**3GPP TSG RAN WG1 Meeting #104b-e R1-21xxxxx**

**E-meeting, April 12 – April 20, 2021, 2021**

**Agenda Item: 8.3.4**

**Source: Moderator (Huawei)**

**Title: Feature lead summary#1 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] |

This document summarizes the key issues discussed under agenda item 8.3.4 based on the views in [2][3][4][5][6][7][8][9][10][11][12][13][14][15], and aims to discuss a set of issues in RAN1#104-e.

# 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. The following sections summarize the discussion for the remaining error components.

## Downlink frame timing error ()

In the RAN1#104-e meeting, we have agreed to use ±100 ns 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. It is FFS whether to apply the same value to RTT-based propagation delay compensation.

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

Final LS is approved in [R1-2102245](file:///C:\Users\L00367611\AppData\Roaming\Microsoft\Docs\R1-2102245.zip)

In this meeting, Nokia (R1-2102821) proposes to use the same value for RTT-based propagation delay compensation.

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| Nokia R1-2102821  Related to the FFS point on value for RTT-based PDC techniques, we would like to note the following:  The absolute SFN timestamp found in *referenceTimeInfo-r16* IE can be generated by the gNB-DU. The timestamp is therefore subject to an error between the gNB-DU and the air interface timing. Apart from this, the UE is tracking the DL frame timing to determine the SFN boundaries. Therefore, all evaluations of Uu interface accuracy must include both errors, a DL frame timing error and the gNB-DU SFN to air interface error.  The DL frame detection error is therefore present in all PD estimation options when it comes to determining a reference point at the UE for either TA (UL Tx = DL Rx – TA) as well as an Rx-Tx measurement at the UE. During RAN1#104-e, there had been discussions that a smaller value may be applicable considering other RS usage such as CSI-RS and PRS. We would like to re-iterate our related comment here, that improvements using more wide-band reference signals can improve the detection accuracy of the first detected path. But this would equally apply to TA and RTT based PDC methods as the first detected path is equally used for the TA operation as well as RTT based measurements and feedback. Therefore, the same values should be applied for RTT and TA based methods unconditionally.  **Observation 2: The downlink frame detection error at the UE is present at all PD estimation options due to the reference point detection related to SFN boundary referred from** *referenceTimeInfo-r16***. Improved accuracy of the DL frame detection error by using other DL RS such as PRS equally improves the performance of TA-based and RTT-based PDC methods.**  Therefore, the same value should apply to TA and RTT-based methods by agreeing the following:  **Proposal 3: 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, if downlink frame timing detection error needs to be considered separately.** |

Ericsson (R1- 2102748) uses ±116ns in evaluation for RTT-based propagation delay compensation.

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| 1. : ±116 ns. This is obtained using the method shown in Table 1, but with minimum PRS bandwidth of 24 PRB. It is noted that the PRS bandwidth can be as large as 272 PRBs. In general, the larger the bandwidth of the DL reference signal used for timing detection, the smaller the DL timing detection error. |

**Feature lead**: It makes sense that same value for downlink frame timing error should be applied for both TA-based PDC method and RTT-based PDC method for fair comparison. Since we agreed to use 100 ns for TA-based PDC method, the same value should be used for RTT-based PDC method also. In addition, if we want to take another value, it seems evaluations are needed to check what over value to be used. Therefore, the following tentative proposal is made for further discussion and it would be good to hear the views from other companies also.

### First round discussion

**Proposal 2.1-1**:**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, if downlink frame timing detection error needs to be considered separately.**

**Please provide your views on the above proposal 2.1-1. If you don’t agree with it, please provide the value with justification here also.**

|  |  |
| --- | --- |
| *Company* | *View* |
| OPPO | Ok with Proposal 2.1-1. |
| CATT | We are fine with FL proposal. |
| ZTE | We are fine with this proposal. |
| Vivo | Agree with FL’s proposal. |
| Nokia, NSB | We agree with Proposal 2.1-1 |
| Intel | Agree, that would align the assumptions for TA-based and RTT-based |
| Qualcomm | We cannot agree with this proposal. In fact, we prefer a simple solution. i. e., we evaluate the propagation delay of existing TA scheme first. If it meets the requirement, then we are done. However, if it does not work, we need a new scheme without touching the existing TA mechanism. Therefore, it is not good to combine the two schemes. |
| HW/HiSi | Agree with the proposal. |
| LG | Fine with the proposal. |
| Samsung | OK with the proposal |

#### Summary of the status for first round

**Proposal 2.1-1**:**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, if downlink frame timing detection error needs to be considered separately.**

|  |  |
| --- | --- |
| Support | 9 - *OPPO, CATT, ZTE, vivo, Nokia/NSB, Intel, Huawei/HiSilicon, LG, Samsung* |
| Not support | 1 – *Qualcomm*   * ***Qualcomm****: A new scheme without touching the existing TA mechanism can be used if TA-based scheme cannot meet the budget.* * ***Feature lead****: The reason from companies is that if a new scheme to estimate the downlink frame timing detection error is used for RTT-based method, then the new scheme can be used for enhanced TA-based method also. Therefore, it is not fair to use the worse value for TA-based but use enhanced one for RTT-based.* |

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

In RAN1#103-e, we have agreed to use 65ns 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 R1-2100730  The 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, 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.*

**Feature lead**: Based on the discussion in RAN1#104-e meeting, it seems further discussion is not helpful. This is an important issue and we need to make decision. Therefore, I would like to encourage people check if you can accept it.

### First round discussion

**Proposal 2.1-2: 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.**

**Please comment if you have strong concern on the above proposal.**

|  |  |
| --- | --- |
| *Company* | *View* |
| OPPO | The value of 65ns comes from RAN4-defined TAE range of 65ns, where TAE is defined as the largest timing difference between any two signals belonging to different antenna connectors or TAB connectors. The claim of 32.5ns assumes the “intended DL Tx timing” always aligns with the center of TAE range, which is however not guaranteed. For example, the two antenna connectors have DL-Tx timing apart from each other by 65ns, and gNB mistakenly takes the later-Tx connector from the two as the “intended DL Tx timing” while the signal carried by the earlier-Tx connector becomes the “first path”.  Therefore, we do not see a good reason to change existing RAN1 agreement on **e*rrorBS,DL,TX***.  Anyhow, if we are the only company concerning the proposal, we do not insist. |
| CATT | We are fine with FL proposal. |
| ZTE | We are fine with this proposal. |
| Vivo | We are fine with FL proposal. |
| Intel | Any value is acceptable. We don’t think this is the main limiting factor in the analysis. |
| Qualcomm | We prefer 65ns and share the same view with OPPO and Ericsson. |
| HW/HiSi | We agree with the proposal. |
| LG | We are fine with the proposal. |
| Samsung | We can live with either 65ns and count half of it in the equation, or take 32.5ns in the equation. But we think the first one make more sense. |

#### Summary of the status for first round

* + **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.*

# 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, FFS whether to use ±32.5 ns or 64 ns for the valuation.
  + For smart grid, it was agreed to use 65ns or 200ns for the evaluation.
* **Downlink frame timing error ():** 
  + Depending on the reply from RAN4
* **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 [16]

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

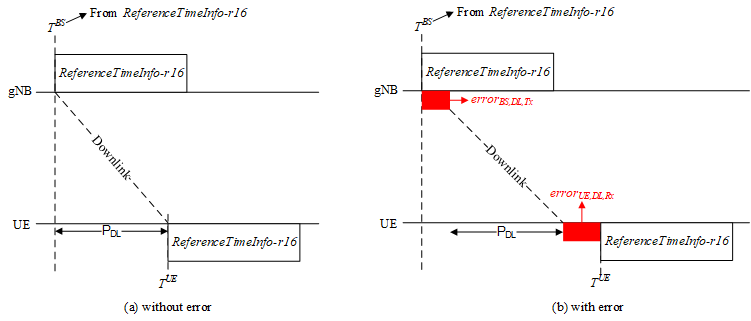
Based on the contributions, the views are still very diverse. Instead of looking at the equations from different companies, I think we need to achieve common understanding on how to achieve the final equation step by step, otherwise it would be very difficult for us to achieve consensus.

