**3GPP TSG RAN WG1 Meeting #102-E R1-200xxxx**

**e-Meeting, August 17th – 28th, 2020**

**Source: Intel Corporation**

**Title: Summary of [102-e-NR-Pos-Enh-Eval-Acc-Lat]**

**Agenda item: 8.5.2**

**Document for: Discussion and Decision**

# Introduction

In this contribution, we provide overview of evaluation results provided in contributions submitted for Rel.17 NR Positioning Enhancements WI [1]-[20]. In addition, we try to formulate tentative conclusions and proposals for discussions based on provided results.

Please refer to Section 2 if you are interested to check the overview of the contributions. The summary of the discussed aspects and tentative proposals for further discussion are provided in Section 3.

# Review of Submitted Contributions

In this contribution, we provide overview of evaluation results provided in contributions submitted for Rel.17 NR Positioning Enhancements WI [1]-[20]. In addition, we try to formulate tentative conclusions and proposals for discussions based on provided results.

## Source #1

In [[1], Huawei], the evaluations of multiple positioning techniques (DL-TDOA, DL-TDOA+DL-AOD, UL-TDOA, UL+TDOA+UL-AOA, Multi-RTT) is presented for baseline scenarios with and without UE/gNB calibration errors. In addition, InF-DH scenario with variable UE/gNB antenna height was analysed. The super-resolution measurement algorithms without LOS/NLOS detection is applied.

**Accuracy analysis**

The following observations are made based on presented results for baseline scenarios:

* Hybrid positioning can help to improve the positioning accuracy
* Positioning accuracy of the center area UEs is generally higher than the edge area UEs
* For InF-SH,
	+ Accuracy of less than 0.2m@90% can be achieved with DL-TDOA+DL-AOD and UL-TDOA+UL-AOA in FR2
	+ Accuracy of less than 0.5m@90% can be achieved with UL-TDOA+UL-AOA in FR1 and Multi-RTT in FR2

The following observations are made based on presented results for modified InF-DH with clutter parameters {40%, 3m, 5m} with variable and fixed UE/gNB antenna height for UL+TDOA+UL-AOA and Multi-RTT in FR1 and FR2:

* For modified InF-DH,
	+ Accuracy of less than 0.5m@90% cannot be achieved without NLOS/LOS detection

For evaluation of the DL-TDOA, UL-TDOA, UL+TDOA+UL-AOA and Multi-RTT in FR1, with calibration errors (gNB Rx/Tx time error T1=1.4ns; UE Rx/Tx time error T1=5.6ns) the following observations are made under above assumptions:

* Positioning accuracy of R16 Multi-RTT deteriorated greatly than other positioning methods with UE/gNB calibration error.
* Positioning accuracy of less than 0.5m@90% can be achieved with UL-TDOA+UL-AOA.

**UE power consumption analysis**

The UE power consumption for the following cases involving PRS measurement and SRS transmission are provided (power model is based on TR 38.840):

* PRS with no CDRX / PRS with CDRX and PRS always in or outside on-duration
* SRS with no CDRX / SRS with CDRX and SRS always in on-duration

The following observations are made:

* PRS measurement takes 7% power consumption without C-DRX and ~18% power consumption with C-DRX
* SRS transmission takes 1% power consumption without C-DRX and 2.7% power consumption with C-DRX

## Source #2

In [[2], vivo], the DL-TDOA, UL-TDOA, UL-AOA and Multi-RTT positioning accuracy analysis is provided for InF-SH and InF-DH scenarios for convex and all UEs.

**Horizontal accuracy analysis**

The following observations are made for different positioning techniques:

* DL-TDOA positioning，
	+ performance target [0.2m 90%]
		- can be achieved in InF-SH and InF-DH with the baseline assumptions for convex UEs
		- can be achieved in InF-SH for FR2 for all UEs
		- **cannot be achieved** in InF-SH for FR1 and InF-DH for FR1 and FR2 for all UEs
* For UL-TDOA positioning,
	+ performance target [0.2m 90%]
		- can be achieved in InF-SH and InF-DH with the baseline assumptions for convex UEs
		- can be achieved in InF-SH for FR2 for all UEs,
		- **cannot be achieved** in InF-SH for FR1 and InF-DH for FR1 and FR2 for all UEs
* For UL-AOA positioning,
	+ performance target [0.2m 90%]
		- **cannot be achieved** in InF-SH and InF-DH scenarios.
* For RTT positioning,
	+ performance target [0.2m 90%]
		- can be achieved in InF-SH for FR2 for all UEs,
		- **cannot be achieved** in InF-SH for FR1 and InF-DH for FR1 and FR2 for all UEs.

Based on provided results it is concluded that:

* Performance target [0.2m 90%] can be achieved in InF-SH and InF-DH with baseline assumptions for all the Rel-16 timing-based positioning techniques.

**Vertical accuracy analysis**

Paper additionally provides vertical positioning evaluations with DL-TDOA and AOA/ZOA for InF-SH and InF-DH scenarios for FR1. The following observations are drawn:

* For DL-TDOA positioning，
	+ performance target [1m 90%]
		- can be achieved In InF-SH and InF-DH scenarios for FR1 with baseline assumptions.
* The uniformly distributed UE height and BS height have no benefit for vertical positioning
* For vertical evaluation with AOA/ZOA technique,
	+ performance target [1m 90%]
		- can be achieved In InF-SH scenario
		- cannot be achieved InF-DH scenario for FR1 with baseline assumptions

**Latency Analysis**

Two options of e2e latency are analyzed: UE-to-UE and LCS-to-UE. It is also noted that the process of the UE-based and UE-assisted positioning is different in terms of latency.

