**3GPP TSG RAN WG1 Meeting #104-e** [**R1-2101764**](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101764.doc)

**e-meeting, January 25th – February 5th, 2021**

**Source: Moderator (CATT)**

**Title: FL Summary for accuracy improvements by mitigating UE Rx/Tx and/or gNB Rx/Tx timing delays**

**Agenda item: 8.5.1**

**Document for: Discussion and Decision**

# Introduction

This document provides a summary of the following email discussion for AI 8.5.1:

[104-e-NR-ePos-01] Email discussion/approval on accuracy improvements by mitigating UE Rx/Tx and/or gNB Rx/Tx timing delays with checkpoints for agreements on Jan-28, Feb-02, Feb-05 – Ren Da (CATT)

One of the RAN1 objectives of this work item is to:

* Specify **methods**, **measurements**, **signalling, and procedures** for improving positioning accuracy of the Rel-16 NR positioning methods by mitigating UE Rx/Tx and/or gNB Rx/Tx timing delays, including [RAN1]
	+ DL, UL and DL+UL positioning methods
	+ UE-based and UE-assisted positioning solutions

The document covers the following aspects related to potential enhancements related to the accuracy improvements by mitigating UE Rx/Tx and/or gNB Rx/Tx timing delays based on the contributions [1-19]:

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| 2 Methods of mitigating UE/gNB Rx/Tx timing delays3 Mitigation of Rx/TX timing delays3.1 Rx/Tx timing error groups3.2 Mitigating gNB Tx timing errors (for RSTD and DL positioning)3.3 Mitigating gNB Rx timing errors for UL RTOA3.4 Mitigating UE Tx timing errors for UL RTOA3.5 Mitigating UE Rx timing errors for RSTD3.6 Mitigating Tx/Rx timing errors for multi-RTT positioning3.7 Feasibility/Capability of the calibration of UE/gNB Tx/Rx timing errors4 Additional proposals4.1 Measurement Enhancements4.2 Antenna array phase center offset4.3 Spatial relation of SRS with DL PRS or SSB4.4 Beam and delay group sweeping |

**Notes:**

* The following highlights will be used in this summary:
	+ “Pink highlights” are used for proposals with high priority
	+ “Yellow highlights” are used for proposals with medium priority
	+ “Turquoise highlights” are used for offline consensus/conclusion
	+ “Grey highlights” are used for proposals resolved in this meeting.

Note: The above priority highlights are used mainly as a suggestion of the priority for *online* discussion. The priority indications may be changed based on the received comments. During the email discussion, interested companies are encouraged to provide comments to all proposals regardless of the priority indications.

* When providing the comments, it would be helpful to indicate explicitly whether to“*support*”, or “*not support*”, or provide a suggestion of modification. A comment of “*high/medium/low priority*” is only interpreted as a suggestion for the priority for email/online discussions. For a proposal with multiple options, it would be helpful to indicate which of the option(s) are “*supported*” and/or “*preferred*”.
* For a proposed enhancement, if we cannot reach a consensus, we may conclude that “*a consensus cannot be reached for the proposed enhancement*” for this email discussion in this meeting. It does not necessarily mean the proposed enhancement will not be further discussed in future meetings.

# Methods of mitigating UE/gNB Rx/Tx timing delays

Submitted Proposals (related to the methods of mitigating UE/gNB Rx/Tx timing delays)

* (Huawei [R1-2100195](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100195.doc)) Proposal 1:
	+ Introduce a calibration UE with the known location to mitigate the gNB timing error.
* (ZTE [R1-2100293](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100293.doc)) Proposal 2:
	+ In order to mitigate the Tx/Rx timing delay for DL-TDOA/UL-TDOA positioning method, considering the following enhancements in Rel-17
		- The TRP should have capability to do mutual-calibration and feed back the Tx timing delay difference and Rx timing delay difference.
		- For UE based positioning, network should provide TRP-side Tx timing delay difference in assistance data.
		- Provide by network or report by UE to indicate whether UE uses the same RF chain to transmit or receive signals from different TRPs.
* (CAICT [R1-2100308](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100308.doc))Proposal 1:
	+ Differential positioning technique could be considered to compensate synchronization error and Rx/Tx transmission delays.
* (CATT [R1-2100385](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100385.doc)) Proposal 4:
	+ NR Rel-17 should support the methods of mitigating UE Rx/Tx and/or gNB Rx/Tx timing delays based on a double differential scheme with a reference UE.
* (vivo [R1-2100445](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100445.doc))Proposal 1
	+ ‘Reference UE’ based differential positioning method should be supported to assist UE and gNB Rx/Tx timing delay mitigating.
		- ‘The reference UE’ can measure/transmit positioning signals from/to multiple TRPs and report the measurement results to the LMF as normal UEs
		- The accurate and reliable location of ‘the reference UE’ should be known by the LMF and the UE itself
* (vivo [R1-2100445](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100445.doc))Proposal 2
	+ AoA-based RX/TX timing delay mitigating method should be considered as an alternative method to ‘reference UE’ based differential positioning method.
* (Nokia [R1-2100548](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100548.doc)) Proposal 2:
	+ To mitigate UE and gNB Rx/Tx timing delays a solution not relying on reference devices should be specified if possible.
* (Apple [R1-2101387](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101387.doc)) Proposal 1:
	+ In order to estimate and correct the effective timing error, support in Rel-17 timing calibration, using reference points (UE/gNB) with precise location information known to the network.
* (Intel [R1-2100657](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100657.doc)) Proposal 1:
	+ Inter-gNB (or TRP) calibration procedure to estimate TX/RX timing errors is left up to network implementation
	+ Define gNB TX/RX timing errors measurement report formats to report the data from gNB to LMF (or gNB/LMF to UE)
* (Intel [R1-2100657](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100657.doc)) Proposal 2 (General solution targeting all timing-based positioning methods):
	+ Support gNB TX/RX timing errors measurement report signaling from gNB to LMF (or gNB/LMF to UE), including the following information/measurements
		- Alt.1:
			* Measured propagation time (*ti-j*) between gNBs
			* Reference propagation time (*Tij*) between *i*th and *j*th nodes (gNBs or TRPs) derived based on known gNB coordinates
		- Alt.2:
			* Difference of the above measurements, i.e. Δ*ti-j* = *ti-j* - *Tij*
* (CMCC [R1-2101046](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101046.doc)) Proposal 1:
	+ For TDOA-based positioning, a unified framework to estimate Tx/Rx timing errors and NW synchronization error can be defined.
* (CMCC [R1-2101046](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101046.doc)) Proposal 2:
	+ Support the measurement and reporting among the TRPs to estimate the timing errors.
* (CMCC [R1-2101046](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101046.doc)) Proposal 3:
	+ Support the enhancement of jointly using timing-based and angle-based method to improve the accuracy in the presence of Rx/Tx transmission delays.
* (MediaTek [R1-2101140](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101140.doc)) Proposal 2-1:
	+ The mitigation of RX/TX timing delays could be achieved by 1), conduct the calibration to derive the analog domain delay 2), adopt the positioning methods using differential measurements.
* (MediaTek [R1-2101140](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101140.doc)) Proposal 2-3:
	+ Consider the combination of measurements for DL-TDOA and UL-TDOA, which is able to handle the synchronization error and to reduce the impact of timing delays
* (Qualcomm [R1-2101468](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101468.doc)) Proposal 2:
	+ Support mechanisms and signaling to enable PRS reception by TRPs and associated reporting of gNB measurements derived on PRS reception and/or PRS transmission timing.
		- FFS: Signaling details and procedures

Submitted Proposals related to joint measurements for mitigating UE/gNB Rx/Tx timing errors

* (OPPO [R1-2100128](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100128.doc)) Proposal 3:
	+ For DL TDOA positioning, Rel-17 can support the joint measurement of timing based and angle based positioning per DL PRS resource.
* (OPPO [R1-2100128](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100128.doc)) Proposal 4:
	+ For UE-assisted DL TDOA positioning, Rel-17 can support the joint report of timing based and angle based positioning per DL PRS resource.
* (OPPO [R1-2100128](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100128.doc)) Proposal 6:
	+ For NR UL RTOA based positioning, Rel-17 can support the joint measurement and report of UL timing based and UL angle based positioning for the SRS resources for positioning.
* (OPPO [R1-2100128](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100128.doc)) Proposal 8:
	+ For multi-RTT positioning, Rel-17 can support the joint measurement and report of multi-RTT based positioning and UL angle based positioning on the SRS resources for positioning.
* (CMCC [R1-2101046](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101046.doc)) Proposal 3:
	+ Support the enhancement of jointly using timing-based and angle-based method to improve the accuracy in the presence of Rx/Tx transmission delays.
* (vivo [R1-2100445](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100445.doc))Proposal 2
	+ AoA-based RX/TX timing delay mitigating method should be considered as an alternative method to ‘reference UE’ based differential positioning method.
* (MediaTek [R1-2101140](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101140.doc)) Proposal 2-3:
	+ Consider the combination of measurements for DL-TDOA and UL-TDOA, which is able to handle the synchronization error and to reduce the impact of timing delays
* (Qualcomm [R1-2101468](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101468.doc)) Proposal 3:
	+ Support enhancements in the reporting of the positioning measurements (from the UE and the gNB) to enable reporting in a single report multiple measurements:
		- Enable multiple measurement reporting in a single report with timestamps derived on the same TRP & PRS resources

FL comments

From the above-submitted proposals, different methods were proposed for the estimation/calibration/elimination of the UE/gNB Rx/Tx timing delays, which may be grouped into the following categories:

**Method 1:** UE/gNB TX/RX timing errors are estimated/calibrated by the use of the existing timing measurements (e.g., RSTD, RTOA, UE/gNB Rx-Tx time differences) (e.g., [1][2]),

**Method 2:** UE/gNB TX/RX timing errors are estimated/calibrated with the combination of the existing timing and angle measurements (e.g., RSTD, UE Rx-Tx time difference, AOA/AOD) (e.g., [1] [2][12])

**Method 3:** /gNB TX/RX timing errors are estimated/calibrated based on the DL PRS measurements provided by TRPs (e.g., [3][8][12][17])

**Method 4:** /gNB TX/RX timing errors are estimated/calibrated based on the DL PRS measurements provided by UEs at known locations (e.g., reference/calibration UEs) with differential techniques (e.g., [2][4][5][6][14][16])

For methods 1 and 2, enhancements of measurement reporting (e.g., both the timing and angle measurements) may be needed for both UE and gNB. For example, a UE/TRP needs to provide both timing and angle measurements, which are obtained from the same DL PRS resources and/or UL SRS resources, in a single measurement report (e.g., [1][6][14][17])

For methods 3, it may require the enhancement for a TRP to measure the DL PRS transmitted from the neighboring TRPs and reports the measurements or report the calibration results to the LMF;

For methods 4, it may require the enhancement to configure or trigger the reference UEs to measure and report the measurements to LMF;

In addition, there are suggestions of consulting with RAN4 on the feasibility/capability of the estimation/calibration/compensation of Rx/Tx timing delays.

