**3GPP TSG RAN WG1 Meeting #104-e R1-210xxxx**

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

**Source: Moderator (CATT)**

**Title: FL Summary #2 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 delays  3 Mitigation of Rx/TX timing delays  3.1 Rx/Tx timing error groups  3.2 Mitigating gNB Tx timing errors (for RSTD and DL positioning)  3.3 Mitigating gNB Rx timing errors for UL RTOA  3.4 Mitigating UE Tx timing errors for UL RTOA  3.5 Mitigating UE Rx timing errors for RSTD  3.6 Mitigating Tx/Rx timing errors for multi-RTT positioning  3.7 Feasibility/Capability of the calibration of UE/gNB Tx/Rx timing errors  4 Additional proposals  4.1 Measurement Enhancements  4.2 Antenna array phase center offset  4.3 Spatial relation of SRS with DL PRS or SSB  4.4 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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100195.doc)) Proposal 1:
  + Introduce a calibration UE with the known location to mitigate the gNB timing error.
* (ZTE [R1-2100293](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100293.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100308.doc))Proposal 1:
  + Differential positioning technique could be considered to compensate synchronization error and Rx/Tx transmission delays.
* (CATT [R1-2100385](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100385.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100445.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100445.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100548.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101387.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100657.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100657.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101046.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101046.doc)) Proposal 2:
  + Support the measurement and reporting among the TRPs to estimate the timing errors.
* (CMCC [R1-2101046](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101046.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101140.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101140.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101468.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100128.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100128.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100128.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100128.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101046.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100445.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101140.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101468.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:** UE/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. |
| ZTE | Ok with the understanding. |
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## Estimation of UE/gNB Tx/Rx timing errors based on existing UE/TRP measurements

FL Comments

UE/gNB TX/RX timing errors may be estimated/calibrated by the use of the existing timing measurements (e.g., RSTD, RTOA, UE/gNB Rx-Tx time differences) (e.g., [1][2]) and the combination of the existing timing and angle measurements (e.g., RSTD, UE Rx-Tx time difference, AOA/AOD) (e.g., [1] [2][12]).

Proposal 2-1 (revised)

* + 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 measurement  2, 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. |
| OPPO | We don’t see much benefit to report multiple measurements of the same type in one report.  On the other hand, report multiple meaurements of different types will be useful. I mean it is benefical to to support the joint reporting of timing-based and angle-based measurement.  In DL-TDoA measurement reporting specified in Rel-16, the UE reports RSTD measurement and can also report the RSRP measurement of DL PRS resources used to measure the RSTD. However, the measurement results for these two types of positioning may not be suitable for joint processing. On potential issue is that the RSTD is measured from one DL PRS resource set while a valid RSRP should be measured from only one DL PRS resource. For better performance, the joint measurement and reporting of timing based and angle based positioning per DL PRS resource is preferred. Thus, Proposal 2-1 is suggesting to ensure the measurements on the same DL PRS resources.  As for the spec impact, we see that the meausruement for different positioning method should be basd on the same PRS resource, which is not mandatory in Rel-16 spec.  In summary, We suggest to revise Proposal 2-1 for the joint reporting of timing-based and angle-based measurement   * + . Support UE ~~should~~ to ~~support reporting~~ report multiple measurements of different types (e.g., 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 |
| FL | Although LPP supports including multiple types of measurements in one single repor with each measurement having its own timestamp, there is currently no requirement to enforce the DL and UL measurements are associated with the same set of DL PRS and UL SRS resources and the same timesteps, which could potentially cause a problem when the measurements are combined for the purpose of positioning (e.g., Multi-RTT) as mentioned in QC’s comments or for for the estimation of the Rx/Tx timing errors (e.g., combination of RSTD, UE/gNB Rx-Tx time difference). The intention of the proposal might be cleaer if Proposal 2-1 and Proposal 2-2 are discussed together, as suggested by Qualcomm.  How about we combine Proposal 2-1 and Proposal 2-2 as follows?   * Support enabling:   + a UE to report multiple measurements (including RSTD, DL RSRP, UE Rx-Tx time difference measurements) in a single measurement report to LMF, and   + a TRP to report multiple measurements (including RTOA, UL RSRP, gNB Rx-Tx time difference measurements) in single measurement report to LMF, and   + the UE and TRP’s measurements in the reports are measured from the same set of DL PRS and UL SRS resources with the timestamps derived from the DL PRS and UL SRS occasions within the same measurement window |
| vivo 2 | We can understand the intention of FL, HW, and QC from the discussion and the updated proposal. But this AI is for mitigating RxTx Timing delays, we can’t identify the benefits clearly of this updated proposal sub-bullet 1and 3 for mitigating RxTx Timing delays.  1) one is multiple reporting with different stamps for a measurement report, we also want to confirm its significance for mitigating or estimating the group delays.  3) another is “the same set of DL PRS resources” for different methods, we think it only can be used to combine the different methods and can’t mitigate the Rx/Tx timing error as Rx/Tx timing error exists in both TDOA and Multi-RTT. |
| ZTE | From the comments above, we understand that the intention of this proposal is to report multiple timestamped measurements from different occasions in a single report, where the report includes the same type of measurement. We agree with Fraunhofer, we can come back later until the definition of timing delays and relevant enhancements are clear. |
| LG | We are fine with the FL’s modified proposal in principle. We also think that RSTD and Rx-Tx time difference measurements obtained within the strictly similar time would be required to mitigate timing error. |
| Huawei/HiSilicon | Regarding the updated proposal from the FL:  First bullet: we are not clear about the scope. Does it include both cases for multiple measurements of the same type, and multiple measurements of different types that are derived based on the same resource (set)?  Second bullet: In our view, TRP to report multiple measurement each associated with one occasion is already supported in NRPPa. Companies want it to be more specific, we can be fine if the proposal regarding AoA ambiguity in ePos-02 is treated in the same way.  Third bullet: the relationship with the first two bullets is not clear. We understand it is more of a clarification on the first two bullets, instead of a parallel proposal. Can the FL clarify? |
| Ericsson | We support the FL second proposal, but we would like further clarification. Our understanding of the proposal is illustrated below. In some cases, it would be good that the instance contain only one PRS occasion, so we propose that there could be a way to request measurements based on single occasions.  Diagram  Description automatically generated with medium confidence  **Revised proposal:**  **support enabling**   * **a UE to report multiple measurement intstances (of RSTD, DL RSRP, UE or Rx-Tx time difference measurements) in a single measurement report to LMF, and** * **a TRP to report multiple measurement instances (of RTOA, UL RSRP, or gNB Rx-Tx time difference measurements) in a single measurement report to LMF, and** * **Each measurement instance is reported with its own timestamp reflecting its measurement time window** * **FFS: the measurement instance can be configured to include only one PRS occasion** |
| Lenovo,Motorola Mobility | Supportive of the intention of the updated proposal, although the key difference of the proposed enhancement of reporting the timestamp associated with a PRS/SRS occassion vs current Rel-16 support of collecting multiple types of measurements in a single report with each measurement having its own timestamp should be made clear. Support Ericsson’s updated proposal. |
| FL | For vivo’s comment, ideally we should avoid different stamps. But, since the measurement is done within a window, the reports from UE and TRP may not have the same timestamps. The intention to have the same set of DL PRS resources is that there can be different Tx timing errors for different DL PRS resources (it may be more clear to “the DL PRS resources associated with the same Tx TEG” once we have the consensus to use the term TEG”. It may be fine to not explicitly mention it, since the DL/UL resources are configured by the network.  For HW’s comment, my consideration is to allow multiple measurements of the different types (e.g., multiple measurements of both RSTD and UE Rx-Tx time difference). The 3rd bullet is a condition on the measurement report for both 1st and 2nd bullet. The structure may need to be modified if that is not clear.  For Ericsson’s suggestion of modification, it looks fine to me with the following changes. Here I assume the network may confugre the measurement time window for the measurements;  **Support enabling**   * **a UE to report multiple measurement intstances (of RSTD, DL RSRP, UE or Rx-Tx time difference measurements) in a single measurement report to LMF, and** * **a TRP to report multiple measurement instances (of RTOA, UL RSRP, or gNB Rx-Tx time difference measurements) in a single measurement report to LMF, and** * **Each measurement instance is reported with its own timestamp within the configured measurement time window** * **FFS: the measurement instance can be configured to include only one PRS occasion** |