### First round discussion

I made some draft steps as below as the starting point for further checking:

**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**



**Question 3.1-1:** **Do you agree with the equation for actual time clock at the UE side in step 1 above,** i.e.  *and*  also need to be considered for the procedure of signaling the RRC containing the reference time clock from gNB to UE, regardless whether it is needed for propagation delay estimation error or not**? If your answer is NO, please explain which part is wrong and why it is wrong.**

|  |  |
| --- | --- |
| *Company* | *View* |
| OPPO | *Agree.* |
| CATT | *Yes* |
| ZTE | *Yes. We think we can use the equation in the step 1 above to determine the actual time clock at the UE side by taking BS transmitting timing error and downlink frame timing detection error into account.* |
| Vivo | Agree. |
| Nokia, NSB | *We agree. and need to be accounted for reflecting the error related to the SFN boundary, which can be offset by compared to the timestamp in referenceTimeInfo and which affects the UE detection accuracy of the first path.* |
| Intel | Agree |
| Qualcomm | Agree |
| HW/HiSi | Agree |
| LG | Agree |
| Samsung | Agree |

#### Summary of the status for question 3.1-1 in first round

|  |  |
| --- | --- |
| Support | 10 – *OPPO, CATT, ZTE, vivo, Nokia/NSB, Intel, QC, Huawei/HiSilicon, LG, Samsumg* |
| Not support | 0 |

**FL recommendation**: All companies agree with the equation to represent the actual time clock at the UE side. Let’s take it as agreed assumption for the analysis for the following steps.

**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.

**Question 3.1-2:** **Do you agree with the equation for estimated time clock at the UE side in step 2 above? If your answer is NO, please explain which part is wrong and why it is wrong.**

|  |  |
| --- | --- |
| *Company* | *View* |
| OPPO | *Agree.* |
| CATT | *Yes* |
| ZTE | *Yes. We agree with the equation above for estimated time clock at the UE side.* |
| Vivo | Agree with the equation. |
| Nokia, NSB | We agree. |
| Intel | Agree |
| Qualcomm | Agree |
| HW/HiSi | Agree |
| LG | Agree |
| Samsung | Agree |

#### Summary of the status for question 3.1-2 in first round

|  |  |
| --- | --- |
| Support | 10– *OPPO, CATT, ZTE, vivo, Nokia/NSB, Intel, QC, Huawei/HiSilicon, LG, Samsung* |
| Not support | 0 |

**FL recommendation**: All companies agree with the equation to represent the estimated time clock at the UE side. Let’s take it as agreed assumption for the analysis for the following steps.

**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

**Question 3.1-3:** **Do you agree with high level error components above for overall time synchronization error? If your answer is NO, please explain which part is wrong and why it is wrong.**

|  |  |
| --- | --- |
| *Company* | *View* |
| Feature lead | Companies may say that since we are calculating difference of actual time clock and estimated time clock, then the difference should be . However, in my understanding, since the value for each error component can be positive or negative, i.e. ± X, thus the maximum error should be the sum of all positive values. |
| OPPO | Agree. |
| CATT | Yes |
| ZTE | We agree with the view that each error component can be positive or negative. However, if these three components are totally independent, we think the maximum error should be the sum of all positive values for the components. But we can see that is also affected by the BS transmitting timing error and downlink frame timing detection error as shown in step 4. It makes the issue a bit complex. We should use the same assumption for the BS transmitting timing error and downlink frame timing detection error in step 1 and step 2, respectively. For step 3, it would be better to use for further analysis. |
| Vivo | Yes. |
| Nokia, NSB | We partly agree with the FL.  We agree with the expression for the upper bound , but we disagree regarding capturing in both and . The UE decides which DL RS(s) it uses to determine the refSFN boundary indicated in referenceTimeInfo. It is very likely that the UE will use the same (or alternative another DL RS affected by similar channel conditions) as the one used for TA / RTT based PD estimation. Therefore, the assumption of uncorrelated error source is true for different sources, but for the same source, it is not. We disagree with the assumption of completely uncorrelated error sources, which would result in being captured 1.5 times in . |
| Intel | Yes in principle, but when error\_UE\_DL\_RX is going to be considered as part of TA/RTT, the sign needs to be carefully accounted. |
| Qualcomm | Yes |
| HW/HiSi | Agree |
| OPPO-2 | @ZTE,@Nokia:  Here is what 38.331 says for the reference SFN associated with ReferenceTimeInfo-r16: “The UE considers this frame (indicated by *referenceSFN*) to be the frame which is nearest to the frame where the message is received (which can be either in the past or in the future).” In other words, the DL-Rx timing in step-1 is more related to the DL frame detection timing of the frame carrying this ReferenceTimeInfo IE (that is where the wording of “nearest” comes from). This timing may or may not be the same as the one used in step-2 for PD estimation, depending on channel variation and the coordination between step-1 (which is likely in RRC layer) and step-2 (which is in likely in MAC layer). Given we are dealing with “error budget”, which needs to cover the “worst case”, to assume uncorrelated between step1 and step2 seems safer than assuming the constant error across two steps. In addition, it is usually not a valid assumption that the time tracking circuit in UE would keep the output timing constant over a time and that period of time can be coordinated with PHY/MAC layer procedures. |
| LG | Yes in principle. The above assumption is a safe assumption so it could be used. However, As Nokia mentioned, we cannot sure and are totally independent random variable. (i.e., whether transit timing error is a kind of constant error or can be different in each trial within a boundary). |
| Samsung | We are fine in principle. |

**.**

#### Summary of the status for question 3.1-3 in first round

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| --- | --- |
| Support | 9 – *OPPO, CATT, vivo, QC, Huawei/HiSilicon* |
| Agree in principle | 9 –*ZTE, Nokia/NSB, Intel, LG*   * ***ZTE****: should be used instead of .* * ***Nokia/LG****: The and for signing the reference time clock is not independent from the one for propagation delay estimation, i.e. it cannot be captured multiple times.* |
| Not support | 0 |

**FL recommendation**: Companies are encouraged to check the reply from OPPO above and provide your further views.

**Question 3.1-4:** **Do you agree that the above step 1 to step 3 are applied to both TA based PDC and RTT based PDC? If your answer is NO, please explain why.**

|  |  |
| --- | --- |
| *Company* | *View* |
| Feature lead | In my understanding, the above three steps are the same for both TA-based PDC and RTT-based PDC. The only difference between TA-based PDC and RTT-based PDC is the equation for .  For TA-based PDC, the equation of is as defined in step 4 below. For RTT-based PDC, the equation will be discussed in section 4.2. |
| OPPO | Agree most of parts, except the formula of is indeed for TA-based PDC only, but not for RTT-based PDC. |
| CATT | Yes |
| ZTE | Yes, the step 1 to step 3 above can be used for both TA-based and RTT-based solution. |
| vivo | Yes. We agree with the same steps for both TA-based PDC and RTT-based PDC. |
| Nokia, NSB | We agree with the FL.  One concern raised is whether the detection errors are captured in the Rx-Tx based procedure, and our understanding is clearly that they are, also if we just call it an Rx-Tx inaccuracy (as the detection error will contribute to this). |
| Intel | Yes, with the note in 3.1-3 |
| Qualcomm | Yes. |
| HW/HiSi | Agree |
| LG | Yes. We have similar view to OPPO |
| Samsung | Yes. |

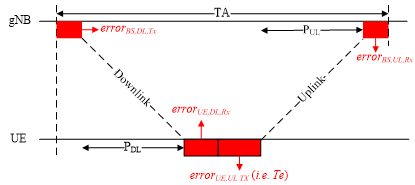
#### Summary of the status for question 3.1-4 in first round

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| --- | --- |
| Support | 10 – *OPPO, CATT, ZTE, vivo, Nokia/NSB, Intel, QC, HW/HiSi, LG, Samsung*  *Note: is only for TA-based PDC, not applied to RTT-based PDC for sure.* |
| Not support | 0 |

**FL recommendation**: All companies agree that step 1 to step 3 are applied to both TA based PDC and RTT based PDC. Let’s take it as agreed assumption for the analysis for RTT-based PDC as shown in section 4.3.

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

for TA-based compensation.



Assuming , the downlink propagation delay is calculated as:



Then the error of the downlink propagation delay is:



* study the following two options (which option to choose depend on the reply from RAN4):
  + **Option 1:**  <= Te
  + **Option 2:**  = Te and considered separately
* study whether in the above equation should be included or not for .
  + Note 1: Not including implies that gNB needs to take it out for TA estimation, which may depend on the gNB implementation and may be different from the existing TA estimation procedure at the gNB side. Companies are encouraged to check.
  + Note 2: Option 1c for TA-based PDC enhancement as in section 4.1 may be able to get rid of since it will introduce a separate procedure for synchronization compensation here instead of reusing the normal TA procedure.