Contribution provides analysis of

* e2e latency and higher layer latency
	+ 100ms e2e latency cannot be reached with Rel-16 DL positioning
	+ Concluded: Physical layer latency is the major part of total positioning latency
* Physical layer latency for DL positioning solutions
	+ $T\_{PRS}$ is the periodicity of PRS
	+ $ T\_{Process time} $is up to UE ability and the signal that needs to measure, as usually
	+ $T\_{ measGap}$ is the periodicity of the measurement gap
	+ $T\_{gap,request}$ is the time to request the gap
	+ $T\_{gap,configuration}$ is the time required by UE to configure gaps; RRC reconfiguration delay
	+ $T\_{pusch reporting time}$ is the time to report
	+ Concluded: Physical layer latency needs to be reduced in R17
* Latency analysis for RRC\_IDLE/RRC\_INACTIVE UEs
	+ Additional latency of 40~200ms will be introduced if the UE switches to connected state from idle state for positioning measurement and report

## Source #3

In [[3], ZTE], evaluation results for DL-TDOA with and w/o network synchronization error are provided using MUSIC super-resolution algorithm for FR1 and FR2. The following major conclusions are drawn:

* For InF-SH scenario,
	+ horizontal location error is larger than 40 m for most of cases with 50 ns synchronization error at the percentile of 90% UEs
	+ assuming ideal synchronization and all UEs are inside convex hull, the horizontal positioning accuracy of 90% UEs is less than 0.450 m in FR1, while the value is 0.044 m in FR2
* For InF-DH scenario,
	+ following cases with clutter settings {40%, 2m, 2m} can meet sub-meter level requirement,
		- at the percentile of 50% UEs when all UEs are inside convex hull in FR1
		- at the percentile of 47% UEs when all UEs are uniformly distributed in FR1
		- at the percentile of 67% UEs when all UEs are inside convex hull in FR2
		- at the percentile of 50% UEs when all UEs are uniformly distributed in FR2

It was also observed that vertical accuracy requirement (i.e. 1 m for 90% of UEs) can be met in selected cases based on current assumptions and Rel-16 positioning method under perfect synchronization condition.

## Source #4

In [[4],Sony], the evaluation of positioning accuracy and latency is provided for DL-TDoA and DL-TDoA+ AoD technique with and without LOS detection.

The following observations are made based on provided results:

* In InF-SH scenario,
	+ the target of horizontal positioning accuracy in FR2 is nearly achieved by using positioning technique enhancements, i.e. incorporating legacy DL-TDOA and AoD with NLOS detection.
* In InF-DH scenario,
	+ the target of horizontal positioning accuracy cannot be met by using positioning technique enhancements, i.e. incorporating legacy DL-TDOA and AoD with NLOS detection.
* In InH-OO scenario,
	+ the target of horizontal positioning accuracy can be met by using positioning technique enhancements, i.e. incorporating legacy DL-TDOA and AoD with NLOS detection.

Based on latency analysis the following is recommended:

* RAN1 to study the operation of aperiodic PRS and fast positioning measurement report in order to meet positioning latency requirements.

## Source #5

The work in [[5], CATT] provides initial simulation data for NR positioning performance in InF scenarios. The following positioning techniques were analyzed: DL-TDOA, UL-TDOA, UL-TDOA+UL AoA, Multi-RTT. The MUSIC algorithm was used for estimation of signal location parameters together with 2D or 3D positioning using Chan’s algorithm.

* For DL-TDOA positioning and UEs within convex hull,
	+ range of horizontal accuracy is from 0.04m (InF-SH-2D/FR2) to 1.50m(InF-DH-3D/FR2) at 90% CDF point
	+ range of vertical accuracy is from 0.63(InF-SH-3D/FR2)m to 3.06(InF-DH-3D/FR2)m at 90% CDF point
	+ horizontal accuracy obtained from the UEs within Convex Hull performs better than that of all UEs (0.20 m vs 0.42 m at CDF 90% point)
	+ vertical accuracy obtained from the UEs within Convex Hull and that of all UEs are nearly the same
* For UL-TDOA positioning method and UEs within convex hull,
	+ range of horizontal accuracy is from 0.05m (InF-SH-2D/FR2) to 1.94m (InF-DH-3D/FR2) at 90% CDF point
	+ range of vertical accuracy is from 0.83m (InF-SH-3D/FR2) to 3.13(InF-DH-3D/FR2) at 90% CDF point
	+ horizontal accuracy obtained from UEs within Convex Hull performs better than that of all UEs (0.26 m vs 0.52 m at 90% CDF point)
	+ vertical accuracy obtained from UEs within Convex Hull and that of all UEs are nearly the same
* For UL-TDOA+UL-AOA positioning,
	+ range of horizontal accuracy is from 0.15m to 0.27m at 90% CDF point
	+ range of vertical accuracy is from 0.63m to 2.26m at 90% CDF point
* For Multi-RTT positioning,
	+ range of horizontal accuracy is from 0.07m to 0.56m at 90% CDF point
	+ range of vertical accuracy is from 2.18m to 2.82m at 90% CDF point

## Source #6

In [[6], Intel], performance of DL-TDOA, UL-TDOA, and Multi-RTT techniques has been evaluated for InF-SH baseline, InF-DH baseline, and InF-DH optional scenarios in FR1 and FR2 bands. It has been shown that LOS/NLOS links classification provides a significant performance gain, especially in the InF-DH scenario, where the probability of LOS is smaller. The analysis was done assuming perfect synchronization and no quantization errors for UE measurement reporting.

The following conclusions are made:

* Performance of the Rel.16 positioning techniques highly depends on the measurement data set used in the estimation
* Usage of the LOS links only provides better performance compared to the case when both LOS and NLOS links are utilized
* The required performance can be achieved, if the sufficient amount of the LOS links can be detected and the NLOS links can be discarded based on the LOS/NLOS links classification
* The best performance can be achieved with Multi-RTT measurement technique

Combination of Multi-RTT estimations with the vertical AoA measurements was evaluated with a conclusion that Multi-RTT + vertical AoA measurements further improves positioning performance in the InF scenarios.

The analysis of Multi-RTT was also made assuming practical algorithm for LOS/NLOS classification. The usage of the practical LOS/NLOS classification algorithms was shown to provide significant improvement in the positioning accuracy and should be considered as an enhancement for Rel.17 positioning techniques.

Finally, initial latency analysis was provided. The presented analysis for average latency and resource utilization required for DL/UL positioning procedure shows the benefit of on demand resource allocation for transmission of positioning reference signals.

## Source #7

The following performance results were provided in [OPPO, [7]] for DL-TDOA in InF scenarios:

* In InF-SH scenario, < 1m accuracy for 90% of UEs is achievable
* In InF-DH scenarios, < 1m accuracy for 90% of UEs is not achievable
	+ D = 20m can achieve 2.47m accuracy for 90% of UEs
	+ D = 50m can achieve 13.19m accuracy for 90% of UEs

In the evaluation, positioning method was based on Chan algorithm with equally weighted TOA covariance. The maximum-likelihood detection to obtain 1/4Ts resolution and good quality of TOA measurement was applied.

