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

**E-meeting, January 25 – February 5, 2021**

**Agenda Item: 8.3.4**

**Source: Moderator (Huawei)**

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

**Document for: Discussion and Decision**

# Introduction

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

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| 1. Enhancements for support of time synchronization: 2. RAN impacts of SA2 work on uplink time synchronization for TSN, if any. [RAN2] 3. Propagation delay compensation enhancements (including mobility issues, if any). [RAN2, RAN1, RAN3, RAN4] |

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 RAN1#102-e and RAN1#103-e, 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#103-e meeting, the UE downlink frame timing error has been discussed but no conclusion could be reached. The controversial point is how to interpret the RAN4 specification.

Based on views from contributions submitted in this meeting, company position is summarized as below:

* **Option 1**: 100ns i.e. same as gNB UL detection error
  + ***Support:*** *Nokia, OPPO, Ericsson, vivo, Huawei/HiSilicon*
* **Option 2**: Downlink frame timing error is not needed to be considered separately
  + ***Support:*** *ETRI, CATT, Qualcomm*

**Feature lead**: According to the RAN4 specification as copied below, it should be clear that Te and DL frame detection error should both be considered in the evaluation of time synchronization accuracy of PD estimation options based on TA.

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| 7.1.2 Requirements The UE initial transmission timing error shall be less than or equal to Te where the timing error limit value Te is specified in Table 7.1.2-1. This requirement applies:  - when it is the first transmission in a DRX cycle for PUCCH, PUSCH and SRS or it is the PRACH transmission.  The UE shall meet the Te requirement for an initial transmission provided that at least one SSB is available at the UE during the last 160 ms. The reference point for the UE initial transmit timing control requirement shall be the downlink timing of the reference cell minus . The downlink timing is defined as the time when the first detected path (in time) of the corresponding downlink frame is received from the reference cell. *N*TA for PRACH is defined as 0.  (in *Tc* units) for other channels is the difference between UE transmission timing and the downlink timing immediately after when the last timing advance in clause 7.3 was applied. *N*TA for other channels is not changed until next timing advance is received. The value ofdepends on the duplex mode of the cell in which the uplink transmission takes place and the frequency range (FR). is defined in Table 7.1.2-2. |

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| 1). 38.133 section 7.1.1 says:  "The uplink frame transmission takes placecid:image001.png@01D6F5AD.02632E50 before the reception of the first detected path (in time) of the corresponding downlink frame from the reference cell."  ***View from OPPO****: Noted that the spec clearly says it is the "detected" DL frame timing that UE uses to apply TA. In other words, the UE does NOT necessarily know where in time the "true" first arrival path is. If UE does, that "true" path would become the "detected" path. Then the error between the "detected" path and the "truly arrival" path is not counted in the remaining spec content in that spec section. That spec section describes everything by assuming the "detected" path.*  2).38.133 section 7.1.2.1 says:  " When the transmission timing error between the UE and the reference timing exceeds ±Te then the UE is required to adjust its timing to within ±Te. The reference timing shall be cid:image002.png@01D6F5AD.02632E50 before the downlink timing of the reference cell."  ***View from OPPO****: The above text clear says the error Te is between the actual UL Tx timing and the reference UL Tx timing -- there is no DL Tx timing (which is cid:image002.png@01D6F5AD.02632E50away) involving here.*  *With above spec texts from RAN4, I hope it can be clear to the group that error\_{UE,DL,Rx}=100ns is not counted in Te.* |

**Proposal 2.1-1:Take 100 ns as the assumption for downlink frame timing detection error at the UE for evaluation of the overall time synchronization error at least for TA based propagation delay compensation.**