**Question 3.1-5:** **Do you agree with the above step 4 for for TA-based PDC? If your answer is NO, please explain why. Please also provide your views on the second FFS (i.e. whether to include ) if your answer is ready now, or you can just indicate need more time to check instead of simply saying NO.**

|  |  |
| --- | --- |
| *Company* | *View* |
| OPPO | Agree the above  **for TA-based PDC.**  Regarding to FFS, we suppose all companies agree the starting-point equation , which says the TA length on UE side equals to round-trip delay. This equation requires a prerequisite that DL-Tx and UL-Rx have certain alignment on gNB side. Then impacts the accuracy/reliability of gNB-side “alignment” between DL-Tx and UL-Rx, or equivalently, the accuracy/reliability of equation itself. Therefore, should show up somewhere in the mathematical analysis . We do not quite catch up how Option 1c can escape from this general logic. |
| CATT | Yes, we prefer to option 1 and it is better to wait or RAN4’s response. |
| ZTE | Yes, we support the equation in step 4 for for TA-based PDC. We think should be included since this error exists anyway and the gNB cannot take it out when estimating the TA for the UE. |
| Vivo | Yes. For option 1 and option 2, we can wait the RAN4’s response. |
| Nokia, NSB | should not be in included in .  reflects the error between the air interface time and the timestamp provided in referenceTimeInfo. The error can be bounded by TAE which is the current assumption in this analysis. The error should be accounted for in the RRC related error sources (i.e. step 1), and not as a part of the PD estimation.  Regarding Te (i.e. Option 1 vs. Option 2), we think we should wait for the related RAN4 reply. |
| Intel | This part is agreeable. Note that based on review of RAN4 inputs to April meeting, it seems the majority is for Option 1. |
| Qualcomm | Agree the above  **for TA-based PDC.** |
| HW/HiSi | Agree  For the second FFS, whether to include in the above equation, based on legacy TA it is included, since the legacy TA does not need to consider PDC. For PDC, it is also ok not to include it for the evaluation here. |
| LG | Agree. For FFS, we think it is better to wait RAN4 input. |
| Samsung | Agree. And wait for RAN 4 feedback on FFS part. |

#### Summary of the status for question 3.1-5 in first round

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| --- | --- |
| Support | 10 – *OPPO, CATT, ZTE, vivo, Nokia/NSB, Intel, QC, HW/HiSi, LG, Samsung* |
| Not support | 0 |

**FL recommendation**: It seems all companies agree the equation in principle, though there are different views on FFS. We can agree the high level equation first.

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

**Proposal 3.1-1:Take the following equation for evaluation of the overall time synchronization error for TA based propagation delay compensation:**

* study which option to use depending on RAN4 LS reply:
  + **Option 1:**  <= Te
  + **Option 2:**  = Te and is considered separately
* study whether to include highlight in Red above

|  |  |
| --- | --- |
| *Company* | *View* |
| OPPO | Agree |
| CATT | In our understanding, evaluation of the overall time synchronization error for TA based propagation delay compensation should be |
| ZTE | We think the equation should be further discussed. As we explained above, we should use the same assumption for each of the BS transmitting timing error and downlink frame timing detection error in the different steps.  In the Figures above, the BS transmitting timing error and downlink frame timing detection error are both positive. In this case, the final results should be  according to our suggestion in step 3 above.  However, this is not the maximum value for the  In our paper, we give an example, where we can get the maximum value for . It is also captured below for convenience. In this case, the BS transmitting timing error is negative while the other components are positive. And the final result would be |
| vivo | We agree with the equation. |
| Nokia, NSB | Do not support Proposal 3.1-1 (i.e. the equation)  should not be captured twice. The UE is likely to use the DL RS(s) that it used for TA to determined its refSFN and hence the error should only be captured once or the two times it is mentioned should be considered to be correlated ( is subtracted).  should only be considered in relation to refSFN acquisition, and not for PD estimation. According to our view, the following should be used instead: |
| Intel | Need time to check how this stacks with Option 1 vs Option 2 asked to RAN4. |
| Qualcomm | Agree with the main equation. |
| HW/HiSi | Agree. |
| LG | Agree |
| Samsung | Agree with Nokia |

#### Summary of the status for proposal 3.1-1 in first round

|  |  |
| --- | --- |
| Support | 9 – *OPPO, vivo, Qualcomm, HW/HiSi, LG* |
| Not support | 9 –*CATT, ZTE, Nokia/NSB, Samsung* |

**FL recommendation**: This is related to the discussion under question 3.1-3. We need to further discuss there first.

## Overall time synchronization error over Uu interface

According to the LS [16] 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 |

Although the discussion on the equation to calculate the total error is still ongoing, some companies also provide some evaluation in the contribution based on their equation, which is summarized as shown in the following table.

**Table 1** Summary of overall synchronization error over Uu interface

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Source | Control-to-control | | Smart grid | |
| 15kHz | 30kHz | 15kHz | 30kHz |
| Nokia | 458ns | 328ns | 525ns | 395ns |
| ZTE | 340.5ns | 210ns | 475.5ns | 345ns |
| Vivo | 457.5 | 327.5 | 457.5 | 327.5 |
| Intel | 441 | 310 | 576 | 445 |
| Ericsson | 579.5 |  | 579.5 |  |
| Huawei, HiSilicon | 490 | 360 | 625 | 360 |
| Qualcomm | 546 |  | 546 |  |
| Samsung | 408 | 277.5 | 408 | 277.5 |
| MediaTek | 440.5 |  | 575.5 |  |
| CATT | 440 | 310 | 440 | 310 |
| OPPO | 458 | 360 | 458 | 360 |

### First round discussion

Based on the above table, the following observations can be seen:

**Observation 1**: **Rel-16 TA-based propagation delay compensation is sufficiently to be used as propagation delay estimation for the smart grid scenario with no enhancements needed.**

**Observation 2: Enhancement for propagation delay compensation is needed for control-to-control scenario.**

|  |  |
| --- | --- |
| *Company* | *View* |
| Feature lead | The status of this observation from RAN1#104-e is as below:   * ***Support observation 2:*** *CATT, Samsung, Vivo, ZTE, Intel, Huawei/HiSilcion, LG, Ericsson, ETRI* * ***Not support:*** *MTK*   + *Given the small ISD for a typical control-to-control use-case deployment, the estimated timing error is within the Uu timing budget provided by RAN2.*   If I got the point from MTK correctly, they assume that for control-to-control propagation delay compensation is not needed for control-to-control, i.e. UE can just the received timing directly, therefore no any enhancement needed also. Not sure if all companies have a chance to look that analysis from MTK, therefore one question is set below for companies to check. |
| OPPO | Observation-2 is indeed not an “observation”, but a proposal. A fair observation can be “**TA-based propagation delay compensation cannot meet error budget for control-to-control scenario**”. Our view is RAN1 should firstly test the enhancement effectiveness and feasibility before committing the need of enhancement.  For Observation-1, we have two comments.   1. What is “Rel-16 TA-based propagation delay compensation”? Is there such PDC feature in Rel-16? 2. When we calculate the total error for smart grid scenario, we assume that is no larger than half of TA command granularity, which is true when the TA loop is quite stable and there is no need for gNB to send non-zero TA command to UE. However, if this condition is no longer true and the TA command can be larger than one single TA granularity, it means could be larger than half TA command granularity depending on “when” the UE measures/retrieves its TA interval for PD calculation. So the claim saying “TA-based PDC is sufficient ….” Sounds too strong. A fair statement seems to be “TA-based PDC *can* meet error budget for smart grid scenario”. |
| CATT | Support observation 2. |
| ZTE | We support observation 2. |
| Vivo | Support observation 2. |
| Nokia, NSB | Agree with Observation 1 and Observation 2.  Legacy TA (Release-15 and Release-16) is perfectly accurate for the smart grid scenarios and hence we should be sure to support it as a method for PDC in Release-17. No additional solution is needed.  Concerning PDC for the control-to-control scenario, we agree that PDC is not needed for control-to-control scenarios with only small ISD. However, there can be cases where the ISD is sufficiently large to require PDC to achieve sufficiently accuracy absolute time synchronization.  We expect that not many deployments indoor for control-to-control will actually need PDC. Therefore it is our recommendation that RAN1 first ensures that TA is specified as one option for PDC, and then spends the remaining time, to identify an supplementary procedure which can be used e.g. in the cases where PDC is needed for the control-to-control scenario. |
| Intel | Support. At this point it is hard to envision all possible deployment options. Furthermore, we already observed the deployments of a few TRP in a larger area, which is highly dependent on the facility structure, etc. In these cases, ISD of > 60-100 m are easily possible, based on planning choices, which leads to UE-BS distances larger than 33 m. |
| Qualcomm | We support observation 2. |
| LG | We Support the observations. |
| Samsung | We support observation 2. |

|  |
| --- |
| *MTK R1-2102698*  To justify the necessity of using propagation delay compensation, first, we need to find/calculate the maximum distance between the gNB and UE that achieves the Uu timing synchronization budget. Second, we compare the calculated maximum distance, for each use case, to the provided inter-BS distance from SLS assumptions in TR 38.824 [4]. The Uu timing budget consists of:  Uu timing budget = gNB tx timing error () + Max propagation delay + UE rx timing error ()  Where gNB transmission error is the timing error between the actual transmission and the assumed transmission at the transmitter side of gNB, propagation delay is the time needed for a signal to travel from a gNB to a UE, and the UE timing detection error is the uncertainty associated with the UE downlink frame timing detection. The maximum propagation delay and the maximum distance that achieves the Uu timing budget requirements can be found for each use case as:   * **Control-to-control use case**: we substitute the timing synchronization budget and errors in the above formula:   Uu timing budget (±275ns) = 65ns + Max propagation delay + ~100ns  Resolving this results in the maximum propagation delay, which is equal to 110 ns. This can be translated into the maximum distance between UE and gNB, which equals to 33 m. This means that if the propagation distance between the gNB and UE for control-to-control use case is ≤ 33 m, then there is no need for propagation delay compensation. Now, given that the typical inter-BS distance for the factory automation at 4 GHz is equal to 20 m, thus, we can conclude that there is no need for using propagation delay compensation in control-to-control use case.   1. ***For control-to-control use case, the maximum distance between the UE and gNB that achieves the Uu timing budget is larger than the typical inter-BS distance in factory automation scenario.*** 2. ***Do not support introducing propagation time delay compensation for control-to-control use case.*** |