### Proposal 2-1 (Revision 1)

* Support enabling
  + a UE to report multiple measurement intstances (of RSTD, DL RSRP, UE or Rx-Tx time difference measurements) in a single measurement report to LMF, and
  + a TRP to report multiple measurement instances (of RTOA, UL RSRP, or gNB Rx-Tx time difference measurements) in a single measurement report to LMF, and
  + Each measurement instance is reported with its own timestamp within a [configured] measurement time window
* FFS: the measurement instance can be configured to include only one PRS occasion
* FFS: details of signalling and procedures

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| **Company** | **Comments** |
| Nokia/NSB | We are not strongly against this type of proposal but trying to understand how it fits into the scope of this AI. If agreed how does this allow timing errors to be mitigated? If I follow the discussion above correctly then this just make it “easier” for the LMF to see measurements that are made with the same resources. But a smart implementation of Rel-16 would already be able to do this, no? |
| FL | The proposal is tightly related to the method of using both gNB and UE measurements for the estimation of the timing errors. In this case, there is a need for matching the measurements provided by the UE and the measurements provided by the gNB. It also helps Multi-RTT positioning, where it is desirable that UE/gNB Rx-Tx time difference measurements are matched and obtained in the same measurement window. |
| ZTE | 1. From the proposal we can not distinguish that, whether a single measurement report contains only RSTD measurements/only DL RSRP measurements, or, a single measurement report contains RSTD+RSRP+Rx-Tx time difference measurement. 2. Does a PRS occasion means a PRS resource or a time occasion of transmitting/receiving PRS? 3. What is the definition of single measurement report , does it mean “ProvideLocationInformation” message in LPP and “ MEASUREMENT RESPONSE” message in NRPPa?   With these questions above,we have similar concerns as Nokia and we are not sure the benefit of this. |
| MTK | 1, the wording reads like that the measurement results taken in different time instance **for each** measurement type can be merged into a single report. Also the measurement results taken in different time instance **for several** measurement types can also be merged together into a single report.  We don’t understand how the combination of RSTD and UE RX-TX time difference can help solve the timing delay. And we think that a single report may just consider a single measurement type, with multiple time-stamps. And the measurement results in different time instance **are not averaged**, because the timing delays would be changing with time |
| vivo | Sorry for we have the same understanding as Nokia and MTK, we don’t know how to mitigate or estimate the timing errors with the above information. For our method in 2.4, it only needs to configure smaller periodicity for reference UE, then the timing error estimated by reference UE can be compensated to other UE. Or the proposal means UE should not report the average or the filtered result of multiple measurements?  Besides, what is the spec impact? |
| Huawei/HiSilicon | In our understanding, for the TRP to report multiple measurement instances, it is already supported in spec, and if we want to make it clear, other features that face the same issue deserve to be treated equally.  In addition, for the third sub-bullet under the first bullet, we are not sure what the “configured measurement window” is, and suggest to have FFS on that.  In summary, we are OK with the following modification. Proposal 2-1 (Revision 1)  * Support enabling   + a UE to report multiple measurement intstances (of RSTD, DL RSRP, UE or Rx-Tx time difference measurements) in a single measurement report to LMF, and   + a TRP to report multiple measurement instances (of RTOA, UL RSRP, or gNB Rx-Tx time difference measurements) in a single measurement report to LMF, and   + Each measurement instance is reported with its own timestamp ~~within a [configured] measurement time window~~     - FFS: The measurement instances are within a [configured] measurement time window * FFS: the measurement instance can be configured to include only one PRS occasion * FFS: details of signalling and procedures |
| OPPO | We are ok with the 1st and 2nd sub-bullet of Bullet#1 if they are intended to report measurement results of the different types. For this case   * we should add a restriction that these measurement results are based on the same resource(s). * The 2rd sub-bullet is not needed   If multiple results are only the multiple instants of the same type, as some comments said, they are used by LMF to mach some results that they are closed enough in time domain   * For the three examples given by QC’s comment, when the measuremnts are based on different RS resources, we don’t think matching some results that are closed in the time domain can offer any gain. We cannot enfore UE to use the same RS resource(s) for different reporting that are associated with different positioning methods * Even in this case, the measurement time window is not needed as well since it is up to LMF how to match the measurement results from different reporting. Moreover, when UE/TRP are doing measurement X for one positioning method A, it does not know when the other meansuremt Y for positioning method B were/will be done, where LMF will matche measurement results Y and X at some later time. Thus, adding a window for the reporting does not facilitate LMF |
| CATT | Support. In our understanding, this proposal is one kind of enhancement to measurements. If each measurement instance among multiple measurement instances in a single measurement report is reported with its own timestamp within a short measurement time window, it will help LMF to track and compensate the timing delay errors based on such enhancements, especially the timing delays related to time drifts. |

## TRP measurement enhancements

### Proposal 2-2 (merged with Proposal 2-1)

* + 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 Signallin 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. |
| OPPO | Support 2-2 if it is for the joint reporting of timing-based and angle-based measurement. Suggest to modify the proposa as below   * + Support a TRP to report multiple measurements of different types (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 ignallin and procedures |
| ZTE | Similar comments as proposal 2-1. |
| Lenovo,Motorola Mobility | Same response as in 2-2 |
| FL | Based on the comments, Discussion of proposal 2-2 is merged with Proposal 2-1. |

## Estimation of gNB Tx/Rx timing errors based on DL PRS measurements from TRPs

FL Comments

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

### Proposal 2-3

* Support the following mechanisms and Signalling 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 method  2, 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 side  3, 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 Signalling 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) |
| OPPO | Can we treat the TRP(s) measuring DL PRS as some reference UE although they use different protocols to communicate with LMF? Thus, we share the similar view as QC |
| ZTE | We support the FL’s proposal.  To vivo, LOS connection between TRP is not necessary. The propagation time in the air will be canceled, please refer to our contribution.  To Huawei’s concern, TRP may reserve some time for listening, so UE will not receive the PRS during the reserved time. Regarding the antenna down tilting of the TRP, we agree this would be a problem. But this would have less impact on timing measurement than angle measurement.  To Ericsson, the measurement can also use for monitoring timing errors.  Agree with QC’s proposal. The discussion should be aligned across all subagendas. |
| FL | At least 4 companies (vivo, Huawei, Ericsson, Apple) have the similar concern on the proposed enhancement, i.e., it requires a TRP to measure the DL PRS from another TRP, which is not supported in the current specification and TRP implementation. Thus, the proposed enhancement may have significant impact on the specification and TRP implementation.  Suggest further email discussion to see if the opponents can be to convinced to adopt the proposed enhancement. |
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## Mitigating UE/gNB Tx/Rx timing errors based on DL PRS measurements from reference UEs