**Please comment if you have strong concern on the above proposal 2.1-1.**

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| *Company* | *View* |
| CATT | We prefer Option 2 because we think Te already considers Downlink frame timing error and 100 ns as the assumption for downlink frame timing detection error isn’t necessary. |
| OPPO | We agree with including DL frame timing detection in the error modeling and also agree with using 100ns. But we think this error is equally applicable to both TA-based estimation and RTT-based estimation. This error is counted in both one-way propagation delay estimation (via Tx-to-Rx interval on UE side) and clock-compensation (via the difference between the actual clock-arrival time and UE conceived clock-arrival time). |
| Samsung | For the case considering Te, we think there is no need to count again. But if for the evaluation of some method where Te is not used. We are fine to take 100ns as the assumption. |
| Nokia, NSB | We are fine with FL proposal to take 100ns.  Based on our evaluations R1-1900935, the DL reference signal can be for example PSS/SSS or DM-RS on PBCH, or a dedicated DM-RS transmission on PDSCH, or even DL-PRS. In this study we consider the case of DM-RS on PBCH, where the accuracy is estimated to ~130ns (one shot). Higher accuracies can, however, be achieved with time tracking algorithms at the UE or relying on more wideband DL reference signals (e.g. CSI-RS or DM-RS on PDSCH) which can further enhance the accuracy to the considered 100ns. |
| vivo | We agree with FL’s proposal. We think this error should be considered for both TA-based method and RTT-based method for PDC. |
| MediaTek | In our view, downlink frame timing detection error is already considered as part of Te, hence, there is no need to double-counting the error. However, for the cases where Te is not considered, downlink frame timing detection error can be considered. |
| ZTE | The UE transmits the uplink signal based on the detected DL timing and the TA. Both of the DL detection error and UL transmission error exist just like the BS transmission timing error and the BS detection error we have agreed. The UE believe the calculated time is the clock when the detect the DL frame. Therefore, the DL detection error should be considered since it can affect the detection time. We are fine with the assumption of 100ns for DL detection error.  In addition, we believe this error should be considered for both TA-based method and RTT-based method. |
| Intel | Agree with 100 ns to progress evaluation |
| HW/HiSi | Agree with the proposal. |
| LG | We support the proposal. |
| Ericsson | Agree with FL proposal 2.1-1.  Furthermore, we also agree with several companies that this error should be considered for RTT-based method also, and the value can be smaller than 100ns considering that better DL RS is used for measurement. |
| ETRI | Our understanding is similar to MediaTek. |

#### Summary of the status for proposal 2.1-1 based on first round email discussion

* ***Support proposal 2.1-1:*** *OPPO, Nokia/NSB, Vivo, ZTE, Intel, Huawei/HiSilicon, LG, Ericsson*
* ***Downlink frame timing detection error is not needed for the case that Te is already considered*** 
  + *CATT, MediaTek, Samsung, ETRI*
* ***Downlink frame timing detection error should be applied to both TA based PDC and RTT-based PDC*** 
  + *OPPO, Vivo, ZTE, Ericsson (potential smaller than 100ns)*

### Second round email discussion

Based on the views in the first round email discussion and summary above, proposal 2.1-1 is revised as below for further discussion:

**Revised proposal 2.1-1:Take 100 ns as the assumption for downlink frame timing detection error** () **at the UE for evaluation of the overall time synchronization error ~~at least~~ for TA based propagation delay compensation, regardless of whether Te is considered or not.**