**Question 3.2-1:** **Do you agree with the analysis in R1-2102698 for control-to-control scenario, i.e. no propagation delay compensation is needed for control-to-control and thus no any enhancement needed, at least for deployment with smaller ISD e.g. 33 m?**

|  |  |
| --- | --- |
| *Company* | *View* |
| OPPO | Even though the analysis in R1-2100578 is for “4GHz case + typical ISD of 20m” rather than the more general situations, it raised good point that it can be a better choice NOT to run PDC in some situations, such as:   * The total error in propagation delay estimation can exceed the one-way propagation delay itself. * The estimated one-way propagation delay turns to be negative. (In Rel-16 IAB, the estimated one-way propagation delay is thrown away if being negative).   The proposal 1 in R1-2100578 can be one of the choices provided to RAN2. |
| CATT | First of all, we need check the assumption on the typical inter-BS distance for the factory automation at 4 GHz equal to 20 m is valid or not.  If yes, we can consider no any PDC on deployment with smaller ISD which depends on budget value per Uu interface. |
| ZTE | If the distance between UE and gNB for control to control is less than 33m in practice, we also believe the enhancement is not needed for control to control. But we need to check if we can use this assumption in our analysis first.  The reference in MTK’s paper is from the SLS assumption for factory automation in our understanding. We think it is not sufficient and more information is needed to justify the assumption. |
| Vivo | For smaller ISD, we also think PDC may not be required. But the evaluation assumption should be further clarified. |
| Nokia, NSB | We agree that PDC is not needed for control-to control scenarios with small ISDs.  However, there can be cases where the ISD is sufficiently large to require PDC to achieve sufficiently accuracy absolute time synchronization. We expect that not many deployments indoor for control-to-control will actually need PDC. |
| Intel | Do not really agree since there is no “typical case” for factory automation / control-to-control. Please see our reply above. |
| Qualcomm | No. More study is needed. |
| HW/HiSI | We agree with the analysis in R1-2102698 that no propagation delay compensation is needed for control-to-control if the propagation distance between the gNB and the UE (i.e. cell radius) ≤ 33 m.  However for the control-to-control scenario, a service area of 1000m×100m is assumed and we are not sure whether it is always feasible to deploy so many gNBs that a maximum cell radius ≤ 33 m can be ensured in this area. |
| LG | We also think PDC is not necessary if service area is small so propagation delay is less than threshold. However, we cannot sure it is correct assumption if we follow existing evaluation scenario assumption. |
| Samsung | Prefer more study |

#### Summary of the status for question 3.2-1 in first round

* No compensation is needed for small ISD.
  + **7 companies:** *Oppo, CATT, ZTE, vivo, Nokia, Hw/HiSi, LG*
* Do not agree with this analysis from MTK since there is no typical deployment scenario for control-to-control or feel that more study is needed
  + **2 companies:** *Qualcomm, Intel*

**FL recommendation**: Although some companies comment that more study needed to align the assumption, I think we may not need to spend much effort time on this, since it is true there is no typical case defined yet for control-to-control, which means we would need to introduce some enhancements to ensure all scenario can work well. Therefore, I would like make some observation below to see if we can conclude this discussion here.

**Revised observation 2: Enhancement for propagation delay compensation is needed for control-to-control scenario at least for the deployment scenario with large ISD, e.g. larger than 20 m.**

# 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**: **When a PD estimation is to be acquired after DRX for both TA-based PDC and RTT-based PDC?**

|  |
| --- |
| *Nokia R1-210821*  **Considerations when comparing PD estimation Option 1 (incl variants) and Option 2.**  When it comes to the evaluation assumptions applicable for Option 1 (and variants) and Option 2, we need to remember that in the process of evaluating time synchronization accuracies of PD estimation options a fair evaluation is essential to ensure the right options for the desired accuracies are chosen. For this matter, it is important that we do not make option specific assumptions that other options would also be impacted of, e.g. what reference signals are applied and what bandwidths and channel conditions are present/available.  **Proposal 5: Assume equivalent downlink and uplink frame detection error assumptions at all considered PD options to ensure unbiased evaluation.**  Caution is needed regarding the assumption on when DL PD estimation is assumed to be acquired after a DRX period. Figure 1 provides an example timeline related to PD estimation after a DRX period.  Timeline  Description automatically generated  Figure 1. Timeline example for PD compensation times after DRX, either at time a or time b.  If a PD estimation is to be acquired immediately after the UE wakes up from a DRX period (the UE has not yet transmitted anything), the best PD estimation will be the latest one acquired (from an earlier wake-up period, e.g. using either RTT­1/2 or NTA1/2 as per Figure 1). This applies to all PD estimation options considered and is illustrated with PD option a in Figure 1. If PD option a is to be further considered in RAN1, it would need to be discussed what the accuracy of using a PD estimation from a previous DRX cycle.  If the PD estimation is to be acquired after the gNB issues an additional signal based on the uplink transmission detected arrival time, the gNB may issue an updated timing advance value, a PD estimation signal, or even a reference signal to complete an Rx-Tx measurement procedure. In this case, the UE may use an updated PD estimate (from either NTA2/2 or RTT2/2), which is illustrated as PD option b in Figure 1. Here, the PD accuracy evaluation assumptions should be quite different;   * For timing advance the UE will have an up to date NTA value and hence Te does not apply anymore. Instead, the TA adjustment error would be applicable. * For an Rx-Tx procedure, as both an UL and DL reference signal has been available, e.g. CSI-RS in DL and some UL transmission (e.g. SRS), the Rx-Tx measurement can be conducted, but if the initial UL transmission is used, Te would still apply. * The UE potentially has acquired multiple DL reference signals to enhance its DL frame timing accuracy.   Two options could be considered to align the assumptions between Rx-Tx and timing advance moving forward:   * Option a. The UE utilize a PD estimation from its previous DRX awake period, as the UE needs an PD estimation immediately after waking up from DRX. A similar error related to using an old PD for PDC applies to all PD estimation options. * Option b. The UE may acquire an up-to-date PD estimation after waking up from DRX. This implies that the gNB may signal an updated timing advance value (if needed) or complete a Rx-Tx measurement procedure to acquire an updated RTT estimation.   Opt. a is aligned with the current discussion in RAN1 and if the assumption of using Te in the evaluations is maintained, then an implementation error similar to Te should be applied to both options 1 and 2 based on TA and Rx-Tx measurements. Alternatively, it should be agreed to not capture Te for both PD estimation procedures with the argument that the initial UL transmission is not involved. Opt. b is a somewhat leaner approach as it assumes that the UE acquire a PD update after waking up from DRX (even simpler if it is assumed that the initial UL transmission is not involved), and would be applied for both PD estimation options based on TA and by the use of Rx-Tx measurements.  This issue had been discussed during RAN1#104-e, without any conclusion. It has been discussed that it may be better to request feedback from RAN2 on this issue. As noted in the discussions, clearly the same assumption when combing back from DRX would need to be applied to both methods – as otherwise, the comparison of the methods (and the evaluated related t-sync performance) may present different assumptions when re-turning from DRX.  **Proposal 6: For a fair comparison between PD estimation Option 1 (TA) and Option 2 (RTT), alignment on when a PD estimation is acquired after DRX is required. RAN1 should ask RAN2 when a PD estimation can be assumed to be acquired after DRX, either:**   * **Option a. The UE utilize a PD estimation from its previous DRX awake period, as the UE needs a PD estimation immediately after waking up from DRX. A similar error related to using an old PD for PDC applies to all PD estimation options.** * **Option b. The UE may acquire an up-to-date PD estimation after waking up from DRX. This implies that the gNB may signal an update timing advance value or complete a Rx-Tx measurement procedure.**   **Proposal 7: After having RAN2 feedback on the PD estimation assumptions after DRX, align the assumption across PD estimation Options 1 (TA) and 2 (RTT).** |