FL Comments

UE/gNB TX/RX timing errors may be 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])

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 delays  2, 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 Signalling 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’. |
| Samsung | This proposal and together with above proposal 2-3 seem creating a “reference UE” and a “reference TRP”, respectively. Especially for the purpose of estimating the TRP side errors, so the question is that do we need both types of “reference”? Not sure how accurate of this “reference UE”, but I guess it should be no better than the fixed/planed located “reference TRP”.  Another aspect is that what the true spec impact here? A UE (whether its location is known or not) can always be triggred to do DL PRS measurement/report and/or UL SRS-pos transmission, maybe I missed some rules here so hope there could be some clarification. |
| OPPO | There may be two different approach use a reference UE  Approach 1:   * 1. determine the real position of the UE (non-3GPP)   2. transit the real positioning info to UE (non-3GPP)   3. UE does measurements (3GPP)   4. UE sends reports to LMF (3GPP)   5. LMF do the calculation (implementation, transparent to the spec)   Approach 2:   * 1. determine the real position of the UE (non-3GPP)   2. transit the real positioning info to LMF (non-3GPP)   3. UE does measurements (3GPP)   4. UE sends reporting to LMF (3GPP)   5. LMF do the calculation (implementation, transparent to the spec)   We think the proposal is aligned with Approach 1. The differences between the two approaches as below  1. Step 1.2 and 2.2. We think they all use non-3GPP mechanism  2. Step 1.4 need specification as UE need to report the real positioning info to LMF whereas Step 2.4 can reuse the current spec.  Thus, what’s the benefit of Approach 1 compared to Approach 2? Why cannot we use Approach 2 that has no spec impact. |
| ZTE | We have concerns about this. Firstly, We wonder whether this reference UE can move like a normal UE or just stays at a certain position. If it can move, then how does the gNB know its accurate location at different time? It’s hard to ensure that reference UE and normal UE are within the same coverage of multiple TRPs. If it’s fixed, the reference UE is just like another TRP. So, we think this can be merged into proposal 2-3, whether the reference can be a TRP or a UE can be discussed in following meetings. |
| LG | We have similar view with Ericsson. |
| Huawei/HiSilicon | To OPPO:  Our understanding is that 2.4 may be 3GPP compliant with the current specification, as first UE should not report its location along with the location. In addition, we think that the LPP session should only be instigated with the LCS request, in which case the calibration device may not have any corresponding LCS request, e.g. which entity is the location consumer? |
| Lenovo,Motorola Mobility | Support in principle, share Nokia’s view as to how to address the similar reference UE discussions in other AIs. |
| OPPO | Based on Huawei’s comment, I update the components of two approaches by adding the component “NW requests the reporting” ( the components are not listed to follow the real service procedures)  Approach 1:   * 1. determine the real position of the UE (non-3GPP)   2. transit the real positioning info to UE (non-3GPP)   3. UE does measurements (3GPP)   4. NW requests the reporting   5. UE sends reports to LMF (3GPP)   6. LMF do the calculation (implementation, transparent to the spec)   Approach 2:   * 1. determine the real position of the UE (non-3GPP)   2. transit the real positioning info to LMF (non-3GPP)   3. UE does measurements (3GPP)   4. NW requests the reporting   5. UE sends reporting to LMF (3GPP)   6. LMF do the calculation (implementation, transparent to the spec)   We think the proposal is aligned with Approach 1. The differences between the two approaches as below  1. Component 1.2 and 2.2. We think they all use non-3GPP mechanism  2. Component 1.5 need specification as UE need to report the real positioning info to LMF whereas Step 2.5 can reuse the current spec.  3. Component 1.4 and 2.4 is the same functionality, and they has the same impact on specification if there is any.  Thus, Approach 2 has no or less spec impact. |
| FL | My understanding is that in Rel-16 LMF may/can collect the information for the estimation and/or elimination of the gNB Rx/Tx timing delays from random positioning occasions triggered by LCS. But, Rel-16 does not support the mechanisms for LMF to explicitly request a UE to transmit SRS or receive DL PRS for the purpose of mitigating gNB Rx/Tx timing delays. We can further discuss the issue related to how to determine a UE is in a known location and what UE is qualified to be the reference UE etc. once we have the consensus to support the mechanisms.  For QC’s comment, I would suggest still having separate discussion of Proposal 2-3 and 2-4 even though they can be coverd in the same term of “reference device”. Proposal 2-3 requires a TRP to measure and report the DL PRS from another TRP, it has much larger impact on both TRP implementation and the signalling support (NPPa). Proposal 2-4 has basically no small impact on UE implementation, and small impact on the signalling. I would take the suggest of the wording changes from QC for the revision of the proposal.  For Nokia’s comment, I would suggest we start the discussion in this AI at least for the purpose of mitigating Rx/Tx timing errors. If there is any similar proposal in other AI, we can discuss the additional changes.  For ZTE’s comments, we assume there is no constraint on whether the UE is stationry or moving. It will be up to LMF’s implementation and algorithms on how to use the measurements from UE for mitigating the Rx/Tx timing errors. |

### Proposal 2-4 (Revision 1)

* Specify procedural and Signalling enhancements to enable a UE 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,

Comments

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| **Company** | **Comments** |
| Nokia/NSB | We support in principle this proposal. Also okay for us to change UE to (UE/TRP/node). We would also like to highlight the potential need for capability signalling for this type of device with known location. We are open to discussing those details later in the WI however. |
| ZTE | We would like to combine proposal 2-3 and 2-4 for discussion at this stage, the reference positioning entity can be UE or gNB. Additionally, we still have some concerns about the reference UE. The reasons are as follows:   1. If different UEs have different measurement error due to equipment differences, measurement error of the reference UE is not equal to that of the normal UE needed for positioning. Thus, new timing errors will be introduced rather than mitigated. 2. It’s hard to ensure that reference UE and normal UE are within the same coverage of multiple TRPs. 3. Compared with reference UE, a reference TRP may be more easy to implement. |
| vivo | We prefer to modify as follows   * Specify procedural and Signalling enhancements to enable a UE 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: reporting reference UE coordinate information to the LMF |
| Huawei/HiSilicon | We support this proposal, and OK to change UE to (UE/TRP/node) as well, which serves the baseline for further discussion. |
| OPPO | Some companies believe the solution based on reference TRP/UE can be based on implementation and has no spec impact. As shown by Approach 2 in our previous comment, it is possible to enable this functionality with spec change. Thus, it is premature to say we will specify something in this stage. Further discussions are needed |
| CATT | We support to introduce the reference UE/TRP in Rel-17. In GNSS domain, it is common to correct the positioning errors and provide high accuracy positioning services based on the reference station. The reference UE/TRP will play different roles for different positioning methods, e.g., timing delay error mitigation for time-based positioning method or antenna calibration for angle-based positioning method. |
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# Mitigation of Rx/TX timing delays

