multiple-RTT with prediction solution based on UE-specific TA report.  **Proposal 2**: RAN1 study finer than 1 ms granularity for UE-specific TA report via MAC CE.  **Proposal 3**: RAN1 study configuration of time interval between each UE-specific TA report to allow sufficient accuracy of the verification of the UE position in single satellite scenario. |
| [**R1-2208436**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2208436.zip) | Huawei, HiSilicon | **Proposal 1:** Support reuse the existing reference signal (e.g. CSI-RS) for DL-TDOA and multi-RTT to minimize the resource overhead and UE power consumption due to UE location verification. |
| [**R1-2208663**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2208663.zip) | vivo | **Proposal 1:**   * Reuse existing DL-TDoA method already specified in TN which is enough for UE location verification in NTN. |
| [**R1-2208694**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2208694.zip) | ZTE | **Proposal 1:** 3D positioning methods should be applied even if 2D positioning error is the performance metric.  **Proposal 2:** Single-satellite based multi-RTT positioning method can be used for UE location verification for LEO.  **Proposal 3:** The earth moving beam case is deprioritized for single satellite based location verification.  **Proposal 4:** TA report based location verification method can be investigated as alternative to legacy multi-RTT positioning method.  **Proposal 5:** TA report with higher granularity can be investigated to improve the location verification performance.  **Proposal 6:** UE can be assigned with reliability flag based on verification result to reduce the frequency of location verification.  **Proposal 7:** Network will reject access from UE assigned with unreliable flag and accept access from UE assigned with reliable flag without location verification. |
| [**R1-2208835**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2208835.zip) | OPPO | Proposal 1: RAN1 to send an LS to SA3 to ask for the confirmation on whether a TA reported by a non-trustful UE is considered to be trustful for positioning purpose.  Proposal 2: RAN1 to take DL-TDOA as a baseline method with higher priority. |
| [**R1-2208955**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2208955.zip) | CATT | **Proposal 1:** The DL-OTDOA method with perfect time synchronization should be treated as the baseline, due to the less impaction in satellite rapid motion and SNR deterioration in UL compared with Multi-RTT method.  **Proposal 2:** The position of UE may be supposed on the surface of earth, and the horizontal position error can be defined as the distance between the actual UE position and the projecting point on the earth surface of the calculated UE position.  **Proposal 3:** For the DL-OTDOA method, the range of DL SNR is approximately from -3.51dB to 6.64dB both in LEO 600km and 1200km scenarios.  **Proposal 4:** The SNR is the major factor to impact the PRS timing measurement error in AWGN channel, and the evaluated results of accuracy of PRS measuring in NR RAT-dependent position methods can be reused in NTN scenarios.  **Proposal 5:** In LEO 600km scenario, the horizon position error can be achieved less than 10km above 97% by collecting 10 measurements in about 180s when the UE’s elevation angle is above 30º.  **Proposal 6:** In LEO 1200km scenario, the horizon position error can be achieved less than 7km above 100% by collecting 15 measurements in about 280s with the elevation angle beginning at 30º, meanwhile the total measuring time reduced to 120s with collecting 7 measurements to satisfy the accuracy when the elevation angle beginning with 60º. |
| [**R1-2209072**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2209072.zip) | Intel Corporation | **Proposal 1**:  The following enhancements are considered to enable UL-TDOA for single satellite-based positioning   * Reporting of the TA values applied for each SRS transmission * Reporting of the TA value applied for the 1st SRS transmission and fixed TA for other SRS transmissions   **Proposal 2**:  The following enhancement is considered for DL-TDOA for single satellite-based positioning   * Reporting of RSTD values for multiple measurements of single PRS resource (periodic or semi-persistent) with a PRS transmission for the same PRS resource as a time reference   **Proposal 3**:   * For Multi-RTT positioning with single satellite, RX-Tx Time difference reported by the UE shall consider the autonomous TA applied by the UE |
| [**R1-2209115**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2209115.zip) | Sony | **Proposal 1:** RAN1 should consider positioning measurement intervals for the chosen RAT-dependent positioning methods for the single satellite case.  **Proposal 2:** RAN1 should consider whether or not UE mobility should be taken into account.  Observation 1: A malicious UE intent on reporting a fake location can also report fake location verification measurements commensurate with its fake location.  **Proposal 3:** RAN1 shall define network location verification methods that are immune to spoofing by malicious UEs intent on reporting a fake location |