### First round discussion

**Proposal 4.1-1: Send a LS to RAN2 to ask which option RAN1 should take as the assumptions on when a PD estimation is to be acquired after DRX for both RTT-based PDC and TA-based PDC:**

* **Option 1: The UE utilize a PD estimation from its previous DRX awake period**, as the UE needs an PD estimation immediately after waking up from DRX. A similar error related to using an old PD for PDC applies to all PD estimation options.
* **Option 2: The UE may acquire an up-to-date PD estimation after waking up from DRX.** This implies that the gNB may signal an update timing advance value or complete a Rx-Tx measurement procedure.

|  |  |
| --- | --- |
| *Company* | *View* |
| OPPO | We understand the issue, but do not get why RAN2 can be more knowledgeable than RAN1 in answering this question. Whether PDC should use an up-to-date PD or likely-to-expire PD seems PDC error performance related, and therefore a part of RAN1 work. From RAN1 perspective, we think this can be UE implementation issue: if UE receives referenceTimeInfo-r16 after DRX wake-up, the UE can either update its local clock timing using the earlier PD estimation (obtained prior to DRX) or discard the received referenceTimeInfo-r16 (meaning no clock time update). This means the error performance analysis in RAN1 should assume Option 2 but UE is not prevented from using Option 1 occasionally.  Note that the UE behavior between TA-based PDC and RTT-based PDC could be different. UE can derive PD based on TA at any time, but has to wait for RTT from gNB side (e.g., T\_delta MAC-CE) for RTT-based PDC.  One issue in RTT-based PDC that is similar to this DRX-related issue is the potential inconsistent RTT pairing in PD derivation, which is caused by the fact that the RTT measurements in gNB and UE are not coordinated – the RTT measurement (say in gNB) happens before a TA command being applied on UE side and the RTT measurement (in UE) happens after the TA command being applied. Then the error of PD contains half of TA command value (not TA command granularity). |
| CATT | We are fine with FL proposal. |
| ZTE | When a UE gets the time clock based on the estimated PD and the time reference information from the network, the UE does not need to update the time clock until it believes the time clock is not correct any more, for example, due to the uncertainty of a long running of the local time system. So the UE does not need to update the time clock frequently.  For the TA-based solution, the UE can estimate the PD at any time as long as it has a valid TA.  In option 1, as shown in the Figure 1 above, why does not the UE estimate the PD before entering the DRX, i.e., when the UE receives TA1 or RTT1 from the network?  It seems the difference between the option 1 and option 2 for the analysis in RAN1 is the whether Te is considered if our understanding is correct. It leads to different analysis results. The objective is to improve the time accuracy of the Uu interface. So it is straightforward to use the best option to get a lower achievable time synchronization accuracy and RAN1 can make this decision in our opinion. |
| Vivo | In our view, both options can be workable. We think the related procedure and parameters for option 1 and option 2 should be further clarified to reach common understanding. |
| Nokia, NSB | We support Proposal 4.1-1 to get RAN2 clarification on Option 1 versus Option 2 above. |
| Intel | Tend to agree with OPPO thinking. It is uncertain whether RAN2 has better understanding of this aspect. May be a more proper approach is to make an assumption, e.g. Option 2, and proceed. |
| Qualcomm | We are fine with FL proposal. |
| HW/HiSi | Fine to send LS to ask help from RAN2. |
| LG | We are fine with the proposal |
| Samsung | We think this can be discussed with RAN 1. |

#### Summary of the status for proposal 4.1-1 in first round

|  |  |
| --- | --- |
| Yes | *CATT, Nokia/NSB, QC, HW/HiSi* |
| No | *OPPO, ZTE, Intel, Samsung* |

## TA-based propagation delay compensation

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

**Issue 4.2-1**: **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 is 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 based on inputs from RAN4 though. In RAN1#104-e meeting, the following proposal was given but no consensus achieved:

***Revised proposal xx: Send a LS to RAN4 to ask for feedback on the following three questions:***

* ***Question 1:*** *Is it feasible to assume a smaller value than the current Te for UEs supporting accurate PDC and the use of accurate PDC assuming the same definition of Te in the current RAN4 specification? If the answer is yes, please also provide feedback on how much it can be reduced, e.g. reduced to (1/4)\*Te.*
* ***Question 2:*** *Is it feasible to assume a smaller uplink transmission timing error than Te in RRC connected mode, e.g. assuming non-contention based PRACH or SRS with pre-defined TA? If the answer is yes, please also provide the potential smaller value we can assume for propagation delay compensation.*
* ***Question 3:*** *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, e.g. reduced to (1/4)\*for enhanced TA command indication granularity.*
* ***Note:*** *For the purpose of satisfying time synchronization target, sum of the two errors (UE transmit timing error (Te) and error from TA granularity) need to be small, e.g. ~110ns or lower at least for SCS 15 kHz.*

Before sending LS to RAN4 to ask for the inputs, RAN1 would need to evaluate and provide some examples on the reduced Te or enhanced TA indication granularity to RAN4 first, then RAN4 can further check the feasibility.

Some companies (e.g. Huawei, Vivo, Ericsson, Intel, Nokia) provide some evaluations on the potential required Te and/or TA indication granularity or whether TA-based PDC enhancements can meet the budget or not, however the views are diverse since the value would highly depend on the equation to calculate the overall synchronization error as discussed in section 3.1. Therefore, let’s focus on the equation there first, and once we achieve some common understanding there, we can further discuss issues in this section.

**Feature lead**: Delay the discussion here till we achieve some common understanding on the equation to calculate the overall synchronization error as shown in section 3.1.

**Issue 4.2-2**: **Whether to introduce a separate procedure for gNB to estimate the propagation delay?**

It is assumed that the current Te given in RAN4 spec is defined assuming channel/signal used during initial access, e.g. SSB for downlink frame timing error and contention based PRACH for uplink transmit timing error.

In RAN1#104-e meeting, Samsung proposed to adopt a new way for gNB to estimate the propagation delay, i.e. estimate the propagation delay based on non-contention based PRACH or SRS with pre-defined TA, which may provide the room to reduce the uplink transmission timing error smaller than Te. Pre-defined TA is to avoid TA adjustment error. However, it seems further discussion needed to allow companies to fully understand it.

### First round discussion

**Question 4.2-1:** **Do you agree that we can introduce a separate procedure to estimate the propagation delay assuming non-contention based PRACH or SRS with pre-defined TA in RRC connected mode for TA-based PDC method? If yes, how to define the pre-defined TA to be used?**

|  |  |
| --- | --- |
| *Company* | *View* |
| OPPO | Not really.  As we mentioned in last RAN1 meeting, the timing error tolerance for PRACH (as in TS 38.104) is quite large (on level of microsecond, and TS38.104 does not seem to differentiate between contention-based case and non-contention-based case). For SRS/PUSCH with pre-defined TA, our questions are:   1. Whether is the current numerical assumption of still applicable to UL channels with pre-defined TA? 2. Whether is the gNB required to perform multiple separate FFT operations per symbol (one FFT for all UE’s with legacy TA, and one additional FFT for EACH UE with pre-defined TA)? 3. Whether is the proposal leading to some new RAN1 impacts to UL channel multiplexing (e.g. the multiplexing between one channel with legacy TA and another channel with pre-defined TA)? |
| CATT | In our understanding, this question is related to option 2 of proposal 4.1-1. If option 2 can be supported and TA-based PDC method can’t be satisfied with the requirement, non-contention based PRACH or SRS with pre-defined TA in RRC connected mode for TA-based PDC method can be considered. |
| ZTE | The non-contention PRACH can be used for the TA-based solution.  For the SRS with pre-defined TA, more details are needed. In our understanding, this may have a bit more spec impacts since SRS is transmitted based on the valid TA in the current spec. In addition, we are not sure if the network can estimate the valid TA based on the SRS with pre-defined TA since SRS has the normal CP. |
| Nokia, NSB | No.  We do not see any benefits in such procedure. The only error sources that a pre-determined TA will alleviate is the adjustment accuracy and adjustment accuracy is not considered when we consider Te. It has been argued by some companies that the proposed procedure would also be capable of improving the signaling granularity, but if we consider TA based on Release-16 with timing delta MAC CE the gain expected of such signal is very small. |
| Qualcomm | No. We share the same view with OPPO. |
| HW/HiSi | We would like to discuss further to get a better understanding.  In general, we think it is fine to use other signals to estimate the propagation delay, if a better accuracy can be obtained. As mentioned by the FL, how do we calculated the pre-define TA? And how does its choice impact the propagation delay estimation error? |
| LG | According to our assumption, dominant error component are UE and gNB’s fundamental error and not channel-specific. We think it is difficult to alleviate error budget and it would be similar to RTT-based mechanism with new RTT ping signal in the end. |
| Samsung | We like to have more discussion. We think this related the potential benefit from RTT based. |

## RTT based propagation delay compensation

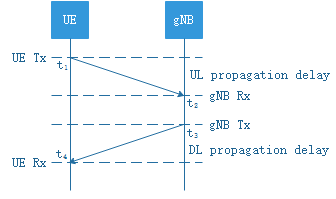
For RTT based delay compensation, propagation delay estimation is based on an RAN managed Rx-Tx procedure intended for time synchronization.