**Note:** It seems that the terms “mitigation, estimation, compensation, calibration, elimination, etc.” are used in the contribution for the mitigation for UE/gNB Rx/Tx timing delays. To avoid confusion, it might be better for us to use the same terminology in our discussion, e.g.,

* “Estimation of Rx/Tx timing delays”: It means the estimation of the values of the UE/gNB Rx/Tx timing delays for supporting the mitigation of Rx/Tx timing delays;
* “Calibration/Compensation of Rx/Tx timing delays”: It means the use of the estimated/known Rx/Tx timing delay values to remove the impact of the UE/gNB Rx/Tx timing delays;
* “Cancellation of Rx/Tx timing delays”: It means the cancellation of the impact of the UE/gNB Rx/Tx timing delays on the measurements or position solutions without the necessity of estimating the values of Rx/Tx timing delays.
* “Mitigation of Rx/Tx timing delays”: It is a general term, which means the mitigation of the impact of Rx/Tx timing delays on the timing measurements and position solution with any of potential approaches.

Comments on above suggestion

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| **Company** | **Comments**  |
| Huawei/HiSilicon | Just to clarify our understanding* “Estimation” is delay estimate per TRP/UE chain
* “Calibration/Compensation” is per TRP/UE chain based on “estimation”
* “Cancellation” is per TRP/UE chain pair
* “Mitigation” can be through either “Calibration” or “Cancelation”
 |
| FL | To HW’s comments, yes, that is basically what I am thinking. |
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### Proposal 2-1

* + UE should support reporting multiple measurements (including RSTD, RSRP, UE Rx-Tx time difference measurements) with timestamps derived on the same set of DL PRS resources to LMF in a single measurement report
	+ FFS: details of signalling and procedures

Comments

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| **Company** | **Comments**  |
| MTK | 1, the wording of the proposals maybe confusing. It reads like we want to include RSTD RSTP UE RX-TX time difference measurements together in a single report. We think the intention should be for **each** measurement **method**, the conducted measurement**s** within a period of time can be reported with the corresponding time-stamp for each measurement2, if there is NO average among measurements on multiple occasions (one measurement on one occasion), then for each measurement in a single occasion, as it is tagged with the corresponding time-stamp, or the differential time-stamp from previous time-stamp (the first measurement gives absolute time-stamp and second measurement gives relative time-stamp from the first one), is okay for us |
| vivo | Not support. We don't understand the purpose of Propsal2-1 here, since the Rel-16 spec already supports UE reporting RSRP along with RSTD or Rx-Tx measurement. If the proposal is for reporting { RSTD, RSRP, UE Rx-Tx }together, we don’t think it can mitigate the Rx/Tx timing error. |
| Huawei/HiSilicon | Support, but the wording “UE should support” is not typically used in the WI.In our understanding, the proposal is to allow UE to report measurements in multiple measurement occasions in the single report.Perhaps the Proposal can be reformulated as* + Support a UE to report multiple measurements of the same type (including RSTD, RSRP, UE Rx-Tx time difference measurements) with timestamps derived on different periodic occasions for the same set of DL PRS resources to LMF in a single measurement report
	+ FFS: details of signalling and procedures
 |
| CMCC | This proposal seems ambiguous to us. To our understanding, the mitigation method and the associated measurement reporting should be positioning method specific, generally proposing that multiple measurements should be reported is quite unclear to us how would it work. |
| CATT | Support. |
| FL | For MTK and vivo’s comments, the motivation is that multiple companies have proposed to use the combination of the measurements for the estimation of the timing errors. Yes, Rel-16 already supports reporting the combination of the measurements. However, for the estimation of Rx/Tx errors, it might be desirable to use measurements measured with the same set of resources and at the same time (or time duration). I assume that is why some companies proposed to further enhancement of the measurement reporting. For HW’s comment, I would say the modification helps the clarify the intention of the proposal.For CMCC’s comment, I assume LMF may request the multiple measurements for supporting a positioning method for a UE. For Rel-17, I assume we may also further discuss whether LMF can request extra measurements for supporting both positioning of a UE, or also the estimation of the Tx/Rx timing errors.  |
| Qualcomm | I was also confused by this proposal initially, but the reply from HW and FL clarified.Indeed, this does not try to include in a single report different type of measurements (except those already existing in Rel-16, i.e. Timing & RSRP exists in a signle report). It tries to say that, in a single measurement report, e.g. in the RTT report, include the Rx-Tx/RSRP measurements that may be derived across multiple time-stamps. As a simple example, consider a toy example where there is just a single gNB with a single PRS resource configured, and the Measurement reporting happens every 10 PRS instances, then this proposal will enable that a UE can send 10 Rx-Tx measurements within a single reporting. We think this can be useful for several reasons: * For MRTT, it can help the LMF better “match” the reported UE Rx-Tx with the reported gNB Rx-Tx. In the current specification, the measurements may be non-aligned, resulting into making the timing errors due to different time-stamps prominent
* When the UE sends 2 reports, e.g., an RTT and a TDOA report, with this proposal, both of them will have measurements derived on the same time-stamps, enabling better combination of those,
* When a UE sends a DL-TDOA report, and a gNB sends an UL-TDOA report, both reports will have measurements derived on the same time-stamps, enabling combination at the LMF of those methods
* It can help the LMF track non-idealities related to time-drifts at the UE or the gNB side

However, what is missing is to have to do the same enhancement from the gNB side which seems to be shown in the proposal below; we think both should be treated jointly; it wouldn’t make sense to agree on the first and not the 2nd.  |
| Nokia/NSB | What is the specification impact of this proposal? Looking at the LPP sepc the IE nr-DL-PRS-RSRP-Result-r16 is already supported as part of DL-TDOA and multi-RTT (both of which also support time stamping). If this is related to multiple measurements being made within a single report then can the proponents clarify how that helps to alleviate Rx/Tx timing delays?  |
| Ericsson | The current formulation of the proposal is confusing. We suggest the following revised proposal:“Reporting multiple timestamped measurement occasions in a single measurement report from UE to LMF with all measurements being performed on the same DL PRS resources is supported in NR Rel-17”Similar to the second comment from MTK, we think there should be NO averaging among the measurements on multiple occasions here. We suggest to study signalling and procedures for controlling how the UE averages and reports over multiple PRS occasions. |
| Fraunhofer | The proposal is early at this stage, the relevance to timing delays mitigation is subject to the latter proposals which are still under discussion. |
| Apple | Clarification is needed. We understand different intentions from the proposal (at least 2): 1-multiple measurements are associated with the same PRS reception and so the same time stamp (if this is the case we are OK to further discuss). 2- A single measurement report carries multiple reports where each report is associated with its time stamp (if this is the intention we like to know the group delays can be estimated, as Nokia/NSB mentioned).  |
| China Telecom | We support the proposal with HW’s clarification. |

### Proposal 2-2

* + Support a TRP to report multiple measurements (including RTOA, AoA and gNB Rx-Tx time difference) with timestamps derived from the same set of UL SRS for positioning resources, in a single measurement report.
	+ FFS: details of signalling and procedures

Comments

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| **Company** | **Comments**  |
| MTK | Similar to the above proposal 2-1, if no average among measurements across occasions is conducted, we are okay |
| vivo | In general, we are okay with the proposal as AoA method is not affected by the Rx/Tx Transmission delays and can provide high UE location accuracy. But we wonder about the intention about “the same set of UL SRS”. |
| Huawei/HiSilicon | Support in principle. In our understanding that the current NRPPa already supports the functionality, but neither stage-2 nor stage-3 is explicit on such an implementation.We understand the intention of this proposal is the counterpart at TRP side to the UE side. |
| CMCC | Support of using the UL-AoA measurement to calibrate the impact of timing delays on the timing-based positioning methods.  |
| CATT | Support. |
| Qualcomm | Support and should be agreed together with Proposal 2-1. To Huawei: NRPPa description tends to be not very clear, and the fact that the Information Elements appear as if it is supported, it is a “gray” area, and should be formalized as we are doing for the UE’s report. |
| Nokia/NSB | Similar comments as on proposal 2-1. |
| Ericsson | We have a similar comment as in proposal 2-1. Suggest the following revision:“Reporting multiple timestamped measurements occasions in a single measurement report from gNB to LMF with all measurements being performed on the same UL SRS resources is supported in NR Rel-17 ”As proposals 2-1/2-2 are the UE/TRP counterparts, we suggest to discuss and agree them together. |
| Fraunhofer | Same as in proposal 2-1 |
| Apple | Similar comments to Proposal 2-1 |
| China Telecom | Support. |

### Proposal 2-3

* Support the following mechanisms and signaling for the estimation of the gNB Rx/Tx timing delays
	+ enabling a TRP to measure DL PRS transmitted from other TRPs
	+ enabling a TRP to report DL PRS measurements to LMF
	+ FFS: the details of signaling, measurements, and procedures

Comments

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| **Company** | **Comments**  |
| MTK | 1, we want to understand whether gNB can measure its own round trip timing delays (DAC to antenna and back to ADC). At UE side, we think it could be feasible. If each TRP can measure its own round trip timing delays, for example, sending a signal from baseband and measure the phase difference when received in baseband. Then there is no need to use this method2, we can further check with RAN4 on the feasibility of round trip timing delays. We think the one side delay is very challenging, but the round trip delay measurement gets more chance to achieve for both gNB and UE side3, That using another TRP to measure signals from other TRPs is to assume that the TRP locations are known. We wonder how precisely the locations can be determined? |
| vivo | Not support. We have some concerns as follows: Since current TRP/gNB is not allowed to measure PRS, once inter-TRP Rx/Tx timing delay is applied, all the gNBs/TRPs in a certain scenario are required to measure PRS, and transfer the measurement results. The impact on the spec is large.Besides, since the panel of one TRP has a certain downward tilt angle which is assumed to be basically fixed, we are not sure whether an effective air interface connection can be established between the TRPs, especially the air interface connection of LOS. In addition, if there are fixed obstructions among the TRPs which need to be calibrated, so that sufficient LOS connections cannot be ensured between these TRPs, and furthermore the Rx/Tx timing delay of these TRPs cannot be calibrated. Due to the fixed location of the TRPs and obstructions, these TRPs cannot always be calibrated. . |
| Huawei/HiSilicon | We have some technical concerns on the procedure.First, it should be common understanding that PRSs from different TRPs on the same layer are transmitted simultaneously, and this approach, however, seems to put some gNBs on listening mode on the time when PRS is supposed to transmit.Second, this will increase hardware of the gNB for FDD bands, as gNB is not required to implement Rx chains on DL carriers.Third, the PRS targeting coverage is optimized for the UE, e.g. via downtilt considering UE should be below gNB, but to allow gNB to properly hear the PRS will somehow require additional optimization for PRS transmission direction. |
| CMCC | Support.As per HW’s concern, for the first understanding, we believe it is the case for the R16 periodic DL PRS; however, considering that in the SI phase, companies reached a consensus to specify the on-demand DL PRS, we think that their transmission occasions of different TRP would be different. One possible solution can be configuring the on-demand DL PRS in Flex resources among TRPs, the measurement then can be performed. Regarding the antenna down tilting of the TRP, we also think it may be a shortcoming of this solution; however, since the channel between TRPs are more likely to be LOS and quite ideal, the estimation and calibration performance would be ensured. |
| CATT | Support. |
| Qualcomm | I think Proposal 2-3 and 2-4 should be combined within an umbrella of a “reference device/node/entity” and leave it at that level at this meeting. It is the first meeting of the WI, and it seems that both proposals are trying to enable “calibration of the errors”. In Proposal 2-3 the assumption is that the gNB have known location (which is indeed true), and in Proposal 2-4, we just call it “UE with known location”. Note also that there are similar discussions in the other subagends. I think it is a great opportunity to acknowledge that procedures related to calibration is needed across all methods and not limit to “timing errors” in the subagenda, and “AoD“ in the 2nd and “AoA” in the 3rd. Suggest to combine 2-3 and 2-4 as follows:***Specify procedural and signaling enhancements to enable devices with known location to support the following functionalities:**** ***measure DL PRS and report associated measurements (e.g., RSTD, Rx-Tx time difference, RSRP) to the LMF;***
* ***transmit SRS and enable TRPs to measure and report measurements (e.g., RTOA, Rx-Tx time difference, AOA) associated with the reference device to the LMF;***
* ***FFS: the details of the signaling, the measurements, the parameters related to the Rx and Tx timing delays,***
* ***FFS: Device with the known location being a UE and/or a gNB***