* **FFS:the value of for RTT-based propagation delay compensation**

**Please comment if you have strong concern on the above revised proposal 2.1-1.**

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| *Company* | *View* |
| OPPO | We would have concern on the main bullet and the FFS part, which leaves possibility to make RTT-based compensation to use a different fro TA-based. If that happens, RAN1 ends up with following logic:   * The DL timing detection error on the UE side, even based on the same hardware and the same channel condition, is somehow strangely dependent on how the UE chooses to estimate the one-way propagation delay (TA vs. RTT), which may or may not happen in PHY layer at all. * The comparison between TA-based compensation and RTT-based compensation is no longer purely solution-dependent, but also analysis assumption dependent.   We believe =100ns should apply to RTT-based compensation as well if it is agreed for TA-based compensation.  Feature lead>> Since there is different view on RTT-based, let’s focus on TA-based first, and at least achieve some progress here first. As Nokia and Qualcomm comment, this might be the best we can achieve. |
| CATT | We still think taking 100 ns as the assumption for downlink frame timing detection error () is unnecessary because Te is limit value of the timing error for initial transmission and already considers downlink frame timing detection error which is hard to be estimated. |
| Qualcomm | We support this proposal to move forward. In addition, we can remove the parameter Te from the equation. i. e., just keep the original three errors as it is and not apply the approximation of . As a result, majority of the total error equation will be aligned as  -  Feature lead>> Even we remove Te from the formula, the controversial point is still there, e.g. your assumption is that , which actually means that is included in Te. |
| Nokia, NSB | Similar as Qualcomm, maybe this is the best we can do now. But still need it would be good to have common understand if Te is now applied or not (consistently by all the companies) as otherwise the evaluation results of different companies will not be comparable. Also the assumption on the DRX issue below (Option 1 vs. Option 2) could have some impact here.  Feature lead>> Agree. For TA-based solution, the current assumption is option 1, maybe we can focus on option 1 here first and further discuss other cases if needed. |
| ZTE | We are fine with the assumption of 100ns for downlink frame timing detection error. When we determine the UE detected downlink frame timing, the assumption should be considered. However, when we determine the uplink frame transmitting timing, **only the Te** defined by RAN4 should be used. The Te defined by RAN4 includes two components. One is the downlink timing detection error. The other is the uplink transmitting timing error, which is similar as the BS transmitting timing error. It should be noted, both of the two components may affect the uplink frame transmitting timing. There is no need to define the separate requirements for the two components since the purpose is to determine the UL frame transmitting timing. Only a whole error is defined by RAN4. In our understanding, the first detected path corresponds to the ‘truly arrival path’. |
| vivo | The timing error with hardware-[dependent](http://www.baidu.com/link?url=YNkuQeMF3GoTUpwsCPwTdMaMbanVI44mQy1DMGf9C0bjprjKqHOdwycy2cWXcXM6F1nvEn3Ch7R5FwwKsOkmSZk846m5U0itN2kt8iklgyiI3sosQmNsbOgvPDVerya6) and channel-[dependent](http://www.baidu.com/link?url=YNkuQeMF3GoTUpwsCPwTdMaMbanVI44mQy1DMGf9C0bjprjKqHOdwycy2cWXcXM6F1nvEn3Ch7R5FwwKsOkmSZk846m5U0itN2kt8iklgyiI3sosQmNsbOgvPDVerya6) should base on the same assumption between TA-based and RTT-based method.  We also think the equation should be aligned before making conclusion.  We support =100ns for both TA-based and RTT-based compensation. |
| Samsung | It is clear that different companies have different understanding. Although RAN 4 spec said “first detected path”. It is unclear on how to defined “detected path” in the test, i.e. how to check the “detected path” at UE side during the test.  We proposed to agree to  **Take 100 ns as the assumption for downlink frame timing detection error** () **at the UE for evaluation of the overall time synchronization error ~~at least~~ for TA based propagation delay compensation, at least when Te is not considered**   * It is up to company whether is considered or not when Te is used for calculating the total error * **FFS:the value of for RTT-based propagation delay compensation**   We think in the end, whether to consider will not impact on the final observation.  Feature lead>> It may not have impact on the observations, but still good to achieve common understanding to show more accurate estimation if we can. |
| Huawei, HiSilicon | It seems that different companies have different understandings about “detected path” in the RAN4 spec, that leads to different views about whether Te includes the DL timing detection error or not. If that is the case, we are wondering if it is possible to also ask RAN4 about whether Te includes DL timing detection error or not, considering that RAN4 experts may have a better understanding of the RAN4 spec. Since we are anyway discussing to send a LS to RAN4 to ask if it is feasible to improve Te in section 4.1.2.1, we could also include this question.  For evaluation, we would prefer to use the same value for both TA-based and RTT-based compensation. Since the downlink detection error may be same for TA-based and RTT-based compensation if the UE detects the downlink timing based on the same RS. |
| OPPO-2 | @companies still believing DL-Rx error is part of Te: the testability for “detected path” or “” is not defined in RAN4 spec (we all know that). So it is RAN4 logic that this testability question should not be answered by 3GPP. That is also why RAN1 comes up with its own assumption on 100ns (already agreed) for this whole error analysis. The question raised on testability seems to challenge how RAN1 can justify this 100ns assumption.  It cannot be clearer to us that:   * is between “moment of first detected DL path” and “truly arrival moment of truly one-way DL propagation at UE”. * Te is between “actual UL Tx timing” and “moment of first detected DL path - (N\_{TA}+N\_{TA,offset})”.   How come one is contained by another?  Further, it is RAN4 tradition that the UE Tx requirements and UE-Rx requirements are separated in different spec sections, so the Te should not touch any requirement on UE Rx side.  At last, is kind of performance-oriented metric which is surely not part of section 7.1 of 38.133 that gives requirements on hardware implementation. If Te can contain , it means no matter how DL Rx sync timing is bad due to poor channel, this badness cannot go beyond what RAN4 requirement says, which is hard to understand and guarantee.  @HW/HiSi, it is unfortunate for RAN1 to ask RAN4 such a simple question whose answer is already clearly marked in RAN4 spec. |
| CATT2 | Regarding whether downlink frame timing detection error can be included in the total error equation or not, we are fine with either of two proposals from HW and Samsung.  1. Sending LS to RAN4 to ask RAN4 about whether about whether Te includes DL timing detection error or not.  2. Below Samsung’s proposal  **Take 100 ns as the assumption for downlink frame timing detection error** () **at the UE for evaluation of the overall time synchronization error ~~at least~~ for TA based propagation delay compensation, at least when Te is not considered**   * It is up to company whether is considered or not when Te is used for calculating the total error * **FFS:the value of for RTT-based propagation delay compensation** |

