**3GPP TSG RAN WG1 Meeting #106-e R1-xxxxxxx**

**E-meeting, August 16th – 27th, 2021**

**Agenda Item: 8.3.4**

**Source: Moderator (Huawei)**

**Title: Feature lead summary on propagation delay compensation enhancements**

**Document for: Discussion and Decision**

# Introduction

The revised IIoT / URLLC work item description for Rel-17 [1] has enhancements for time synchronization as one of its main objectives:

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| 1. Enhancements for support of time synchronization:
2. RAN impacts of SA2 work on uplink time synchronization for TSN, if any. [RAN2]
3. Propagation delay compensation enhancements (including mobility issues, if any). [RAN2, RAN1, RAN3, RAN4]
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This document summarizes the key issues discussed under agenda item 8.3.4 based on the views in [3][4][5][6][7][8][9][10][11][12][13][14], and aims to discuss a set of issues in RAN1#106-e. The agreements in past meetings are captured in the Appendix.

# Remaining issues on error components

There are several aspects which have impact on the timing accuracy between UE and gNB. In the previous meetings, we discussed the potential error components that would have impact on the time accuracy one by one, and achieved agreements on most of the error components as shown in the Appendix. One remaining issue is how to interpret the agreed value for BS transmit timing error.

## How to interpret the agreed value for BS transmit timing error

In RAN1#103-e, we have agreed to use 65 ns to represent the BS transmit timing error for the control-to-control scenario.

Agreements:

* Take 65 ns as the assumption of transmit timing error for evaluation of the overall time synchronization error for control-to-control.

In RAN1#104-e meeting, Nokia (R1-2100730) propose to clarify if this should be interpreted as a maximum (<) or a relative (±) value.

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| --- |
| Nokia R1-2100730The agreed number of 65ns originates from the TAE requirement from TS 38.104, where the TAE represents the relative maximum timing error between any two antenna ports (i.e. <65ns). So, our interpretation of the agreed value is to use <65ns which translates to ±32.5ns per gNB antenna port.**Proposal 1: The agreed 65ns value used to represent the BS frame transmission error should be interpreted as ±32.5ns to represent a single gNB antenna port frame transmission error for the control-to-control scenario.**  |

In RAN1#104-e meeting and RAN1#104b-e, the following was proposed based on inputs from companies with the corresponding status as below:

* ***errorBS,DL,TX (i.e. ±32.5 ns) is included in the equation for calculating the overall time synchronization for the control-to-control scenario.***
	+ **Support*:*** *CATT, Nokia/NSB, Vivo, ZTE, Intel, LG, Samsung, ETRI, Huawei/HiSilicon, MTK, ZTE*
	+ **Support ±65ns:** *OPPO (fine to follow the majority view for using 32.25ns if only one or two companies have concern)*
	+ **Strong concern:** *Ericsson, Qualcomm*
		- *65ns defined for TAE is used to represent BS transmit timing error due to lack of better standardized values, since it is expected that transmit timing error is approximated as ±65ns.*
		- *±65ns is a safer assumption because there is no guarantee for the correct DL Tx timing to stay at the middle of 65ns interval*
		- *The assumption for the previous agreements is ±65ns.*

In RAN1#106-e meeting, Nokia (R1-2106638) and vivo (R1-2106590) discuss this issue and propose ±32.5 ns.

**Feature lead:** this issue was already discussed in both RAN1#104-e meeting and RAN1#104b-e meeting, and unfortunately company positions keep no change and consensus cannot be achieved. It is expected that further email discussion won’t bring us anywhere, thus the issue will be considered as low priority for now, and later if necessary we can come back to this issue.

**Proposal 2.1-1: e*rrorBS,DL,TX* (i.e. ±32.5 ns) is included in the equation for calculating the overall time synchronization for the control-to-control scenario.**

# Evaluation on the achievable time synchronization accuracy over Uu interface in Rel-16

In order to evaluate whether any enhancements needed in Rel-17 to meet the requirement, we need the check the performance that can be achieved by Rel-16 mechanisms first.

The potential error components that will have impact on the time synchronization accuracy over Uu interface are as below:

* **BS transmit timing error (**:
	+ For control-to-control, it was agreed to use 65 ns for the evaluation.
	+ For smart grid, it was agreed to use 65ns or 200ns for the evaluation.
* **Downlink frame timing error ():**
	+ Based on the reply from RAN4, it is already included in Te
* **UE Initial transmit timing error (**Te**)** :
	+ The value defined in Table 7.1.2-1 for initial transmit timing error (Te) in TS 38.133



* **BS detecting error ()** :
	+ 100 ns
* **Asymmetry between downlink and uplink channel ()**:
	+ Not considered
* **TA indicating error ()**: Details as shown in section 3.2.3.3 in R1-2007068
	+ ±8\*64\*Tc/2μ
* **TA adjustment accuracy ()**:
	+ Not considered
* **Indication error**
	+ 5ns, it is already included in the network part budget.

## Equation to calculate the overall time synchronization error over Uu interface

In RAN1#104b-e meeting, the following 4 basic steps were made for better understanding how to get the equation to calculate the overall time synchronization error over Uu interface. It is common understanding that step 1 to step 3 are applied to both TA-based PDC and RTT-based PDC.

**Step 1**: gNB sends the reference time clock (i.e. *referenceTimeInfo-r16*) to UE, and the actual time clock at the UE side should be

* BS transmit timing error **for transmitting the RRC signaling containing the reference time clock**
* Downlink frame timing detection error **for receiving the RRC signaling contacting the reference time clock**



**Step 2**: When the UE receives *referenceTimeInfo-r16*, UE obtains indicated by *referenceTimeInfo-r16*. After UE does the propagation delay compensation, the estimated time clock at the UE side is

* DL propagation delay estimation error, e.g. for TA-based PDC. Note that details for is defined in step 4 below.

**Step 3**: The overall time synchronization error (i.e. the difference between the actual time clock in step 1 and the estimated time clock in step 2) is

**Step 4**: Discuss and determine error component(s) for DL propagation delay estimation (i.e. )

For TA-based PDC, the following working assumption were achieved in RAN1#104b-e:

Working assumption:



In RAN1#105-e meeting, RAN1 received the LS [15] from RAN4 to inform that downlink frame timing detection error is already included in UE transmit timing error (i.e. Te defined in section 7.1.2 in TS 38.133). Thus it is clear that , so the two alternatives in above WA can be updated as below:

* **Alt. 1**:

* **Alt. 2**:
	+ [Note: Alt.2 assumes that the time of PD estimation is close to the time of PD compensation, in which case the DL frame timing error and BS transmit timing error for propagation delay estimation is correlated to that for the transmission of RRC signaling carrying the reference time clock]

At this stage, I would recommend not to discuss and fight more on which alternative to choose, because the key question now is whether/how much it is feasible to reduce Te and TA indication granularity, which needs inputs from RAN4. For example, if based on the analysis from RAN4, Te and TA indication granularity cannot go down to meet the budget even with Alt.2 above, then there is no point to argue here.

## Overall time synchronization error over Uu interface in Rel-16

According to the LS from RAN2, the single Uu interface budget for control-to-control scenario and smart grid scenario are as shown below:

|  |  |
| --- | --- |
| **Scenario** | **Single Uu interface Budget** |
| Control-to-Control | ±145ns to ±275ns |
| Smart Grid | ±795ns to ±845ns |

In RAN1#104bis-e meeting, the following is agreed. Then it is clear that PDC based on existing Rel-15/Rel-16 TA procedure and associated granularity, with no enhancements in RAN1, is sufficient for smart grid, and RAN1 needs to further study and specify the feasible enhancement (if any with RAN1 spec impact) for propagation delay compensation for control-to-control scenario.

Agreements:

* Observation 1: Propagation delay compensation based on existing Rel-15/Rel-16 TA procedure and associated granularity, with no enhancements in RAN1, is sufficient for meeting the Uu interface synchronicity error budget in LS R2-2010837 for the smart grid scenario.
* Observation 2: RAN1 needs to further study and specify the feasible enhancement (if any with RAN1 spec impact) for propagation delay compensation for control-to-control scenario, in order to meet the synchronicity budget of Uu interface in LS R2-2010837.

Some papers submitted to RAN1#106-e discuss the overall time synchronization error over Uu interface in Rel-16 also. Since we already have the above two observations, there is no need to spend time on this aspect again.

# Potential enhancements for propagation delay compensation

In RAN1#102-e meeting, the following option 1 and option 2 are agreed for further study in RAN1.

* **Option 1**: TA-based propagation delay
	+ **Option 1a**: Propagation delay estimation based on legacy Timing advance (potentially with enhanced TA indication granularity).
	+ **Option 1b**: Propagation delay estimation based on timing advanced enhanced for time synchronization (as 1a but with updated RAN4 requirements to TA adjustment error and Te)
	+ **Option 1c:** Propagation delay estimation based on a new dedicated signaling with finer delay compensation granularity (Separated signaling from TA so that TA procedure is not affected)
* **Option 2**: RTT based delay compensation:
	+ Propagation delay estimation based on an RAN managed Rx-Tx procedure intended for time synchronization (FFS to expand or separate procedure/signaling to positioning).

## Common issues for enhancements for propagation delay compensation

There are some issues that are common for both RTT-based PDC and TA-based PDC.

**Issue 4.1-1: whether should be included in PD estimation errors?**

In RAN1#106-e meeting, Nokia (R1-2106638) propose to not include in PD estimation error. And ZTE (R1-2106738) propose to include in PD estimation error.

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| Nokia (R1-2106638)**Proposal 5: should only be accounted for in the SFN boundary estimation related errors and not in the PD estimation errors.**  |

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| ZTE (R1-2106738)***Proposal 2:*** *should be included in the DL propagation delay estimation error* |

**Feature lead:** In RAN1#104bis-e, we have already agreed a WA for two alternatives about the overall time synchronization error for TA based propagation delay compensation. Thus we don’t need to discuss whether should be included in PD estimation error or not. In addition, at this stage seems no point to argue on which alternative to choose, because the key question now is whether/how much it is feasible to reduce Te and TA indication granularity, which needs inputs from RAN4. For example, if based on the analysis from RAN4, Te and TA indication granularity cannot go down to meet the budget even with Alt.2 above, then there is no point to argue here.

## TA-based propagation delay compensation

This section will discuss some key issues for TA-based propagation delay compensation.

**Issue 4.2-1: Whether we need to use timing advance adjustment accuracy instead of Te for the evaluation of TA-based PDC?**

We already reached the following agreements below.

**RAN1#102-e**

Agreements:

The value defined in Table 7.1.2-1 for initial transmit timing error (Te) in TS 38.133 should be considered for evaluation of the time synchronization.

Agreements:

Timing advance adjustment accuracy defined in Table 7.3.2.2-1 in TS 38.133 is assumed for evaluation of the time synchronization.

**RAN1#103-e**

Agreements:

TA adjustment accuracy is not considered for the evaluation of time synchronization error.

**RAN1#104bis-e**

Agreement:

Take the following as the evaluation assumptions for both RTT-based PDC and TA-based PDC.