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

* (Huawei [R1-2100195](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100195.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100195.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100293.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100385.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100385.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100385.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100445.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100445.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100308.doc))Proposal 2:
  + Tx group delay needs to be sent to the receiver side.
* (Fraunhofer [R1-2101131](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101131.doc)) Proposal 1:
  + Enable Rx/Tx timing delays reporting dependent on the applied transmission/reception spatial filter.
* (Fraunhofer [R1-2101131](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101131.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101140.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100752.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100752.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100752.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101210.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101468.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101468.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101754.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101754.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101754.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100128.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100128.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100385.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100385.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100657.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101046.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101140.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101754.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100128.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100385.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100657.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101140.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100128.doc)) Proposal 7:
  + To reduce the impact of Tx/Rx timing delay on multi-RTT positioning method:
    - The UE may compensate the value of in reported Rx/Tx time difference by implementation
    - The TRP may compensate the value of in reported Rx/Tx time difference by implementation
* (Intel [R1-2100657](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100657.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100657.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101140.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101140.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101754.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101754.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

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| --- | --- |
| **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 1  One 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. |
| OPPO | Firstly, we suggest to restrict the terminologies only for discussion now. We cannot predict the exact wording for spec if the corresponding solution is agreed.  Adopt the following definitions of Tx/Rx timing error groups just for discussion:  ….  Secondly, more discussion is needed on the conditions where the time error can be regarded as the same. It is likely RAN4 should be involved |
| vivo2 | To QC: In SI, we have proposed clarifying the reason and scope of Rx/Tx Timing error. Unfortunately, there is no agreement or conclusion for it. But we think it was caused by the group delay between the Baseband unit and Radio Frequency unit and are generated per panel independently as the following agreement.   |  | | --- | | Agreement:  Optional: The UE/gNB RX and TX timing error, in FR1/FR2, can be modeled as a truncated Gaussian distribution with zero mean and standard deviation of T1 ns, with truncation of the distribution to the [-T2, T2] range, and with T2=2\*T1:   * T1: [X] ns for gNB and [Y] ns for UE * FFS: X, Y * Note: RX and TX timing errors are generated per panel independently * FFS: how the Rx and Tx timing errors are applied |   If “even within a single TXRU, there may be timing differences between the transmitted PRS resources”, we think it out of R17 scope. |
| ZTE | 1. Do not support the first bullet. We think that the granularity of dividing TRPs to different TEGs are too small. TRPs are assumed to calibrate the timing delays between different TEGs inside itself by implementation while UE may not have this capability. 2. Support the second bullet. A UE may have different RF chains and doesn’t have the capability to calibrate between different RF chains. |
| LG | We are supportive of the modified proposal for the purpose of the discussion, but we have a similar clarification question on whether this timing error includes sync error or not. |
| MTK | Our understanding is,  1, for different RF chain for transmission or receiving, we can’t assume that the delay is the same  2, for the same RF chain, the delay is still time varying due to temperature-dependent nature at RF part. This means we can’t assume the delay is always the same under same RF chain for transmission/receiving  3, UE may compensate its own RX timing delays, no matter using which panel for receiving. The residual error after compensation is a random variable which can’t be derived. Otherwise and similarly, we can derive white noise value and cancel it, then the channel coding is not needed anymore  Some feedback for QC’s explanation (thanks Alex).  For one RSTD measurement, it is to take the differential of two time of arrival measurements. We see the following conditions. For a UE,  1, If the two TOA measurements are conducted at the same time instance and by the same RF chain and same frequency layer, then RX side timing delay would be cancelled for this RSTD measurement  2, If the two TOA measurements are conducted at different time and by the same RF chain and same frequency layer, then RX side timing delay may not be cancelled perfectly for this RSTD measurement. We need to understand whether this is useful case, because DL-PRS is comb structure, which allows multiple TRPs to transmit at the same time. So UE can form the RSTD measurement based on the TRPs transmitting at the same time (same slot, different comb index). If UE reports this RSTD value to location server and notify that, the two TOA measurements are performed at different time instance, what the location server can do? Drop it? If location server would drop it, why UE sends such reporting? It waste uplink resource  3, If the two TOA measurements are conducted at the same time and by different RF chain, for example, different panels and same frequency layer, then RX side timing delay may not be cancelled perfectly for this RSTD measurement. For this case, UE may support simultaneous reception from two panels (with different QCL type-D), and this should be UE capability. Also, if UE reports this RSTD to location server, and also reports that the RSTD is derived by different TEG, then what the location server can do? The root cause should be, UE should avoid using different panels to receive for getting RSTD under higher accuracy requirement  4, If the two TOA measurments are conducted at the same time and by different RF chain, for example, using same panel and different frequency layer, the RX side timing delay may not be cancelled perfectly for this RSTD measurement. This is because the RF side timing delay could also be frequency dependent (nature of RLC filters in RF circuit). For this case, we wonder why higher accuracy positioning (especially for IIOT scenario) considers inter-freq measurement for positioning?  5, If the two TOA measurement are conducted at different time and by different RF chain, then RX side timing delay may not be cancelled perfectly for this RSTD measurement. And this case should be avoided for higher accuracy purpose  6, if one RSTD measurement using two TOA measurements at the same time, say T1, and by the same RF chain, and another RSTD measurement using other two TOA measurements at the same time, say T2, and by the same RF chain. T1 != T2, then both the two RSTD measurements are not impacted by RX side timing delay  So, we really doubt what the location server can do when UE reports a RSTD value in which the two TOA measurements are from 2 RX TEG  Therefore, we don't think RX TEG is so needed. |
| Huawei/HiSilicon | To MTK:  For case 3, our understanding is that it may be possible that different Rx/Tx chains at the UE may not have the simultaneous visibility/quality toward the same TRP. Identify the UE Rx/Tx TEG info may be helpful. This is applicable to both FR1 and FR2. |
| MTK | To HW:  UE’s panels may have different “visibility” due to cell phone time-varying orientation. Our point of view is, when forming a RSTD measurement, the two TOA measurements may need to be from the same panel for receiving.  We don't see the benefit that we form a RSTD measurement by the two TOA measurements from different panels for receiving. And then UE tells the location server that I do so. What location server can do after getting this message?  For a same pair of TRPs for transmission, UE may use different panels for measurement, each panel to derive its own RSTD measurement. UE can choose to report the RSTD measurement based on the receiving from the panel of good quality. This is UE implementation. We also want to understamd how it could be helpful if UE reports such panel information (or RX TEG) to location server? |
| FL | It is important for us to have the same undersytanding on whether there is a need to introduce the concept of “timing error group”, and whether to we need to have all of the four TEGs, namely TRP Tx TEG, TRP Rx TEG, UE Tx TEG, and UE Rx TEG. My suggestion is to use some online time to discuss it, so we will all in the same undersytanding. |

### Proposal 3-1 (Revision 1)

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

* 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.