| [**R1-2209265**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2209265.zip) | Xiaomi | **Proposal 1**: Both the gNB and the AMF could be responsible for the location verification.  **Proposal 2:** The RTT estimation error due to the movement of the satellite should be taken into account.  **Proposal 3:** The RTT estimation error on the feeder-link can be handled the gNB.  **Proposal 4:** The RTT estimation error on the service-link can be reported by the UE.  **Proposal 5:** The DL-TDOA solution is feasible to support the network verified location.  Proposal 6: The delay required for verifying the location needs to be further considered to avoid the impact to the service. |
| [**R1-2209398**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2209398.zip) | Lenovo | **Proposal 1:** RAN1 to confirm that the network verification accuracy requirement is at least in the range between 5-10 km for NTN. FFS whether additional requirements need to be defined for other services, e.g., emergency services.  **Proposal 2:** RAN1 to further study enhancements (if needed) to both PRS/SRS configuration design for NTN RAT-dependent positioning techniques.  **Proposal 3:** RAN 1 to clarify if hybrid positioning methods (RAT dependent and RAT independent) are under the scope of study.  **Proposal 4:** RAN1 to further study DL-TDoA/UL-TDoA and Multi-RTT timing-based positioning techniques and associated adaptations for NTN to verify UE reported location  **Proposal 5:** For NTN network, UE position is determined based on the propagation delay differences between satellite(s) and UE.  **Proposal 6:** For NTN network, satellite positions for different time instances are useful to determine the propagation delay difference between satellite and UE.  **Proposal 7:** Further study application of Multi-RTT based solution to difference scenarios including GEO, LEO, HAPS.  **Proposal 8:** RAN1 to further study DL/UL angle-based and NR ECID positioning techniques and associated adaptations for NTN to verify the UE reported location.  **Proposal 9:** Characteristics for single satellite and multiple time instances should be taken into account when designing schemes for network to verify UE reported location.  **Proposal 10:** The network entity performing the UE location verification may be up to RAN2 and SA2 decision depending on the type of location service request. |
| [**R1-2209600**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2209600.zip) | Apple | **Proposal 1:** The network verifying UE location only occurs in UE’s RRC connected state.  **Proposal 2:** In NGSO scenario, RAN1 to treat different satellite locations of the same NGSO satellite at different time instances as different gNB locations in terrestrial network positioning methods.  **Proposal 3:** For network verifying UE location in NGSO scenario, gNB reports satellite ephemeris information to LMF.  **Proposal 4:** For network verified UE location with DL TDOA positioning method, the LMF based scheme is used.  **Proposal 5:** For network verified UE location with DL TDOA positioning method, the time differences between multiple DL PRS transmission instances need to be reported from gNB to LMF.  **Proposal 6:** For network verified UE location with UL TDOA positioning method, the time differences between multiple UL SRS transmission instances need to be reported from UE to LMF.  **Proposal 7:** In NGSO scenario with multi-RTT positioning method, consider that the distance between satellite and UE at the time of downlink transmission is different from the distance between satellite and UE at the time of uplink transmission.  **Proposal 8:** In NGSO scenario with multi-RTT positioning method, do not support the scheme that RTT is obtained as the sum of UE reported total TA and the timing error of the uplink reference signal. |
| [**R1-2209643**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2209643.zip) | InterDigital, Inc. | **Proposal 1:** Study achievable accuracy of IDLE mode positioning for NTN  **Proposal 2:** Study feasibility of IDLE mode positioning methods using SRS for positioning and/or PRACH  **Proposal 3:** Send an LS to RAN2 to prioritize IDLE mode positioning in RAN2 positioning and consider NTN based scenario (e.g., moving TRP) |