#### Summary of the status for revised proposal 2.1-1 based on first round email discussion

* ***=100ns should apply to both TA-based compensation and RTT-based compensation.***
  + *OPPO, Vivo, Huawei/HiSilicon*
* ***Downlink frame timing detection error is not needed for the case that Te is already considered*** 
  + *CATT, MediaTek, Samsung, ETRI, ZTE*
* ***Feature lead:*** *Still different understanding on whether downlink frame timing detection error is included in Te or not. The only way we can do is to ask for some clarification from RAN4.*

### Third round email discussion

Based on the views in the first and second round email discussion and summary above, proposal 2.1-1 is revised as below for further discussion:

**Revised proposal 2.1-1:Take 100 ns as the assumption for downlink frame timing detection error** () **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**
* **FFS same value applied to RTT-based propagation delay compensation**

**Please comment if you have strong concern on the above revised proposal 2.1-1.**

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| *Company* | *View* |
| OPPO | RAN1 has been given clear RAN4 spec texts that show Te does not include downlink frame timing detection error. Could opponent companies also point out the RAN4 spec text that could make people think the opposite? |
| Ericsson | Regarding is included in Te or not: our understanding is the same as OPPO bullets. These are quite clear in RAN4 spec. We do not see the point of sending LS to RAN4, as it is clear that UE cannot possibly be required to know the true downlink frame arrival time. Thus it is not possible that Te is measured according to the true downlink frame arrival time. We would be OK if the question is: “**RAN4 to ask for clarification on whether** Te is measured according to the true downlink frame arrival time.”  Regarding TA-based vs RTT based: we agree that downlink frame timing detection error would be the same for both methods if everything is the same (same hardware, same DL reference signal). However, TA-based method and RTT-based methods are different because of the different DL RS used to measure the DL frame timing.   * For TA-based, if legacy TA method, no requirement on DL RS is assumed. In other words, the DL frame timing may be measured based on SSB. If new requirement is introduced on DL RS (e.g., minimum bandwidth of the DL RS has to be 5 MHz) for TA-based method, then may reduce. * If RTT-based, the DL RS for DL frame timing measurement is PRS, or some CSI-RS with certain requirements (e.g., minimum bandwidth) if RAN1 decides to specify dedicated DL RS for time sync.   We suggest the following:  **Take ±100 ns as the assumption for downlink frame timing detection error** () **at the UE for evaluation of the overall time synchronization error when no additional condition is applied to DL reference signal for downlink frame timing measurement, for example, in legacy TA-method.** |
| Intel | Based on the citations from RAN4 specification, we are not sure if RAN4 itself can come up with a different understanding from the main bullet. Overall, this aspect does not deserve a standalone LS, however could be clarified the way Ericsson suggested as part of another more important LS, if any (e.g. being discussed for enhanced requirements).  We also second Ericsson observation, that RTT could use other DL signals for frame timing detection and the error value could be different. In the same, we can agree that it is < ±100 ns, i.e. not worse than that. |
| Nokia, NSB | Support revised proposal 2.1-1.  To us, it is clear that the UE cannot know the true DL arrival time, and the RAN4 specs also clearly states “first **detected** path” – therefore asking about any ‘true’ value (only, as suggested by Ericsson)) would be almost be like a waste of the LS. Based on our understanding Te is independent error to DL reception error at the UE and applicable to initial transmission in DRX, but I guess the intention here would be to ask RAN4 for related clarifications (but let’s not use any ‘true’ in here).  On the FFS (2nd bullet): OK to have it there. Overall, it seems strange to take option specific assumptions especially if the same underlying RS are applied. TA can also benefit from the same RS used for RTT, therefore, if we assume a specific RS for RTT the same accuracy should be assumed for TA (as the UE will use the same hardware / estimators for a certain RS – and not specific to any of the discussed alternatives). |
| HW/HiSi | Support |

## 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.

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.** |

**Feature lead**: It is true that the TAE represents the relative maximum timing error between any two antenna ports, however my original interpretation is that the maximum BS transmit timing error at a single antenna port can be 65 ns also depending on different implementations. But can hear more views from other companies.