Comments

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| --- | --- |
| **Company** | **Comments** |
| CATT | Support Proposal 3-1. In any case, we can discuss whether the concept of TEG should be introduced. For the timing delay error information in transmitting side (including UE transmitting SRS-Pos in UL-TDOA, or TRP transmitting DL-PRS in DL-TDOA, the Tx TEG look like necessary information, for LMF or UE to mitigate the timing delay error. Maybe we can firstly converge on this point, i.e., the necessity of UE Tx TEG and TRP Tx TEG. For the timing delay error information in transmitting side, RX TEG may be optional considering that the receiver maybe compensate the timing delay error when reporting the measurement results. So, our suggestion is to first discuss whether TX TEG needs to be introduced. |
| Nokia/NSB | First, thanks to the FL for the effort to mangage the difficult discussion. Overall we are okay to introduce such definition but as commented online we feel that this proposal is continuing to kick the can down the road by not defining what “Tx timing errors” means. It is clear from contributions and discussion that different companies have different understand of what is included in these timing errors. Perhaps as a way forward we could first agree to something which lists the options like the following (just draft version):  Proposal:  Timing Errors include:   * Option 1: Group delays * Option 2: Synchronization offset delays * Option 3: Phase Center offset delays * Option 4: Combination of 1+2. * Option 5: Combination of 1+3. * Option 6: Combination of 1+2+3.   From our side we support option 5 as we see this issue being most critical for multi-RTT where synchronization offset is already not a factor but we are open to other options as well. Companies could then study these different options leading up to RAN1#104-b. |
| FL | For NOK’s comment, the issue here is that depending on the understanding of the synchronization offset.  If the time synchronization error is the timing error at the TRP Tx antenna, then includes Option 1, gNB clock offset and Option 3. If the time synchronization error refers only to gNB clock error, then Option 2 may not be separable from Option 1 and Option 3. Please also see my comment in the following table. |
| ZTE | As we commented in GTW session, the definition of timing errors should be clarified and TEGs at UE side should be considered first.   1. the TRP is assumed to have the capability to calibrate timing errors between different RF chains, which is kind of an implementation work. 2. At UE side, some UEs may have different RF chains and low capability, different RF chains cannot calibrated with each other. In this situation, UE may request TRPs to send PRSs towards RF chain 1 or RF chain 2, UE can transmit through RF chain 1 or RF chain 2, and the RF chain information(TEG information) should be defined so that LMF can combine the schemes with the same UE TEG, e.g. DL-TDOA+UL-TDOA. |
| MTK | Okay, let me use the following figure to discuss, and also leverage Nokia’s proposal in above    1, in SI, we seem to consider the group delay between antenna to ADC, and the delay between DAC to antenna, as the TX timing delay and RX timing delay respectively. The group delay is mainly induced by the RLC filters of RF circuit  2, In the beginning we think that if we use “timing error” here, it should be a residual (and differential) value between an unknown group delay value and the estimated value. If we don't estimate it, then the timing error would represent the whole unknown group delay value. Now it seems that it is open to consider more impairments. We illustrate in below  3, In the figure, as we look at the parameter “mu”, it is the time offset between TRP TX slot timing and UE RX slot timing (and we assume TRP TX slot timing and TRP RX slot timing are aligned). Normally “mu” would be related to TOF between UE and its serving cell. “mu” could be changed due to sampling clock offset so that UE have the symbol length not exactly equal to that of gNB. For example, gNB transmits with the elementary period Ts (32.55ns), but UE’s elementary period is (1+ 1e-6)\*Ts. gNB may also have the sampling clock offset. From UE perspective, “mu” can be adjusted dynamically at least based on using TRS to observe channel impulse response. We can also say that **“mu” is related to sampling clock offset difference between a TRP and a UE**. So it looks like **“mu” belongs to option 2.** It is one digital clock, even though there are multiple panels in UE side.  4, in the figure, as we look at the parameter “delta”, it is the time offset between 2 TRPs (synchronization error). “delta” could be time varying because each TRP has its own sampling clock offset. Therefore, **“delta” is related to sampling clock offset difference between 2 TRPs**. So it looks like **“delta” also belongs to option 2. “delta”** can be cancelled by combining the DL-RSTD and UL-RSTD measurements ( differential of 2 UL-RTOAs), or consider the combination of UE RX-TX time difference measurement and gNB RX-TX time difference measurement  5, phase center of antenna seems to have been considered under GNSS for higher accuracy. Frankly speaking, we are not quite familiar with it. It deserves more study so we are not objecting it  6, Our current position for timing error definition is to slightly modify option 1 and keep option 5 FFS,   * Option 1: Group delays   + Note: it is a differential value between an unknown group delay value and its estimated value. If it is not estimated, then the timing error represents the whole unknown group delay value * FFS on Option 5: Combination of 1+3 (Option 3: Phase Center offset delays).. |
| OPPO | Without the specific value of the margin, we cannot know whether it is feasible for TRP/UE to make any decision based on these definitions:  1. If the margin is a large value, it is useless  2. If the margin is a small value (e.g., ns level) , from RAN1 perspective, it is not clear whether TRP/UE can measure the timing difference with sufficient accuracy. We should consult RAN4 on this issue.  If RAN1 decides to introduce the concept of “timing error group”, it should be used for both UE and TRP.  p.s., I withdraw my second comment raised in GTW session. |

### Discussion of the definition of Tx/Rx Timing Errors

Based on the offline/online comments, some companies requested the clarification of the Tx/Rx timing errors as well as the relationship with gNB time synchronization before further discussion of TEGs:

1. The definition of Tx timing error and Rx timing error;
2. The relationship between gNB Tx timing error and gNB time synchronization;
3. The impact of Tx timing error and Rx timing error on the timing related measurements;

Interested companies are invited to present their views in the following table.