| [**R1-2209649**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2209649.zip) | Ericsson Limited | [Proposal 1 UE reporting of timing advance cannot be trusted for the purpose of network-verified UE location in NTN.](#_Toc115422863)  [Proposal 2 Send LS to RAN plenary to seek a clarification on the interpretation of latency requirements and trust in UE RRC measurements (and if it is actually the RRM measurements that is meant instead of the RRC measurements). What measurements can be trusted? When and how often does the network need to verify the UE reported location? In case UEs shall be denied service until the UE reported location is verified by the network, what is an acceptable delay for the network verification procedure?](#_Toc115422864)  [Proposal 3 RAN1 to discuss the achievable accuracy with the angle of arrival method, and with the E-CID method based on measurements on the same satellite as well as hybrid combinations.](#_Toc115422865) |
| [**R1-2209751**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2209751.zip) | Samsung | **Proposal 1:** The ambiguity of the mirror image position is resolved by very low resolution DL-PRS beamforming or UL angle of arrival determination.  **Proposal 2:** Study low resolution DL-PRS and low resolution UL angle of arrival determination to decide which one offers a more efficient solution for the ambiguity of the mirror image position.  **Proposal 3:** Single-satellite multi-RTT positioning method can be used for UE location verification for LEO constellation. The RTT measurements are performed by the same satellite at different time instances. |
| [**R1-2209922**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2209922.zip) | NTT DOCOMO, INC. | **Proposal 1:**  Consider both single and multiple satellites scenario for verification of UE location in NTN.  **Proposal 2:**  For time-based RAT dependent positioning methods applied to NTN, study what additional information should be reported by UE and/or gNB to let LMF obtain the required results for positioning.  **Proposal 3:**  For time-based RAT dependent positioning methods in single satellite scenario,   * Multiple times of measurements are performed and reported with location information of the single satellite for each measurement.   **Proposal 4:**  For time-based RAT-dependent positioning methods, study impact on the movement of satellite.   * E.g., when the UE location is derived by gNB/LMF from propagation delays, determine the applied location of the satellite (i.e., a reference location of satellite) in order to eliminate/reduce the inaccuracy due to satellite movement.   **Proposal 5:**  For multi-RTT positioning method, consider applying UE/gNB Rx-Tx time difference measurements as baseline  **Proposal 6:**  Deprioritize the discussion on UE location verification during initial access. |
| [**R1-2210005**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2210005.zip) | Qualcomm Incorporated | Proposal 1: Support TA report of an SRS transmission for network verification of UE location.  Proposal 2: RAN1 to identify NTN specific assistance data and information elements to be reported for Network verified UE location.  **Proposal 3**: For network verification of UE location, consider the following methods:   * Multi-RTT for single NGO satellites * DL TDOA with possible RTT for the serving satellite for multi-satellite case. |
| [**R1-2210050**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2210050.zip) | Nokia, Nokia Shanghai Bell | **Proposal 1**: the UE reported location cannot be used in the network based UE location estimation.  **Proposal 2**: RAN1 to consider other measurement approaches than current standardized methods (e.g., Multi-RTT and DL/UL-TDOA) to solve the network verified UE position problem..  **Proposal 3:** RAN1 to consider to combine UE neighbor measurements to solve the ambiguity between mirror points. |
| [**R1-2210069**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2210069.zip) | PANASONIC | **Proposal 1:** Adopt Multi-RTT as a method for network-based UE location verification.  **Proposal 2**: RAN1 should carefully consider the number of required RTT-measurements for multi-RTT. |
| [**R1-2210195**](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_110b-e/Docs/R1-2210195.zip) | LG Electronics | **Proposal #1:** Prioritize multi-RTT, DL/UL-TDOA for NW verified UE location. FFS on further down-selection.  **Proposal #2:** For RTT determination, option 1 is supported.   * Option 1: The multi-RTT positioning method makes use of the UE Rx-Tx time difference measurements of downlink signals (i.e. PRS) received from the satellite, measured by the UE and reported to the gNB and the measured gNB Rx-Tx time difference measurements, of uplink signals transmitted from UE (i.e. UL-SRS).   **Proposal #3:** If multi-RTT is selected as a baseline scheme for NW verified UE location, study at least followings   * How to handle timing error/delay due to processing time in satellite and movement of satellite and/or UE * Configuration of DL-PRS and SRS for the multiple measurement of UE Rx-Tx time difference |