## Source #8

The following results were provided in [BUPT, [8]]. The following assumptions were used for analysis:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Scenario | InF-SH/FR1 | InF-DH/FR1 | InF-SH/FR2 | InF-DH/FR2 |
| CDF percentile | 90% | 90% | 90% | 90% |
| CDF value | 0.617m | 0.293m | 0.179m | 0.116m |

The results were obtained using phase tracking algorithm for measurement and under the following evaluation assumptions:

|  |  |
| --- | --- |
| **Parameter** | **[Source 4, InF-DH, FR2]** |
| Channel model (baseline, otherwise state any modifications) | Baseline |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) | TS38.211 R16 PRS comb-12 pattern |
| Reference signal (type of sequence, number of ports, …)  | TS38.211 R16 PRS |
| Number of symbols used per slot per positioning estimate | 12 symbols |
| Number of slots per positioning estimate | 8000 slots |
| Power-boosting level | 1 |
| interference modelling (ideal muting, or other) | ideal muting |
| Description of Measurement Algorithm (e.g. super resolution, interference cancellation, ….) | Phase tracking |
| Description of positioning technique / applied positioning algorithm (e.g. Least square, taylor series, etc) | Chan |
| Network synchronization assumptions | Perfect Synchronization |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | Ideal alignment |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | nrof antenna elements used |
| Additional notes, if any |   |

## Source #9

The following proposals and observations are made in [[9], Samsung]:

* With increased NLOS probability, positioning accuracy degrades significantly
* Performance of DL-TDOA in InF scenario is as follows:
	+ For InF-SH scenario,
		- the target of less that 1m positioning accuracy with 90% availability can be achievable;
	+ For InF-DH scenario,
		- the positioning accuracy with 90% availability is quite large due to NLOS and the errors in TOA estimation
* The target requirements for NR positioning enhancement should be
	+ horizontal positioning accuracy < 1m
	+ latency < 1s
* In addition, power consumption can also be considered which can be reflected as aspects such as signaling overhead.

## Source #10

The analysis of DL-TDoA and DL-AoD for InF-SH and InF-SL scenarios was provided in [[10], Mediatek]. The IFFT and super-resolution algorithms were applied in the study.

* For DL-TDOA in InF-SH (inter-site distance (ISD) 50m):
	+ positioning error <1m for 80% UEs (super resolution algorithm for TOA estimation)
	+ positioning performance for super resolution algorithm with best 10 TRPs is better than for IFFT based algorithm with best 16 TRPs
* For DL-TDOA in InF-SL: (ISD 20m):
	+ DL-TDOA positioning error <1m for 80% UEs if UE applies super resolution algorithm for TOA estimation and all links have LOS channel assumption
	+ For realistic channel model, super resolution algorithm doesn’t lead to better positioning accuracy. In this scenario, DL-TDOA can achieve positioning error < 2m for 80% UEs with UE applying IFFT based algorithm for TOA estimation
* For DL-AoD in InF-SH:
	+ Even assuming all LOS channel, DL-AoD technique cannot achieve error <1m for 80% UEs
	+ For realistic channel. We see that DL-AoD can only achieve error < 2.4m for 80% UEs
* For DL-AoD in InF-SL:
	+ DL-AoD error <70cm for 80% UEs assuming all links are LOS
	+ For realistic channel model, DL-AoD can only achieve error < 1.5m for 80% UEs
	+ Performance in InF-SH is worse than that in InF-SL. This is because ISD in InF-SH is larger than that in InF-SL. Note that under the same AoD estimation error, large ISD would lead to larger positioning error

## Source #11

The contribution in [[11], CMCC] focused on latency analysis. It has the following key observations and proposals:

Observations:

* The current higher layer procedure is long and complicated, and the latency can be further reduced, e.g., by enabling enhanced higher layer architecture and signalling procedure.
* To achieve a physical layer procedure of less than 10ms, the configuration of the DL PRS periodicity is limited and the DL PRS overhead would be heavy.

Proposals:

* In Rel-17 target positioning requirements for commercial use cases:
	+ End-to-end latency for position estimation of UE (< 100 ms)
	+ Physical layer latency for position estimation of UE (< 50 ms)
* In Rel-17 target positioning requirements for IIoT use cases:
	+ End-to-end latency for position estimation of UE (<10ms)
	+ Physical layer latency for position estimation of UE (<10ms)

## Source #12

In [[12], InterDigital], the latency analysis has been completed. From the physical layer perspective, the latency is divided into four delay components, including the following:

* T1 – time duration for positioning initialization
* T2 - Time duration for RS reception/transmission and processing
* T3 - Time duration for measurement reporting and processing
* T4 - Time duration for data forwarding/routing and processing in network

At UE, T1, T2 and T3 contain physical layer delay components for PRS processing while T1 and T2 contain delay components related to transmission of SRS.

It is proposed:

* For latency analysis at UE for Rel. 17 enhanced techniques, analyse delay at T1, T2 and T3, separately

## Source #13

The work in [[13], Lenovo, Motorola Mobility] mainly discusses latency aspects for NR Positioning study in Rel.17. The following main views are presented on various discussion aspects:

**On scenarios and latency analysis**

* For NR positioning enhancements in Rel-17, deprioritize the end-to-end latency impact and analysis for commercial use cases and if time permits, this evaluation can be also included as part of study in a best effort manner.
* For NR positioning enhancements in Rel-17, at least only reasonable values below 100ms, e.g. 20ms of end-to-end latency performance requirement for UE position estimation in IIoT use cases should be considered for further down-selection.

**On UE state transition and latency analysis**

* For NR positioning enhancements in Rel-17, the latency due to any state transition delays and existing RACH procedures should be ignored for the positioning latency evaluation.
* For NR positioning enhancements in Rel-17, the latency evaluations should be carried out with the assumption that the UE is already in RRC\_CONNECTED state.

**On guidance on latency analysis from other WGs**

* Consider the input and guidance from SA2 and RAN3 WGs regarding the detailed positioning latency evaluations from CN and NG-RAN.
* Consider the input and guidance from the RAN2 WG regarding the detailed latency evaluations of the LPP procedures.

**On E2E latency evaluation**

* The end-to-end positioning latency can be collectively evaluated in terms of the CN, LMF, NG-RAN, LPP and physical layer procedures.