**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

**Feature lead:** The views on the equation is very diverse, thus we have to discuss with the following questions to achieve common understanding one-by-one.

### First round discussion for issue 4.3-1

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.

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-TX  Where:  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

|  |  |
| --- | --- |
| **Definition** | The gNB Rx – Tx time difference is defined as TgNB-RX –TgNB-TX  Where:  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 we need to consider and**  **for DL propagation delay estimation error for RTT-based PDC? Please provide your reason also.**

|  |  |
| --- | --- |
| *Company* | *View* |
| OPPO | *In our understanding, the above equation is double-counting, because*   * *;* |
| CATT | *We need consider*  and for RTT-based PDC |
| ZTE | *Yes. They should be considered since they can affect the actual transmission timing of the DL signal and UL signal, respectively.* |
| vivo | and also should be considered for RTT-based PDC. |
| Nokia, NSB | No.  The reference point is the Tx and Rx antenna connector and their relative timing error is expected to be very small / negligible |
| HW/HiSi | We do not to consider them, because based on the definition of UE/gNB Rx – Tx time difference above, the reference point for transmit measurement is the antenna connector. |
| LG | No. According to definition FL brought, it seems negligible. Anyhow, we can support to add those error term for safety or setting upper bound. |
| Samsung | *We need consider*  and for RTT-based PDC |

**Question 4.3-2: Do we need to consider and**  **for DL propagation delay estimation error for RTT-based PDC? Please provide your reason also.**

|  |  |
| --- | --- |
| *Company* | *View* |
| OPPO | *Same comment as for Question 4.3-1.* |
| CATT | *We need consider*  and for RTT-based PDC |
| ZTE | *Yes. They should be considered since they can affect the actual detected timing of the UL signal and DL signal, respectively.* |
| Vivo | and should also be considered for RTT-based PDC. |
| Nokia, NSB | *Yes.*  and reflects the UE and gNB detection accuracy of the first detected path, so they need to be considered. |
| HW/HiSi | We think it is necessary to consider them, because TgNB-RX/ TUE-RX is defined by the first **detected** path in time which may have errors compared to the first **actual** path in time. |
| LG | Yes |
| Samsung | *We need consider*  and for RTT-based PDC. |

Another issue is whether and how to consider the measurement inaccuracy of gNB Rx-Tx time difference, and the measurement inaccuracy of UE Rx-Tx time difference, respectively. The problem is that there is no any definition in RAN4 for NR yet. If need to be considered, we need RAN4 to provide some values for us to use also. In theory, it should be included.

**Question 4.3-3: Do we need to consider** ? **If your answer is yes, do we need to ask RAN4 to provide inputs on the potential value?**

* + and reflects the measurement inaccuracy of gNB Rx-Tx time difference, and the measurement inaccuracy of UE Rx-Tx time difference, respectively.

|  |  |
| --- | --- |
| *Company* | *View* |
| OPPO | Do not need to consider ; otherwise timing errors at gNB/UE Tx/Rx are double-counted. |
| CATT | We need consider and it depends on which one (gNB or UE) executes PD estimation. |
| ZTE | Yes, we think they should be considered.  We can ask RAN4 to provide the inputs but this should be delayed. We should finish the analysis of the TA-based solution first to see if TA-based solution is adequate. |
| vivo | should be considered for RTT-based methods. We share the similar views with ZTE to analyze the TA-based solution firstly. The RAN4 input is needed. |
| Nokia, NSB | No,  From our understanding and and and will reflect the same errors and hence only one of them will be needed. For simplicity, and for comparison with TA, we prefer to use and . |
| HW/HiSi | For evaluation, we think using and is sufficient.  The measurement inaccuracy of gNB/UE Rx-Tx may be based on PRS, we are not sure whether it can be directly used here. However we are open to further discuss this. |
| LG | We think those are negligible and already reflected in Q 4.3-2. |
| Samsung | Agree with HW |

Some companies also mentioned that gNB eventually need to signal to UE about the propagation delay. Therefore, an additionally ignaledg to indicate propagation delay cannot be avoided. The granularity of propagation delay indication will also affect the total error. I think this is only for gNB-based RTT PDC assuming gNB pre-compensation is not used. Companies view are needed.

**Question 4.3-4: Do you agree that is only needed for gNB-based RTT PDC without gNB pre-compensation? If your answer is NO, please provide your reason also.**

* + is to reflect the error due to the granularity of propagation delay indication

|  |  |
| --- | --- |
| *Company* | *View* |
| OPPO | **is needed for:**   * gNB-based RTT PD estimation together with UE-based PD compensation (no gNB pre-compensation); or * UE-based RTT PD estimation together with gNB-based pre-compensation. |
| CATT | Yes |
| ZTE | Yes. It should be considered since the the PD is signaled between the gNB and UE and signaled PD granularity will affect the estimated time clock just like the TA granularity in the TA-based solution. |
| Vivo | Yes. |
| Nokia, NSB | No,  No matter which entity is doing PDC, an Rx-Tx measurement needs to be ignaled. Our understanding is that the inaccuracy caused by the granularity of the Rx-Tx measurement report is to be captured in . |
| Intel | We think error\_indication is needed for both UE-based compensation (gNB TxRx time difference signaled to UE), and for gNB-based pre-compensation (UE TxRx time difference signaled to gNB) |
| LG | Yes |
| Samsung | Yes |

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

For positioning, PRS is used for estimating Rx-Tx time difference. The question here is that for time synchronization, whether other DL reference signal other than PRS can be used or not? We did the discussion in RAN#104-e and the status is as below:

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**Question: Whether DL reference signals other than PRS could be used for DL time estimation at UE side?**

* **No:** *CATT, ETRI*
  + PRS is sufficient for RTT-based PDC
* **UE implementation issue:** *OPPO*
* **Yes:** *Samsung, Nokia/NSB, Vivo, ZTE, Intel, LG, Ericsson,* 
  + *For the purpose of time synchronization, there might not be the same accuracy requirement as for positioning, and hence some of the enhancements introduced for positioning with higher power density and large bandwidths might not be needed for all time synchronization use cases*
  + *There might not be any need for the gNB to initiative PRS transmissions only for the sake of time synchronization, if other reference signals are available and can provide sufficient accuracy, e.g. CSI-RS.*

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Accordingly a proposal was made in RAN1#104-e, which can be the starting point of the discussion in this meeting.

### First round discussion for issue 4.3-2

**Proposal 4.2-1: DL reference signals other than PRS could be used for DL time 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 DL time estimation or not**
* **FFS whether which DL reference signal to be used is UE implementation or not, i.e. whether we need to explicit define the reference signal to be used in the specification or not.**

|  |  |
| --- | --- |
| *Company* | *View* |
| Feature lead | If possible, **please also provide your views on what signal to be used and your views on the two FFS**. I think in the end we may also need to discuss whether any restriction on the RS needed or not in order to meet the budget, e.g. the bandwidth. But at this stage difficult to discuss since we still don’t have agreement on the equation.  In my understanding, we cannot leave it to UE implementation, since the value of the error components would depend on the RS to be used, e.g. measurement inaccuracy, downlink frame timing error, etc. |
| OPPO | Is the discussion here intended to establish, per specification wise, the reference signal which the UE uses to lock on DL-Rx timing? If so, it seems the discussion pre-assumes a change to existing TA mechanism (note that the existing TA timing does not restrict, per spec wise, the dependency on certain specific DL RS). In our view, the DL-RS other than PRS is certainly eligible to be used, but RAN1 does not need to explicitly add RS to or remove RS from the current DL-RS list that the UE uses for DL synchronization. BTW, we assume this DL-RS discussion (if taken for RTT-based PDC) is also applicable to TA-based PDC. |
| CATT | We would like to modify Proposal 4.2-1 as blow  DL reference signals ~~other than~~ e.g. PRS could be used for DL time 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 DL time estimation or not * FFS whether which DL reference signal to be used is UE implementation or not, i.e. whether we need to explicit define the reference signal to be used in the specification or not. |
| ZTE | At least the SSB and the TRS can be used for DL time estimation.  We do not see the need to indicate which DL RS is used for DL time estimation since UE can use any DL signals as long as the DL signals satisfy the requirement and this should be up to UE implementation. |
| vivo | In our view, DL RSs satisfying the timing error requirement can be used for DL time estimation. The corresponding restriction e.g. the bandwidth should be further studied. |
| Nokia, NSB | Support Proposal 4.2-1  We agree with the FL that we need to discuss if any restrictions are needed. From our understanding we need a selected DL and UL RS in order to determine related performance requirements. As the budgets are quite large, it makes sense to capture a variety of configurations and RS.  PRS can be used, but it should not be the only option, as others and more commonly used can be used as well, such as CSI-RS or even PSS/SSS will be sufficient in some cases.  For Option 2, the gNB needs to configure the UE with a DL and UL reference signals to be used for Rx-Tx measurement (i.e. there needs to be a defined relationship of the UL & DL RS to define the measurement). |
| Intel | DL PRS framework is heavily optimized for inter-cell and inter-frequency measurements. For the purpose of PDC, this design is not required. Thus, other signals can be used with similar success. |
| Samsung | We want to study the accuracy of other RS than PRS. We don’t want to conclude that some method can be achieved only with PRS. So, a proper assumption should be carefully choosed. |