To Huawei: The feature may eventually call it a UE, which can be “attached to the gNB” similar to IAB approach.  |
| Ericsson | We do not support this proposal. We share similar concerns with vivo and Huawei. In addition, we think this proposal is essentially trying to specify mechanisms for performing radio sync over the air. Network sync errors were discussed in the SI phase but are not within the scope of this work item. Recall from the SI phase that this can be done proprietarily with no need for specification impact. |
| Apple | We share similar views with vivo on specification impact, but if majority thinks it’s ok to have a reference entity, then going with QC’s proposal is preferred (to combine 2-3 and 2-4) |

### Proposal 2-4

* Support the following mechanisms for the estimation and/or elimination of the gNB Rx/Tx timing delays:
	+ Enable a UE with a known location to measure DL PRS and report the measurements (e.g., RSTD, UE Rx-Tx time difference, RSRP) to LMF;
	+ Enable a UE with a known location to transmit SRS for positioning and enable the neighboring TRPs to measure and report the measurements (e.g., RTOA, gNB Rx-Tx time difference, AOA) associated with the UE to LMF;
	+ FFS: the details of the signaling, the measurements, and the parameters related to the gNB Rx and Tx timing delays

Comments

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| **Company** | **Comments**  |
| MTK | 1, we should first clarify whether each TRP can measure its own round trip timing delays2, again, UE with a known location, how precisely the location can be determined? |
| vivo | Support. From our contribution, it can be observed that ‘reference UE’ based method can be used in differential method to assist calibration of the TRP Rx/Tx timing delay and provide high accuracy. For scenarios where few TRPs are deployed or LOS links are sufficient such as indoor factory scenarios, fewer ‘reference UEs’ can guarantee the accuracy of the estimation and bring less overhead. For scenarios where many TRPs are deployed or LOS links are insufficient such as UMa scenario, more ‘reference UEs’ may be needed, however, to a certain extent, the large overhead can be solved according to the mobility of the UE.For the accuracy of reference UE location from MTK, the location of reference UE is precise, it can use the same way as TRP to obtain its location especially in InF scenario. |
| Huawei/HiSilicon | Support. We think that setting the reference device to a “UE” would maximize reuse of the existing framework. |
| CMCC | We are basically fine with the proposal. In our views, enabling a reference UE with known location in the deployment, which is an RTK-like method, is feasible to assist the estimation and mitigation of the gNB Rx/Tx timing delay. One potential issue is that the propagation environment around the reference UE may have great impact on the estimation and calibration performance (e.g., enough LOS links are required), therefore the location of the reference UE should be carefully designed. |
| CATT | Support. |
| Qualcomm | I think Proposal 2-3 and 2-4 should be combined within an umbrella of a “reference device/node/entity” and leave it at that level at this meeting. It is the first meeting of the WI, and it seems that both proposals are trying to enable “calibration of the errors”. In Proposal 2-3 the assumption is that the gNB have known location (which is indeed true), and in Proposal 2-4, we just call it “UE with known location”. Note also that there are similar discussions in the other subagends. I think it is a great opportunity to acknowledge that procedures related to calibration is needed across all methods and not limit to “timing errors” in the subagenda, and “AoD“ in the 2nd and “AoA” in the 3rd. Suggest to combine 2-3 and 2-4 as follows:***Specify procedural and signaling enhancements to enable devices with known location to support the following functionalities:**** ***measure DL PRS and report associated measurements (e.g., RSTD, Rx-Tx time difference, RSRP) to the LMF;***
* ***transmit SRS and enable TRPs to measure and report measurements (e.g., RTOA, Rx-Tx time difference, AOA) associated with the reference device to the LMF;***
* ***FFS: the details of the signaling, the measurements, the parameters related to the Rx and Tx timing delays,***
* ***FFS: Device with the known location being a UE and/or a gNB***

To Huawei: The feature may eventually call it a UE, which can be “attached to the gNB” similar to IAB approach.  |
| Nokia/NSB | We may be okay in principle but we should discuss this as part of the reference UE discussion happening in other AIs as well.  |
| Ericsson | We wonder what is the specification impact for this (particularly the last FFS). In our understanding, a reference UE can use the current standards, and we don’t see need for further specification changes.  |
| Fraunhofer | Support. Agree with Nokia. |
| Apple | Support |
| China Telecom | Support. And we can think it may be necessary to discuss in what condition a UE can be chosen as the ‘UE with a know location’. |
|  |  |

# Mitigation of Rx/TX timing delays

Submitted Proposals (general proposals for mitigating Rx/TX timing delays)

* (Huawei [R1-2100195](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100195.doc)) Proposal 2:
	+ Support UE to report of the panel information for DL reception and UL transmission to LMF, and leave the network assisted/controlled panel selection up to Rel-17 MIMO WI.
* (Huawei [R1-2100195](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100195.doc)) Proposal 3:
	+ Given the existing positioning calculation assistance data framework, resource-specific RTD and RTD drift rate should be low priority.
* (ZTE [R1-2100293](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100293.doc)) Proposal 2:
	+ In order to mitigate the Tx/Rx timing delay for DL-TDOA/UL-TDOA positioning method, considering the following enhancements in Rel-17
		- The TRP should have capability to do mutual-calibration and feed back the Tx timing delay difference and Rx timing delay difference.
		- For UE based positioning, network should provide TRP-side Tx timing delay difference in assistance data.
		- Provide by network or report by UE to indicate whether UE uses the same RF chain to transmit or receive signals from different TRPs.
* (CATT [R1-2100385](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100385.doc)) Proposal 1:
	+ For UE-based DL-TDOA positioning, one of the following methods can be used to help UE eliminate the influence of Tx timing delay and synchronization error of TRPs:
		- Method1: Provide UE the information of Tx timing delays of RF chains of the TRPs for transmitting DL-PRS, or the difference of the Tx timing delays of RF chains between TRPs. The time offset between TRP clocks needs also to be provided if the TRP clocks are not perfectly synchronized.
		- Method2: Provide UE the information of the time synchronization error at the Tx antennas between the TRPs.
* (CATT [R1-2100385](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100385.doc)) Proposal 2:
	+ For UE-assisted DL-TDOA positioning, one of the following methods can be used to help LMF eliminate the influence of timing delay and synchronization error of TRPs:
		- Method1: Provide LMF the information of Tx timing delays of RF chains of the TRPs for transmitting DL-PRS, or the difference of the Tx timing delays of RF chains between TRPs. The time offset between TRP clocks needs also to be provided if the TRP clocks are not perfectly synchronized.
		- Method2: Provide LMF the information of the time synchronization error at the Tx antennas between the TRPs.
* (CATT [R1-2100385](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100385.doc)) Proposal 3:
	+ For the UL-TDOA positioning, the following method can be used to help LMF eliminate the influence of UE timing delay error:
		- Provide LMF the Tx timing delays of RF chains of the UE for transmitting SRS-Pos, or the difference of the Tx timing delays of RF chains between UE Tx RF chain with index=m and index=n.
* (vivo [R1-2100445](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100445.doc)) Proposal 3:
	+ To avoid Rx/Tx timing delay from affecting angle estimation for DL-AoD and UL-AoA method, support to limit to only one TXRU (or panel) used by the gNB for positioning.
* (vivo [R1-2100445](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100445.doc))Proposal 2
	+ AoA-based RX/TX timing delay mitigating method should be considered as an alternative method to ‘reference UE’ based differential positioning method.
* (CAICT [R1-2100308](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100308.doc))Proposal 2:
	+ Tx group delay needs to be sent to the receiver side.
* (Fraunhofer [R1-2101131](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101131.doc)) Proposal 1:
	+ Enable Rx/Tx timing delays reporting dependent on the applied transmission/reception spatial filter.
* (Fraunhofer [R1-2101131](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101131.doc)) Proposal 2:
	+ Enable reporting of TRD information from both UE and TRP, which includes at least:
		- TRP reports to the LMF Tx timing delay information on the beams used to transmit DL-PRS
		- UE reports to the LMF Tx timing delay information on the beams used to transmit SRS for positioning
		- LMF reports to the UE Tx timing delay information on the beams used to transmit DL-PRS in UE-based mode
* (MediaTek [R1-2101140](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101140.doc)) Proposal 2-2:
	+ The on-demand UE specific calibration gap for the on-the-fly calibration could be considered
* (InterDigital [R1-2100752](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100752.doc)) Proposal 1:
	+ - Support distribution of correction information from the LMF to assist the UE to remove timing offsets from measurements
* (InterDigital [R1-2100752](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100752.doc)) Proposal 2:
	+ - Support periodic, semi-persistent and on-demand based distribution of timing offset information from the network to the UE.
* (InterDigital [R1-2100752](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100752.doc)) Proposal 3:
	+ - For on-demand based distribution of correction information, distribution of timing offset is followed by additional measurement reporting from the UE
* (Samsung [R1-2101210](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101210.doc)) Proposal 1:
	+ For UE Rx/Tx timing error mitigation, UE can report the capability for the Rx/Tx timing error estimation and correction. For UEs without the capability of Rx/Tx timing error correction, they can report the antenna panel index associated with PRS reception and SRS transmission to LMF.
* (Qualcomm [R1-2101468](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101468.doc)) Proposal 1:
	+ Support UE and gNB reporting enhancements for the purpose of providing information, to the entity performing the positioning calculation, related to which measurements can be assumed to have a same Tx, or Rx, or Rx-Tx timing error.
		- Applicable to both UE-assisted and UE-based methods
		- FFS: Further signaling details, capabilities, procedures.
* (Qualcomm [R1-2101468](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101468.doc)) Proposal 4:
	+ Include transmit time difference information for each DL-PRS Resource of a TRP with respect to a reference in the position calculation assistance data
		- FFS: Details on the transmit time difference signaling
* (Ericsson [R1-2101754](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101754.doc))Proposal 1:
	+ Specify signaling from the UE to the network of which ‘delay group’ is associated with each SRS-transmission from the UE.
* (Ericsson [R1-2101754](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101754.doc))Proposal 4
	+ Include indication of delay group used for the DL PRS reception and the corresponding TOA measurement both for the reference TRP and for the target TRP in the DL RSTD measurement report.
* (Ericsson [R1-2101754](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101754.doc))Proposal 5
	+ Specify multi delay group RSTD measurements and the corresponding configuration and measurement reporting signalling.