## Source #14

The paper in [[14], LGE] mainly discuss latency related aspects. Based on discussions the following observations and proposal are drawn:

**On latency of higher layers**

* In perspective of end-to-end latency, there are 3 types of location service procedure such as NI-LR / MT-LR / MO-LR and more than one scenarios are included in each type.
* LPP(a) message and the signalling which is exchanged between UE and/or gNB and/or server and/or functions(application/network) can be different depending on the scenario.

**Physical layer latency analysis for DL based positioning**

* In perspective of physical layer, minimum latency for grant based positioning measurement exceeds the target delay [10] ms according the following table.

|  |  |
| --- | --- |
| **Procedure** | **Latency** |
| Measurement gap request | 1ms |
| Measurement gap configuration | 10ms  |
| PRS reception | 3ms for FR1 / 1.5ms for FR2 |
| Scheduling request | 0.68ms |
| UL grant | 2.68ms |
| Reporting measurement result | 1.21ms |
| Total minimum elapsed time | 18.57ms for FR1 / 17.07 for FR2 |

* Rel-17 NR positioning SI needs to study PRS measurement latency and PRS reporting latency at least for the physical layer latency enhancement.

## Source #15

The initial evaluation results as well as consideration on latency analysis are provided in [[15], Nokia]. In terms of performance accuracy, the following data are reported

Table 1. CDF Summary of Initial Results for DL TDOA for Horizontal Error

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Scenario, Fc, BW** | **50%** | **67%** | **80%** | **90%** |
| InF-SH, 3.5 GHz, 100 MHz | 0.98 m | 1.47 m  | 2.13 m  | 4.35 m  |
| InF-DH, 3.5 GHz, 100 MHz | 1.71 m | 3.15 m  | 4.39 m | 7.16 m |
| IOO, 3.5 GHz, 100 MHz | 1.17 m | 1.92 m  | 3.24 m | 6.50 m |
| UMi, 3.5 GHz, 100 MHz | 5.29 m | 9.59 m | 14.92 m | 23.81 m |

and the following observations are made:

* Performance of DL-TDOA is significantly worse in InF-DH compared with InF-SH. Meeting the strictest accuracy requirements for InF-DH may be challenging.
* Performance of DL-TDOA is better in the InF-SH scenario compared with IOO.
* Performance of DL-TDOA is limited by the granularity of RSTD measurements.

**On latency**

It is proposed that RAN1 assumes some baseline values for different higher layer signalling delays (e.g., each LPP signalling step takes X ms where X is FFS) and send LS to RAN2/3 with baseline values for confirmation/feedback.

## Source #16

Contribution [[16], Fraunhofer IIS, Fraunhofer HHI] focuses on the ToA performance in InF scenarios and complement it by an analysis on the achievable positioning accuracy. In addition, the impacts of Absolute Time-of-Arrival model (AToA) and K-Factor are analyzed. The following observations are made based on provided analysis:

* For InF-LOS channels, simple ToA-Estimators method provide high accuracy
* The ToA estimation error for LOS is significantly smaller (median value 0.5ns @ SNR= 0dB) compared to the ToA-Error for NLOS generated by AToA model (median value 31ns)
* With the given AToA model, a reliable LOS/NLOS detector is essential to achieve high positioning accuracy with probability of LOS according to the statistics of the deployment
* Technologies allowing a reliable LOS/NLOS detection and/or a ToA quality indicator shall be studied with high priority
* The Absolute ToA model does not differentiate between the different InF NLOS scenarios. The statistical properties may be dependent on deployment scenarios and environment characteristics.
* Characterize the positioning technologies versus channel parameters. At least the following complementary analysis shall be derived from the simulations:
	+ ToA estimator accuracy relative to the delay introduced by the AToA model
	+ ToA estimator accuracy versus K-factor

## Source #17

The paper [[17], CeWIT] provides the initial evaluation results for Rel.17 use cases. The following performance results were reported for DL-TDoA for ideal synchronization.

|  |  |  |
| --- | --- | --- |
|  | Baseline InF-SH | Baseline InF-DH |
| Bandwidth | 50% | 67% | 80% | 90% | 95% | 50% | 67% | 80% | 90% | 95% |
| 20MHz | 2.31m | 3.52m | 4.9m | 8.95m | - | 2.47m | 3.3m | 5.2m | 9.5m | - |
| 50Mhz | 1.23m | 1.62m | 2.32m | 3.73m | 6.13m | 1.03m | 1.63m | 2.14m | 3.2m | 8.9m |
| 100MHz | 0.6m | 0.85m | 1.41m | 1.78m | 4.18m | 0.61m | 0.96m | 1.4m | 1.9m | 3.2m |
| 200MHz | 0.3m | 0.52m | 0.95m | 2.70m | 4.18m | 0.35m | 0.55m | 0.84m | 1.37m | 2.0m |

* Bandwidth of PRS is a critical parameter to define the accuracy of positioning in both the IIoT scenarios. Similarly, determining the LOS path will improve the accuracy of position at least in case of InF-DH scenario.

It is also observed that network synchronization error is critical factor in Rel.17 positioning enhancement as it degrades the positioning accuracy significantly. Tight synchronisation close to ideal is necessary for Rel.17 scenarios.

Finally, the following proposals are made:

* LOS path detection and hybrid positioning techniques should be studied in positioning enhancement study.
* Network synchronization error techniques should be studied in Rel.17 to achieve required accuracy.

## Source #18

The evaluation results in [[18], Qualcomm] are provided for multiple scenarios. Contribution also briefly outlines TOA estimation as well pruning and outlier rejection algorithms.

**Horizontal Accuracy Analysis**

The following observations are made based on analysis of InF scenarios:

* IIOT requirement (<20cm accuracy) can be met at 90%, 50%,20%, 7% when T1 = 0, 0.5, 1, 2 ns at both Tx and Rx side in InF-SH FR2 scenario.
* IIOT requirement (<20cm accuracy) can be met at 68%, 27%, 11%, 4% when T1 = 0, 0.5, 1, 2 ns at both Tx and Rx side in InF-DH FR2 scenario.
* For InF-SH scenarios, the 0.5ns resolution limit for UE-assisted TDOA and RTT is not enough to meet the 20 cm requirements.