**Question 2.2-1: Do you think that the agreed 65 ns value used to represent the BS transmit timing error should be interpreted as ±32.5 ns to represent a single gNB antenna port transmit timing error for the control-to-control scenario?**

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| *Company* | *View* |
| CATT | From our point of view, if 65ns used to represent the maximum BS frame transmission error ±32.5 ns can be interpreted as a single gNB antenna port transmit timing error for the control-to-control scenario. |
| OPPO | Not necessarily. 65ns is a safer assumption because there is no guarantee for the correct DL Tx timing to stay at the middle of 65ns interval. In addition, we do not think the change of this value from 65ns to the half could make any outstanding difference, and if it does, the RAN1 conclusion could become risky in practice. |
| Samsung | We think 65ns is BS transmission timing error. But when we calculate the propagation delay error, half of it is used. |
| Nokia, NSB | Agree with Samsung here – if 65ns is used, then only half of the error should be applied. If ±32.5 ns, then the full value should be used. So the decision here and the decision on the formula are therefore connected.  We prefer ±32.5 ns as explained in R1-2100730 |
| vivo | We are fine with it.  BS transmit timing error can be interpreted as ±32.5 ns to represent a single gNB antenna port transmit timing error for the control-to-control scenario. |
| ZTE | We are fine with the proposal.  The 65ns is defined as the transmission timing error between the antennas of the gNB. It means the the transmission timing error of the single port should be less than ±32.5ns such that the defined requirement can be satisfied. |
| Intel | Fine with the proposal |
| HW/HiSi | No strong view. We tend to agree with Oppo are fine with +/- 32.5 ns if this is the majority view. |
| LG | Fine with the proposal. |
| Ericsson | Do not support.  We recognize 65ns is from TAE. Due to lack of better standardized values, we can accept that BS frame transmission error is approximated as ±65ns, i.e., giving a reference point (another antenna port in TAE definition), an antenna port does not deviate more than 65ns. It is not possible to use ±32.5ns, since it is not stipulated anywhere that the two antenna ports are tuned to a perfect reference time at the middle. |
| ETRI | We are fine with the proposal. |

#### Summary of the status for Question 2.2-1 based on first round email discussion

**Question 2.2-1: Do you think that the agreed 65 ns value used to represent the BS transmit timing error should be interpreted as ±32.5 ns to represent a single gNB antenna port transmit timing error for the control-to-control scenario?**

* **±32.5*:*** *CATT, Nokia/NSB, Vivo, ZTE, Intel, LG, Samsung(maybe), ETRI*
* **±65ns:** *OPPO, Ericsson, Qualcomm*
  + *65ns is a safer assumption because there is no guarantee for the correct DL Tx timing to stay at the middle of 65ns interval*

**Feature lead**: It is true that the TAE represents the relative maximum timing error between any two antenna ports, however my original interpretation is that the maximum BS transmit timing error at a single antenna port can be 65 ns also depending on different implementations. However, it seems majority view is ±32.5, therefore OPPO and Ericsson are encouraged to think again whether ±32.5 is acceptable or not.

### Second round email discussion

Based on the views in the first round email discussion and summary above, the following proposal 2.2-1 is made for further 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 provide your comment on the above proposal 2.2-2.**

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| *Company* | *View* |
| OPPO | To our understanding, RAN1 just “borrows” this 65ns value from RAN4 defined TAE for single carrier MIMO, but this “borrowing” does not imply a derivable logic connection between **e*rrorBS,DL,TX***(which is error between actual DL-Tx time and gNB-conceived DL-Tx timing) and TAE (which is the relative difference between any two NR signals or antenna connectors). We think it is fairly ok to assume the two numbers are kind of “around the same level”. But we are not sure whether changing down to 32.5ns could be too optimistic. Anyhow OPPO can follow the majority view even though we do not see the motivation strong enough to change the RAN1 agreement. |
| CATT | We prefer FL proposal 2.1-1 |
| Qualcomm | We do not support this proposal. It is not obvious that we can use 32.5ns directly. |
| Nokia, NSB | We support this proposal.  Using this, the overall for control-to-control then the overall time synchronization can be calculated using **Option 2** as per **Section 3.1**. |
| ZTE | We are fine with the proposal. |
| Vivo | We are fine with this proposal. |
| Samsung | We are fine with the proposal. And in this case, we agree with Nokia that is used for the calculation other than for calculation of the total error. |
| Huawei, HiSilicon | We are fine with the proposal. |