|  |  |
| --- | --- |
| **Company** | **Comments** |
| FL | 1. The definition of Tx timing error and Rx timing error;   First, the reference point of timing related measurements are defined at Tx/Rx antenna (or antenna connector).  The true TOA is the time when a signal arrives at the Rx antenna.  The measured TOA is the time that the estimated (observed) TOA of the signal at the Rx antenna in BB processing  Rx timing error = (the estimated TOA) – (the true TOA)  Rx timing error is impacted by the Rx RF chain delays if not fully compensated and receiver internal clock offset.  Different Rx RF chains/panels may have different RF delays.  The real TOD is the time when a signal departures from the Tx antenna.  The calculated TOD is the time of the calculated TOD of the signal at the Tx antenna in BB processing  Tx timing error = (the real TOD) - (the calculated TOD)  Tx timing error is impacted by the Tx RF chain delays if not fully compensated and also transmitter internal clock offset.  Different Tx RF chains/panels may have different RF delays.   1. The relationship between gNB Tx/Rx timing error and gNB timing synchronization error   Network Tx time synchronization requirements are defined at the TRP Tx antennas. If a network is precisely time synchronized, then the DL PRS signals leaves TRP Tx antenna at the same time. Tx timing errors can be seen as zero. Thus, the estimation and calibration of the TRP timing errors equals to the estimation and calibration of the TRP synchronization errors.  For TRP Rx timing, there is so far, to my knowledge, no time synchronization requirements, although to support UL TDOA, the network needs to implement TRP Rx time synchronization.   1. The impact of Tx timing error and Rx timing error on the timing related measurements   DL RSTD measurement accuracy is impacted by difference of TRP Tx timing errors and UE Rx timing error;  UL RTOA measurement accuracy is impacted by UE Tx timing error and TRP Rx timing error;  UE Rx-Tx time difference measurement accuracy is impacted by UE Tx timing error and UE Rx timing error;  gNB Rx-Tx time difference measurement accuracy is impacted by TRP Tx timing error and TRP Rx timing error; |
| MTK | Our comments in above may also apply here |
| vivo | Maybe “doesn’t” is missing in the following part  For TRP Rx timing, there is so far, to my knowledge, no time synchronization requirements, although to support UL TDOA, the network doesn’t need to implement TRP Rx time synchronization. |
| Huawei/HiSilicon | We suggest to have the following clarification.  1. Clarification #1: TEG is the concept to differentiate something INTERNAL for a node (TRP/UE), which means different nodes should naturally be regarded as different TEGs, e.g. different TRP already belongs to different TEGs, and a TRP and a UE belongs different TEGs.  2. Clarification #2: The necessity to enable the TEG concept for a node, replies on that the node has at least two “TEGs” for a single link direction.  3. Clarification #3: Different TEGs can be collocated.  4. Clarification #4: TEGs within a node can be implicit, e.g. different positioning frequency layers on different bands may belong to different TEGs for both TRP and UE.  5. Clarification #5: Inter-TEG error mitigation should include intra-node TEG error mitigation (e.g. different panel identification), and inter-node TEG error mitigation (Rx/Tx timing error calibration between TRPs).  Regarding clarification from Nokia, our understanding is that the purpose of introducing TEG is targeting group delay. Whether the method to mitigate the inter-TEG error can also be applied to phase offset and baseband clock error can be up to implementation.  For phase offset, we would like to understand whether the phase centre changes over the beam coefficient or a target direction. In our understanding, this may require beam-specific or UE/TRP specific ARP change. We understand the motivation here is for UE even using the same Tx/Rx with different beamformer or toward different TRP, the TDOA method cannot entirely cancel the offset.  Regarding the interpretation of the FL on the questions, it is aligned with our understand.  Regarding the comment that Rx TEG is not needed to define, our understanding is that it is only valid that if the same RS is received by the concerned Rx’s at the same time. However, this may not be the case due to blockage issue, especially at UE side. Even if the signal can be received by multiple Rx’s at the same time, we are not clear whether Rx group delay is comparable with the geographical distance between the Rx’s. |
| OPPO | 1) **Tx timing error:** From the perspective of positioning accuracy, it is more useful to consider the Tx timing dfferences between the transmissions of the different RS resource. Thus, it should include group delays, synchronization offset delays, phase Center offset delays and some other potential factors  **Rx timing error:** In addition to the factors pointed by FL, we would like to add one factor for UE: UE may adjust the Rx timing based on the SS/TRS of the serving cell.  2) It is difficult, if not impossible, to differentiate the impact of different factors (e.g., group delay, un-perfect synchronization) on the “timing delay” |
| FL | To vivo’s comments, for UL TDOA, the reference point of Rx time of RTOA is Rx antenna. Thus, my understanding is that the network needs support the Rx time synchronized for all TRPs.  For HW’s comments, “Clarification #1 ~ 5”, I basically share the same understanding.  For OPPO’s 1st comment: I share the same view that Tx timing error is associated with RS resources, e.g., one TRP Tx TEG may be associated with one or more DL PRS resources. For Rx timing error, it is unclear to me how adjustment of the Rx timing impact the Rx timing error. I assume the value of the time adjustment is known to the UE, and thus, should be compensated in the reported measurement. |
| CATT | We share the same views with FL. In Rel-16, all the time-based measurement, including RSTD, RTOA or Rx-Tx time difference, measured by UE or TRP between their antenna as defined in TS 38.215. Synchronization error may be integrated with the Tx timing delays together, and they can't be divided into two separate parts. |
| Huawei/HiSilicon | I am a bit confused by “UE may adjust the Rx timing based on the SS/TRS of the serving cell” raised by OPPO. Why would serving cell DL sync affect positioning? To my understanding, positioning can work without serving cell at all.  For TDOA based positioning, as long as the UE Rx timing error is common for the RSTD TRPs (likewise, the UE Tx timing error for the UL RTOA TRPs), they can be cancelled. This problem will raise if UE has two Rx chain (Tx chains) each associated with its independent error source, but we do not see why it is related to the DL timing of the serving cell.  There should be some clock drift at UE side, resulting in PRS Rx timing slightly deviated from one slot to another slot, but even 0.2 ppm clock will only deviate maximum 200ps for every 1ms, which should have very small impact on the accuracy if PRS reception is within two slots.  From our side, we see RSTD grouping based on UE Rx TEG and UL RTOA grouping based on UE Tx TEG a good feature. As for TRP side TEG, for indoor use case, we are OK to keep it on the table, but it needs further study on the use cases.  To CATT, in my understanding, synchronization error can be more easily mitigated than group delay error, e.g. using multi-RTT or DL-TDOA+UL-TDOA (differential multi-RTT). However, if the group delay error can somehow be mitigated using a method, synchronization error can also likely be mitigated. |

## 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 (closed)

* Support a TRP to provide the association information of Tx TEGs with DL PRS resources to LMF.
* FFS: details of signalling and procedures

Comments

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| **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. |
| OPPO | All the proposals in Section 3 are based on the reporting/indication of information of Tx/Rx TEGs. It is preferred to discuss as the first step that  1. whether / how Tx/Rx TEG is defined  2. In what conditions the reception/transmission can be regarded with the same Tx/Rx TEG  If we address the above issue, we can apply the agreement for each positioning methods directly with some potential modification. If we cannot agree on the above issues, it seems difficult to make progress for the proposes 3-x. |
| ZTE | We think that the granularity of dividing TRPs to different TEGs are too small. We agree with HW that all the DL PRS resource sets of a TRP should be corresponding to the same “TEG”,so multiple TEG within a TRP are not necessary. As for the second bullet, how to measure the Rx or Tx timing errors per TRP or Tx/Rx timing errors between TRPs needs further discussion. |
| LG | We are open to discuss the necessity of the first bullet, but we have the same view with other companies on the second bullet, which is not necessary. If the TRP knows the error terms, the TRP simply cancel it from the measurement. |
| FL | Based on the comments, most companies do not think it is necessary to have the 2nd bullet, but support to have the 1st bullet. Some companies also think there is no need to have the 1st bullet, which can be further dicussed after we discuss Proposal 3-1. |
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Proposal 3-2b (closed)

* 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-r16  RTD-InfoListPerFreqLayer-r16 ::= SEQUENCE (SIZE(1..nrMaxTRPsPerFreq-r16)) OF RTD-InfoElement-r16  RTD-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 understanding  1. 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. |
| ZTE | Similar view as comments on proposal 3-2a that, We think that the granularity of dividing TRPs to different TEGs are too small. |
| LG | Similar comment as Proposal 3-2a. |
| FL | Based on the comments, it seems it would be better for us to first discuss Proposal 3-2a and then further discuss Proposal 3-2b. |

### Proposal 3-2 (Revision 1)

Consider the following options for mitigating TRP Tx timing errors and/or UE Rx timing errors for DL TDOA:

* Option 1:
  + Support a TRP to provide the association information of DL PRS resources with Tx TEGs to LMF
* Option 2:
  + Support LMF to provide the association information of DL PRS resources with Tx TEGs to UE for UE-based positioning
* Option 3:
  + Support a TRP to provide the Tx timing errors per Tx TEG to LMF
* Option 4:
  + Support LMF to provide the Tx timing errors per TEG of TRP to a UE for UE-based positioning
* Option 5:
  + Support a UE to provide the association information of RSTD measurements with UE Rx TEG(s) to LMF when the UE reports the RSTD measurements to LMF
* FFS: details of signalling and procedures
* **Note**: Depending on the discussion results, none/one/multiple of above options may be adopted in Rel-17.