**Issue 4.3-3**: **Whether to take gNB based pre-compensation or UE-based compensation?**

|  |
| --- |
| *Intel R1-2103031*  **Option 2 – RTT-based UE compensation or gNB pre-compensation**  The RTT-based compensation could be realized using the existing gNB Rx-Tx time difference and UE Rx-Tx time difference measurements, or re-defined Rx-Tx time difference using other signals. In this matter, there are two possible flavors:   * Alt. 1: UE side compensation. A UE measures UE Rx-Tx time difference and receives from gNB the gNB Rx-Tx time difference, so that total PD can be calculated and compensated. The signaling in this case should be UE-specific. This introduces additional signaling overhead in DL, same way as UE-specific pre-compensation at gNB, where reference timing information is assumed to be delivered in dedicated RRC message.   + In order to reduce the gNB Rx-Tx time difference signaling overhead towards UEs, group-common signaling options could be considered at physical or higher layer. * Alt. 2: gNB side pre-compensation. A UE measures UE Rx-Tx time difference and reports it to gNB. gNB measures the gNB Rx-Tx time difference, receives the UE Rx-Tx time difference, and pre-compensates the reference timing information before sharing it with the UE. From perspective of the overall signaling exchange, this alternative may be a bit easier to implement if the UE Rx-Tx time difference measurement is defined as just another regular measurement as part of *MeasurementReport*.   **Observation 2**   * *RTT-based propagation delay compensation requires additional UE-specific signal exchange between gNB and UE:*   + *In DL direction, group-common signalling could be utilized to reduce overhead.* |

In addition, there is an LS R1-2102293 from RAN3 mentioning that gNB-based pre-compensation may have impact on RAN3.

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*RAN3 has begun discussing propagation delay compensation (PDC) enhancements, including gNB-based PDC (i.e. propagation delay pre-compensation by the gNB).*

*RAN3 considers that gNB-based PDC may have RAN3 specification impacts. However, it is RAN3 understanding that support for gNB-based PDC is up to RAN1 and RAN2 decisions. Therefore, RAN3 will not further discuss gNB-based PDC unless support for the functionality is first confirmed by RAN1/RAN2.*

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**Feature lead:** Whether to take gNB-based pre-compensation or UE base compensation was discussed in RAN1#104-e but no consensus was achieved. Since it will have impact on the detailed design, it seems we will have to discuss again. In addition, if we decide to take gNB-based compensation, we would need to inform RAN3 earlier since it will have impact on RAN3.

### First round discussion for issue 4.3-3

**Question 4.3-5: Which option do you prefer for RTT-based PDC, gNB-based compensation or UE-based compensation?**

|  |  |
| --- | --- |
| *Company* | *View* |
| **Feature lead** | Status on this question from last meeting:   * **RTT-based UE compensation:** *OPPO, CATT, Nokia/NSB, Samsung, Intel, ZTE, LG*   + *Easier for the UE to handle as the UE can simply change the timestamp provided in ReferenceTimeInfo*   + *No RAN3 impact* * **RTT-based gNB compensation:** *CATT, Samsung, Ericsson, Intel, LG* * **Feature lead:** Based on the current position, it seems hard to say which one is better. Maybe leave time for companies to check more and we can further discuss next meeting.   Note that once we achieve consensus here, the conclusion (i.e. UE-based or gNB-based) may be applied to non-RTT based method also. |
| OPPO | Slight preference on UE-based. |
| CATT | RTT-based UE compensation should be considered with high priority because UE compensation is already supported in Rel-16.  If RTT-based UE compensation can’t be satisfied with the requirement, we can consider RTT-based gNB compensation. |
| ZTE | UE-based solution is our preference since it has limited spec impact. The gNB-based compensation can be considered only if the UE-based solution cannot address the issue. |
| vivo | These two methods have no obvious difference for PDC. We slightly prefer UE-based compensation considering the potential spec impact. |
| Nokia, NSB | We prefer UE based compensation.  However, it is our understanding that the entity conducting PD estimation and PD compensation does not have to be the same as a PD estimation can be signaled to the other entity (e.g. if the UE conducts PDC, it can be provided the PD estimation from the gNB) or vise-versa. Therefore, we propose that RAN1 only considers the estimation accuracy, and not the signaling details and which entity conducts PDC, and leaves these details to RAN2. |
| Intel | We actually think gNB-based approach has a limited RAN1&RAN2 spec impact (new measurement IE definition mainly), although has some RAN3 impact. While UE-based approach requires new indication design to signal gNB Tx-Rx time difference to the UE.  Instead of debating on which option to support, we can define all the components needed for both options. |
| HW/HiSi | We are open to further discuss these options and have no strong view yet.  However, gNB-based compensation may have RAN3 impact, and the gNB may not know the UE’s TA when DL timing is changed and the UE adjusts TA automatically. |
| LG | We slightly prefer UE-based compensation. Since it would have less spec impact, there is no strong reason to use gNB-based compensation unless only gNB-based scheme satisfies requirements. |
| Samsung | We can study both. |

## Implicit propagation delay compensation

OPPO (R1-2102396) proposes an implicit PDC method as below:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| *OPPO R1-2102396*   |  |  | | --- | --- | | Message flow in Method-1 (Implicit PDC) | Message flow in Method-2 (Explicit PDC, assuming PDC is performed on UE side) | | 1. UE sends to gNB at UE’s local time : a message containing . The gNB needs to measure and record reception time . An example candidate for this message is RRC referenceTimeInfo-r16. 2. gNB sends to UE a message containing . 3. gNB sends to UE at gNB’s local time : a message containing . The UE needs to measure and record reception time . An example of this message is RRC referenceTimeInfo-r16. 4. UE derives based on , and , and may change its clock time accordingly. | 1. gNB sends to UE a message containing RTT measured in gNB. An example of this message is T\_delta MAC-CE from Rel-16 IAB protocol. 2. gNB sends to UE at gNB’s local time : a message containing . UE needs to measure and record reception time . An example of this message is RRC referenceTimeInfo-r16. 3. UE sets its clock time to at moment of , where is the estimated one-way propagation delay based on gNB-side RTT and UE-side TA interval. (The one-way delay estimation becomes TA-based if gNB-side RTT is deemed to be known to UE without need of signaling) |   ***Observation-1: The explicit-PDC (RTT-based PDC) method may need message exchange between gNB and UE in both MAC layer (for propagation delay estimation) and RRC layer (for propagation delay compensation). Then for explicit PDC, it can be a question how to get synchronization procedure in specification to involve two different protocol layers (MAC and RRC) in order to minimize the synchronization error. Such question, however, falls out of RAN1 scope.***  ***Observation-2: The explicit-PDC (RTT-based PDC) method can be sensitive to inconsistent RTT measurements (i.e., for the two RTT measurements in gNB and UE, one is done before TA adjustment and another is done after TA adjustment).***  ***Proposal-1: RAN1 to take implicit PDC method into account for enhancing time synchronization.***   * ***The method targets to find the difference between two local clock times respectively in gNB and UE.*** * ***Both gNB and UE individually transmit at least one message to each other, where the message contains the local clock time corresponding to the time at which the message is sent.***   + ***Note: The current spec already supports such message sent from gNB to UE.*** * ***gNB sends to UE another message corresponding to the information of its local clock time corresponding to the time at which the above-mentioned message from the UE is received at the gNB.***   ***Proposal-2: With implicit PDC, RAN1 relies on averaging technique (as gNB/UE implementation issue) to statistically reduce impacts from the errors generated in gNB/UE Tx/Rx, rather than asking RAN4 to tighten UE hardware requirements and/or parameters.*** |

**Feature lead**: Since the method is raised the first time, companies are encouraged to check and if there is any question or comments would be good to share.