#### Summary of the status for proposal 2.1-2 based on first and second round email discussion

* **Support*:*** *CATT, Nokia/NSB, Vivo, ZTE, Intel, LG, Samsung, ETRI, Huawei/HiSilicon, OPPO (fine)*
* **±65ns:** *Ericsson, Qualcomm, OPPO*
  + *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*
* **Feature lead**: As company commented above, there is no better standardized values for BS transmit timing error, therefore difficult to judge which side is right. The only way here is to follow the majority view. If people still have concern,

### Third round email discussion

Based on the views in the first and second round email discussion and summary above, the proposal 2.2-1 made in the second round email discussion is kept, here is to check if still any strong concern:

**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 any strong concern.** If you support or can accept this proposal no need to fill in the table to save your time.

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| *Company* | *View* |
| Ericsson | Do not support the proposal.  When the value of the error components were discussed, we understood that they always have ± associated with the value. Otherwise, it does not make sense that the values of the components can be summed up, if some have ± already, while the others need to be applied with /2. Note that all equations submitted companies show summation of components.  Thus, the existing agreement of 65ns means ±65ns if RAN1 was not sloppy.  The earlier agreement (copied below) means ±65ns, ±130ns, ±200ns, ±82.5ns. It was unfortunate that RAN1 was sloppy. When RAN1 agreed on Option 1, ±65ns was selected in our understanding.  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     To avoid this type of debate, we recommend that RAN1 agreements below (RAN1#103e) are updated with ±100ns, ±200ns, ±65ns.  Agreements:  100 ns is assumed for BS detecting 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 |
| Intel | No strong preference. We don’t see this factor as the most limiting in the overall budget. |
| Nokia, NSB | Support the proposal. |
| HW/HiSi | Support |

## BS transmit timing error for smart grid scenario

In RAN1#103e, the following agreement was achieved:

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

Nokia proposes to use ±100ns (i.e. corresponding to option 1) to represent the BS frame transmission timing error for the smart grid scenario.

**Feature lead**: Based on the discussion in RAN1#103-e, it seems difficult to achieve consensus on one of the options at this stage, therefore the intention for the agreement is to leave companies to pick one of them to evaluate the overall synchronization error, since in any case it seems the budget for smart grid would be sufficient. Therefore, I would suggest no more discussion on this in RAN1#104-e, and depending on the outcome for question 2.2-1 the values used here can be translated accordingly, e.g. if the answer to question 2.2-1 is yes, then ±100 ns can be used if option 1 is picked.

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| *Company* | *View* |
| CATT | We prefer to Option 2 and BS frame transmission timing error for the smart grid scenario should use the same value on BS frame transmission timing error for control to control. |
| OPPO | Agree with FL. Our conclusion on smart grid remains the same across {65,100,200}ns. |
| Samsung | Suggest to use 65ns as well. |
| Nokia | We agree with the option 1 and therefore BS transmit timing error of ±100 ns would be consider for the smart grid use case. |
| Vivo | We agree with FL’s suggestion. |
| MediaTek | In our view, only Option 2 should be considered, so smart-grid and control-to-control scenarios use the same value.  Although, this may not affect the outcome of going above or below the budget, but it will be more accurate estimation of the error with the TA-based method. |
| ZTE | We are fine with the FL’s suggestion. |
| Intel | Fine with the conclusion |
| HW/HiSI | Agree. |
| LG | We are fine with the proposal. |
| Ericsson | We are OK to leave this as two values, since the conclusion does not change either way for smart grid use case.  On the other hand, in our view, all values should have ±, even though sometimes RAN1 agreement was sloppy. Thus the two options means ±200ns and ±65ns. |
| ETRI | Agree with the suggestion. |
| Qualcomm | Agree. |

# 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.

Based on the agreements achieved in RAN1#102-e and RAN1#103-e and the views in the contributions, the potential error components that will have impact on the time synchronization accuracy over Uu interface are as below:

* **BS transmit timing error (**:
  + For control-to-control, it was agreed to use 65ns for the evaluation.
  + For smart grid, it was agreed to use 65ns or 200ns for the evaluation.
* **Downlink frame timing error ():** Details as shown in section 2.1
  + Value to be decided
* **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

Once the factors that will have impact on the error of the time synchronization are set, we need some method to calculate the overall error of the time synchronization based on Rel-16 mechanism to see whether enhancement is needed or not, if needed then how to improve the accuracy of time synchronization. Note that the overall time synchronization error for the enhanced schemes (i.e. propagation delay compensation and RTT-based propagation delay compensation) can be further evaluated in section 4.