* The UE may acquire an up-to-date PD estimation after waking up from DRX. This implies that gNB may signal an update timing advance value or complete a Rx-Tx measurement procedure.
* *errorUE,DL,RX* is based on other signals (e.g. CSI-RS) instead of SSB.
* *errorBS, UL,RX* is based on other uplink signals instead of contention based PRACH, e.g. SRS.
* Further study and specify new procedure/signaling (if necessary) to ensure that the PD estimation can be acquired after DRX for the adopted PDC method.

In RAN1#106-e meeting, Nokia (R1-2106638) propose to use TA adjustment error instead of Te for evaluation, because based on RAN1#104-bis agreement the UE may acquire an up-to-data PD estimation after waking up from DRX.

**Feature lead**: this is related to the interpretation about the RAN4 spec marked in yellow below. However, I would like to recommend not to discuss it for now, because similar as the above, the key question now is whether/how much it is feasible to reduce Te, TA indication granularity and TA adjustment accuracy, which needs inputs from RAN4. For example, if based on the analysis from RAN4 there is no way to improve the TA adjustment accuracy, it is expected difficult to meet the budget by TA-based PDC also.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 7.1.2.1 Gradual timing adjustmentRequirements in this section shall apply regardless of whether the reference cell is on a carrier frequency subject to CCA or not. When the transmission timing error between the UE and the reference timing exceeds ±Te then the UE is required to adjust its timing to within ±Te. The reference timing shall be  before the downlink timing of the reference cell. All adjustments made to the UE uplink timing shall follow these rules:1) The maximum amount of the magnitude of the timing change in one adjustment shall be Tq.2) The minimum aggregate adjustment rate shall be Tp per second.3) The maximum aggregate adjustment rate shall be Tq per 200 ms. where the maximum autonomous time adjustment step Tq and the aggregate adjustment rate Tp are specified in Table 7.1.2.1-1.Table 7.1.2.1-1: Tq Maximum Autonomous Time Adjustment Step and Tp Minimum Aggregate Adjustment rate

|  |  |  |  |
| --- | --- | --- | --- |
| Frequency Range | SCS of uplink signals (kHz) | Tq | Tp  |
| 1 | 15 | 5.5\*64\*Tc | 5.5\*64\*Tc |
|  | 30 | 5.5\*64\*Tc | 5.5\*64\*Tc |
|  | 60 | 5.5\*64\*Tc | 5.5\*64\*Tc |
| 2 | 60 | 2.5\*64\*Tc | 2.5\*64\*Tc |
|  | 120 | 2.5\*64\*Tc | 2.5\*64\*Tc |
| NOTE: Tc is the basic timing unit defined in TS 38.211 [6] |

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**Issue 4.2-2: Required reduced Te and/or TA indication granularity for TA-based PDC**

Based on the discussion in previous meeting, it seems common understanding that option 1a itself cannot meet the requirement anyway even enhanced TA indication granularity is introduced. However, there are different views on whether combination of option 1a + option 1b or option 1c can meet the requirement or not, which would depend on how much Te and/or TA command indication granularity can be reduced, which are up to RAN4 though. Therefore, RAN1 needs to provide the required reduced Te and/or TA indication granularity needed to RAN4, then RAN4 can further evaluate whether/how it is feasible to achieve those reduced value for Te and/or TA command indication granularity.

Based on the contribution submitted to RAN1#106-e meeting, the reduced Te and/or TA indication granularity is summarized as shown in Table 4.2-1 below. For convenience, the two alternatives achieved based on the working assumption in RAN1#104bis and the LS reply from RAN4 as discussed in section 3.1 are copied here.

* **Alt. 1**:

* **Alt. 2-1**:
* **Alt. 2-2**:

Note that evaluations not using the alternatives in the working assumption are not included here in the table.

Table 4.2-1 Reduced Te and/or TA indication granularity needed for TA-based PDC to meet the requirement

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Source** | **SCS** | **Reduced Te** | **Reduced TA command indication granularity** | **overall synchronization error** | **Assumptions** |
| Intel(R1-2107587) | 15 kHz | (1/4)\* Te | (1/4)\* (16\*64\*Tc/2μ) | 328 | Equation Alt. 1 with 65 ns for  |
| 30 kHz | (1/4)\* Te | (1/4)\* (16\*64\*Tc/2μ) | 295 | Equation Alt. 1 with 65 ns for  |
| Huawei(R1-2107678) | 15 kHz | (0.1)\*Te | (1/16)\* (16\*64\*Tc/2μ) | 275 | Equation Alt. 1 with 65 ns for  |
| 30 kHz | (0.1)\*Te | (1/16)\* (16\*64\*Tc/2μ) | 265 |
| OPPO(R1-2107276) | 15 kHz | No change | No change | 573 | Equation Alt. 1 with 65 ns for  |
| CATT(R1-2106966) | 15 kHz | No change | No change | 813.75 | Equation Alt.1 with 32.5 ns for  |
| 30 kHz | No change | No change | 553.75 |
|  |
| Huawei(R1-2107678) | 15 kHz | (0.78)\*Te | (1/16)\* (16\*64\*Tc/2μ) | 275 | Equation Alt.2-1 with 65 ns for  |
| 30 kHz | (0.78)\*Te | (1/16)\* (16\*64\*Tc/2μ) | 220 |
| Intel(R1-2107587) | 15 kHz | (1/4)\* Te | (1/4)\* (16\*64\*Tc/2μ) | 196 | Equation Alt.2-1 with 65 ns for  |
| 30 kHz | (1/4)\* Te | (1/4)\* (16\*64\*Tc/2μ) | 164 |
| OPPO(R1-2107276) | 15 kHz | No change | No change | 441 | Equation Alt.2-1 with 65 ns for  |
| Qualcomm(R1-2107340) | 15 kHz | No change | No change | 546 | Equation Alt.2-1 with 65 ns for  |
| Vivo(R1-2106590) | 15 kHz | (4/5)\* Te: 312 ns | (1/4)\* (16\*64\*Tc/2μ): 65 ns | 271 | Equation Alt.2-1 with 32.5 ns for *Note: Alt.2-1 with 32.5 is equal to Alt.2-2 with 65* |
| 30 kHz | No change: 260 ns | (3/4)\* (16\*64\*Tc/2μ): 97.5 ns | 264 |
| CATT(R1-2106966) | 15 kHz | No change | No change | 407.5 | Equation Alt.2-1 with 32.5 ns for *Note: Alt.2-1 with 32.5 is equal to Alt.2-2 with 65* |
| 30 kHz | No change | No change | 277.5 |
|  |
| ZTE(R1-2106738) | 15 kHz | (1/2)\* Te | (1/2)\* (16\*64\*Tc/2μ) | 245 | Equation Alt.2-2 with 65 ns for *Note: Alt.2-1 with 32.5 is equal to Alt.2-2 with 65* |
| 30 kHz | No change | No change | 277.5 |
| Huawei(R1-2107678) | 15 kHz | (0.94)\*Te | (1/16)\* (16\*64\*Tc/2μ) | 274 | Equation Alt.2-2 with 65 ns for  |
| 30kHz | (0.94)\*Te | (1/16)\* (16\*64\*Tc/2μ) | 209 |
| OPPO(R1-2107276) | 15 kHz | No change | No change | 408 | Equation Alt.2-2 with 65 ns for  |

Based on the above table, it can be seen that if Te and/or TA command indication granularity can be reduced, there is some chance that TA-based PDC can meet the budget for control-to-control scenarios, of course depending on how much Te and TA command indication granularity can be reduced, which needs inputs from RAN4.

Based on the equations in Alt.1 & Alt.2 in the working assumption, the following table 4.2-2 can be achieved.

Table 4.2-2 Sum of Te and error from TA indication granularity for TA-based PDC to meet the single Uu interface budget

|  |  |
| --- | --- |
|  |  |
| ±275 ns single Uu interface budget | ±145 ns single Uu interface budget |
| Equation Alt. 1 | ~55 nse.g. (1/10)\*Te + (1/2)\*(1/16)\* (16\*64\*Tc/2μ) | N/A |
| Equation Alt. 2-1 | ~320 nse.g. (4/5)\*Te + (1/2)\*(1/16)\* (16\*64\*Tc/2μ) | ~60 nse.g. (1/10)\*Te + (1/2)\*(1/16)\* (16\*64\*Tc/2μ) |
| Equation Alt. 2-2 | ~385 nse.g. (9/10)\*Te + (1/2)\*(1/16)\* (16\*64\*Tc/2μ) | ~125 nse.g. (1/4)\*Te + (1/2)\*(1/16)\* (16\*64\*Tc/2μ) |

Note that (1/2)\*(1/16)\* (16\*64\*Tc/2μ) is used here for because it is assumed that at least the existing work in Release-16 for IAB for Timing Delta MAC CE can be reused, which can achieve 64\*Tc for FR1 for the indicating granularity.

### First round discussion for issue 4.2-2

For TA-based PDC, we really need to send LS to RAN4. Hopefully all can be constructive and let’s work together to get the LS out. If ideally we can get the LS back in time, then still there is chance for us to complete TA-based PDC in Rel-17, though indeed it is expected very challenging.

**Proposal 4.2-1: Send LS to RAN4 to ask for feedback on the following questions:**

* **Question 1**: Is it feasible to assume a smaller value than the current Te for the use of propagation delay compensation, assuming the same definition of Te in the current RAN4 specification or new definition/procedure? If the answer is yes, please also provide feedback on how much it can be reduced **at most**, e.g., some value in the range of [(1/10) \* Te, (9/10) \* Te].
* **Question 2**: Is it feasible to introduce enhanced TA command indication granularity and enhanced TA estimation accuracy? If the answer is yes, please also provide feedback on how much it can be reduced **at most**, e.g. reduced to (1/16)\* (16\*64\*Tc/2μ) for enhanced TA command indication granularity.
* Note : The alternatives in the working assumption achieved in RAN1#104bis-e together with the examples in Table 4.2-2 will be included in the LS to give some background for RAN4