**Question 4.4-1:** **Do you have any comment/question on implicit PDC proposed in R1-2102396?**

|  |  |
| --- | --- |
| *Company* | *View* |
| OPPO | The ultimate target of this PDC work is not the estimation of one-way propagation delay, but the synchronization between local clock in gNB and local clock in UE, or equivalently the timing difference between the two local clocks. The implicit PDC directly accomplishes this target without separate the PD estimation and PD compensation in two steps, which count and twice.  The implicit PDC derivation makes uses of the local clock time differences between gNB and UE that are spent on DL transmission and UL transmission respectively; it does not use any RTT, so the inconsistent RTT pairing and TA command granularity are not problems here.  The implicit PDC can support averaging technique more easily than other solutions, to lower the needs for RAN4 to raise the UE hardware requirements. The implicit PDC provides the so-far lowest clock sync. Error, and it does not introduce additional RAN1 work. |
| CATT | For implicit PDC method, both UE&gNB need still send local time to gNB.  Implicit PDC method still introduces indication error and propagation error twice.  So if RTT-based method is required, it is enough that TXRX time difference is shared one time between UE and gNB.  [OPPO resp.] There is no timing to be measured twice in implicit PDC, which means no timing error has the chance to be counted twice. |
| Nokia, NSB | Our understanding of this procedure is that PD is “implicitly” compensated by the exchange of timestamps in both UL and DL directions.  If that is the case, then the method is still subject to the errors related to providing a timing understanding in both directions. Similar errors which is present with the so called “explicit” PDC methods.  [OPPO resp.] This “implicit PDC” surely shares the same error sources as “explicit PDC” for , , and . But each of these error sources is counted only once, since the timing retrieval on each gNB/UE Tx/Rx end occurs only once, and each error has the coefficient of ½. This is different from explicit PDC, which needs to access gNB DL Tx timing and UE DL Rx timing twice, which lead to the coefficient equal to 3/2 for these two errors in the worst case.  Further, our contribution in R1-2102396 shows following differences from explicit PDC:   * The overall sync error for implicit PDC does not contain the term like . * The overall sync error for implicit PDC indeed contains the accumulated quantization error in (three) timing indications sent between gNB and UE. However, because the quantization error in each referenceTimeInfo is only 5ns, the overall quantization error is very small: (3\*5)/2-5=2.5ns (pls refer to our TDoc for calculation details, including the reason for -5), which is less than the quantization error caused by T\_delta MAC-CE. * The error caused by inconsistent RTT measurement for RTT-based explicit PDC is not considered or modeled so far in the error analysis. Then it seems RAN1 has to find solution to ensure the issue has no impact eventually to the one-way delay estimation. The issue was once discussed in Rel-16 IAB but RAN1 does not seek further solution given Rel-16 IAB handles only fixed IAB and it is assumed TA command is not sent frequently for child IAB node. But this assumption may not fit the PDC scenarios. This implicit PDC method can leave the inconsistent RTT issue away, because   + what the method needs to use (such as instant clock times for Tx/Rx) is not changed by non-zero TA command while what the TA command changes (such as RTT on gNB or UE side) is NOT used by the method.   + The RTT-based explicit PDC has no coordination of RTT measurements between gNB and UE, while the implicit PDC builds the timing relationship based on the same pairing of DL and UL transmissions. Note: the RTT-based explicit PDC does not even require a “real” UL transmission – so far in the spec the TA interval is measured against the starting of UL frame, which may or may not correspond to a real UL transmission from the UE. This can a problem because the TA adjustment (which impacts RTT) is NOT ALWAYS under control of gNB. So the UL-Rx timing assumed by the gNB may or may not correspond to the UL-Tx timing assumed by the UE. One example is the case in which the cell with 15kHz SCS is in the same TAG with another cell with 30kHz SCS. Then according to 38.213, the TA command for this TAG is relative to 30kHz SCS and, most critically, the TA adjustment on cell of 15kHz SCS MAY be rounded for certain timing alignment. Here “MAY be rounded” is up to UE implementation and transparent to gNB. This is another source of inconsistent RTT between gNB and UE. This issue was also discussed in Rel-16 IAB in Rel-16 IAB maintenance phase. At that time RAN1 decided not to have a spec change because this issue is either light-weighted due to rare TA commands anyway or able to be handled by child IAB node implementation (e.g., never doing the rounding). But it can be a different story when it comes to normal UE. Regardless of UE or child IAB, it is undesirable to change the existing UE/IAB-MT behavior in TA procedure just due to one-way propagation delay estimation.   So in short, there are quite a few RAN1 issues ahead for RTT-based explicit PDC. In order to solve these issues, RAN1 may end up with PDC-oriented specifications in some places. But most of these spec impacts could have been avoided in implicit PDC.  From our understanding, an averaging technique will not help lowering the error sources of either Te or TA command granularity as the first will depend on UE behavior and the latter will require many samples (without the UE or the channel changing) to get a decent average.  [OPPO resp.] As mentioned above, the implicit PDC has no impact from TA command granularity. The averaging does not intend to lower an error of certain specific error sources like Te, but the accumulated error of and . Suppose a worse case where the averaging can only effectively lower timing errors at Rx ends for DL-Rx in UE and UL-Rx in gNB (ie.leave Te aside). The total error contribution at these two ends is roughly (100+100)/2=100ns based on current RAN1 preference. Assume the averaging over two samples can statistically reduce the total by 50ns. Our TDoc shows the current RAN1 assumption gives implicit PDC a total error of 330ns. Reduction of 50ns due to averaging reaches 280ns, which is very close to RAN2 budget (275ns) for control-to-control. The averaging can be further done over more samples until it can meet RAN2 budget.  Further, the implicit PDC does not “require” many samples to work. The averaging technique can be considered an implementation-based enhancement. Even without averaging, the total error of implicit PDC is still the lowest among all solutions currently on the table. On the other hand, we do not see there is any problem in having a sufficient number of samples to do the averaging. |
| Intel | This method can be studied further. |
| Qualcomm | Further study is needed. |
| HW/HiSi | What is the difference compared to the RTT-based method in which the gNB sends Rx-Tx timing difference i.e. to the UE?  [OPPO resp.] Mathematically speaking, the “implicit PDC in TDoc 2396” is equivalent to “RTT-based explicit PDC in TDoc 2396”. You won’t find final differences between the two regarding to overall formulation and error performance. However, the “RTT-based explicit PDC in TDoc 2396” is NOT the exact one that people discussed so far for RTT-based PDC; instead, it is a very specific version of RTT-based PDC with following narrow-downs:   * It assumes the same DL transmission is used in PD estimation (step-2) and PD compensation (step-1). * It assumes RTT measurement on gNB side is synchronized with RTT measurement on UE side. * It assumes the RTT measurements are based on the real DL transmission and real UL transmission, so there is no RTT inconsistency due to UE autonomous TA adjustment in a virtual measurement of RTT interval (“virtual” means the RTT measurement is not based on a real DL transmission or a real UL transmission).   The question is: is it an easy job to do all these narrow-down work in RAN1? And is the effort worth it if there is another method (i.e., the implicit PDC) sitting aside and being able to offer these narrow-downs by nature without RAN1 spec impact? |
| LG | We think this scheme is similar to RTT-based method. In other word, implicit PDC is RTT-based mechanism which start from UE-side. Considering limited clock accuracy of UE comparing to gNB, it should be clarified what is difference and what is beneficial point compared to the RTT-based method. |

# 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. R1-2102396 Enhancement for support of time synchronization OPPO
4. R1-2102497 Discussion on propagation delay compensation enhancements ZTE
5. R1-2102525 Discussion on propagation delay compensation enhancements vivo
6. R1-2102632 Discussion on propagation delay compensation enhancements CATT
7. R1-2102698 Discussion on propagation delay compensation for time synchronization MediaTek Inc.
8. R1-2102748 Propagation Delay Compensation Enhancements for Time Synchronization Ericsson
9. R1-2102821 Discussion on enhancements for propagation delay compensation Nokia, Nokia Shanghai Bell
10. R1-2103031 Further analysis and design considerations regarding propagation delay compensation Intel Corporation
11. R1-2103167 Enhancements for support of time synchronization for enhanced IIoT and URLLC Qualcomm Incorporated
12. R1-2103240 Discussion for propagation delay compensation enhancements Samsung
13. R1-2103328 Propagation delay compensation enhancements ETRI
14. R1-2103351 Discussion on propagation delay compensation enhancements LG Electronics
15. R1-2103398 Enhancements for support of time synchronization Huawei, HiSilicon, SIA

# 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.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **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:\Users\c00387628\AppData\Local\Temp\Docs\R1-2102245.zip).