Submitted Proposals (more specific for DL positioning)

* (OPPO [R1-2100128](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100128.doc)) Proposal 1:
	+ For DL TDOA positioning, Rel-17 can support the transfer of Tx timing delays of TRPs from NR-RAN node to LMF via NRPPa.
* (OPPO [R1-2100128](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100128.doc)) Proposal 2:
	+ For UE-based DL-TDOA method, Rel-17 can support the signaling of the Tx timing delays of corresponding TRPs from LMF to UE via LPP.
* (CATT [R1-2100385](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100385.doc)) Proposal 1:
	+ For UE-based DL-TDOA positioning, one of the following methods can be used to help UE eliminate the influence of Tx timing delay and synchronization error of TRPs:
		- Method1: Provide UE the information of Tx timing delays of RF chains of the TRPs for transmitting DL-PRS, or the difference of the Tx timing delays of RF chains between TRPs. The time offset between TRP clocks needs also to be provided if the TRP clocks are not perfectly synchronized.
		- Method2: Provide UE the information of the time synchronization error at the Tx antennas between the TRPs.
* (CATT [R1-2100385](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100385.doc)) Proposal 2:
	+ For UE-assisted DL-TDOA positioning, one of the following methods can be used to help LMF eliminate the influence of timing delay and synchronization error of TRPs:
		- Method1: Provide LMF the information of Tx timing delays of RF chains of the TRPs for transmitting DL-PRS, or the difference of the Tx timing delays of RF chains between TRPs. The time offset between TRP clocks needs also to be provided if the TRP clocks are not perfectly synchronized.
		- Method2: Provide LMF the information of the time synchronization error at the Tx antennas between the TRPs.
* (Intel [R1-2100657](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100657.doc)) Proposal 3 (Targeting DL-TDOA):
	+ Support gNB TX timing errors measurement report signaling from gNB to LMF (or gNB/LMF to UE), including the estimated timing error difference (Δ*eTX*,*ij*) between the TX timing error for the *i*th (*eTX*,*i*) and *j*th (*eTX*,*j*) nodes (gNBs or TRPs):
		- Δ*eTX*,*ij* = *eTX*,*i* - *eTX*,*j* (i.e. inter gNB Tx-Tx timing error difference)
* (CMCC [R1-2101046](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101046.doc)) Proposal 1:
	+ For TDOA-based positioning, a unified framework to estimate Tx/Rx timing errors and NW synchronization error can be defined.
* (MediaTek [R1-2101140](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101140.doc)) Proposal 2-4:
	+ For DL-RSTD measurements for DL-TDOA technique, gNB may report the calibrated TX timing delays to the location server, together with the time stamp of making calibration. The location server may further provide the reported TX timing delays of gNBs to UE for UE based mode
* (Ericsson [R1-2101754](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101754.doc))Proposal 6
	+ RAN1 should study further under what circumstances the UE should be capable to perform multi delay group RSTD measurements, e.g. if multi delay group RSTD measurements can be performed using 1) different symbols of the same DL PRS, 2) different repetitions of the same DL PRS, 3) different occasions of the same DL PRS, 4) different DL PRSs transmitted from the same TRP, and/or 5) simultaneous reception of the same DL PRS.

Submitted Proposals (more specific for related UL positioning)

* (OPPO [R1-2100128](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100128.doc)) Proposal 5:
	+ For NR UL RTOA based positioning, Rel-17 can support the transfer of Rx timing delays of TRPs from NR-RAN node to LMF via NRPPa.
* (CATT [R1-2100385](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100385.doc)) Proposal 3:
	+ For the UL-TDOA positioning, the following method can be used to help LMF eliminate the influence of UE timing delay error:
		- Provide LMF the Tx timing delays of RF chains of the UE for transmitting SRS-Pos, or the difference of the Tx timing delays of RF chains between UE Tx RF chain with index=m and index=n.
* (Intel [R1-2100657](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100657.doc)) Proposal 4 (Targeting UL-TDOA):
	+ Support gNB RX timing errors measurement report signaling from gNB to LMF (or gNB/LMF to UE), comprising the estimated timing error difference (Δ*eRX*,*ij*) between the RX timing error for the *i*th (*eRX*,*i*) and *j*th (*eRX*,*j*) nodes (gNBs or TRPs):
		- Δ*eRX*,*ij* = *eRX*,*i* – *eRX*,*j* (i.e. inter gNB Rx-Rx timing error difference)
* (MediaTek [R1-2101140](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101140.doc)) Proposal 2-5:
	+ For UL-RTOA measurements for UL-TDOA technique, gNB may autonomously correct the calibrated RX timing delays before reporting the measurements to the location server. The timing delay reporting may not be needed

Submitted Proposals (more specific for Multi-RTT)

* (OPPO [R1-2100128](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100128.doc)) Proposal 7:
	+ To reduce the impact of Tx/Rx timing delay on multi-RTT positioning method:
		- The UE may compensate the value of $τ\_{TX}^{UE}+τ\_{RX}^{UE}$ in reported Rx/Tx time difference by implementation
		- The TRP may compensate the value of $τ\_{TX}^{TRP}+τ\_{RX}^{TRP}$ in reported Rx/Tx time difference by implementation
* (Intel [R1-2100657](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100657.doc)) Proposal 5 (Targeting Multi-RTT):
	+ Support gNB TX/RX timing errors measurement report signaling from gNB to LMF (or gNB/LMF to UE), including the total estimated timing error (*ei*) for the *i*th node (gNB or TRP) as a sum of the TX timing error (*eTX*,*i*) and RX timing error (*eRX*,*i*):
		- *ei* = *eTX*,*i* + *eRX*,*i* (i.e. gNB Tx+Rx timing error sum)
* (Intel [R1-2100657](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100657.doc)) Proposal 6:
	+ Do not report the total UE TX+RX timing error and keep its estimation and compensation as implementation specific.
* (MediaTek [R1-2101140](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101140.doc)) Proposal 2-6:
	+ For UE RX-TX time difference measurements for M-RTT technique, UE may autonomously correct the RX timing delays before reporting the measurements to the location server. Meanwhile, gNB may report the calibrated TX timing delays to the location server, together with the time stamp of making calibration
* (MediaTek [R1-2101140](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101140.doc)) Proposal 2-7:
	+ For gNB RX-TX time difference measurements for M-RTT technique, gNB may autonomously correct the calibrated RX timing delays before reporting the measurements to the location server. Meanwhile UE may report the calibrated TX timing delays to the location server, together with the time stamp of making calibration
* (Ericsson [R1-2101754](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101754.doc))Proposal 7
	+ Introduce a delay group indication in the UE RX-TX time difference measurement report. Introduce also a coupling between the UE RX-TX time difference measurement and an UL SRS transmission. Let the delay group indication refer both to the TOA measurement and to the SRS transmission.
* (Ericsson [R1-2101754](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101754.doc))Proposal 8
	+ Introduce the possibility to configure the UE to perform delay group panel UE RX-TX time difference measurements, i.e. one UE RX-TX time difference measurement for each delay group and TRP.

## Rx/Tx timing error groups

FL Comments

For both UE and gNB, it is expected that a large portion of the RX/TX timing delays will be pre-calibrated for supporting the transmission and reception of the positioning reference signals. The problem we are dealing with should be the remaining RX/TX timing delays, or RX/TX timing errors, after the pre-calibration. If we further consider that the impact of the remaining *RX/TX timing delays* and the UE/gNB baseband clock offsets are not be separable, it might also be more proper to use the term “*RX/TX timing errors”* (as already used by a number of companies), instead of “*RX/TX timing delays”*. In addition, different Rx/Tx antenna panel/RF chains may have the same or different RX/TX timing delays, i.e., RX/TX timing delays are related to individual antenna panel/RF chains. Many companies have proposed to associate RX/TX timing delays with antenna panels /RF chains (e.g., [2][3][5][15][16][17][19]). To avoid directly using antenna panel ID (or RF chain ID) that are tightly associated with physical implementation, it was suggested (e.g., in [19]) to introduce a new term ‘delay group” to represent the transmissions/receptions that have similar timing delays. Thus, it is suggested to introduce the concept of Tx/Rx timing error groups in the following proposal.

### Proposal 3-1

The following definitions of Tx/Rx timing error groups are used for the purpose of discussion:

* Tx ‘timing error group’ (Tx TEG): A Tx TEG is associated with the transmission of one or more DL PRS resources, or one or more UL SRS for positioning resources, which have the same Tx timing errors. Different Tx TEGs have different Tx timing errors;
* Rx ‘timing error group’ (Rx TEG): A Rx TEG is associated with one or more DL or UL measurements, which have the same Rx timing errors. Different Rx TEGs have different Rx timing errors.
	+ Note: DL measurements included in an Rx TEG may be obtained from DL PRS resources that are in the same DL Tx TEG or different DL Tx TEGs of a TRP. Similarly, UL measurements included in an Rx TEG may be obtained from UL SRS for positioning resources that are in the same UL Tx TEG or different UL Tx TEGs of a UE.

Comments

|  |  |
| --- | --- |
| **Company** | **Comments**  |
| MTK | 1, Even in a timing error group, the timing error is still time-varying, and the error is the residual after estimation so that the error itself is a random variable 2, if the timing error is a random variable, what is the benefit to define the TEG? The rapporteur can explain more?3, we think the RX timing delay can be corrected before measurement reporting. So the RX TEG seems not needed  |
| vivo | Firstly, we would like to align the understanding of TRP. In the R17 simulation assumption, only one TXRU is supported for TRP, whether different TEG can be seen in a TRP is worth discussing.

| gNB antenna configuration | (M, N, P, Mg, Ng) = (4, 4, 2, 1, 1), dH=dV=0.5λ  | (M, N, P, Mg, Ng) = (4, 8, 2, 1, 1), dH=dV=0.5λ – Note 1One TXRU per polarization per panel is assumed |
| --- | --- | --- |