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| --- | --- |
| *Company* | *View* |
| **Feature lead** | 1. As defined in Table 7.1.2-1 in TS 38.133 below, the existing Te is given based on SSB. It is expected that if some new reference signal, e.g. TRS, can be used then it is possible to achieve smaller value of Te, since wider bandwidth is available for TRS. Table 7.1.2-1: Te Timing Error Limit

|  |  |  |  |
| --- | --- | --- | --- |
| Frequency Range | SCS of SSB signals (kHz) | SCS of uplink signals (kHz) | Te |
| 1 | 15 | 15 | 12\*64\*Tc |
| 30 | 10\*64\*Tc |
| 60 | 10\*64\*Tc |
| 30 | 15 | 8\*64\*Tc |
| 30 | 8\*64\*Tc |
| 60 | 7\*64\*Tc |
| 2 | 120 | 60 | 3.5\*64\*Tc |
| 120 | 3.5\*64\*Tc |
| 240 | 60 | 3\*64\*Tc |
| 120 | 3\*64\*Tc |
| Note 1: Tc is the basic timing unit defined in TS 38.211 [6] |

 |
| CATT | We are fine with FL proposal. |
| Ericsson | We do not object to sending LS to RAN4 to ask for potential enhancements of Te and TA command indication. However, the questions phrased above are confusing.For Question 1, based on the RAN4 reasoning that led to the standardized values of Te (e.g., R4-1711514 Qualcomm, R4-1713648 Ericsson), Te value is obtained by adding some margin to the minimum DL frame timing detection error. The minimum DL frame timing detection error (without any margin) is inverse of the DL BW of the signals used for timing estimation. For Te, SSB is used as DL signal for timing estimation. Thus, if Te is to be reduced, typically a DL signal with wider bandwidth than SSB is expected. But “assuming the same definition of Te” means that RAN4 should estimate the possible reduced value of Te,new based on SSB as before. Thus, clarification text can be added to Question 1: “RAN4 can take the following assumptions: Existing conditions in Te requirement applies, including: “The UE shall meet the Te requirement for an initial transmission provided that at least one SSB is available at the UE during the last 160 ms.” [38.133].”Feature lead>> Update the proposal accordingly. For the sentence “The UE shall meet the Te requirement for an initial transmission provided that at least one SSB is available at the UE during the last 160 ms.”, I think it should be included in the existing conditions, thus no need to specifically spell it out. For Question 2, the assumptions for potentially reduced TA command granularity should be clarified. Currently, the TA command granularity (e.g., ±260 ns (= ±8\*64\*Tc) for SCS=15 kHz, ±130 ns (±4\*64\*Tc) for SCS=30kHz, etc) correspond to the time error tolerance of PRACH detection (e.g., 520 ns and 260ns for SCS=15 kHz and 30 kHz, respectively), see Table 8.4.2.1-1 of 38.104. If RAN4 is asked to check potentially reduced TA command granularity, it should be clarified if existing PRACH is assumed, or a new PRACH of wider bandwidth can be introduced for time sync purpose. It is noted that wider bandwidth PRACH was adopted for NR-U, i.e., length 571 and length 1151 PRACH sequence for unlicensed band). Thus clarification text can be added to Question 2: “Exiting definition of Timing Advance Command MAC CE (not “Absolute Timing Advance Command MAC CE”) is assumed, where the timing advance command is contained in Random Access Response. If a PRACH of wider bandwidth is needed for the gNB to achieve the reduced TA command granularity, please provide info on the corresponding PRACH that UE should use.” Feature lead>> I think the above clarification is mainly on TA adjustment accuracy. After further thinking, I think we can remove TA adjustment accuracy for now, since the main point now is whether/how much to reduce Te and TA indication granularity. In addition, I still add something to make it more clear the reference for the exact valueFor both Question 1 and 2: It should also be clarified that RAN1 are interested in SCS={15, 30} kHz. Thus: “Both SCS15 kHz and 30 kHz are assumed for both control-to-control and smart grid for evaluation of the time synchronization (RAN1#102e agreement).”Feature lead>> Update accordingly. |
| Nokia, NSB | Support.We would have preferred to apply Recommendation 3 to ensure that RAN1 can select a PDC method timely for RAN2 to finish the PDC framework for R17. But it seems that pursuing enhancements to legacy TA is still having significant support in RAN1, hence an LS is needed to clarify the feasibility.An enhancement to TA requirements would not come without implications to e.g. DL and UL reference signal bandwidth associated to the requirement, so we would propose that the LS also asks RAN4 on the assumptions related to that.Feature lead>> Agree, but I guess ok to update a little bit to make it clearer to RAN4 and also address concern from companies.  |
| ZTE | We are fine with the proposal.BTW, there is no further discussion on the two alternatives for TA-based solution, e.g. further evaluation or something. Is the FL intention that RAN1 will further discuss TA-based solution only after receiving the reply LS from RAN4 if this LS is approved?Feature lead>> The high priority now is to send the LS to RAN4 for TA-based PDC for now. Without input from RAN4, it seems further discussion will not bring us anywhere. However, we can see the situation later to see if anything independent of the inputs from RAN4 can be discussed.  |
| Vivo | We are fine with FL proposal. |
| HW/HiSi | Support the proposal |
| LG | Support the proposal |
| Qualcomm | We do not support this proposal. We prefer a separate and clear design for PDC with no touching on the existing TA solution. |

### Second round discussion for issue 4.2-2

Based on the inputs in section 4.2.1, the proposal is revised as below. **Please all companies check the reply from me in section 4.2.1 to understand the reason to make the change**.

**Revised Proposal 4.2-1: Send LS to RAN4 to ask for feedback on the following questions:**

* **Question 1**: Is it feasible to assume a smaller value than the current Te for the use of propagation delay compensation, assuming the existing conditions in TS 38.133 for Te requirement or new conditions (e.g. using TRS instead of SSB)? If the answer is yes, please also provide feedback on how much it can be reduced **at most**, e.g., some value in the range of [(1/10) \* Te, (9/10) \* Te].
* **Question 2**: Is it feasible to introduce enhanced TA command indication granularity? If the answer is yes, please also provide feedback on how much it can be reduced **at most**, e.g. reduced to (1/16)\* (16\*64\*Tc/2μ) similar as the granularity for Rel-16 IAB based on the Timing Delta MAC CE.
* Note: Both SCS15 kHz and 30 kHz are assumed for both control-to-control and smart grid for evaluation of the time synchronization (RAN1#102e agreement).
* Note : The alternatives in the working assumption achieved in RAN1#104bis-e together with the examples in Table 4.2-2 will be included in the LS to give some background for RAN4

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| --- | --- |
| *Company* | *View* |
| **Feature lead** | 1. As defined in Table 7.1.2-1 in TS 38.133 below, the existing Te is given based on SSB. It is expected that if some new reference signal, e.g. TRS, can be used then it is possible to achieve smaller value of Te, since wider bandwidth is available for TRS. Table 7.1.2-1: Te Timing Error Limit

|  |  |  |  |
| --- | --- | --- | --- |
| Frequency Range | SCS of SSB signals (kHz) | SCS of uplink signals (kHz) | Te |
| 1 | 15 | 15 | 12\*64\*Tc |
| 30 | 10\*64\*Tc |
| 60 | 10\*64\*Tc |
| 30 | 15 | 8\*64\*Tc |
| 30 | 8\*64\*Tc |
| 60 | 7\*64\*Tc |
| 2 | 120 | 60 | 3.5\*64\*Tc |
| 120 | 3.5\*64\*Tc |
| 240 | 60 | 3\*64\*Tc |
| 120 | 3\*64\*Tc |
| Note 1: Tc is the basic timing unit defined in TS 38.211 [6] |

 |
| Qualcomm | We do not support this proposal. We prefer a separate and clear design for PDC with no touching on the existing TA solution. |
| Intel | For Round 1 and Round 2, we would like to clarify that agreeing to send this LS should not pause discussion on RTT-based method. We think that the potential LS reply would be received quite late for RAN1 to take actions, regardless of the reply content.In summary, we agree to send this LS based on condition that RAN1 continues design of non-TA based PDC. |

## RTT based propagation delay compensation

For RTT based delay compensation, propagation delay estimation is based on an RAN managed Rx-Tx procedure intended for time synchronization.

**Issue 4.3-1: Equation to calculate the overall time synchronization error over Uu interface for RTT-based PDC?**

As discussed in section 3.1, step 1 to step 3 should be common for both RTT-based PDC and TA-based PDC, and the difference is the detailed equation for .

**Step 4a**: Discuss and determine error component(s) for DL propagation delay estimation (i.e. )

for RTT-based compensation.



For RTT based delay compensation, propagation delay estimation is based on the RAN managed Rx-Tx procedure. **Note that the ones highlight in Red below needs to be further discussed**.





* + is to reflect the error due to report granularity of Rx-Tx time difference
	+ and reflects the measurement inaccuracy of gNB Rx-Tx time difference, and the measurement inaccuracy of UE Rx-Tx time difference, respectively.
	+ is to reflect the error due to the granularity of propagation delay indication, **and it is applied only for gNB-based RTT, i.e. it is not needed for UE-based RTT**.

**Feature lead:** The views on the equation is very diverse as summarized in the table below based on the contributions submitted to RAN1#106-e, thus we have to discuss with the questions in section 4.3.1 to achieve common understanding one-by-one.

### First round & Second round discussion for issue 4.3-1

**Proposals not changed based on first round email discussion yet. Companies are encouraged to check the replies and provide your further comments if any.**

The first issue is whether to consider UE and BS transmit timing error. According to the definition for Rx – Tx time difference below, the reference point for transmit measurement is antenna connector as highlight in yellow below, it seems in this case and don’t need to be considered. However, companies view are needed before making any decision here.

Similarly, whether to include and also need to be discussed. Based on the definition highlight in blue, since it is defined by the first detected path, it seems and need to be considered. **However, the question is whether these two errors are already included in the measurement accuracy defined in RAN4**, if yes then there is no need to include these two errors separately again.

5.1.30 UE Rx – Tx time difference

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| --- | --- |
| **Definition** | The UE Rx – Tx time difference is defined as TUE-RX –TUE-TXWhere:TUE-RX is the UE received timing of downlink subframe #*i* from a Transmission Point (TP) [18], defined by the first detected path in time.TUE-TX is the UE transmit timing of uplink subframe #*j* that is closest in time to the subframe #i received from the TP.Multiple DL PRS resources can be used to determine the start of one subframe of the first arrival path of the TP.For frequency range 1, the reference point for TUE-RX measurement shall be the Rx antenna connector of the UE and the reference point for TUE-TX measurement shall be the Tx antenna connector of the UE. For frequency range 2, the reference point for TUE‑RX measurement shall be the Rx antenna of the UE and the reference point for TUE‑TX measurement shall be the Tx antenna of the UE. |
| **Applicable for** | RRC\_CONNECTED |

5.2.3 gNB Rx – Tx time difference

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| --- | --- |
| **Definition** | The gNB Rx – Tx time difference is defined as TgNB-RX –TgNB-TXWhere:TgNB-RX is the Transmission and Reception Point (TRP) [18] received timing of uplink subframe #*i* containing SRS associated with UE, defined by the first detected path in time.TgNB-TX is the TRP transmit timing of downlink subframe #*j* that is closest in time to the subframe #*i* received from the UE.Multiple SRS resources for positioning can be used to determine the start of one subframe containing SRS.The reference point for TgNB-RX shall be:- for type 1-C base station TS 38.104 [9]: the Rx antenna connector,- for type 1-O or 2-O base station TS 38.104 [9]: the Rx antenna (i.e. the centre location of the radiating region of the Rx antenna),- for type 1-H base station TS 38.104 [9]: the Rx Transceiver Array Boundary connector.The reference point for TgNB-TX shall be:- for type 1-C base station TS 38.104 [9]: the Tx antenna connector,- for type 1-O or 2-O base station TS 38.104 [9]: the Tx antenna (i.e. the centre location of the radiating region of the Tx antenna),- for type 1-H base station TS 38.104 [9]: the Tx Transceiver Array Boundary connector. |