The UMi/UMa scenarios are analyzed with the Tx/Rx timing error and/or network sync error according to truncated Gaussian Distribution [-2\*T1,2\*T1] nsec, as agreed in previous 3GPP RAN1 meetings. Both TDOA and M-RTT results are shown. In addition, the likelihood fusion algorithm is considered in evaluations. The following observations are made based on analysis of UMi/UMa scenarios:

* For UMiFR1 scenarios,
	+ Tx/Rx calibration with T1 = 5 nsec or above shows a noticeable degradation to performance of RTT Positioning when using either a baseline, or an advanced positioning engine algorithm.
	+ RTT performance with realistic Tx/Rx calibration errors achieves better performance than TDOA with realistic network sync and Tx/Rx calibration errors.
* For UMi FR2 scenarios,
	+ With gNB sync errors T1 larger than 10ns, TDOA cannot meet the commercial requirement (1m at 80%).
	+ TDOA can meet with commercial requirement with calibration errors T1 smaller or equal to 1ns. RTT can meet the same requirement with calibration errors between T1 = 0.5~1ns(or say smaller or equal to 0.5ns) in comb2.
	+ TDOA can meet with commercial requirement with calibration errors T1 smaller than 2ns (or say smaller or equal to 1ns). RTT can meet the same requirement with calibration error smaller than 0.5ns in comb6.

The following observations are made for InH scenario:

* For InH FR2 scenarios
	+ With gNB sync errors T1 larger than 10ns, OTDOA cannot meet the commercial requirement (1m at 80%).
	+ RTT has inferior performance compared with OTDOA with calibration errors only in the worst-case model assumptions. (4 independent calibration errors are added per TRP in RTT, compared with 2 independent calibration errors in the RSTD with OTDOA).
	+ OTDOA can meet commercial requirement with calibration errors T1 smaller than 2ns (or say smaller or equal to 1ns). RTT can meet the same requirement with calibration errors between T1 = 0.5~1ns (or say smaller or equal to 0.5ns).

**Latency Analysis**

The detailed E2E latency study is presented including analysis of physical layer latency and higher layer latency.

In terms of physical layer latency, the following observation was made:

* The PHY-layer latency in NR Rel-16 Positioning (starting from the transmission of the location request from the serving gNB, up to the succesfull decoding of the PUSCH containing the Positioning report from the serving gNB) ranges in the interval [57-823] msec depending at least in the following factors (the list may not exhaustive):
	+ UE timeline of UL data transmission (UE PUSCH preparation time)
	+ UE timeline of DL data transmission (UE PDSCH processing time)
	+ SR-based or grant-free UL configuration
	+ Numerology of PUSCH, PDSCH
	+ FDD or TDD and frame structure configuration
	+ PRS processing capabilities
	+ PRS periodicity
	+ Measurement gap periodicity
	+ gNB processing assumptions with regards to PUSCH decoding, RRC processing time
	+ RRC processing time at the UE
* With regards to PHY-layer latency analysis, the following components seem to be the most time-consuming:
	+ Measurement gap Configuration & Triggering of Location-Request
	+ PRS availability & Alignment (e.g. Periodic PRS with long periodicity)
	+ Number/length of PRS instance(s) required to be measured
	+ UE PRS processing time

## Source #19

In [[19], Ericsson], simulation results are presented for positioning accuracies in UMa, UMi, IOO, and baseline InF scenarios. All DL-TDOA simulations are done for Rel. 16 12 symbol, comb-12 DL-PRS. For UL-TDOA simulations, 2 symbol, comb-2 SRS is considered.

**UMa**

* A significant performance gap exists between the achievable and Rel. 17 target accuracies in UMa scenario. It is proposed to exclude UMa scenario from Rel. 17 evaluations.

**UMi**

* Target accuracy of <1 m for general commercial use cases can be achieved in UMi (FR1) scenario with potential enhancements. Early results also show that Rel. 17 target accuracies can be met in UMi (FR2). It is proposed to include UMi scenario in Rel.17 evaluations.
* The UMi NLOS excess delay is far from negligible when targeting 1m accuracy and needs to be modelled. It is proposed to use the same lognormal parameters for the NLOS excess delay in UMi as the ones defined for the InF model in 38.901, i.e. log10(NLOS excess delay/1s) is normally distributed with mean mu=-7.5 and standard deviation sigma=0.4.

**InH(OO)**

* Target accuracy of <1 m for general commercial use cases can be achieved in IOO (FR1) scenario with potential enhancements. Early results show that Rel. 17 target accuracies can be met in IOO (FR2). It is proposed to consider IOO scenario in Rel. 17 evaluations.
* The IOO NLOS excess delay is far from negligible when targeting 1m accuracy and needs to be modelled. Use the same lognormal parameters for the NLOS excess delay in IOO as the ones defined for the InF model in 38.901, i.e. log10(NLOS excess delay/1s) is normally distributed with mean mu=-7.5 and standard deviation sigma=0.4.

**InF**

* Simulation results suggest that Rel. 17 target accuracies can be met in InF-SH (FR1).
* A significant performance gap exists between the achievable and Rel. 17 target accuracies in InF-DH (FR1).
* Rel. 17 target accuracies are met in FR2 in InF SH scenario if there are no RX/TX timing errors but not with 8ns RX/TX timing errors.
* Rel. 17 target accuracies are not met in FR2 in InF DH scenario.
* RX/Tx error affects achievable positioning accuracy.
* Consider Rx/Tx error for Rel. 17 evaluations.

# Summary of Discussion Aspects

The following aspects were discussed/mentioned in submitted contributions:

## Analysis of physical layer latency for NR positioning

The latency aspect was discussed and evaluated in multiple contributions. In general latency may need to be studied separately for DL only, UL only, DL+UL positioning solutions as well as for UE based and UE-assisted approaches. The most complete analysis of physical layer latency for positioning was provided in [2], [18]. Based on review of contribution the following proposal can be formulated

**Tentative Proposal #1**

* RAN1 to separately study physical layer latency for DL only, UL only, DL+UL positioning solutions as well as for UE-based and UE-assisted approaches
* The PHY-layer latency in NR Rel-16 Positioning (starting from the transmission of the location request from the serving gNB, up to the successful decoding of the PUSCH containing the Positioning report from the serving gNB) ranges in the interval [X, Y] ms where X and Y are TBD and depends at least on the following factors (the list may not exhaustive):
	+ UE timeline of UL data transmission (UE PUSCH preparation time)
	+ UE timeline of DL data transmission (UE PDSCH processing time)
	+ SR-based or grant-free UL configuration
	+ Numerology of PUSCH, PDSCH
	+ FDD or TDD and frame structure configuration
	+ PRS processing capabilities
	+ PRS periodicity
	+ Measurement gap periodicity
	+ gNB processing assumptions with regards to PUSCH decoding, RRC processing time
	+ RRC processing time at the UE

Based on presented analysis so far, the following proposal seems can be concluded.