# RAN1#110 Agreements

The following RAN1 agreements on Network verified UE location for NR NTN were made at RAN1 Meeting #110:

Agreement

The following 3GPP defined RAT dependent positioning methods shall be considered as starting point for the study on Network verified UE location in case of NGSO based NTN deployment:

* Multi-RTT
* DL/UL-TDOA

Note-1: Other methods (e.g. AoA based) are not precluded

Note-2: RAT independent positioning methods are not under the scope of the study

Agreement

For evaluating positioning performance in NTN, the following metrics apply.

* Horizontal accuracy:
* **Horizontal accuracy is the difference between a calculated horizontal position by the network and the actual horizontal position of a UE (for evaluation purposes)**
* **At least CDFs of horizontal positioning errors are used as a performance metrics in NR positioning evaluations**
* **At least the following percentiles of positioning error is analyzed 50%, 67%, 80%, 90%, 95%**

Agreement:

**The following parameters are assumed for the evaluation of RAT dependent positioning methods study in NTN:**

|  |  |
| --- | --- |
| **Parameter** | **Description/Value** |
| **Scenarios** | Rural, LOS |
| **Satellite Orbit** | 600km, optional: 1200km |
| **Satellite parameters** | Reuse Set-1satellite parameters as in table 6.1.1.1-1/2 of TR38.821 |
| **Channel model/ Delay spread** | Based on section 6.7.2 of TR 38.811 |
| **FR/Carrier frequency** | FR1: 2GHz, S-band (n256). Optional: FR2 |
| **BW** | To be reported by companies |
| **Subcarrier spacing, kHz** | 15 for FR1, optional: 120 kHz for FR2 |
| **Number of satellite in view** | 1 for single satellite case, |
| **Orbit inclination** | To be reported by companies |
| **UE type** | Handheld terminal, Optional: VSAT |
| **UE related parameters** | Handheld UE characteristics as in Table 6.1.1.1-3 of TR38.821 with update of polarization, Tx/Rx antenna gain, and antenna type and configuration as agreed under AI 9.12.1 |
| **Positioning signals (Note 1)** | To be reported |
| **Reference Signal Physical Structure and Resource Allocation (RE pattern)** | To be reported |
| **RS type of sequence/number of ports** | To be reported |
| **Number of symbols used per occasion** | To be reported |
| **number of occasions used per positioning estimate** | To be reported |
| **Time window for measurement collection** | To be reported |
| **Interference modelling (ideal muting, or other)** | To be reported |
| **Reference Signal Transmission Bandwidth** | To be reported |
| **Reference point for timing measurement** | Satellite |
| **Description of positioning technique / applied positioning algorithm** | To be reported |
| **UE speed** | 3km/h |
| **Maximum timing measurement error** | To be reported |
| **Performance metrics** | Horizontal accuracy (UE 2D position accuracy) |
| **Additional notes, if any** | Note 1: Time-related measurements can be performed via other downlink and uplink signals than PRS and SRS    Note 2: The corresponding link budget should also be reported and the verification procedure should be done within the restriction of minimum elevation angle for service, e.g., 30 degree for LEO |

# References

1. RP-222654, Revised WID: NR NTN (Non-Terrestrial Networks) enhancements, Thales
2. 3GPP TR 38.882, UE location for Non-Terrestrial-Networks (NTN) in NR (Release 18)
3. 3GPP TS 38.305 V17.1.0, Stage 2 functional specification of User Equipment (UE) positioning in NG-RAN
4. R1-2208389 Discussion on network verified UE location in NR NTN THALES
5. R1-2208396 Network verified UE location for NR NTN MediaTek Inc.
6. R1-2208436 Discussion on network-verified UE location for NR NTN Huawei, HiSilicon
7. R1-2208663 Discussions on network verified UE location for NR NTN vivo
8. R1-2208694 Discussion on network verified UE location for NR NTN ZTE
9. R1-2208835 Discussion on network verified UE location for NR NTN OPPO
10. R1-2208955 Evaluations on network verified UE location for NR NTN CATT
11. R1-2209072 On network verified UE location for NR NTN Intel Corporation
12. R1-2209115 Network verified UE location for NR NTN Sony
13. R1-2209265 Discussion on the network verified location xiaomi
14. R1-2209398 NTN NW verified UE location Lenovo
15. R1-2209600 Discussion on Network Verified UE Location Apple
16. R1-2209643 UE location determination during initial access in NTN InterDigital, Inc.
17. R1-2209649 On network verified UE location in NR NTN Ericsson Limited
18. R1-2209751 Network verified UE location for NR NTN Samsung
19. R1-2209922 Discussion on Network verified UE location for NR NTN NTT DOCOMO, INC.
20. R1-2210005 Network verified UE location for NR NTN Qualcomm Incorporated
21. R1-2210050 Further discussion on Network Verified UE Positioning Nokia, Nokia Shanghai Bell
22. R1-2210069 Discussion on network verified UE location for NTN PANASONIC
23. R1-2210195 Discussion on network verified UE location for NR NTN LG Electronics