**Question 4.3-1: Do you agree that there is no need to include and**  **for DL propagation delay estimation error for RTT-based PDC? Please provide your reason also.**

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| --- | --- |
| *Company* | *View* |
| **Feature lead** | According to the definition for Rx – Tx time difference above, the reference point for transmit measurement is antenna connector as highlight in yellow below, it seems in this case and don’t need to be considered.*Note that here is just to say there is no need to include these two errors for DL propagation delay estimation , for the overall synchronization error at least should still be considered as discussed in section 3.1.*  |
| CATT | Based on our formula derivation, and should be considered.Feature lead>> According to the definition in RAN4 spec, the reference point for TUE-RX measurement shall be the Rx antenna connector of the UE and the reference point for TUE-TX measurement shall be the Tx antenna connector of the UE. Therefore, for example should not be included for UE Rx-Tx time difference, since UE can exactly know the time that the UE transmits the uplink signal, it doesn't matter whether there is any error for the uplink transmit timing compared to the DL frame timing. Note that we define for TA-based PDC (i.e.) would also include the potential error of DL frame timing error as replied by RAN4. As to the potential transmit timing error introduced due to UE internal implementation, it is expected that these kind of errors will be included in the Rx-Tx time difference accuracy.  |
| Ericsson | We believe and (NOTE: not ) need to be considered, assuming the UE receives reference time clock (e.g., *referenceTimeInfo-r16*) and performs propagation delay compensation. That is, these error components are the timing error for receiving the DL signal carrying *referenceTimeInfo-r16*. They exist irrespective of which method is used to estimate PDC, since they are outside of PDC error.Feature lead>> As highlight in blue above in the first row, here is only for estimation of PD, not the overall synchronization error. I think the logic and proposal here is aligned with your proposals, you can tell that from proposal 4.3.1-1 below.  |
| Nokia, NSB | AgreeThe Rx-Tx measurement requires the gNB and UE to timestamp the exact time of transmission. On the other hand, the TX errors are to reflect applicability of UL transmission time based on an inaccurately applied TA (at the UE) and TAE at the gNB which does not affect the capability to timestamp the time of transmission. |
| ZTE | Even though the defined reference point for the measurment is antenna connector, it does not mean that we do not need to consider the transmitting time error for DL propagation delay estimation error. The transmitting time error leads to the transmitter does not know exactly the transmission time of the signal at the Tx antenna connecter. Therefore, they should be considered.Feature lead>> According to the definition in RAN4 spec, the reference point for TUE-RX measurement shall be the Rx antenna connector of the UE and the reference point for TUE-TX measurement shall be the Tx antenna connector of the UE. Therefore, for example should not be included for UE Rx-Tx time difference, since UE can exactly know the time that the UE transmits the uplink signal, it doesn't matter whether there is any error for the uplink transmit timing compared to the DL frame timing. Note that we define for TA-based PDC (i.e.) would also include the potential error of DL frame timing error as replied by RAN4. As to the potential transmit timing error introduced due to UE internal implementation, it is expected that these kind of errors will be included in the Rx-Tx time difference accuracy. |
| Vivo | For UE Rx-Tx time difference, should be included for DL propagation delay estimation error for RTT based PDC because the gNB DL transmit error was not taken into UE Rx-Tx time difference measurement accuracy requirements.Accordingly, for gNB Rx-Tx time difference, should be included for DL propagation delay estimation error for RTT based PDC because the UE uplink transmit error was not taken into gNB Rx-Tx time difference measurement accuracy requirements.Feature lead>> According to the definition in RAN4 spec, the reference point for TUE-RX measurement shall be the Rx antenna connector of the UE and the reference point for TUE-TX measurement shall be the Tx antenna connector of the UE. Therefore, for example should not be included for UE Rx-Tx time difference, since UE can exactly know the time that the UE transmits the uplink signal, it doesn't matter whether there is any error for the uplink transmit timing compared to the DL frame timing. Note that we define for TA-based PDC (i.e.) would also include the potential error of DL frame timing error as replied by RAN4. As to the potential transmit timing error introduced due to UE internal implementation, it is expected that these kind of errors will be included in the Rx-Tx time difference accuracy. |
| Hw/HiSi | Agree that there is no need to include and for the DL propagation delay estimation error. The reason is that the UE Rx-Tx time difference and the gNB Rx-Tx time difference as defined in TS38.215 are using the antenna connector as the reference point for UE-TX measurement and gNB-TX measurement. |
| LG | Support. We agree that there is no need to add separated error component since error components could be combined by setting reference point each other. Especially if error indication can be measured/assumed regardless of frame timing, that should be fine. |
| Qualcomm | As described in our contribution, and should be considered for total error. |
| Intel | We believe the fact that the measurements are defined using the antenna connector as a reference point does not lead to the assumption that the mentioned error components are not considered.The other question would be whether these error components can be eliminated by the UE and gNB when calculating RX-TX time difference, and here the answer would be ‘yes’. |

**Question 4.3-2: Do you agree that we only need to include one of the following two component combinations for DL propagation delay estimation error for RTT-based PDC? If yes, please provide which component combination you prefer and your reason.**

* + **Component combination 1**: +
	+ **Component combination 2:**  +, where and reflects the measurement inaccuracy of gNB Rx-Tx time difference, and the measurement inaccuracy of UE Rx-Tx time difference, respectively.

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| *Company* | *View* |
| **Feature lead**  | Based on the definition highlight in blue above for the time different definition in RAN4, since it is defined by the first detected path, it seems and need to be considered. However, the question is whether these two errors are already included in the measurement accuracy defined in RAN4, if yes then there is no need to include these two errors separately again.On the other hand, if we include and in the equation, then we may don’t need to consider and again. Note that RAN4 is discussing time difference definition for PRS for positioning, in theory RAN4 should define similar measurement accuracy for RTT-based PDC also. If and will be defined in RAN4 for RTT-based PDC, then it seems more accurate to use and since it may reflect other errors also in addition to and . |
| CATT | We prefer to include Component combination 1.:UE detecting error of downlink signal for RX timing at UE side*:gNB* detecting error of uplink signal for RX timing at gNB side |
| Ericsson | Both components need to be included, with modifications.* For component 1: as explained for Question 4.3-1, (NOTE: not ) and need to be considered, which is the timing error for receiving the DL signal carrying *referenceTimeInfo-r16*.
* For component 2, ( +)/2 is needed to reflect PDC error.

Feature lead>> Please check the reply to you under question 4.3-1. I think the logic and proposal here is aligned with your proposals, you can tell that from proposal 4.3.1-1 below.  |
| Nokia, NSB | Agree and prefer Component combination 1.As we see it, the difference between Component combination 1 and combination 2 is that component combination 2 aims to reuse existing RAN4 performance requirements whereas component combination 1 is generic and not associated with performance requirements (yet).Feature lead>> Correct. Though in the end RAN4 will still need to define the Rx-Tx time difference accuracy if some new RS will be introduced. But at least from evaluation perspective, the ones defined already for PRS can be used as the reference if necessary.  |
| ZTE | We think the component combination 1 together with the errors in Q4.3-1 should be included as explained above. In addition, the Rx-Tx time difference indication error should also be included as it should be delivered from one to another for the propagation delay determination. Feature lead>> Please check the reply to you for Q4.3-1.  |
| vivo | Both component combinations are needed at this stage. The and , which refers to gNB Rx-Tx time difference measurement accuracy and UE Rx-Tx time difference measurement accuracy defined by RAN4, may not include and completely.Feature lead>> In theory these should be included in the measurment accuracy. Companies are encouraged with your RAN4 colleagues internally to save some exchange time across working groups.  |
| HW/HiSi | We prefer to include Component combination 2.The reason is that for RTT-based PDC, the gNB and the UE need to measure the Rx – Tx time difference which is similar to measurements in positioning. Thus according to the definition of the UE/gNB Rx-Tx time difference, our understanding is that the measurement accuracy already includes and . |
| LG | We prefer combination 2. It is clearer to show what are considered in each error component. |
| Qualcomm | We prefer to consider both of the combinations |
| Intel | Both options look correct, under appropriate assumptions.For further discussion in RAN1 we can prioritize Combination 1. |

Some companies also mentioned that gNB eventually need to signal to UE about the propagation delay. Therefore, an additionally signal to indicate propagation delay cannot be avoided. The granularity of propagation delay indication will also affect the total error. As described above, this is only for gNB-based RTT PDC assuming gNB pre-compensation is not used. For UE-based RTT PDC, is not needed since no signalling needed to indicate the estimated propagation delay. Based on the discussion in previous meeting, gNB-based RTT may have RAN3 impact thus UE-based RTT seems better. However, it was concluded in previous meeting that whether to do gNB-based RTT or UE-based RTT depends on RAN2.

Though the overall equation would depend on the understanding for the above two questions, the following proposal is made as the starting point for RTT-based PDC.

**Proposal 4.3.1-1:Take one of the following two alternatives as the equation for evaluation of the overall time synchronization error for RTT-based propagation delay compensation:**

* **Alt. 1:**
	+ is to reflect the error due to report granularity of Rx-Tx time difference
	+ and reflects the measurement inaccuracy of gNB Rx-Tx time difference, and the measurement inaccuracy of UE Rx-Tx time difference, respectively.
* **Alt. 2:**
	+ is to reflect the error due to report granularity of Rx-Tx time difference

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| *Company* | *View* |
| **Feature lead**  | There are several other proposed equations from the contributions submitted in RAN1#106-e, however it looks to me that the two alternatives in the proposal here seems more reasonable. Please all double check step 1 to step 3 om section 3.1 and step 4a in section 4.3, to understand the logic of the proposal here before providing your views here.  |
| CATT | We proposes Alt.3 is as below:Feature lead>> Please check the replies to above questions, and then see if you will change your mind.  |
| Ericsson | Alt 1 |
| Nokia, NSB | Alt. 2From our understanding, the two are similar as the RxTx diff error is predominantly an Rx error. We prefer to keep the evaluation notation similar as to TA. We would also prefer not includingfollowing the same reasoning of TA-based Alt.2 equation.Feature lead>> Let’s address other issues first, and then if necessary we can add one more alternative not to include  corresponding to TA-based PDC.  |
| ZTE | This is related to the Q4.3-2 and also which alternative is selected for TA-based solution as the same equation should be used for fair comparison. Our preference is Feature lead>> Please check the replies to above questions, and then see if you will change your mind. |
| vivo | We suggest the following equation:Feature lead>> Please check the replies to above questions, and then see if you will change your mind. |
| HW/HiSi | We prefer Alt 1 |
| LG | Support Alt. 1 |
| Qualcomm | We support Alternative 1. |
| Intel | Alt.2, and we should also discuss the aspect of correlated / non-correlated error components for reference timing info delivery and propagation delay compensation.  |

**Issue 4.3-2: What reference signal to use for estimating Rx-Tx time difference for time synchronization?**

In RAN1#104bis-e meeting, the following is agreed with two FFS.