**Tentative Proposal #2**

* The physical layer latency for NR positioning needs to be enhanced to meet most stringent requirement of I-IOT use cases of 10ms

Companies are invited to provide views on tentative proposals #1 and #2 above.

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| **Company** | **Comments** |
| vivo | In general, we agree with proposal#1 and #2. But there are some modification for proposal #1 considering the **RRC processing time (ie,10ms) well over the PUSCH process time (ie, 4.25OS)** We propose the sub-bullet # 1 #2 #9 are modified as below* + UE PUSCH preparation time, alignment time and duration time (sub-bullet # 1)
	+ UE PDSCH processing time (sub-bullet # 2)
	+ gNB processing time for PUSCH decoding (sub-bullet # 9)
	+ RRC processing time at the gNB (sub-bullet # 9)

Furthermore, we think it is necessary to interpret the related RRC signaling for the ‘RRC processing time’, such as RRC processing time for MG request and configuration. |
| Nokia/NSB | On FL proposal 1: * In the second bullet we aim at a definition of physical layer latency for positioning but this seems to assume UE assisted mode and DL based, correct? If the first bullet is agreeable then we suggest to have a second bullet which defines the physical layer latency for the various cases that we plan to investigate (for example in UL based there is no PUSCH sent containing a report) or we provide a definition that is agnotsitc to the specific case. Then in a third bullet we may list the factors that contribute.
* On the proposed [X,Y] range. Is the intention to define both a maximum and minimum latency for a single shot positioning fix (i.e, only one PRS occasion) or is this also somehow tied to the latency required to meet a given accuracy? Defining/analyzing a maximum value Y may be a bit tricky in our view.

On FL proposal 2: * Suggest to say requires enhancements in place of needs to be enhancemed.
 |
| Huawei/HiSilicon | For proposal #1, there is a proposal from FL also for physical layer latency definition in email thread of 102-e-NR-Pos-Enh-Eval-Addl-Scenarios where we tend to think is a right place to discuss the physical layer latency. Also, the definition of physical layer latency should be applicable to UE measurement (when applicable) and gNB measurement (when applicable) for DL-only positioning, UL-only positioning, multi-RTT positioning and NR E-CID positioning.For proposal 2, the enhancement should be discussed in the email thread of 102-e-NR-Pos-Enh-Pot-Pos-Enh. |
| CATT | For Proposal #1, For the first bullet, since UE-based and UE-assisted approaches can be DL only, UL only and DL+UL, suggest making the following changes:* RAN1 to separately study physical layer latency for DL only, UL only, DL+UL positioning solutions for UE-based and UE-assisted approaches

For Proposal #2, given this AI focuses on the evalution, the proposal may be:* The physical layer latency for NR positioning needs to be evaluated to see if most stringent requirement of I-IOT use cases of 10ms can be met.
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## Analysis of e2e/higher layer latency for NR positioning

Companies also discuss the other E2E / higher layer latency components. It seems there is no common understanding in terms of which WG should analyse the E2E / higher layer latency. It is typically a scope of RAN2 WG. It is important to align on common understanding among all RAN WGs and therefore it is suggested to discuss the following proposal:

**Tentative Proposal #3**

* Send LS to RAN WG2 and WG3 and ask to provide list of latency components with corresponding range of values for existing and enhanced NR positioning solutions

Companies are invited to provide views on proposal above regarding e2e / higher layer latency analysis.

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| **Company** | **Comments** |
| vivo | We are okay to have a common understanding of the higher latency. For RAN1, we prefer to focus on the physical layer latency. |
| Nokia/NSB | Support the proposal. It might be good after converging on proposals 1-2 to send a list of scenarios for range values to RAN2/3. For example we may ask RAN2/3 to approximate minimum latency that can be achieved for DL positioning in UE assisted, UL positioning in UE assisted, etc.  |
| Huawei/HiSilicon | We see the intention of sending the LS is to have an end-to-end latency evaluations. However, we doubt the LS is helpful because this latency analysis may involve core network also which may be outside RAN2 or RAN3 expertise.  |
| CATT | Support. Although we may not obtain all of the answer of higher-layer latency from RAN2/3 as pointed out, we can at least get some inputs from them,which would help the evaluation of the e2e latency. |

## Target horizontal/vertical positioning accuracy requirements

Given that positioning error target requirements were not finalized at the previous meeting many companies tend to use evaluation results and either suggest target requirements based on results or make a conclusion whether certain positioning technique can meet requirement aligned with company view. In order to address this problem, it is suggested to agree on target requirements in agenda item for evaluation methodology.

The following data can be considered as an input to the discussion in evaluation methodology agenda item for I-IoT scenarios:

* CDF percentile – 90%
* Horizontal error – select among the following alternatives
	+ Alt.1 < 0.2m
	+ Alt.2 < 0.5m
* Vertical error < 1m

**Tentative Proposal #4**

* Discuss and agree on target positioning accuracy requirements in AI 8.5.1 to avoid duplication

Companies are invited to provide views on proposal above.

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| **Company** | **Comments** |
| vivo | Agree with P4 |
| Nokia/NSB | Support.  |
| Huawei/HiSilicon | Agree |
| CATT | Support |

## Target latency requirements

Given that latency target requirements were not finalized and require further discussion on latency components, it is suggested to agree on target e2e latency requirements in agenda item for evaluation methodology.

The e2e latency of 10ms can be considered as an input to the discussion in evaluation methodology agenda item for I-IoT scenarios.

**Tentative Proposal #5**

* Discuss and agree on target latency requirements in AI 8.5.1 to avoid duplication

Companies are invited to provide views on proposal above.