Besides, the benefits and applicable scenario of this definition need to be clarified |
| Huawei/HiSilicon | In our view, the definition here should not be interpreted as being captured as is in the spec. This name is for discussion purposes.In our understanding, we do not think Tx TEG/Rx TEG should be associated with gNB/TRP side. |
| CATT | Support. The TEG should be associated with the transmission of DL-PRS/SRS-Pos(Tx TEG), or measurements(Rx TEG), which have the same timing errors.The definition of TEG can facilitate the subsequent discussion. |
| FL | For MTK’s comments, the assumption is that there are remaining Tx/Rx errros after the manufacture calibration. The remaining Tx/Rx errros may be random, but biased, and may or many not be further calibrate and/or estimated for improving the positioning performance. One of the purpose of define TEG is to indicate the measurements may be impacted by different timing errors in case different antenna panels with different trains are used for measurements. For vivo, it is correct that only single TXRU is used as baseline simulation assumption. The issue here is whether in a practical implementation, UE/gNB will always use a single TXRU.For HW’s comment, yes, the definition of the term is used mainly for the purpose of discussion and potential agreement.  |
| InterDigital | Support |
| Qualcomm | Generally support. To MTK: The UE may be measuring RSTDs on PRS resources that are far away in time. The UE may know that there may be some time drift, so it may choose to say that these RSTD are part of a different RxTEG to suggest to the LMF that maybe these measurements should not be subtrached out. The UE may not know houw much is the time drift. If the UE knows, and can remove it from the report, that’s great; the UE will just say that these 2 RSTDs are in the same RxTEG. To vivo: Even within a single TXRU, there may be timing differences between the transmitted PRS resources. E.g, different beams resulting to different Transmisison Times of the PRS resources.To HW: Why it wouldn’t be associated to the gNB? gNBs have timing errors at the Tx and Rx. |
| Nokia/NSB | Is it the correct understanding that Tx and Rx TEG include synchronization offset errors? If yes then we view that as opening the scope of the WID and should inform plenary of this somehow. In addition, we think that phase center offset errors would also fall into these TEGs as we discuss in our contribution and later comments.  |
| Ericsson | We are ok in principle. But it is better to separate the UE and TRP TEGs. Plus, the last Note is not needed as it is obvious. We should also emphasize that the timing errors within a certain margin are in the same timing error group. Revised proposal:* UE Tx ‘timing error group’ (UE Tx TEG): A UE Tx TEG is associated with the transmission of one or more UL SRS for positioning resources, which have the same Tx timing errors within a certain margin.
* TRP Tx ‘timing error group’ (TRP Tx TEG): A TRP Tx TEG is associated with the transmission of one or more DL PRS resources, which have the same Tx timing errors within a certain margin.
* UE Rx ‘timing error group’ (UE Rx TEG): A UE Rx TEG is associated with one or more DL measurements, which have the same Rx timing errors within a certain margin. Different Rx TEGs have different Rx timing errors.
* TRP Rx ‘timing error group’ (TRP Rx TEG): A TRP Rx TEG is associated with one or more UL measurements, which have the same Rx timing errors within a margin.
 |
| Fraunhofer | Needs clarification. What does the “same Tx/Rx timing error” refer to? Is it the antenna connector or the antenna phase center. |
| Apple | The definition still needs clarification: 1) is the error the effective error including delay and sync errro or it is only delay error? 2) if it is after calibration then how the error is determined (before we go to the grouping solution), if it is before calibration/compensation/cancellation then in theory UE Rx group and TRP Tx group delays are canceled (respectively for RTOA and RSTD…) I just mean there are details that seems not fully covered by the proposal  |
| Huawei/HiSilicon | To QC: In our understanding, for a single TRP, there should be typically a single Tx “TEG” and a single “Rx TEG”, otherwise, they can be separated from TRP level, and perhaps also in addition from frequency layer level within a TRP. For the latter, LMF may maintain the TEG error difference across frequency layers through the reference device, and for UE-based positioning, different RTD values can be provided to the UE on difference positioning frequency layers from the single TRP.For UE, due to the coverage, multiple chains associated with more than one “TEG” is highly likely even for FR1. |
| China Telecom | We generally support the proposal. But in what condition we can call it the ‘same Tx/Rx timing error’ may need clarification. |

## Mitigating gNB Tx timing errors (for RSTD and DL positioning)

FL comments

DL measurement accuracy (e.g., RSTD) may be impacted by TRP Tx timing errors. When a UE measures the DL PRS and reports the DL PRS measurements, the UE may not have the information of the TRP Tx timing errors, and thus may not be able to mitigate the gNB Tx timing errors when reporting the DL PRS measurements. Multiple companies (e.g., [1][3][4][5][8][11][13][14][17]) propose to support TRP provide the TRP Tx timing errors to LMF and UE (UE-based positioning) to mitigate the gNB Tx timing errors. gNB Tx timing errors may be different for different antennal panels/RF trains. Thus, there can be multiple gNB Tx timing error groups for a TRP, and each TEG may be associated with one or more DL PRS resources. As an alternative, another proposal is for LMF to provide the differences of the gNB Tx timing errors of TEGs and/or TRPs to UEs.

### Proposal 3-2a

* Support a TRP to provide the association information of Tx TEGs with DL PRS resources to LMF.
* Support a TRP to provide Tx timing errors per Tx TEG to LMF.
	+ FFS: Support a TRP to provide the difference of Tx timing errors between a TEG and a reference TEG to LMF
* FFS: details of signalling and procedures

Comments

|  |  |
| --- | --- |
| **Company** | **Comments**  |
| MTK | 1, “Support a TRP to provide Tx timing errors per Tx TEG to LMF” 🡨 Can the rapporteur explain the “timing error” here is the statistics of the error? Or actually the timing delay? |
| vivo | Same views as proposal 3-1. Whether different TEG can be seen in a TRP needs to be discussed first.Because in our understanding, at least in positioning, one TRP will not deploy more than one antenna panel. Therefore, there will not be multiple groups of ‘Rx/Tx timing delay’ in R17 scope. |
| Huawei/HiSilicon | We do not think the TEG concept has any relevance to the gNB.For TRP to provide association information, we think the baseline should be OK that all the DL PRS resource sets of a TRP (on a single positioning frequency layer or across multiple positioning frequency layers) should be corresponding to the same “TEG”, which is reflected by the SFN initialization time.For TRP to provide Tx timing errors per Tx TEG, we also do not think it is needed, as if the error is already known or estimated by the TRP, TRPs can do compensation on its own, ensuring the existing SFN initialization time is valid. |
| CMCC | We are fine with the first bullet. For the 2nd bullet, in our views, whether to support TRPs to provide Tx timing errors per Tx TEG or not depends on which method is used to mitigate the timing delays. As proposed by proposal 2-3/4, if TRP/reference UE is enabled, then the impact of gNB Tx timing delay difference can be estimated and compensated by the LMF, and therefore no need for the TRP to report its Tx timing error to the LMF. We should decide which mitigation methods will be supported and specified first, and then further discuss detailed information to be provided and exchanged. |
| CATT | Support. |
| FL | For MTK’s comments, the assumption is that there are remaining Tx/Rx errros after the manufacture calibration. The remaining Tx/Rx errros may be random, but biased, and may or many not be further calibrate and/or estimated for improving the positioning performance. One of the purpose of define TEG is to indicate the measurements may be impacted by different timing errors in case different antenna panels with different trains are used for measurements. For vivo, it is correct that only single TXRU is used as baseline simulation assumption. The issue here is whether in a practical implementation, UE/gNB will always use a single TXRU.For HW’s comment, yes, the definition of the term is used mainly for the purpose of discussion and potential agreement.  |
| Qualcomm | From the beginning of the SI, we added timing errors in both UEs and gNBs. I don’t understand why we now say that the gNBs can ensure that all PRS resources have the same exact timing? Each PRS resource may have its own geographic location (as already supported in the spec), and therefore they can have their own timing, if indeed the PRS resources are not collocated. Allowing PRS resources to not be collocated is already in the specification. Assistance data and configuration have in NR Rel-16 a single timing, which is clearly a simplification that was done in NR rel-16. Focusing only on UE errors will not make this discussion to be a “fair” and “constructive” approach of addressing the timing errors and will not be following the intention of the writing of the WID. Discussion on how to mitigate gNB and UE errors should progress in a similar pace. |
| Nokia/NSB | Similar to HW we feel that if the TRP is able to determine the Tx error itself then it should be able to also just correct it locally. Could any proponent explain why this requires signalling?  |
| Ericsson | We are ok with the first bullet. But, regarding the second bullet, we agree with other companies that it is not necessary for the TRP to provide the Tx timing errors to the LMF. It is enough to define the TEG and for the TRP to include the TEG index corresponding to DL PRS resources to the LMF. So we do not suppor the 2nd bullet. |
| Fraunhofer | The TRP may be able to determine a delays with an uncertainty. It might be better in such scenario to provide the LMF or UE with the information, or the timing error can be the uncertainty information.Support the second bullet with the following modification:* Support a TRP to provide PRS timing errors to LMF.
 |
| Apple | The intention is not quite clear (at one hand if TRP is able to determine the Tx error itself then it shall come up with compensation, on the other hand we support a mechansime in which the TRP Tx error is available at LMF, and/or UE). Maybe the proposal should be from the view point of LMF and/or UE in terms of having access to TRP Tx error. Now how this error is determined is a separate discussion (e.g. it could be through reference entity, or TRP report!) |
| China Telecom | We support the first bullet.For the second bullet, we have similar wih other companies that it may not be necessary for the TRP to provide Tx timing errors to the LMF. |

### Proposal 3-2b

* Support LMF to provide the association information of Tx TEGs with DL PRS resources to a UE for UE-based positioning.
* Support LMF to provide the Tx timing errors of a TRP per TEG to a UE for UE-based positioning
	+ FFS: Support LMF to provide the difference of Tx timing errors between a TEG (of a TRP) and a reference TEG (of a reference TRP), to a UE for UE-based positioning
* FFS: details of signalling and procedures

Comments

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| --- | --- |
| **Company** | **Comments**  |
| vivo | In general, we can understand FL's intention. But we think it should be discussed after the understanding, method, and mechanism are clear. |
| Huawei/HiSilicon | If this discussion is about resource-specific RTD, we do not think that it should be a typical use case, as PRS resources from the same PRS resource set are supposedly transmitted from the same Tx chain, and the necessity of further refinement on the resource-specific RTD is still in question. Note that Rel-16 UE-based assistance data already supports RTD per TRP per frequency layer.NR-RTD-Info-r16 ::= SEQUENCE { referenceTRP-RTD-Info-r16 ReferenceTRP-RTD-Info-r16, rtd-InfoList-r16 RTD-InfoList-r16, ...}ReferenceTRP-RTD-Info-r16 ::= SEQUENCE { dl-PRS-ID-Ref-r16 INTEGER (0..255), nr-PhysCellID-Ref-r16 NR-PhysCellID-r16 OPTIONAL, -- Need ON nr-CellGlobalID-Ref-r16 NCGI-r15 OPTIONAL, -- Need ON nr-ARFCN-Ref-r16 ARFCN-ValueNR-r15 OPTIONAL, -- Need ON refTime-r16 CHOICE { systemFrameNumber-r16 BIT STRING (SIZE (10)), utc-r16 UTCTime, ... }, rtd-RefQuality-r16 NR-TimingQuality-r16 OPTIONAL, -- Need ON ...}RTD-InfoList-r16 ::= SEQUENCE (SIZE (1..nrMaxFreqLayers-r16)) OF RTD-InfoListPerFreqLayer-r16RTD-InfoListPerFreqLayer-r16 ::= SEQUENCE (SIZE(1..nrMaxTRPsPerFreq-r16)) OF RTD-InfoElement-r16RTD-InfoElement-r16 ::= SEQUENCE { dl-PRS-ID-r16 INTEGER (0..255), nr-PhysCellID-r16 NR-PhysCellID-r16 OPTIONAL, -- Need ON nr-CellGlobalID-r16 NCGI-r15 OPTIONAL, -- Need ON nr-ARFCN-r16 ARFCN-ValueNR-r15 OPTIONAL, -- Need ON subframeOffset-r16 INTEGER (0..1966079), rtd-Quality-r16 NR-TimingQuality-r16, ...} |
| CATT | Support. |
| InterDigital | Support |
| Qualcomm | Support.Same reply as above which I repeat for the record: * From the beginning of the SI, we added timing errors in both UEs and gNBs. I don’t understand why we now say that the gNBs can ensure that all PRS resources have the same exact timing?
* Each PRS resource may have its own geographic location (as already supported in the spec), and therefore they can have their own timing, if indeed the PRS resources are not collocated. Allowing PRS resources to not be collocated is already in the specification.
* Assistance data and configuration have in NR Rel-16 a single timing, which is clearly a simplification that was done in NR rel-16. Focusing only on UE errors will not make this discussion to be a “fair” and “constructive” approach of addressing the timing errors and will not be following the intention of the writing of the WID. Discussion on how to mitigate gNB and UE errors should progress in a similar pace.