Agreement:

Existing DL reference signal(s) are used for Rx – Tx time difference estimation at UE side for RTT-based propagation delay compensation, if RTT-based propagation delay compensation is supported.

* FFS whether PRS can be used for UE Rx – Tx time difference estimation or not
* FFS which DL reference signal(s) to be used if/when PRS is not used

### First round & Second discussion for issue 4.3-2

**Original proposals not changed based on first round email discussion yet. Companies are encouraged to check the replies and provide your further comments if any.**

In RAN1#106-e meeting, Nokia (R1-2106638) and Huawei (R1-2107678) consider DL CSI-RS for tracking, and Samsung (R1-2106883) consider CSI-RS and SSB. It seems DL CSI-RS for tracking is a promising candidate. Therefore, I made the following tentative proposal for further discussion.

**Proposal 4.3.2-1:If RTT-based propagation delay compensation is supported, CSI-RS for tracking (TRS) is used for Rx – Tx time difference estimation at UE side, if PRS is not available.**

**Proposal 4.3.2-1-x:If RTT-based propagation delay compensation is supported, PRS is used for Rx – Tx time difference estimation at UE side, if PRS is available.**

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| *Company* | *View* |
| CATT | We want to clarify how UE estimates Rx – Tx time difference estimation at UE side based on only CSI-RS.Feature lead>> UE will do the measurement based on the TRS, and the corresponding measurement accuracy will be further discussed in RAN4 as the proposal in section 4.3.3. |
| Ericsson | While it is technically possible to use CSI-RS to achieve PDC accuracy similar to that of PRS, we prefer to prioritize PRS as DL signal, since RAN4 has conducted extensive investigation of UE *RxTxTimeDiff* accuracy using PRS. These can be easily inherited for time sync purpose. If RAN1 uses CSI-RS instead, then substantial investigation work is needed in both RAN1 and RAN4. This may not be feasible given the limited meeting time left.Feature lead>> The problem is that the support of PRS depends on the support of some positioning mechanism. Couple the support of RTT-based PDC with the support of some positioning procedure is not good. In addition, of course if PRS is available, it can be used. I can make another proposal for PRS also just to make it clearer.  |
| Nokia, NSB | Support.According our evaluations provided in our contribution, with the use of CSI-RS for tracking (TRS) to determine the DL timing, the DL RX error is low enough to achieve the strictest requirement from control-to-control even in multipath channel and using a DL bandwidth of 10MHz. Therefore, we support the proposal to use CSI-RS for Rx-Tx if PRS is not available or needed (up to gNB to configure the RS).Feature lead>> Agree. Thanks for the evaluation also.  |
| ZTE | We wonder if UL signal/RS is also needed for Rx-Tx time difference estimation at UE side. According to the definition above, it is understood the UL signal/RS is transmitted in uplink subframe #j.Feature lead>> According to the current RAN4 definition for UE Rx-Tx time difference measurement, only DL RS is considered. |
| vivo | Does it mean that a new procedure would be introduced for propagation delay estimation based on CSI-RS for Rx – Tx time difference estimation at UE side? The accuracy requirement based on CSI-RS for Rx – Tx time difference estimation needs evaluation, e.g. bandwidth, density period of CSI-RS.Feature lead>> Yes. However, it is expected that the work on PRS can be able to provide some reference which can make the work in RAN4 easier.  |
| Hw/HiSi | We are fine with the proposal. |
| Qualcomm | We are OK with the proposal |
| Intel | We support proposal 4.3.2-1, but not sure about 4.3.2-1-x. Usage of PRS may complicate the spec and UE implementation. PRS configurations are provided by LPP, and PDC procedure is targeted to be fully managed by gNB w/o relying on LPP. |

In addition, the UL RS for Rx-Tx time difference estimation at the gNB side needs to be discussed and defined also. In TS 38.215, gNB Rx-Rx time difference is defined based on SRS, it is straightforward to reuse the current mechanisms as much as possible. Therefore, I made the following tentative proposal for further discussion.

**Proposal 4.3.2-2:SRS is used** **for Rx – Tx time difference estimation at gNB side for RTT-based propagation delay compensation, if RTT-based propagation delay compensation is supported,.**

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| --- | --- |
| *Company* | *View* |
| CATT | We want to clarify how gNB estimates Rx – Tx time difference estimation by only SRS at gNB side.Feature lead>> gNB will do the measurement based on the SRS, and the corresponding measurement accuracy will be further discussed in RAN4. It is expected that the current measurement accuracy based on SRS defined for positioning can be reused as much as possible.  |
| Ericsson | Support. We agree that the existing gNB RxTxTimeDiff accuracy defined for SRS for positioning purpose can be easily reused for time sync purpose. |
| Nokia, NSB | Support |
| ZTE | Similar as the last question, we wonder whether DL signal/RS is also needed for Rx-Tx time difference estimation at gNB side. According to the definition above, it is understood the DL signal/RS is transmitted in downlink subframe #j.Feature lead>> According to the current RAN4 definition for gNB Rx-Tx time difference measurement, only SRS is considered.  |
| vivo | Support. |
| HW/HiSi | Support. |
| Qualcomm | Support |
| Intel | Support |

**Issue 4.3-3: general procedures related to RTT-based PDC**

Nokia (R1-2106638) proposes the Rx-Tx configuration and Rx-Tx measurement report as below.

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| --- |
| Nokia (R1-2106638)Proposal 8: The Rx-Tx configuration should contain:* At least one DL RS configuration (FFS which configurations to support)
* At least one UL RS configuration (FFS which configurations to support)
* A relation between DL RS and UL RS (FFS whether to reuse the existing definition from 38.215)

Proposal 9: The Rx-Tx measurement report provided from the gNB to the UE should include at least:* Rx-Tx measurement at fixed granularity (FFS which granularity)
* SRS-Resource-ID
 |

### First round discussion for issue 4.3-3

Based on the description for issue 4.3-2 above, I made the following tentative proposals for further discussion.

**Proposal 4.3.3-1:Support the following Rx-Tx configurations for RTT-based propagation delay compensation, if RTT-based propagation delay compensation is supported.**

* **At least one CSI-RS for tracking (TRS) configuration for Rx – Tx time difference estimation at UE side**
* **At least one SRS configuration for Rx – Tx time difference estimation at gNB side**

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| --- | --- |
| *Company* | *View* |
| CATT | See our comment on Proposal 4.3.2-1 and Proposal 4.3.2-2 Feature lead>> Please check replies above for Proposal 4.3.2-1 and Proposal 4.3.2-2.  |
| Ericsson | We are fine with the intention of the proposal. However, preferably PRS should be reused as the DL RS, not CSI-RS.Feature lead>> Please check replies above in section 4.3.2.  |
| Nokia, NSB | Support |
| ZTE | Does it mean a dediciated TRS/SRS configured for Rx-Tx time difference estimation for propagation delay compensation? Or TRS and SRS should be configured for a connected UE anyway and it is up to the UE implementation to select one of them for measurement.Feature lead>> We need some dedicated configuration, since it will have impact on the measurement accuracy. It seems difficult to leave it to implementation.  |
| Vivo | See our comment onProposal 4.3.2-1 Feature lead>> Please check replies above in section 4.3.2. |
| HW/HiSi | Support |
| Qualcomm | Agree |
| Intel | While we agree with the proposal, we want to understand more whether we may need more than one configuration for DL RS and UL RS |

**Proposal 4.3.3-2:If RTT-based propagation delay compensation is supported and performed at the UE side, the Rx-Tx measurement report provided from the gNB to the UE should include at least:**

* **Rx-Tx measurement at fixed granularity (FFS which granularity)**
* **SRS-Resource-ID**

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| *Company* | *View* |
| CATT | From our perspective, DL signal ID is also needed.Feature lead>> This is only for gNB Rx-Tx time different, thus no need to involve DL signal ID.  |
| Ericsson | This question depends on which entity performs PDC. The proposal above assumes that UE performs PDC, but RAN1 has agreed that it’s up to RAN2 to decide which entity to perform PDC.Feature lead>> Right. I updated the proposal to clarify. In general, it seems companies feel that UE based compensation is better due to no impact at RAN3.  |
| Nokia, NSB | Support |
| ZTE | We believe the DL RS ID should also be needed to indicate the RS for Rx-Tx measurement as pointed out by CATT. In addition, if the DL RS or the UL RS is periodic, we think the specific DL RS/UL RS that the network measures should also be indicated. Otherwise, the UE and the network may measure the different DL/UL RS, which leads to the obtained propagation delay is not as accurate as what we analyze here. Feature lead>> This is only for gNB Rx-Tx time different, thus no need to involve DL signal ID. |
| Vivo | Support |
| Qualcomm | Support |
| Intel | We are not sure if SRS-Resource-ID is always required. In many cases, the reported time difference can be directly associated with a prior SRS transmission, when SRS for PDC is explicitly provided. |

In addition, it is expected that RAN4 needs to define the Rx-Tx time difference measurement accuracy for DL CSI-RS used for Rx-Tx time difference measurement at the UE side. RAN4 is discussing the measurement accuracy for PRS with the current outcome as shown in the following table.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table 10.1.25.2-1: UE Rx-Tx time difference measurement accuracy in FR1 in AWGN

|  |  |
| --- | --- |
| Accuracy | Conditions |
| PRS Ês/Iot | Minimum PRS bandwidth | PRS SCS | PRS resource repetition Note 3 |  | IoNote 4 range |
| NR operating band groupsNote 2 | MinimumIoNote 1 | MaximumIo |
| TcNote 5 | dB | RB | kHz |  |  | dBm / SCSPRS | dBm/BW |
| **SCSPRS=15 kHz** | **SCSPRS=30 kHz** | **SCSPRS=60 kHz** |
| ± [78+δ] | -3 | ≥[24] | 15 | ≥[4] | TBD | TBD | TBD | TBD | TBD |
| ± [59+δ] | ≥[52] | ≥[1] | TBD | TBD | TBD | TBD | TBD |
| ± [30+δ] | >[104] | ≥[1] | TBD | TBD | TBD | TBD | TBD |
| TBD |  | ≥[24] | 30 | ≥[4] | TBD | TBD | TBD | TBD | TBD |
| ± [30+δ] |  | ≥[48] |  |  ≥[1] | TBD | TBD | TBD | TBD | TBD |
| ± [15+δ] |  | ≥[132] |  | ≥[1] | TBD | TBD | TBD | TBD | TBD |
| ± [29+δ] | ≥[24] | 60 | ≥[4] | TBD | TBD | TBD | TBD | TBD |
| ± [15+δ] |  | ≥ [64] |  | ≥[1] | TBD | TBD | TBD | TBD | TBD |
| ± [7+δ] |  | ≥ [132] |  | ≥[1] | TBD | TBD | TBD | TBD | TBD |
| ± [101+δ] | -13 | ≥[24] | 15 | ≥[4] | TBD | TBD | TBD | TBD | TBD |
| ± [75+δ] | ≥[52] | ≥[1] | TBD | TBD | TBD | TBD | TBD |
| ± [39+δ] | >[104] | ≥[1] | TBD | TBD | TBD | TBD | TBD |
| TBD |  | ≥[24] | 30 | ≥[4] | TBD | TBD | TBD | TBD | TBD |
| ± [37+δ] |  | ≥[48] |  | ≥[1] | TBD | TBD | TBD | TBD | TBD |
| ± [16+δ] |  | ≥[132] |  | ≥[1] | TBD | TBD | TBD | TBD | TBD |
| ± [36+δ] | ≥[24] | 60 | ≥[4] | TBD | TBD | TBD | TBD | TBD |
| ± [16+δ] |  | ≥ [64] |  | ≥[1] | TBD | TBD | TBD | TBD | TBD |
| ± [8+δ] |  | ≥ [132] |  | ≥[1] | TBD | TBD | TBD | TBD | TBD |
| NOTE 1: This minimum Io condition is expressed as the average Io per RE over all REs in an OFDM symbol.NOTE 2: NR operating band groups are as defined in Section 3.5.NOTE 3: are configured by higher layer parameter *dl-PRS-ResourceRepetitionFactor, dl-PRS-NumSymbols and dl-PRS-CombSizeN*defined in TS 37.355 [34].NOTE 4: The Io is defined in PRS slots. The same Io range applies to PRS and non-PRS symbols. Io levels are different in PRS and non-PRS symbols within the same slot.NOTE 5: Tc is the basic timing unit defined in TS 38.211 [6]. |