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| **Company** | **Comments** |
| vivo | Agree with P5 |
| Nokia/NSB | Support.  |
| Huawei/HiSilicon | Agree. |
| CATT | Support |

## Performance analysis of horizontal/vertical positioning

Companies have conducted initial evaluation of Rel.16 positioning solutions and checked performance of either horizontal or both horizontal and vertical solutions. In general, it is expected that final conclusions on evaluations will be made at the next meeting since currently performance target are not fixed.

So far, the following initial conclusions and observations can be made:

**Tentative Proposal #6**

* Baseline InF-SH scenario is characterized by high probability of LOS links for positioning. For baseline InF-SH scenario, under perfect synchronization and UE/gNB Tx/Rx calibration,
	+ It is feasible to achieve X = 0.2m accuracy of horizontal positioning at 90% using Rel.16 positioning techniques.
* Probability of LOS links for baseline InF-DH scenario is much lower comparing to InF-SH. For baseline InF-DH scenario, under perfect synchronization and UE/gNB Tx/Rx calibration,
	+ Further analysis is needed to check whether X = 0.2m accuracy of horizontal positioning at 90% using Rel.16 positioning techniques can be met.

Companies are invited to provide views on proposal above and whether it is necessary to capture initial observations based on provided performance data so far or more time is needed for evaluation.

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| **Company** | **Comments** |
| vivo | In general, we agree with proposal#6. It is noted that the target X = 0.2m can be satisfied in our Tdoc for DH. And we also found CATT and Intel( in the LOS case) can reach the target. |
| Nokia/NSB | We are okay with the 2nd bullet but for the first bullet (specifically the sub-bullet) we think it is still too early to declare we can achieve this accuracy. Some companies seem to observe different accuracy levels. At this stage we prefer to avoid this type of conclusion. One question is also that if we can meet InF-SH performance of 20 cm for 90% of UEs, does this mean we will not pursue accuracy enhancements in this Rel?  |
| Huawei/HiSilicon | To us, it is too early to conclude the feasibility of achieving 0.2m accuracy, as our results only show 0.299m@90% for the concerned case. Also, the results vary significantly between different positioning methods and the frequency ranges.  |
| CATT | We are fine to conclude it is feasible to achieve X = 0.2m accuracy of horizontal positioning as long as we made it clear that the conclusion is made under the perfect conditions (no synch error, no Tx/Rx group delays).To Nokia: Our understanding is that the conclusion does not mean we will not pursue accuracy enhancements in this Rel-17, simply because the conclusion is made under ‘perfect’ conditions. It does not mean we are able to meet the requirements in a real InF-SH environment with Rel-16 techniques.  |

## LOS/NLOS detection/classification

One of the major challenges for accurate positioning in InF-DH scenario, is low probability of LOS links and propagation delay offset imposed by NLOS links which causes significant degradation of Rel.16 solutions if no enhancements are considered. The LOS/NLOS classification is considered as a useful approach to improve performance of Rel.16 solutions.

**Tentative Proposal #7**

* Rel.17 NR positioning enhancements support mechanisms for LOS/NLOS classification/detection which is shown to be essential to improve performance of Rel.16 positioning solutions
	+ FFS details

Companies are invited to provide views on proposal above as a potential solution for Rel.17 enhancements.

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| **Company** | **Comments** |
| vivo | Maybe it should be discussed in the enhancement. If we discussed in the evaluation, the simulation algorithm and condition maybe need to clarify. |
| Nokia/NSB | Agree with vivo that maybe enhancements AI is a better place to discuss this proposal. That said from company contributions it is clear that LoS/NLoS classification has an impact on the performance. Perhaps an observation along those lines could be agreeable without mentioning enhancments.  |
| Huawei/HiSilicon | Our understanding is that in this AI, we should only conclude something likeMechanisms for LOS/NLOS classification/detection is shown to be essential to improve performance of Rel.16 positioning solutions. As an enhancement, LOS/NLOS identification can be discussed in another email thread of 102-e-NR-Pos-Enh-Pot-Pos-Enh.  |
| CATT | We suggest making the conclusion in AI 8.5.2 on the importance of LOS/NLOS classification/detection based on the evaluation results. The enhancements could be handled in AI 8.5.3. |

## UE/gNB Tx/Rx calibration errors

The impact of UE/gNB Tx/Rx calibration errors was evaluated and shown to be an important factor that can limit performance of timing-based solutions.

In general, the proper model of UE/gNB Tx/Rx time error is needed. The calibration aspects fit more RAN4 WG scope and thus it needs to be decided how to proceed with evaluations towards next meeting.

**Tentative Proposal #8**

* Alt.1: Calibration errors for UE/gNB Tx/Rx timings are used in future analysis. Select one of the options based on submitted contributions.
	+ Option 1: gNB Rx/Tx Time error T1=1.4ns UE Rx/Tx time error T1=5.6ns
	+ Option 2: Check value of Tx/Rx error suitable to meet X = 0.2m of horizontal positioning accuracy requirement
	+ Option 3: RAN1 sends LS to RAN4 to consult on calibration model for UE/gNB Tx/Rx time error

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| **Company** | **Comments** |
| vivo | The question seems to be also discussed in the AI 8.5.1. For us, it is not clear about the definition of Tx/Rx timings, some company say it can be calibrated before positioning, some companies think only part of it can be calibrated, some companies think it includes the antenna panel switching and timing jitter. We prefer to unify the understanding of Tx/Rx timings.As our understating, the UE/gNB RX and TX timing error is the delay caused by the processing form the baseband to the antennas, or the delay caused by different antenna lengths. If the above understanding is reasonable, we can not understand why the UE Rx/Tx time error is longer than gNB Rx/Tx Time error in option 1. |
| Nokia/NSB | This should be discussed in 8.5.1 in our view as it is already included in the FL summary there.  |
| Huawei/HiSilicon | It seems to be covered by AI 8.5.1.  |
| CATT | We suggest making the conclusion in AI 8.5.2 on the importance of properly handling Tx/Rx group delays based on the evaluation results. The enhancements could be handled in AI 8.5.3. |

## Network synchronization error estimation

Network synchronization error was shown to be critical for TDOA based timing solutions. Several companies mentioned possibility to estimate network synchronization error by UEs/gNBs.

**Tentative Proposal #9**

* RAN1 to further study feasibility of network synchronization error estimation as a part of Rel.17 positioning enhancement solutions

Companies are invited to provide views on proposal above aiming to discuss further efforts on network synchronization error estimation.