One more addition:Actually, It would have been simpler, even in proposal 3-2a to just change “report to the LMF”, to “report to the LMF or UE”. If a report exists to help UE-A gNB timing errors, it should also have a corresponding report to help UE-B TDOA.  |
| Nokia/NSB | Similar comment as on Proposal 3-2a.  |
| Ericsson | Similar comment as Proposal 3-2a. We do not support the second bullet. Providing TEG index with DL PRS resources from the LMF to the UE should be enough. No need to provide the Tx timing errors between TEGs.  |
| Fraunhofer | Support the second bullet with the following modification:* Support LMF to provide the PRS timing errors to a UE for UE-based positioning
 |
| Apple | Similar comment as on Proposal 3-2a. |
| Huawei/HiSilicon | To QC:In our understanding1. Resource-specific ARP does not necessarily lead to resource-specific RTD, because the TRP can do the compensation to unify the TRP specific RTD, as TRP is aware of the resource-specific ARP, if different from the TRP ARP.2. TRP should always try its best to compensate the Rx/Tx error to its knowledge, while LMF may access additional delay information beyond the knowledge of TRP, e.g. through calibration that is transparent to the TRP, so the information that may be transported between TRP and LMF may be different from between LMF and UE (for UE-based positioning). |
| China Telecom | Similar comment as Proposal 3-2a. We support the first bullet. |

## Mitigating gNB Rx timing errors for UL RTOA

FL comments

RTOA measurement accuracy may be impacted by TRP Rx timing errors. Some companies (e.g., [1][8]) propose to support a TRP to provide its Rx timing errors to LMF for UL positioning. However, some others consider there is no need for a TRP to provide its Rx timing errors to LMF, since if a TRP already knows the Rx timing errors, it can/should mitigate the Rx timing errors before report the measurements to LMF(e.g.,[14]). If the TRP does not know the Rx timing errors, one potential solution is to support TRP to provide association information of the RTOA with Rx timing error groups to LMF.

### Proposal 3-3

* Support a TRP to provide the association information of RTOA measurements with Rx TEGs to LMF when the TRP reports the RTOA measurements to the LMF.
	+ FFS: details of signalling and procedures
* FFS: Support a TRP to provide Rx timing errors per Rx TEG to LMF when the TRP reports the UL measurements to LMF.
* Note: If the association information is not provided, it is assumed RTOA measurements have the same Rx timing errors.

Comments

|  |  |
| --- | --- |
| **Company** | **Comments**  |
| MTK | 1, we don’t think there is a need to provide RX TEG to LMF |
| vivo | Same views as proposal 3-2a and 3-2b. |
| Huawei/HiSilicon | We do not think the TEG concept has any relevance to the gNB. |
| CMCC | Refer to our comments on Proposal 3-2a |
| CATT | Support. |
| Qualcomm | Support. Same reply above regarding the procedural. Timing errors exist in both Ues and gNB; discussion should progress in similar pace for both types of devices.  |
| Nokia/NSB | If the TRP can know the RX error then it can correct the measurement itself. If the TRP can’t know the RX error then we could discuss other solutions.  |
| Ericsson | Ok. But the FFS is not needed as we do not see the need for a TRP to provide Rx timing errors to the LMF. |
| Apple | Similar views as 3-2a |
| China Telecom | Similar comment as Proposal 3-2a. |

## Mitigating UE Tx timing errors for UL RTOA

FL comments

UL measurement accuracy (e.g., RTOA) may be impacted by UE Tx timing errors. When a TRP measures the UL SRS and reports the RTOA measurements, the TRP may not have the information of the UE Tx timing errors, and thus may not be able to mitigate the UE Tx timing errors when reporting the RTOA measurements. Some companies propose (e.g., [4][5][13][15]) to support UE to provide the UE Tx timing errors to LMF if the UE can support it. UE Tx timing errors may be different for different antennal panels/RF trains. There can be multiple Tx timing error groups for a UE, and each TEG may be associated with one or more UL SRS resources.

### Proposal 3-4

* A UE should support providing the association information of UL Tx TEGs with the SRS for positioning resources to LMF
* Depending on UE’s capability, a UE may provide the UL Tx timing errors per Tx TEG
	+ FFS: UE may provide the difference of the Tx timing errors between a TEG and a reference TEG to LMF.
* FFS: details of signalling and procedures

Comments

|  |  |
| --- | --- |
| **Company** | **Comments**  |
| vivo | It seems too early to answer whether to support this proposal, considering that we are not yet sure how to estimate or mitigate the Rx/Tx timing error in UE’s Tx TEG.And we should notice that SRS transmission associated with ‘panel ID’ has already been discussed in R17 MIMO enhancements. If this issue is discussed separately in positioning WI, it is very likely that two different ways (or parameters) will appear in the RRC ignalling to indicate the same relationship (SRS transmission associated with ‘panel ID’), which will increase the configuration overhead and cause duplicated work. Do we need to clarify the difference with MIMO study? |
| Huawei/HiSilicon | OK with the first bullet.For the second bullet, our question is why we need UE to report instead of UE to pre-compensate the “known” or “estimated” Tx timing error. |
| CMCC | Generally fine with the first bullet. |
| CATT | Support. |
| InterDigital | Support. UL Tx timing erros can be used by LMF to correct timing related measurements observed from SRS for positioning |
| Qualcomm | Support. To Huawei: Lets take the example of MRTT:. The definition of UE Rx-Tx says, the Timing should be the subframe closest to the DL PRS. Imagine that this is subrame 0. The UE reports Rx-Tx measurement associated with subframe 0. Then, the SRS appears in subframe 10. The UE gets a TA command, or does an autonomous TA correction in the time between subframe 0 and subframe 10; e.g. moves by 10 nsec later. Then, the SRS is 10 nsec later, and the gNB Rx-Tx is overestimated by 10 nsec. If the UE reports a Timing correcton to the LMF, the LMF would receive the gNB Rx-Tx, remive the 10 nsec, and then add it with the UE Rx-Tx, and get a correct RTT. Furthermore, agreeing on UE TxTEG without agreeing on gNB TxTEG, would not be acceptable for us. The spec has DL methods, UL methods, and DL&UL methods. I don’t see why have reporting only from the UE side, when positioning methods are affected equally from errors from both Ues and gNBs. |
| Nokia/NSB | Can the proponents explain the reason that the UE needs to signal this information and not simply correct for it locally?  |
| Ericsson | Ok with the first bullet.We think this proposal should be discsussed together with Proposal 3-3. |
| Apple | We do not support this proposal. Again not clear how UE estimates its Tx timing errors and if estimated, for what positioning measuements those info will be useful and how (e.g. for UL-TDOA in theory UE’s Tx error should be cancelled)  |
| Huawei/HiSilicon | To QC:I am not sure whether this is the correct question to discuss this example, but anyway, we think this is a generic issue when we consider TA. In the example, based on TS 38.215, it depends on whether the Tx timing of subframe #j that is closest in time to Rx timing of subframe #i is based on actually transmission or a virtual transmission, and if it is based on virtual transmission due to e.g. TDD configuration, whether UE should use actual SRS transmission subframe timing to recover the timing of subframe #j or use any other actual Tx transmission subframe timing to recover that of subframe #j. |
| China Telecom | Agree with Huawei/Hisilicon. |

## Mitigating UE Rx timing errors for RSTD

FL comments

UE Rx timing errors will impact the RSTD measurement accuracy. If the Rx timing errors are known to the UE, the UE may remove the impact of Rx timing errors before reporting RSTD measurements(e.g. [14]). In this case, there is no need for a UE to report Rx timing errors. However, the UE may not always have the information of the Rx timing errors. In this case, it would be helpful for the LMF to know the association of the UL measurements with the Rx TEGs.

If UE uses different antenna panels/Rx chains for the receptions of the same or different DL PRS resources. The RSTD measurements may be impacted by different Rx timing errors. There are different proposals on how to deal with the different Rx timing errors. One of the proposals is to provide the association information of RSTD measurements with the Rx TEGs to LMF when the UE reports the UL measurements to the LMF, the LMF will take the information into account. Another possible solution is the UE performs self-estimation/calibration of the offset of Rx timing errors between Rx time error groups, e.g., by tracking the Rx time difference from the antenna panels/Rx RF chains from the same DL RS, i.e., SSB from the serving cell. If self-calibration of Rx timing errors between Rx TEGs are supported by UEs, it may make the solutions of the Rx timing errors much simpler. Also, there is a need to further discussion on how to deal with the impact of the Rx timing errors when a UE uses different antenna panels/RF chains for the receptions of the same or different DL PRS resources if UE cannot support the self-calibration.

### Proposal 3-5

* A UE should support providing the association information of RSTD measurements with different Rx timing errors to the different Rx TEGs to LMF when the UE reports the UL measurements to LMF.
* FFS: Depending UE’s capability, a UE may support providing Rx timing errors per Rx TEG to LMF.
* FFS: details of signalling and procedures

Comments

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| --- | --- |
| **Company** | **Comments**  |
| MTK | 1, we don't see RX TEG reporting is needed |
| vivo | Same views as proposal 3-4 |
| Huawei/HiSilicon | OK with the first bullet.For the second bullet, our question is why we need UE to report instead of UE to pre-compensate the “known” or “estimated” Rx timing error. |
| CMCC | Generally fine with the first bullet. |
| CATT | Support. |
| Qualcomm | Support To MTK: The UE may be measuring RSTDs on PRS resources that are far away in time. The UE may know that there may be some time drift, so it may choose to say that these RSTD are part of a different RxTEG to suggest to the LMF that maybe these measurements should not be subtrached out. The UE may not know houw much is the time drift. If the UE knows, and can remove it from the report, that’s great; the UE will just say that these 2 RSTDs are in the same RxTEG. Furthermore, agreeing on UE RxTEG without agreeing on gNB RxTEG, would not be acceptable for us. Progress should be symmetric.  |
| Nokia/NSB | If the intention is to allow the LMF to know which measurements can be combined for differential purpose then we are open to discuss. If that is not the intention can the proponents explain further? |
| Ericsson | Ok in principle. We do not think the FFS is needed as we do not see a need for UE to provide the Rx timing errors to the LMF. It is enough to send an idenfier of the Rx TEG. But we suggest the following revisions:* A UE should support providing the association information of Rx TEG identifier as part of RSTD measurements to LMF when the UE reports the DL measurements to LMF.
* FFS: details of signalling and procedures
 |
| Apple | Similar comment to as proposal 3-4 |
| China Telecom | Support the first bullet. |

## Mitigating Tx/Rx timing errors for multi-RTT positioning

FL comments

For multi-RTT positioning, the round-trip-time is calculated by the use of the UE Rx-Tx time difference measurements and gNB Rx-Tx time difference measurements. The measurement accuracy of UE Rx-Tx time difference measurements may be impacted by UE Rx and Tx timing errors, and the measurement accuracy of gNB Rx-Tx time difference measurements may be impacted by both gNB Rx and Tx timing errors. If UE Tx and Rx timing errors and gNB Tx and Rx timing errors cannot be compensated, the accuracy of the multi-RTT positioning may be significantly impacted.