Table 10.1.25.2-2: UE Rx-Tx time difference measurement accuracy in FR1 in fading

|  |  |
| --- | --- |
| Accuracy | Conditions |
| PRS Ês/Iot | Minimum PRS bandwidth | PRS SCS | PRS resource repetition Note 3 |  | IoNote 4 range |
| NR operating band groupsNote 2 | MinimumIoNote 1 | MaximumIo |
| TcNote 5 | dB | RB | kHz |  |  | dBm / SCSPRS | dBm/BW |
| **SCSPRS=15 kHz** | **SCSPRS=30 kHz** | **SCSPRS=60 kHz** |
| ± [137+δ] | -3 | ≥[24] | 15 | ≥[4] | TBD | TBD | TBD | TBD | TBD |
| ± [96+δ] | ≥[52] | ≥[1] | TBD | TBD | TBD | TBD | TBD |
| ± [62+δ] | >[104] | ≥[1] | TBD | TBD | TBD | TBD | TBD |
| TBD |  | ≥[24] | 30 | ≥[4] | TBD | TBD | TBD | TBD | TBD |
| ± [68+δ] |  | ≥[48] |  |  ≥[1] | TBD | TBD | TBD | TBD | TBD |
| ± [44+δ] |  | ≥[132] |  | ≥[1] | TBD | TBD | TBD | TBD | TBD |
| ± [59+δ] | ≥[24] | 60 | ≥[4] | TBD | TBD | TBD | TBD | TBD |
| ± [42+δ] |  | ≥ [64] |  | ≥[1] | TBD | TBD | TBD | TBD | TBD |
| ± [36+δ] |  | ≥ [132] |  | ≥[1] | TBD | TBD | TBD | TBD | TBD |
| ± [180+δ] | -13 | ≥[24] | 15 | ≥[4] | TBD | TBD | TBD | TBD | TBD |
| ± [98+δ] | ≥[52] | ≥[1] | TBD | TBD | TBD | TBD | TBD |
| ± [68+δ] | >[104] | ≥[1] | TBD | TBD | TBD | TBD | TBD |
| TBD |  | ≥[24] | 30 | ≥[4] | TBD | TBD | TBD | TBD | TBD |
| ± [85+δ] |  | ≥[48] |  | ≥[1] | TBD | TBD | TBD | TBD | TBD |
| ± [44+δ] |  | ≥[132] |  | ≥[1] | TBD | TBD | TBD | TBD | TBD |
| ± [139+δ] | ≥[24] | 60 | ≥[4] | TBD | TBD | TBD | TBD | TBD |
| ± [66+δ] |  | ≥ [64] |  | ≥[1] | TBD | TBD | TBD | TBD | TBD |
| ± [30+δ] |  | ≥ [132] |  | ≥[1] | TBD | TBD | TBD | TBD | TBD |
| NOTE 1: This minimum Io condition is expressed as the average Io per RE over all REs in an OFDM symbol.NOTE 2: NR operating band groups are as defined in Section 3.5.NOTE 3: are configured by higher layer parameter *dl-PRS-ResourceRepetitionFactor, dl-PRS-NumSymbols and dl-PRS-CombSizeN*defined in TS 37.355 [34].NOTE 4: The Io is defined in PRS slots. The same Io range applies to PRS and non-PRS symbols. Io levels are different in PRS and non-PRS symbols within the same slot.NOTE 5: Tc is the basic timing unit defined in TS 38.211 [6]. |

Table 13.2.2.2-1: gNB Rx-Tx time difference absolute accuracy in FR1 for gNB type 1-C, 1-H and 1-O

|  |  |  |  |
| --- | --- | --- | --- |
| **Accuracy** | **SRS Ês/Iot** | **SCS** | **SRS bandwidth range** |
| **Unit: Tc** | **Unit: dB** | **Unit: kHz** | **Unit: RB** |
| [63] | ≥ -13 | 15 |  44 ≤ BW ≤ 84 |
| [31] |  88 ≤ BW ≤ 168 |
| [15] | 176 ≤ BW |
| [117] | ≥ +3 | 24 ≤ BW ≤ 40 |
| [60] |  44 ≤ BW ≤ 84 |
| [31] |  88 ≤ BW ≤ 168 |
| [15] | 176 ≤ BW |
| [37] | ≥ -13 | 30 |  48 ≤ BW ≤ 84 |
| [15] |  88 ≤ BW ≤ 168 |
| [8] | 176 ≤ BW |
| [31] | ≥ +3 |  48 ≤ BW ≤ 84 |
| [15] |  88 ≤ BW ≤ 168 |
| [8] | 176 ≤ BW |
| [19] | ≥ -13 | 60 |  48 ≤ BW ≤ 84 |
| [8] |  88 ≤ BW  |
| [15] | ≥ +3 |  48 ≤ BW ≤ 84 |
| [8] |  88 ≤ BW  |

Table 13.2.2.2-2: gNB Rx-Tx time difference absolute accuracy in FR2 for gNB type 2-O

|  |  |  |  |
| --- | --- | --- | --- |
| **Accuracy** | **SRS Ês/Iot** | **SCS** | **SRS bandwidth range** |
| **Unit: Tc** | **Unit: dB** | **Unit: kHz** | **Unit: RB** |
| [8] | ≥ -13 | 60 |  132 ≤ BW ≤ 168 |
| [6] | 176 ≤ BW |
| [8] | ≥ +3 | 132 ≤ BW ≤ 168 |
| [6] | 176 ≤ BW |
| [19] | ≥ -13 | 120 |  32 ≤ BW ≤ 40 |
| [8] |  44 ≤ BW ≤ 84 |
| [6] | 88 ≤ BW |
| [15] | ≥ +3 |  32 ≤ BW ≤ 40 |
| [8] |  44 ≤ BW ≤ 84 |
| [6] | 88 ≤ BW |

 |

Similar definition can be considered. For SRS, maybe the current RAN4 definition can be reused, however it is up to RAN4. I made the following tentative proposals for further discussion.

**Proposal 4.3.3-3: Send LS to RAN4 to ask for defining the following for RTT-based propagation delay compensation, if RTT-based propagation delay compensation is supported.**

* **UE Rx-Tx time difference measurement accuracy based on CSI-RS**
* **gNB Rx-Tx time difference absolute accuracy based on SRS**

|  |  |
| --- | --- |
| *Company* | *View* |
| Ericsson | Do not support. RAN1 should agree to support RTT based PDC or not first. RAN1 should not ask RAN4 to do any work without knowing if the work is needed or not. Also: We suggest to reuse PRS For UE RxTxTimeDiff, so that work done in RAN1/RAN4 for positioning purpose can be simply reused. If using CSI-RS, RAN1 and RAN4 need to investigate UE RxTxTimeDiff accuracy based on CSI-RS.Feature lead>> On whether to reuse PRS, please check replies above. Sure the LS will be sent only we agree to support RTT-based propagation delay. The problem right now is that still difficult to agree on the equation to evaluate the overall synchronization error for RTT-based PDC as shown in section 4.3.1, also seems there is no sufficient evaluation in companies papers also. Without the evaluation, it seems difficult to achieve consensus to support RTT-based PDC right now.  |
| Nokia, NSB | **Support in principle**We think we should also capture the bandwidth options to be supported. Our analysis has shown that the following DL RX errors are present.Table 1: 90%ile DL timing error in nanoseconds of CSI-RS for tracking (FR1, 15kHz SCS, -6dB SNR)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **DL #RBs** | **DL BW** | **TDL-A** | **TDL-B** | **TDL-C** |
| **25** | **5 MHz** | 65.1 | 97.7 | 227.9 |
| **52** | **10 MHz** | 32.6 | 65.1 | 97.7 |
| **104** | **20 MHz** | 32.6 | 48.8 | 73.2 |
| **268** | **50 MHz** | 20.4 | 32.6 | 40.7 |

**Therefore, to be more specific, we may ask RAN4 for defining the requirements only for one Ês/Iot (as only serving cell may be considered), for 15KHz and 30 KHz subcarrier spacing, and for up to 10 MHz bandwidth.**Feature lead>> Agree. The problem right now is that not many companies provide evaluation yet, maybe let’s try to get the TRS and RTT-based PDC agreed first.  |
| ZTE | Is the intention to let RAN4 define the new requirement to fulfill the requirement for RTT-based solution? If yes, we think it is a bit early to discuss this issue since we haven’t decided to support RTT-based solution yet. Feature lead>> The problem is not much time left especially considering RAN4 will only have 1 more meeting this year.  |
| vivo | For using PRS, some parameters for the evaluation of RTT-based PDC should be determined firstly, at least including* + - for 30kHz and δ value for 15kHz
		- for fading channel

Feature lead>> The LS is to address your comment here actually, since these value need RAN4 work.  |
| HW/HiSi | Support the proposal |
| LG | Support in principle. In order to support RTT-based PDC with CSI-RS, it would be necessary to clarify whether error budget satisfies with CSI-RS.  |
| Qualcomm | Support the proposal |

## Implicit propagation delay compensation

OPPO (R1-2107276) proposes an implicit PDC method as below:

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *OPPO R1-2107276*Figure Implicit PDC timing diagram with signalling flow (Option-1)The principle of implicit PDC is to obtain an adjusted clock value () on UE side, at any time t, aswhere * is the clock time on UE side that is made synchronized to the clock inside gNB.
* is the nominal clock time locally running inside UE at time t. This clock is not modifiable by procedures such as TA or PDC.
* is the most recent clock error estimation made before time t, where, as shown in Figure 1,
	+ and are respectively the gNB clock time associated with the reception of a PUSCH and UE nominal clock time (i.e., running on ) associated with the transmission of the same PUSCH, where the PUSCH carries a message information relating to . is also delivered back to UE via RRC signaling.
	+ and are respectively the UE nominal clock time (i.e., running on ) associated with the reception of a PDSCH and gNB clock time associated with the transmission of the same PDSCH, where the PDSCH carries a message information relating to .