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| **Company** | **Comments** |
| vivo | I don‘t understand why we discussed the network synchronization in AI 8.5.2. In the last meeting, the 50ns sync error has been agreed as an optional scenario, it is up to companies to provide the evaluation result with the sync error. |
| Nokia/NSB | Agree with vivo that this shouldn’t be discussed in this AI. There are proposals in AI 8.5.3 which may be a better place to discuss this issue.  |
| Huawei/HiSilicon | I guess the intention of this proposal is to stuy the feasibliblity of any enhancement for estimating the NW sync error to be discussed in AI 8.5.3, from this sense, we are ok with the proposal.  |
| CATT | We suggest making the conclusion in AI 8.5.2 on the importance of properly handling network synchronization error. The enhancements could be handled in AI 8.5.3. |

## Granularity of timing report

A few companies have mentioned that granularity of timing measurement reports is a potential limiting factor for timing-based positioning solutions.

**Tentative Proposal #10**

* RAN1 to further study whether Rel.16 granularity of timing measurement reports is enough aiming to conclude at the next RAN1 meeting

Companies are invited to provide views on proposal above regarding enhancement of granularity of timing reporting

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| **Company** | **Comments** |
| vivo | It is up to companies to provide the evaluation result with different granularity. The comparison of the performance with different granularity can be provided by interested companies. |
| Nokia/NSB | We think a general observation on the impat of granularity could be reached in this AI so the proposal is okay in principle for us.  |
| Huawei/HiSilicon | OK. |
| CATT | OK. |

## UE power consumption

One company provided UE power consumption analysis for the cases involving PRS measurement and SRS transmission. UE power consumption is certainly important consideration. In order to conduct such studies, RAN1 needs to decide on UE power consumption model.

**Tentative Proposal #11**

* RAN1 to further discuss details and necessity of UE power consumption evaluations for NR Positioning in Rel.17

Companies are invited to provide views on proposal above including specific details of UE power consumption model.

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| **Company** | **Comments** |
| vivo | We agree with P11.Device efficiency(ie, UE power consumption) is an objective, same with accuracy and latency. And it has the evaluation model or method for accuracy and latency, while the UE power consumption doesn’t have a common evaluation model, it is difficult to evaluate the performance of enhancement.We believe that a quantitative evaluation of power consumption for positioning is necessary. and it will help choosing a suitable positioning solution with efficient power consumption. So we prefer to further discuss the evaluation model of UE power model. |
| Nokia/NSB | As commented in the other AI the prior agreement from RAN1#101-e seems very clear: Agreement:* UE power consumption for NR positioning can be optionally evaluated in the SI.
* Note: It is up to each company on how to evaluate the power consumption for positioning. The UE power consumption models developed in TR38.840 can be considered as the starting point for defining the UE power consumption model for the evaluation for NR positioning

Based on the note we don’t see the need for this proposal.  |
| Huawei/HiSilicon | We view power consumption as an important KPI to provide another perspective to look into positioning performance. Also, the power consumption model seems to being discussed in the email thread of 102-e-NR-Pos-Enh-Eval-Addl-Scenarios.  |
| CATT | It seems to us the previous agreement is good enough. Each company can bring their evaluation results. |

## Unified Template for Collection of Evaluation Results

In order to simplify the work at the upcoming meeting, it is desirable to develop unified across companies (compliant with 3GPP TR styles) template for collection of evaluation results. This template is expected to support evaluation of multiple techniques and simplify analysis of the results. Each company can be requested to provide answers on whether and which performance technique can reach the target performance requirement to draw final observations.

**Tentative Proposal #12**

* RAN1 to design template (during RAN1#102e) for collection of evaluation results at the upcoming meetings aiming to simplify analysis of provided data, preparation of summary/conclusions based on provided evaluation studies and integration of the provided data to 3GPP TR

Companies are invited to provide views on proposal above including desirable features/attributes of the template. If it is agreed, the next step is to design and endorse template.

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| **Company** | **Comments** |
| vivo | We think we can reuse the template in TR 38.855, and companies may provide the evaluation results with the assumptions. |
| Nokia/NSB | From last meeting: Agreement:For TR 38.857, the template used in TR 38.855 for the inclusion of simulation results is reused. In addition, the following parameters should be provided for each scenario together with the simulation results.(table omit for space)We are okay to adapt the template from TR 38.855 if necessary but this seems to already be agreed as the baseline. Perhaps we need some template for accuracy results?  |
| CATT | It seems we can follow the agreement to reuse the template used in TR 38.855. |

# Summary

# References

1. R1-2005252 Performance evaluation for Rel-17 positioning , Huawei, HiSilicon
2. R1-2005380 Evaluation of achievable positioning accuracy and latency, vivo
3. R1-2005463 Evaluation results based on NR Rel-16 positioning, ZTE
4. R1-2005578 Initial Views on Evaluation of Positioning Accuracy and Latency, Sony
5. R1-2005711 Discussion of evaluation of NR positioning performance, CATT
6. R1-2005878 NR Positioning Performance in I-IoT Scenarios, Intel Corporation
7. R1-2005991 Evaluation of NR positioning in IIOT scenario, OPPO
8. R1-2006067 Evaluation of achievable positioning accuracy and latency, BUPT
9. R1-2006149 Evaluation of achievable positioning accuracy and latency, Samsung
10. R1-2006197 Evaluation of DL-TDOA and DL-AoD techniques under IIOT scenarios, MediaTek Inc.
11. R1-2006215 Discussion on achievable positioning latency, CMCC
12. R1-2006239 Discussion on evaluation of latency, InterDigital, Inc.
13. R1-2006323 Considerations for Positioning Latency Evaluation, Lenovo, Motorola Mobility
14. R1-2006375 Discussion on evaluation of achievable positioning accuracy and latency for NR positioning, LG Electronics
15. R1-2006428 Initial results on evaluation of achievable positioning accuracy and latency, Nokia, Nokia Shanghai Bell
16. R1-2006459 Evaluation of positioning enhancements, Fraunhofer IIS, Fraunhofer HHI
17. R1-2006623 Positioning evaluation results for additional commercial use cases, CEWiT
18. R1-2006809 Evaluation of achievable Positioning Accuracy & Latency, Qualcomm Incorporated
19. R1-2006915 Evaluation of achievable positioning accuracy and latency, Ericsson