For mitigating UE RX/TX timing errors, one proposed solution is that UE is responsible for the compensation of the UE Tx/Rx timing errors in UE Rx-Tx time difference measurements by the implementation (e.g., [1][8]).

For mitigating gNB RX/TX timing errors, one proposed solution is that gNB is responsible for the compensation of the TRP Tx/Rx timing errors in gNB Rx-Tx time difference measurements by the implementation (e.g., [1]), while another proposed solution is that the gNB reports TRP ‘Rx timing error + Tx timing error’ to LMF, and then let LMF mitigate the impact of TRP ‘Rx+Tx timing errors’ on gNB Rx-Tx time difference measurements (e.g., [8]).

Another proposed solution to handle the UE/gNB Tx/Rx timing errors in Multi-RTT is that UE and gNB are responsible for the compensation of the UE/TRP Rx timing errors by the implementation, while LMF is responsible for the compensation of the UE/TRP Tx timing errors, which may be provided by UE/gNB or estimated by LMF, to the UE/gNB Rx-Tx time difference measurements (e.g., [14])

If the UE and/or gNB have the information of their Rx/Tx timing errors, it may be reasonable to assume UE/gNB will perform the self-calibration of these errors. That is, UE/gNB Rx-Tx time difference measurements only contain the UE/gNB Rx/Tx timing errors that are unknown to UE/gNB, and cannot removed by self-calibration. In this case, to support LMF to mitigating UE/gNB Rx/Tx timing errors from the UE/gNB Rx-Tx time difference measurements (e.g., through the combination of the measurements), a different proposal is that UE and gNB provide the information of Tx/Rx REGs along with the UE/gNB Rx-Tx time difference measurements in the measurement report to LMF, and LMF will take the information into account during the positioning calculation to minimize the impact of the errors (e.g., [2],[17][19]).

### Proposal 3-6a

* UE should support providing to LMF the association information of UE Rx-Tx time difference measurements with the different UE Rx TEGs if UE Rx-Tx time difference measurements in a measurement report have different Rx timing errors;
* UE should support providing to LMF the association information of UE Rx-Tx time difference measurements with the different UE Tx TEGs if UE Rx-Tx time difference measurements in a measurement report have different Tx timing errors;
	+ Note: A UE Tx TEG may be associated with one or more SRS for positioning resources.
* FFS: details of signalling and procedures

### Proposal 3-6b

* Support TRP to provide to LMF the association information of gNB Rx-Tx time difference measurements with different TRP Rx TEGs if the gNB Rx-Tx time difference measurements in a measurement report have different Rx timing errors;
* Support TRP to provide to LMF the association information of gNB Rx-Tx time difference measurements with the different TRP Tx TEGs if the gNB Rx-Tx time difference measurements in a measurement report have different Tx timing errors;
	+ Note: A TRP Tx TEG may be associated with one or more DL PRS resources.
* FFS: details of signalling and procedures

Comments

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| --- | --- |
| **Company** | **Comments**  |
| MTK | 1, the RX timing error, even due to different panel, could be corrected before measurement reporting. So RX TEG reporting seems not critical |
| vivo | Same views as proposal 3-4 |
| Huawei/HiSilicon | Same comments as before.* UE reporting “TEG” info should be OK.
* UE reporting “TEG” error is not needed.
* gNB reporting “TEG” info or error is not needed.
 |
| CMCC | See comments on 3.2 to 3.5. |
| CATT | Support. |
| Qualcomm | Support. Please see our replies before on the explanations.  |
| Nokia/NSB | If the intention is to allow the LMF to know which measurements can be combined for differential purpose then we are open to discuss. If that is not the intention can the proponents explain further? |
| Ericsson | The UE can provide TEG idenfiers associated with a measurment. No need to reporting the timing errors to LMF.Similarly, gNB can provide TEG idenfiers associated with a measurement. No need to report the timing errors to LMF.Suggest to discuss 3.6a and 3-6b together. |
| Apple | As mentioned previously, the question to us is how the reporting entity determines the association between timing errors and the reception/transmission of RS for positioning is determined, and how estimates the errors. We are OK to further discuss.  |

## Feasibility/Capability of the calibration of UE/gNB Tx/Rx timing errors

Submitted Proposals

* (ZTE [R1-2100293](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100293.doc)) Proposal 1:
	+ Send a LS to RAN4 to check that if it’s feasible the Rx and Tx timing delays can be calibrated and compensated at both UE and TRP side.
* (Ericsson [R1-2101754](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101754.doc))Proposal 9
	+ RAN1 should with help from RAN4 study the possibility to define two (or multiple) sets of requirements (based on UE-capabilities) for RSTD accuracy, UE RX-TX time difference accuracy and UE TX timing accuracy in order to accommodate for both general purpose eMBB UEs and for UEs requiring high (sub-meter) accuracy positioning in e.g. I-IoT scenarios.
* (Ericsson [R1-2101754](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101754.doc))Proposal 10
	+ Send LS to RAN4, requesting RAN4 to investigate the possibility to define two (or multiple) sets of requirements (based on UE-capabilities) for RSTD accuracy, UE RX-TX time difference accuracy and UE TX timing accuracy in order to accommodate for both general purpose eMBB UEs and for UEs requiring high (sub-meter) accuracy positioning in e.g. I-IoT scenarios.

FL comments

It is expected that UE and gNB will conduct at least some kind of calibration of Rx and Tx timing errors for supporting the positioning measurements (RSTD, RTOA, UE/gNB time differences). RAN4 would be the working group to provide the information of the realistic accuracy of the self-calibration of Rx and Tx timing errors, e.g., whether it would be accurate enough to support the Rel-17 target positioning accuracy etc.

### Proposal 3-7

* + Send a LS to RAN4, requesting the following information
		- investigate whether the Rx and Tx timing delays can be calibrated and compensated at both UE and TRP side to support the Rel-17 target positioning accuracy requirements
		- investigate the possibility to define two (or multiple) sets of requirements (based on UE-capabilities) for RSTD accuracy, UE RX-TX time difference accuracy and UE TX timing accuracy in order to accommodate for both general purpose eMBB UEs and for UEs requiring high (sub-meter) accuracy positioning in e.g. I-IoT scenarios.

Comments

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| --- | --- |
| **Company** | **Comments**  |
| MTK |  We support, and we can further check : whether one-side delay (DAC to antenna, and antenna to ADC) can be separately calibrated? Or only the round trip delay (DAC to antenna and back to ADC) can be calibrated with reasonable complexity |
| vivo | Support.If the Rx/Tx timing delays can be calibrated and compensated by the UE or the TRP, the UE or TRP can automatically eliminate the timing delay in the measurement before reporting, which minimizes the specification impact. We are worried that premature normative work will make our efforts in vain before we get a response from RAN4. |
| Huawei/HiSilicon | Not sure RAN4 can handle it. We understand that even in Rel-16 performance WI, RAN4 is still struggling with the residue calibration error. |
| CATT | Support. We believe that RAN4 should be involved when we discuss the feasibility of the schemes to mitigate the Rx/Tx timing delays. |
| Qualcomm | No need to send an LS yet. If RAN1 agrees on the signaling of Timing Groups, then RAN4 may need to work on putting requirements related to these. We believe it is early to send an LS now, when they are still discussing Rel-16 requirements.  |
| Nokia/NSB | We think that RAN1 needs to first get a better understanding of what exactly is in scope of the Rx and Tx timing delays before we can involve RAN4.  |
| Ericsson | We support the second subbullet. |
| Apple | Is the intention of the first bullet to say UE (and gNB) do calibration by itself?  |

# Additional proposals

## Measurement Enhancements

Submitted Proposals

* (LGE [R1-2100708](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100708.doc)) Proposal 1:
	+ Support enhancements for introducing measurement acquisition rule on UE Rx-Tx time difference measurement and gNB Rx-Tx time difference measurement
		- E.g., the same time window for measurement averaging of UE Rx-Tx and gNB Rx-Tx
* (LGE [R1-2100708](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100708.doc)) Proposal 2:
	+ Support enhancements for introducing measurement acquisition rule on RSTD measurement and UE/gNB Rx-Tx time difference
		- E.g., the same time window for measurement averaging of RSTD and UE/gNB Rx-Tx.
* (Qualcomm [R1-2101468](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101468.doc)) Proposal 5:
	+ Support Tx Timing Adjustment information Reporting from UEs to the LMF for DL+UL or UL-only positioning.

FL Comments

In [10], it was observed that the measurement averaging windows are currently up to implementations for both of the UE and the gNB, which may result in inaccurate measurement (e.g., RTT) and thus makes it difficult to use the UE/gNB measurements to obtain the extract TRP timing errors, especially when the UEs are not stationary. It was suggested that both the UE and the gNB should follow an aligned rule to determine a measurement for reporting of the Rx-Tx time difference and RSTD.

In [17], the impact of Tx TA adjustment on UL and DL+UL positioning when the [averaged] measurements obtained from multiple SRS occasion was discussed, where it was proposed for UE to provide the timing adjustment information to LMF to resolve the issue.

We may need to consider some additional rule(s)/enhancements to avoid the potential issues associated with the measurements obtained from multiple DL PRS/UL SRS occasions. One possible solution is to allow the network to configure a time window for positioning, during the time window, the UE should not adjust UL Tx Timing; while the UE may be allowed to adjust and/or report the Tx Timing Adjustment information to the LMF or gNB. Suggest further discussion on whether there is a need to consider additional rules/enhancements on the measurements.

### Proposal 4-1

* + Support LMF to configure a time window for UE/gNB measurements (RSTD, RTOA, UE/gNB Rx-Tx time difference)
	+ Adopt one of the following options:
		- Opt. 1: UE should not make UL Tx timing adjustment for the transmission of SRS for positioning during the time window
		- Opt. 2: UE should support reporting Tx timing adjustment information to LMF [or gNB] if the transmission time of SRS for positioning is changed during the time window

Comments

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| **Company** | **Comments**  |
| vivo | Not sure the issue should be discussed under this AI. |
| Huawei/HiSilicon | We understand the UE Tx timing is also associated reference DL timing, which can also be varying.For Opt.1, this is too restrictive from UE implementation, and may not be valid, as the DL timing can also be changing.For Opt.2, as commented during the online session, if UE changes the Tx timing, the resultant Rx timing at gNB is also changed accordingly, and in addition, the TOA measurement by the gNB has already been done. We are not sure how this information at LMF can help mitigate the UE Tx timing error.In our understanding, the best way to mitigate different average algorithm between TRPs and between UE and TRPs is to adopt the method in Proposal 2-1 and Proposal 2-2. |
| CATT | We slightly prefer Opt.2, but need more study on whether Opt.2 have the benefit to the mitigiation of UE Tx timing delay error. |
| Qualcomm | We prefer Option 2.  |
| Nokia/NSB | We are a bit unclear how this can help with Tx/Rx timing errors? If the LMF has timestamps isn’t this already possible?  |
| Ericsson | We slightly prefer Option 2. With Option 2, RAN4 needs to be involved to set requirements on the timing adjustment information. |
| Apple | In our understanding the reference time for timestamp associated with UE measurement report is UE’s DL refernence. So adjustment of TA should not make a problem if that understanding is correct.  |

## Antenna array phase center offset

Submitted Proposals

* (Nokia [R1-2100548](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100548.doc)) Proposal 1:
	+ RAN1 to include UE antenna array phase center offset impact on UE positioning estimation accuracy and potential correction mechanisms in the work on UE and gNB Rx/Tx timing delay mitigation.
* (Fraunhofer [R1-2101131](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101131.doc)) Proposal 3:
	+ The reference point for TRD determination is the phase center of the transmitted or received beam.