Comments

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| **Company** | **Comments** |
| vivo | Just like FL views (Different Tx RF chains/panels may have different RF delays.) in proposal 3-1. We can’t agree with this description like “Tx timing errors per TEG of TRP”.  We prefer to modify as follows to ensure that more solutions are not excluded  Consider the following options for mitigating TRP Tx timing errors and/or UE Rx timing errors for DL TDOA:   * Option 1:   + Support a TRP to provide the association information of DL PRS resources with Tx TEGs to LMF * Option 2:   + Support LMF to provide the association information of DL PRS resources with Tx TEGs to UE for UE-based positioning * Option 3:   + Support a TRP to provide the Tx timing errors or Tx timing errors difference ~~per Tx TEG~~of one or multiple TRP(s) to LMF * Option 4:   + Support LMF to provide the Tx timing errors or Tx timing errors difference ~~per Tx TEG~~of one or multiple TRP(s) ~~per TEG of TRP~~ to a UE for UE-based positioning * Option 5:   + Support a UE to provide the association information of RSTD measurements with UE Rx TEG(s) to LMF when the UE reports the RSTD measurements to LMF * FFS: details of signalling and procedures * FFS: TEG of a TRP * **Note**: Depending on the discussion results, none/one/multiple of above options may be adopted in Rel-17. |
| Huawei/HiSilicon | We failed to see the need for a node to ~~support~~ report its own timing error to a third party, which means that option 4 should ~~not~~ be excluded.  For others, currently we do not have preference over TEG at TRP side, as we do not think a single TRP is likely to have multiple TEGs for indoor environment, and even if so, we can split the TRP into multiple TRPs, but we are fine to currently include the options.  Regarding comments from revision from vivo, we are not clear why a TRP can provide Tx timing error difference of one (other) or multiple TRPs in Option 3, and we think existing RTD in UE-based assistance data already supports the modified Option 4. |
| CATT | Support. We prefer Option 1+2+3+4. Tx TEG in TRP should be reported to LMF(UE-assisted positioning) or UE(UE-based positioning), since Tx TEG in TRP is more important and Rx timing delay error may be compensated in UE side. |
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## 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

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| **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. |
| ZTE | Same views as proposal 3-2a and 3-2b. |
| LG | Simialr view as 3-2a. |
| FL | Proposal 3-3 is about the TRP Rx timing errors, which are not related to TRP time synchronization errors. Suggest further discussion on the proposal if we can agree to introduce the TRP Rx REGs. |
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### Proposal 3-3 (Revision 1)

Consider the following option(s) for mitigating UE Tx and TRP Rx timing errors for UL TDOA:

* Option 1:
  + Support a TRP to provide the association information of RTOA measurements with Rx TEGs to LMF when the TRP reports the RTOA measurements
* Option 2:
  + Support a UE to provide the association information of SRS for positioning resources with UE Tx TEG(s) to LMF for UL TDOA positioning.
* FFS: details of signalling and procedures
* **Note**: Depending on the discussion results, none/one/multiple of above options may be adopted in Rel-17.

Comments

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| --- | --- |
| **Company** | **Comments** |
| vivo | Same view as proposal 3-2, We can’t agree with this description like “ Rx TEG of TRP”. |
| Huawei/HiSilicon | Currently we do not have preference over TEG at TRP side, as we do not think a single TRP is likely to have multiple TEGs for indoor environment, and even if so, we can split the TRP into multiple TRPs, but we are fine to currently include the options. |
| CATT | Support. We prefer Option 2. Tx TEG in UE should be reported to LMF, since Tx TEG in UE is more important and Rx timing delay error may be compensated in TRP side. |
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## 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 (merged with Proposal 3-2)

* 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

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| **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. |
| ZTE | We are fine with the first bullet. A more reasonable way could be that, UE is restricted to transmit SRS with the same UE Tx TEG by implementation, because some UEs have only one RF chain to transmit. Suggest to remove the second bullet, the UE capability should be discussed in proposal 3-7.Additionally, SRS could be MIMO SRS. |
| LG | Support. We have similar view with QC. |
| FL | Based on the comments, most companies do not think it is necessary to have the 2nd bullet, but support to have the 1st bullet. We may further dicuss the 1st bullet if we can reach the consensus on the UE Tx TEG as shown in Proposal 3-1. |
|  |  |

FL comments

The discussion is merged to Section 3.2

## 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 (merged with Proposal 3-3)

* 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. |
| ZTE | Same view as comments in proposal 3-4. Additionally, UE may indicate in measurement report whether the same RF chain is used for different PRS receptions. |
| LG | We are OK with the first bullet. |
| MTK | For the first bullet: 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. 🡨 this is typo? Why UE reports UL measurement?  We gave detailed description on Proposal 3-1. For the example QC mentioned above, the below is our opinion,  2, If the two TOA measurements are conducted at different time and by the same RF chain and same frequency layer, then RX side timing delay may not be cancelled perfectly for this RSTD measurement. We need to understand whether this is useful case, because DL-PRS is comb structure, which allows multiple TRPs to transmit at the same time. So UE can form the RSTD measurement based on the TRPs transmitting at the same time (same slot, different comb index). If UE reports this RSTD value to location server and notify that, the two TOA measurements are performed at different time instance, what the location server can do? Drop it? If location server would drop it, why UE sends such reporting? It waste uplink resource  3, If the two TOA measurements are conducted at the same time and by different RF chain, for example, different panels and same frequency layer, then RX side timing delay may not be cancelled perfectly for this RSTD measurement. For this case, UE may support simultaneous reception from two panels (with different QCL type-D), and this should be UE capability. Also, if UE reports this RSTD to location server, and also reports that the RSTD is derived by different TEG, then what the location server can do? The root cause should be, UE should avoid using different panels to receive for getting RSTD under higher accuracy requirement |
| FL | Based on the comments, many companies do not think it is necessary to have the 2nd bullet, but supportive to have the 1st bullet. The proposal is revised to include only the 1st bullet. |

FL comments

The discussion is merged to Section 3.3.