The clock synchronization error of implicit PDC (Option-1) is simply the error of , which is given byAssume ReferenceTimeInfo RRC IE is reused as the template to carry UL message <> and DL message <>, the time quantization granularity () in ReferenceTimeInfo IE is 10ns. Consequently, . Because the implicit PDC does not use delay compensation and therefore does not consume 5ns error caused by the ReferenceTimeInfo-r16 quantization in the network part of synchronization budget, the available Uu-interface error budget for implicit PDC is actually 280ns. ***Observation-5: For implicit PDC, the total Uu error budget is 280ns, instead of 275ns.*** The easiest way to remove this 5.3ns gap is to reduce the granularity of time indication in ReferenceTimeInfo RRC IE. Assume the granularity () in ReferenceTimeInfo time indication needs to satisfy . This requires . It should be noted that the granularity of 2ns or 2.5ns for timing indication is not a new lowest record of the timing report granularity in NR. The UE Rx-Tx timing difference report in LPP protocol can have timing granularity as low as 4Tc, which is also about 2ns, in FR1. error_oneway_propagation_delay_estimation1.gifFigure 2 Implicit PDC timing diagram with signalling flow (Option-2)The term of can be equivalently formulated as , which suggests another signaling flow as shown in Figure 2: * Step-1: UE sends a message to gNB, where the message helps UE and gNB to establish the UL-Tx timing in UE () and UL-Rx timing in gNB (). It does not matter whether this uplink message explicitly contains any information or not. The details is up to RAN2.
* Step-2: The gNB sends to UE a DL message containing a timing information relating to , where corresponds to the DL-Tx timing for the transmission of this DL message. The existing RRC message of ReferenceTimeInfo can be reused/extended in this case. The choice is up to RAN2.
* Step-3: The UE calculates , where is the DL-Rx timing corresponding to the reception of the DL message mentioned in Step-2, and is the UL-Tx timing mentioned in Step-1.

Note that the Option-2 above can be considered a special type of RTT-based PDC, where the information delivered from gNB to UE is not “Rx-to-Tx interval duration”, but “Rx-to-Tx mid-point timing”. For Option-2, the clock synchronization error of implicit PDC (Option-2) is given byThen yields .***Observation-6: A small-enough time indication granularity can make the implicit PDC meet the single Uu error budget for control-to-control scenario, without specification impacts in RAN1 and RAN4.*** ***Proposal 1: Suggest RAN2 to adopt implicit PDC for clock synchronization, with following RAN2 specification impacts.***

|  |  |  |
| --- | --- | --- |
|  | ***Option-1*** | ***Option-2*** |
| ***Design of UL RRC message*** | ***One message that contains the local UL-Tx clock timing () associated with the transmission of the message.*** | ***One message that does not necessarily contain explicit timing information, but should be able to help to uniquely identify local UL-Tx clock timing and local UL-Rx clock timing associated with the message.***  |
| ***Design of DL RRC message*** | ***One message that contains a clock time difference () where is the local clock time associated with the reception of UL RRC message (timing determination could be the same as ReferenceTimeInfo), and is the clock time in the received UL RRC message.*** ***Another message that contains the local clock time associated with the transmission of this message (exactly the same interpretation as for ReferenceTimeInfo).***  | ***One message that contains a Rx-to-Tx “mid-point” (), where is the local clock time associated with the reception of above-mentioned UL RRC message, and is the local clock time associated with the transmission of this DL RRC message.***  |
| ***Timing granularity in the DL/UL message*** | ***2ns or 2.5ns*** | ***4ns*** |

 |

### First round & Second discussion

**Clarifications still needed from the proponents for the comments from companies.**

**Feature lead**: There were some initial questions raised by companies for clarification on implicit PDC in RAN1#104bis-e meeting, mainly on the benefits and difference with explicit PDC. However, since the implicit PDC was proposed late (i.e. in RAN1#104b-e) and in RAN#104b-e there was only very initial discussions, the final views from companies are still not clear yet. Therefore, companies are encouraged to provide your further views on implicit PDC method.

**Question 4.4-1: Do you have any further comment/question/views on implicit PDC proposed above?**

|  |  |
| --- | --- |
| *Company* | *View* |
| CATT | We wonder whether is correct or not.We hope proponent to clarify what is the meaning of above formula.It should be clarified what is difference and what is beneficial point compared to the RTT-based method. |
| Nokia, NSB | In our understanding the described implicit PDC relies on UE correcting the clock error (or also known as clock offset) relative to gNBs clock.A first issue is that the gain seems to be minor for introducing such different method (i.e. just 5ns, assuming no referenceTimeInfo error of implicit) if compared e.g. with the introduction of a new indicator without impacting TA requirements. This can be verified by using the same assumptions as in the contribution from Oppo applied to TA-based Alt.2.Another point that is not clear in the procedure, specially the option 2, is that it seems to compete with the current referenceTimeInfo framework, as a UE applying the procedure don’t seem to make use of timing provided in SIB9. So even for a static UE, which propagation delay does not change, will have to keep exchanging DL and UL signal to get an understanding of gNB timing. While if its said that timing from SIB9 or another form of referenceTimeInfo can be used, then there is no gain compared to RTT or a new low granularity indicator, as same errors would apply.Moreover, the procedure seems not scalable as compared to RTT if it comes to meeting tighter requirements, as it seems relying on same TA loop and RS such as SSB for DL tracking (though the assumption for that is not clear in the description).And last but not least, it is not clear that introduction of such method would only require RAN2 impact, as there should still be specification e.g. for UL Tx timing measurements and DL Rx timing measurements . |
| vivo | If our understanding is correct, Rx-Tx time difference at gNB side and the error of UE receiving singles are the same between explicit and implicit PDC method according to the description. Does the implicit PDC method mean the error of UE transmitting signals can be omitted due to the adjustment based on the interior clock time of UE?  |
|  |  |

## Way forward on PDC in RAN1 for Rel-17

Nokia (R1-2106638) propose to adopt Recommendation 3 from RAN#92e plenary email discussion to move forward below.

|  |  |
| --- | --- |
| **On the way forward on PDC in RAN1**The meeting schedule for the RAN working groups involved in PDC in Q2 2021 is as following:* RAN1 has 3 meetings remaining in 2021:
	+ August (RAN1#106-e 16/08-27/08)
	+ October (RAN1#106-bis-e 11/10-19/10)
	+ November (RAN1#107-e 11/11-19/11).
* RAN2 has only two meetings remaining in 2021:
	+ August (RAN2#115-e 08/08-27/08)
	+ November (RAN2#116-e 01/11-12/11).
* RAN3 similarly has also only two meetings remaining in 2021:
	+ August (RAN3#113-e 16/08-26/08)
	+ November (RAN3#114-e 01/11-11/11)
* RAN4 similarly has also only two meetings remaining in 2021:
	+ August (RAN4#100-e 16/08-27/08)
	+ November (RAN4#101-e 01/11-12/11).

As agreed in RAN#92-e the first RRC parameter list should be provided to RAN2 to handle in RAN2#116-e which means that RAN1 should send an LS latest in RAN1#106-bis-e. This leaves RAN1 with RAN1#106-e and RAN1#106-bis-e to complete the ongoing analysis. If RAN1 cannot reach any conclusion without RAN4 involvement, the earliest time RAN1 can receive an LS reply from RAN4 is by RAN1#107-e, assuming the optimistic timeline where RAN1 sends out an LS to RAN4 in RAN1#106-e. RAN4 will not be able to treat the topic before RAN4#101-e as RAN4#100-e and RAN1#106-e completely overlap in time, but can only treat the LS and generate an LS reply in RAN4#101-e. In short, RAN1 needs to decide fast and needs to avoid being dependent on an LS to RAN4 to reach a decision in order to satisfy the RRC parameter list deadline. **Observation 1: If RAN1 sends out an LS to RAN4 in this meeting, the reply LS will be available earliest in the November meeting (RAN1#107-e), which exceeds to agreed deadline for sending an LS to RAN2 on the RRC parameter list.**In RAN#92e the possibility of down-scoping on PDC was discussed. The summary of the email discussion can be found in RP-211569:

|  |
| --- |
| Based on the discussions in the final phase, the following Recommendation3 (revised during final phase) was supported by or was acceptable to at least Nokia/NSB, Sony, Huawei/HiSi, Intel, Bosch, DOCOMO, LG, Ericsson, Huawei/HiSi, and Turkcell (10 companies). * **Recommendation3**: Provide the following RAN guidance on *Propagation delay compensation enhancements [RAN2, RAN1, RAN3, RAN4]*
	+ Support TA-based propagation delay compensation based on the Rel-15/16 timing advance procedure in Rel-17 without changes on existing TA requirements/procedures for use cases with less tight time synchronization requirements such as smart grid.
	+ RAN1/2/4 to focus on RTT-based propagation delay compensation enhancements in Rel-17.

Working groups should strive to minimize the impact on UE complexity.However, ZTE, MTK, OPPO, vivo, CATT, and CMCC (6 companies) still maintained negative views on taking this proposal. Key concerns raised were that RAN1 needs to wait for RAN4’s input on TA-based PDC and more study needs to be done for RTT-based PDC before making such decision.An alternative to Recommendation3 is the following compromise suggested by CATT in the last hours of the final phase email discussions.* **Recommendation3A**: Provide the following RAN guidance on *Propagation delay compensation enhancements [RAN2, RAN1, RAN3, RAN4]*
	+ RAN1 to send an LS to RAN4 in RAN#106-e to check the feasibility and potential enhanced value for Te and TA command indication granularity,
	+ RAN1 and RAN2 to focus on RTT-based propagation delay compensation enhancements while waiting for a reply LS from RAN4.