FL comments

It was observed in [7][13] that the antenna array phase center may not be a “static” point at the antenna connector or antenna center. The phase center offsets may be different for different antenna panels and different beam directions, which may be seen also as timing delays, and have an impact on the measurement and positioning accuracy.

The introduction of the concept of timing error groups may address, to a certain degree, the impact of the antenna array phase centers on the measurement and positioning accuracy. Suggest further discussion on how to consider the impact of the antenna array phase center offsets in addition to the introduction of the timing error groups.

### Proposal 4-2

* Further study the impact of UE antenna array phase center offset on UE positioning estimation accuracy and potential correction mechanisms

Comments

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| **Company** | **Comments**  |
| vivo | We analyzed the contribution seriously containing UE antenna array phase center offset, but we still confused the impact on Rx/Tx timing delay. We hope we can get more explanation. |
| Huawei/HiSilicon | OK with the study. However, to our understanding, this requires understanding what the ground truth of UE location is, if we allow different UE antenna reference point defined. |
| CATT | It is not clear how much impact does this issue have on the positioning accuracy. We prefer this study as low priority in this meeting. |
| Qualcomm | Unclear what we need to study. |
| Nokia/NSB | Support the inclusion of phase center offsets in the Tx/Rx timing delays. As said online we see this as a very critical issue to solve if we truly want to achieve 20 cm level accuracy. To CATT, as shown in our detailed simulation results the impact can be quite significant in a realistic UE. Almost 10 cm of error in some scenarios which is clearly significant for our targeted accuracies. To vivo, thanks for analysing the issue. The figure from our Tdoc (shown here too for convience) is perhaps the best way to explain the impact on Rx/Tx timing delay. The antenna phase center effectively moves based on the AoD/AoA of the signals to/from the UE. This moves the PCO from the ARP shown in the figure (i.e., the location we want to find) and the red dot. It moves it by there being an effective additional delay (i.e., the ToA/ToD error shown here).  |
| Ericsson | The impact of this issue on positioning accuracy is much smaller when compared to that of group delays. Low priority. |
| Fraunhofer | Support also suggest adding TRP to the proposal. Taking timing delay of a TRP is the signal propogation time between the antenna phase center and BB unit, the Tx/Rx delay if grouped according to the Rx antenna position (and not per beam center) the timing error between these beams is ignored.An alternative is to define on the timing delay including the antenna phase center similar to Proposal3-1. |
| Apple | We share similar view as CATT/QC. |

## The spatial relation of SRS with DL PRS or SSB

Submitted Proposals

* (Ericsson [R1-2101754](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101754.doc))Proposal 2
	+ It shall be possible to configure an SRS with a spatial relation towards a DL PRS or SSB together with a configuration to utilize a certain delay group.

FL comments

For the estimation UE TX timing error difference, it was proposed in [19] to configure an SRS with a spatial relation towards a DL PRS or SSB together with a certain delay group, in order to support the UE to transmit each SRS towards TRPs with each delay group (i.e., antenna panel).

Configure an SRS with a spatial relation towards a DL PRS or SSB is supported in Rel-16 without the consideration of the UE Tx timing errors. Adding the timing error group into consideration will obviously increase the difficulty and complexity. Suggest further discuss above proposed enhancement, including the potential benefits and implementation issues.

### Proposal 4-3

* Further study the configuration of an SRS with a spatial relation towards a DL PRS or SSB together with a Tx timing error group

Comments

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| **Company** | **Comments**  |
| vivo | Same view as proposal 3-4, it seems to overlap with MIMO discussion. |
| Huawei/HiSilicon | We noticed that feMIMO WI is also discussing gNB configuring SRS Tx panel, and we would prefer to avoid duplicated discussion. |
| CATT | We share the same view with vivo and Huawei/HiSilicon, prefer to disucss this issue in feMIMO session. |
| Ericsson | In our understaning, FeMIMO will not discuss aspects related to Tx timing error groups. TEGs are to be discussed in ePos.It should be noted that reporting TEG index with measurement works very well when there are many TRPs/many links since this methods rely on a reference TRP per TEG. But in scenarios with limited number of links/TRPs, we think the proposed method in this proposal is beneficial.  |
| Apple | If the intention is to make sure different SRS transmissions are on the panels/beams with similar Tx delay, we are ok to further study |

## Beam and delay group sweeping

Submitted Proposals

* (Ericsson [R1-2101754](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101754.doc))Proposal 3
	+ RAN1 should study beam and delay group sweeping further and consider this method to reduce positioning overhead for specification in Rel. 17.

FL comments

Consider a UL beam may be transmitted with different antenna panels with different Tx timing errors, it was proposed in [19] to further study the beam and delay group sweeping to reduce positioning overhead.

It may increase significantly the overhead if there is both beam and delay group sweepings are used without introducing a proper method for managing the sweepings. Suggest further study the benefits, the methods, the configuration etc. for managing the situation that UL SRS resources (UL beams) may be transmitted with different Tx timing errors.

### Proposal 4-4

* Further study both beam and delay group sweeping and the reduction of positioning overhead

Comments

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| **Company** | **Comments**  |
| vivo | Low priority, we think it should be discussed after the understanding, method and mechanism are clear |
| Huawei/HiSilicon | In our view, the current UE reporting “TEG” info to the LMF is sufficient. |
| CATT | We prefer this study as low priority in this meeting. |
| Nokia/NSB | We are not sure what exactly the proposal would entail. What is the specification impact?  |
| Ericsson | It should be noted that reporting TEG index with measurement works very well when there are many TRPs/many links since this methods rely on a reference TRP per TEG. But in scenarios with limited number of links/TRPs, we think the proposed method in this proposal is beneficial.  |
| Apple | Low priority |

# Others

Submitted Proposals

* (CAICT [R1-2100308](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100308.doc))Proposal 3:
	+ Beam related accuracy and multipath accuracy enhancement need to be further considered.
* (TCL [R1-2100697](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100697.doc))Proposal 1:
	+ Support Closed-loop power control for the transmission of SRS for positioning.
* (TCL [R1-2100697](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100697.doc))Proposal 2:
	+ Support transmission of assistance information to UEs switching between positioning systems to reduce position acquisition delay.
* (Samsung [R1-2101210](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101210.doc)) Proposal 2:
	+ Improving the TA granularity should be support for TA report in E-CID.
* (Samsung [R1-2101210](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101210.doc)) Proposal 3:
	+ Positioning in RRC inactive state should be supported.
* (China Telecom [R1-2101527](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101527.doc)) Proposal 1:
	+ Rel-17 should support additional PRS RE mapping patterns with smaller DL PRS symbol lengths, including the 1-symbol PRS patterns.
* (China Telecom [R1-2101527](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101527.doc)) Proposal 2:
	+ Rel-17 should support the DL PRS frequency domain multiplexed with other DL signals and channels in PRB-level.
* (China Telecom [R1-2101527](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101527.doc)) Proposal 3:
	+ Rel-17 should support additional UL SRS for positioning RE mapping patterns with smaller PRS symbol lengths, i.e. the comb-4 and comb-8 for 1-symbol SRS patterns, the comb-8 for 2-symbol SRS pattern.

FL comments

The above proposals are discussing the positioning enhancements that are not included in the scope of Rel-17 WI objectives at this moment. Suggest considering these proposals as low priority in this meeting.

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| **Company** | **Comments**  |
| CATT | Support these proposals as low priority in this meeting. |
| Nokia/NSB | Agree with FL.  |
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# References

1. [R1-2100128](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100128.doc) Enhancement of timing-based positioning by mitigating UE Rx/Tx and/or gNB Rx/Tx timing delays OPPO
2. [R1-2100195](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100195.doc) Enhancement to mitigate gNB and UE Rx/Tx timing error Huawei, HiSilicon
3. [R1-2100293](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100293.doc) Positioning accuracy improvement by mitigating timing delay ZTE
4. [R1-2100308](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100308.doc) Discussion on accuracy improvements of NR positioning enhancements CAICT
5. [R1-2100385](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100385.doc) Discussion on accuracy improvements by mitigating UE Rx/Tx and/or gNB Rx/Tx timing delays CATT
6. [R1-2100445](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100445.doc) Discussion on methods for RX/TX timing delay mitigating vivo
7. [R1-2100548](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100548.doc) Initial views on mitigating UE and gNB Rx/Tx timing errors Nokia, Nokia Shanghai Bell
8. [R1-2100657](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100657.doc) Mitigation of UE and gNB Tx/Rx timing errors Intel Corporation
9. [R1-2100697](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100697.doc) Positioning enhancement by UE Assistance TCL Communication Ltd.
10. [R1-2100708](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100708.doc) Discussion on accuracy improvement by mitigating UE Rx/Tx and gNB Rx/Tx timing delays LG Electronics
11. [R1-2100752](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2100752.doc) Techniques to improve accuracy in the presence of UE Rx/Tx and/or gNB Rx/Tx timing delays InterDigital, Inc.
12. [R1-2101046](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101046.doc) Discussion on gNB/UE Rx/Tx timing delay mitigation solutions CMCC
13. [R1-2101131](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101131.doc) On methods for Rx/Tx timing delays mitigation Fraunhofer IIS, Fraunhofer HHI
14. [R1-2101140](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101140.doc) The mitigation of  RX/TX timing delays for higher accuracy MediaTek Inc.
15. [R1-2101210](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101210.doc) Discussion on accuracy improvements on timing based positioning solutions Samsung
16. [R1-2101387](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101387.doc) Positioning accuracy enhancements under UE and/or gNB Tx/Rx timing errors Apple
17. [R1-2101468](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101468.doc) Enhancements on Timing Error Mitigations for improved Accuracy Qualcomm Incorporated
18. [R1-2101527](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101527.doc) NR positioning enhancements by mitigating timing delays China Telecom
19. [R1-2101754](file:///E%3A%5C1%20Meetings%5CRAN1%5C2021_01_TSGR_104e%5CDocs%5CR1-2101754.doc) Techniques mitigating UE Rx/Tx timing delays Ericsson
20. RP-202900, “New WID on NR Positioning Enhancements”, CATT, Intel Corporation, Ericsson, December 7th – 11th, 2020.