## 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. |
| ZTE | Same comments as proposal 3-1, 3-2a and 3-4. additionally, we suggest to discuss section 3.1-3.5 first, then we can see whether we need further change to facilitate MRTT method. |
| FL | It seems companies have different views on whether to UE/TRP needs to report the information related to Rx/Tx “TEG”. Maybe we can modify the proposal to list the options of the enhancements for further discussion. |

### Proposal 3-6 (Revision 1)

Consider following options for mitigating UE/TRP Rx/Tx timing errors in Multi-RTT:

* Option 1:
  + Support UE to provide to LMF the association information of UE Rx-Tx time difference measurements with the UE Rx TEGs in the measurement report for multi-RTT positioning
* Option 2:
  + Support UE to provide the association information of UE Rx-Tx time difference measurements with UE Rx TEGs in the measurement report to LMF, and TRP to provide the association information of gNB Rx-Tx time difference measurements with TRP Rx TEGs in a measurement report to LMF for multi-RTT positioning
* FFS: details of signalling and procedures
* **Note**: Depending on the discussion results, none/one/multiple of above options may be adopted in Rel-17.

Comments

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| **Company** | **Comments** |
| vivo | Same view as proposal 3-2, We can’t agree with using this description like “ Rx TEG of TRP” in option. We agree with the FL’s online proposal, we can focus on one panel first especially for TRP. |
| Huawei/HiSilicon | Currently we do not have preference over TEG at TRP side, as we do think a single TRP is not likely to have multiple TEGs for indoor environment, and even if so, we can split the TRP into multiple TRPs, but we are fine to currently include the options. |
| CATT | Support. We think the TRP Rx TEGs or UE Rx TEGs can be reported to LMF together with gNB Rx-Tx time difference or UE Rx-Tx time difference. And it is FFS whether TRP Tx TEG or UE Tx TEGs also need to be reported to LMF. |

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

Submitted Proposals

* (ZTE [R1-2100293](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100293.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101754.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101754.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? |
| Samsung | One clarification question, so the purpose of the LS is to ask RAN4 whether a UE/TRP could measure (then compsensate) and/or calibrate the time errors by themselves, or with the methods we are discussing now in RAN1? |
| ZTE | Support the FL’s proposal |
| LG | Even if we are not sure that RAN4 can work on this, if this LS is to check the feasibility whether the UE and/or TRP can compensate/calibrate ofor both Rx and Tx timing dealys, we are fine. |

# Additional proposals

## Measurement Enhancements

Submitted Proposals

* (LGE [R1-2100708](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100708.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100708.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101468.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. |
| Samsung | Whether this reported timing adjustment is useful or not is dependent on whether gNB can detect the timing adjustment; ideally, yes, if UE Tx timing has a delta\_t, then the gNB receiving time can reflect the delta\_t as well, then it will be eliminated by the difference. However, in reality, whether the gNB detection on the sequence has good enough preciseness or granularity to fully reflect this delta\_t, since a few ns will create larger distance gap. |
| OPPO | For the first bullet, we don’t see the necessity to introduce a time window.  For the second bullet, why is it needed to couple a window for measurement and the reporting of Tx timing adjustment? On the other hand, UE will adjust the timing according to NW’s timing advance command. Does Option.1 intend to not follow the TA command of NW? |
| ZTE | Low priority issue. We should discuss high priority issues first. |
| LG | We are fine either option 1 or option 2. |

## Antenna array phase center offset

Submitted Proposals

* (Nokia [R1-2100548](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100548.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101131.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. |
| OPPO | Antenna array phase center offset is one of factors leading to the timing delay in gNB side. Usually, it is difficult to differentiate the time delay due to non-perfect synchronization, different RF chains or array phase centre offset. We think the solution to address group timing delay is also applicable for this case. |
| ZTE | Not really how this can be related to timing errors. In our understanding, the array phase center could be known to UE once antennas are mounted, so it’s up to UE’s implementation. And also compared with timing errors, this has small impact on positioning. |
| LG | Support for further study. We thinkthat this issue was not treated properly in the SI. |

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

Submitted Proposals

* (Ericsson [R1-2101754](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101754.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 |
| OPPO | Since there are some proposals in other sections related to this one, postpone the discussion until we have a clear view whether and how Tx timing error group is defined/indicated/reported |
| ZTE | Prefer not to discuss in this WI. |
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## Beam and delay group sweeping

Submitted Proposals

* (Ericsson [R1-2101754](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101754.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 |
| OPPO | If some proposal in other section(s) (e.g., Proposal 3-4) is agreed, no need to discuss this solution  On the other hand, as for the Tx timing delay at gNB, is similar sweeping suggest for PRS transmission? |
| ZTE | Low priority issue |
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# Others

Submitted Proposals

* (CAICT [R1-2100308](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100308.doc))Proposal 3:
  + Beam related accuracy and multipath accuracy enhancement need to be further considered.
* (TCL [R1-2100697](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100697.doc))Proposal 1:
  + Support Closed-loop power control for the transmission of SRS for positioning.
* (TCL [R1-2100697](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100697.doc))Proposal 2:
  + Support transmission of assistance information to UEs switching between positioning systems to reduce position acquisition delay.
* (Samsung [R1-2101210](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101210.doc)) Proposal 2:
  + Improving the TA granularity should be support for TA report in E-CID.
* (Samsung [R1-2101210](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101210.doc)) Proposal 3:
  + Positioning in RRC inactive state should be supported.
* (China Telecom [R1-2101527](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101527.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101527.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101527.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100128.doc) Enhancement of timing-based positioning by mitigating UE Rx/Tx and/or gNB Rx/Tx timing delays OPPO
2. [R1-2100195](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100195.doc) Enhancement to mitigate gNB and UE Rx/Tx timing error Huawei, HiSilicon
3. [R1-2100293](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100293.doc) Positioning accuracy improvement by mitigating timing delay ZTE
4. [R1-2100308](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100308.doc) Discussion on accuracy improvements of NR positioning enhancements CAICT
5. [R1-2100385](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100385.doc) Discussion on accuracy improvements by mitigating UE Rx/Tx and/or gNB Rx/Tx timing delays CATT
6. [R1-2100445](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100445.doc) Discussion on methods for RX/TX timing delay mitigating vivo
7. [R1-2100548](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100548.doc) Initial views on mitigating UE and gNB Rx/Tx timing errors Nokia, Nokia Shanghai Bell
8. [R1-2100657](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100657.doc) Mitigation of UE and gNB Tx/Rx timing errors Intel Corporation
9. [R1-2100697](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100697.doc) Positioning enhancement by UE Assistance TCL Communication Ltd.
10. [R1-2100708](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100708.doc) Discussion on accuracy improvement by mitigating UE Rx/Tx and gNB Rx/Tx timing delays LG Electronics
11. [R1-2100752](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2100752.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:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101046.doc) Discussion on gNB/UE Rx/Tx timing delay mitigation solutions CMCC
13. [R1-2101131](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101131.doc) On methods for Rx/Tx timing delays mitigation Fraunhofer IIS, Fraunhofer HHI
14. [R1-2101140](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101140.doc) The mitigation of  RX/TX timing delays for higher accuracy MediaTek Inc.
15. [R1-2101210](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101210.doc) Discussion on accuracy improvements on timing based positioning solutions Samsung
16. [R1-2101387](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101387.doc) Positioning accuracy enhancements under UE and/or gNB Tx/Rx timing errors Apple
17. [R1-2101468](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101468.doc) Enhancements on Timing Error Mitigations for improved Accuracy Qualcomm Incorporated
18. [R1-2101527](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101527.doc) NR positioning enhancements by mitigating timing delays China Telecom
19. [R1-2101754](file:///E:\1%20Meetings\RAN1\2021_01_TSGR_104e\Docs\R1-2101754.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.