Working groups should strive to minimize the impact on UE complexity.Recommendation3A will allow RAN1 and RAN2 to proceed with the work on RTT-based PDC enhancements while RAN4 is formulating their response to RAN1. If RAN4 response on TA-based PDC is not made available on time or if their response is that TA-based PDC is not feasible to meet certain requirements, RAN1 and RAN2 can at least have RTT-based PDC specified in Rel-17 to meet all TSN requirements.**Given the significant number of companies (6 companies) with concerns on Recommendation3, the moderator suggests taking Recommendation3A as a compromise to ensure the support of propagation delay compensation for TSN in Rel-17.** |

With the observation in mind, it is strictly needed that RAN1 reaches a conclusion as fast as possible, and latest in the October RAN1 meeting (RAN1#106-bis-e). We strongly see the need for RAN1 to select an option, possible a compromise to ensure that a PDC framework is in place in Release-17. Further enhancements can be in the scope of Release-18. Still with the observation 1 in mind, **Recommendation 3A is not a feasible** way forward as RAN1 will not be able to make a decision before RAN4 sends the LS reply. Therefore, our proposed way forward in RAN1 is adopt **Recommendation 3**.**Proposal 1: RAN1 must make a compromise in order to move PDC forward in time for support in Release-17. It is proposed to discuss and adopt Recommendation 3 from the RAN plenary email discussion.** |

**CATT (R1-2106966) propose the following.**

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| **CATT (R1-2106966)****Proposal 4: TA-based propagation delay compensation can be considered for enhancement for propagation delay compensation with high priority. After the above-mentioned two LSs to RAN2/RAN4 related to the TA-based enhanced PDC are approved by RAN1, RAN1 can study RTT-based propagation delay compensation in parallel.** |

**Feature Lead:** There were fierce discussions in RAN#92-e on the way forward on PDC in RAN1. However, no any consensus is able to be achieved. For now, I don’t see there is any chance to agree on any of the recommendations based on the discussion in RAN, so let’s not to discuss this aspect at the beginning. However, if the progress for TA-based PDC and RTT-based PDC is still very difficult based on the discussions in this meeting, we may have to re-discuss this again at the end of RAN1#106-e.

# References

1. RP-201310, *Revised WID: Enhanced Industrial Internet of Things (IoT) and ultra-reliable and low latency communication (URLLC) support for NR* , Nokia, Nokia Shanghai Bell
2. R1-2100024 Reply LS on propagation delay compensation enhancements
3. [R1-2106590](file:///D%3A%5CDocuments%5C3GPP%20documents%5CRAN1%5CTSGR1_106-e%5CDocs%5CR1-2106590.zip) Discussion on propagation delay compensation enhancements vivo
4. [R1-2106638](file:///D%3A%5CDocuments%5C3GPP%20documents%5CRAN1%5CTSGR1_106-e%5CDocs%5CR1-2106638.zip) Discussion on enhancements for propagation delay compensation Nokia, Nokia Shanghai Bell
5. [R1-2106682](file:///D%3A%5CDocuments%5C3GPP%20documents%5CRAN1%5CTSGR1_106-e%5CDocs%5CR1-2106682.zip) Propagation Delay Compensation Enhancements for Time Synchronization Ericsson
6. [R1-2106738](file:///D%3A%5CDocuments%5C3GPP%20documents%5CRAN1%5CTSGR1_106-e%5CDocs%5CR1-2106738.zip) Discussion on propagation delay compensation enhancements ZTE
7. [R1-2106883](file:///D%3A%5CDocuments%5C3GPP%20documents%5CRAN1%5CTSGR1_106-e%5CDocs%5CR1-2106883.zip) Discussion for propagation delay compensation enhancements Samsung
8. [R1-2106966](file:///D%3A%5CDocuments%5C3GPP%20documents%5CRAN1%5CTSGR1_106-e%5CDocs%5CR1-2106966.zip) Discussion on propagation delay compensation enhancements CATT
9. [R1-2107276](file:///D%3A%5CDocuments%5C3GPP%20documents%5CRAN1%5CTSGR1_106-e%5CDocs%5CR1-2107276.zip) Enhancement for support of time synchronization OPPO
10. [R1-2107340](file:///D%3A%5CDocuments%5C3GPP%20documents%5CRAN1%5CTSGR1_106-e%5CDocs%5CR1-2107340.zip) Enhancements for support of time synchronization for enhanced IIoT and URLLC Qualcomm Incorporated
11. [R1-2107447](file:///D%3A%5CDocuments%5C3GPP%20documents%5CRAN1%5CTSGR1_106-e%5CDocs%5CR1-2107447.zip) Discussion on propagation delay compensation enhancements LG Electronics
12. [R1-2107495](file:///D%3A%5CDocuments%5C3GPP%20documents%5CRAN1%5CTSGR1_106-e%5CDocs%5CR1-2107495.zip) Discussion on propagation delay compensation for time synchronization MediaTek Inc.
13. [R1-2107587](file:///D%3A%5CDocuments%5C3GPP%20documents%5CRAN1%5CTSGR1_106-e%5CDocs%5CR1-2107587.zip) Further analysis and design considerations for propagation delay compensation methods Intel Corporation
14. [R1-2107678](file:///D%3A%5CDocuments%5C3GPP%20documents%5CRAN1%5CTSGR1_106-e%5CDocs%5CR1-2107678.zip) Enhancements for support of time synchronization Huawei, HiSilicon
15. 3GPP RAN1#105-e, R1-2104171, Reply LS on UE transmit timing error

# Appendix Agreements in the past meetings

**RAN1#102-e**

Agreements:

* Take the following use cases as the representative use cases for further study on propagation delay compensation enhancements in Rel-17.

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| --- | --- | --- | --- | --- |
| **User-specific clock synchronicity accuracy level**  | **Number of devices in one Communication group for clock synchronisation** | **5GS synchronicity budget requirement** **(note)** | **Service area**  | **Scenario** |
| 2 | Up to 300 UEs | ≤900 ns           | ≤ 1000 m x 100 m | * Control-to-control communication for industrial controller
 |
| 4 | Up to 100 UEs | <1  µs | < 20 km2 | * Smart Grid: synchronicity between PMUs
 |

Agreements:

* ±8\*64\*Tc/2μ as the TA indicating error is assumed in the evaluation.

Agreements:

For 5GS synchronicity budget requirement,

* One Uu interface is assumed for smart grid.
* Two Uu interfaces are assumed for control-to-control.

Agreements:

For BS transmit timing error, further study the following three options:

* **Option 1**:65 ns
* **Option 2**:±130ns for the indoor scenario and ±200ns for the smart grid scenario
* **Option 3**:82.5 ns

Agreements:

The value defined in Table 7.1.2-1 for initial transmit timing error (Te) in TS 38.133 should be considered for evaluation of the time synchronization.

Agreements:

Asymmetry between downlink and uplink channel for control-to-control scenario is not considered.

Agreements:

100 ns is assumed for BS detecting error.

Agreements:

Timing advance adjustment accuracy defined in Table 7.3.2.2-1 in TS 38.133 is assumed for evaluation of the time synchronization.

Agreements:

Both 15 kHz and 30 kHz are assumed for both control-to-control and smart grid for evaluation of the time synchronization.

Agreements:

Send an LS to RAN2 with the content including

* Inform RAN2 the two representative use cases concluded in RAN1 for further study;
* Ask RAN2 for input about Uu interface error budget for each of the two use cases;

Agreements:

The following options for propagation delay compensation are further studied in RAN1

* **Option 1**: TA-based propagation delay
	+ **Option 1a**: Propagation delay estimation based on legacy Timing advance (potentially with enhanced TA indication granularity).
	+ **Option 1b**: Propagation delay estimation based on timing advanced enhanced for time synchronization (as 1a but with updated RAN4 requirements to TA adjustment error and Te)
	+ **Option 1c:** Propagation delay estimation based on a new dedicated signaling with finer delay compensation granularity (Separated signaling from TA so that TA procedure is not affected)
* **Option 2**: RTT based delay compensation:
	+ Propagation delay estimation based on an RAN managed Rx-Tx procedure intended for time synchronization (FFS to expand or separate procedure/signaling to positioning).

Draft LS R1-2007445 is approved, with final LS in R1-2007446.

**RAN1#103-e**

Agreements:

* Take 65 ns as the assumption of transmit timing error for evaluation of the overall time synchronization error for control-to-control.
* Asymmetry between downlink and uplink channel for smart grid scenario is not considered.
* ~~TA adjustment accuracy is not considered for the evaluation of time synchronization error.~~
* *errorBS,DL,TX* is included in the equation for calculating the overall time synchronization error.

Agreements:

TA adjustment accuracy is not considered for the evaluation of time synchronization error.

Agreements:

For evaluation of the overall time synchronization error for smart grid, companies can take one of the following two options as the assumption for BS transmit timing error:

* Option 1: 200 ns
* Option 2: 65 ns

**RAN1#104-e**

Agreements:Take ±100 ns as the assumption for downlink frame timing detection error (errorUE,DL,RX) at the UE for evaluation of the overall time synchronization error for TA based propagation delay compensation, if downlink frame timing detection error needs to be considered separately.

* Send a LS to RAN4 to ask for clarification on whether downlink frame timing detection error is included in Te or not
	+ In the LS, to include more details about option 1 (included) & option 2 (not included); also including the necessary background
* FFS whether to apply the same value to RTT-based propagation delay compensation, and the corresponding condition (if any) if the same value will be applied

**Decision:** As per email posted on feb 5th, the draft LS is endorsed. Final LS is approved in [R1-2102245](file:///C%3A%5CUsers%5Cc00387628%5CAppData%5CLocal%5CTemp%5CDocs%5CR1-2102245.zip).

**RAN1#104b-e**

Agreements:If downlink frame timing detection error needs to be considered separately from propagation delay estimation error, take ±100 ns as the assumption for downlink frame timing detection error (errorUE,DL,RX) at the UE for evaluation of the overall time synchronization error for RTT based propagation delay compensation

Agreements: Take the following equation for evaluation of the DL propagation delay estimation error for TA based propagation delay compensation:



* Either option 1 or option 2 below will be applied based on the RAN4 reply to RAN1 LS [R1-2102245](file:///C%3A%5CUsers%5Cc00387628%5CAppData%5CLocal%5CTemp%5CDocs%5CR1-2102245.zip).



* FFS whether *errorBS,DL,TX* in the above equation should be included or not.

Agreements:

* Observation 1: Propagation delay compensation based on existing Rel-15/Rel-16 TA procedure and associated granularity, with no enhancements in RAN1, is sufficient for meeting the Uu interface synchronicity error budget in LS R2-2010837 for the smart grid scenario.
* Observation 2: RAN1 needs to further study and specify the feasible enhancement (if any with RAN1 spec impact) for propagation delay compensation for control-to-control scenario, in order to meet the synchronicity budget of Uu interface in LS R2-2010837.

Working assumption:



Agreement:

Take the following as the evaluation assumptions for both RTT-based PDC and TA-based PDC.

* The UE may acquire an up-to-date PD estimation after waking up from DRX. This implies that gNB may signal an update timing advance value or complete a Rx-Tx measurement procedure.
* *errorUE,DL,RX* is based on other signals (e.g. CSI-RS) instead of SSB.
* *errorBS, UL,RX* iss based on other uplink signals instead of contention based PRACH, e.g. SRS.
* Further study and specify new procedure/signaling (if necessary) to ensure that the PD estimation can be acquired after DRX for the adopted PDC method.

Agreement:

Existing DL reference signal(s) are used for Rx – Tx time difference estimation at UE side for RTT-based propagation delay compensation, if RTT-based propagation delay compensation is supported.

* FFS whether PRS can be used for UE Rx – Tx time difference estimation or not
* FFS which DL reference signal(s) to be used if/when PRS is not used

**Conclusion:**

* Leave it to RAN2 to decide whether to support UE based compensation and/or gNB based compensation for any propagation delay compensation method RAN1 may adopt for Rel-17, if applicable.