Based on the contributions, the following 6 options are proposed:

**Option 1:**

* + ***Support:*** *CATT, Qualcomm, MediaTek*

**Option 2:**

* + ***Support:*** *Intel, Huawei/HiSi, LG, Ericsson, vivo*

**Option 3:**

* + ***Support:*** *~~MediaTek~~*

**Option 4:**

* + ***Support:*** *~~OPPO,~~ Nokia*

**Option 5:**

* + ***Support:*** *Samsung*

***Option 6:***

* + ***Support:*** *ZTE*

**Option 7:**

* + ***Support:*** *OPPO*

**Feature lead:** In RAN1#103-e meeting, the following agreements were achieved, therefore it seems option 3, option 4 and option 5are not aligned with the agreements.

|  |
| --- |
| 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. |

As to option 6, it is expected that the time clock of the UE is equal to the received time clock of the gNB plus the downlink propagation delay as shown in the formula below, therefore it should be “*errorBS,DL,TX*” instead of “-*errorBS,DL,TX*” to be included in the equation. Therefore, it seems option 6 is not appropriate.

,

Then between option 1 and option 2, the difference is whether to consider downlink frame timing error as discussed in section 2.1, since in section 2.1 we propose to include downlink frame timing error, here the starting point is to propose option 2 for further discussion.

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

|  |  |
| --- | --- |
| *Company* | *View* |
| CATT | We prefer to Option1 and shouldn’t be included in formula because Te already considers Downlink frame timing error. |
| OPPO | It seems companies are quite diverging regarding to the total error formula. Then it could be helpful for each proponent to explain their tools in more details, rather than simply shouting out the equations. Here is our explanation (and Option-4 above in FL summary is NOT our equation for total error – it is the one for propagation delay estimation error).  First, we think the total error should be:  Here we assume the DL Tx/Rx timing errors (1st and 3rd terms on right side of above inequality) at gNB/UE are NOT measurable, i.e., they cannot be taken as a part of Tx-to-Rx intervals on both sides of gNB and UE, where “not measurable” means either   * the error cannot be measured once the error is less than a threshold (this would be hardware-dependent, e.g. the Tx is implemented by processor interruption); or * the error can be somehow measured but the measurement at time t1 becomes invalid or not guaranteed at the time other than t1.   Meanwhile, given RAN1 assumes symmetric DL/UL propagation delays, these independent Tx/Rx timing errors cannot be merged into one-way propagation delay either.  Next, the one-way propagation delay estimation error, , is the formula shown in Option 4 above, containing five terms, four of which are the errors generated at gNB-Tx(), gNB-Rx(), UE-Tx(=Te) and UE-Rx(), and the fifth error is the half of TA granularity (). Note that the in one-way propagation delay estimation is not necessary the same as the in the total error equation above (they just share the same math notation). The same applies to . |
| Samsung | Agree with CATT, we think already covered by Te.  Agree with OPPO that should be added as half.  Besides, for some cases, e.g., option 1C, that assuming UE is in connected mode and Te already been overcomed by TA adjustment or finer sync up with gNB, TA adjustment can be used as leftover, as well as can be added in this case. |
| Nokia. NSB | The decision here and the discussion on 65ns vs. ±32.5 ns in Question 2.2-1, are related here (see our comments there)  Assuming 65ns for Question 2.2-1 is used, then we do not agree with this and agree with Samsung that half of is applied. |
| Vivo | We support Proposal 3.1-1. |
| MediaTek | We would like to highlight that we meant instead of in Option-3 above (it was a typo in the contribution).  Thus, we support option-1 as already covered by Te. |
| ZTE | We prefer our proposal, i.e. option 6.  As shown in our paper, the BS transmission timing error and the DL detection error at the UE affect both the calculated receiving time and the actual receiving time. Thus, their effect should be aligned in the analysis for calculated receiving time and the actual time. For example, the BS transmitting timing error leads to the DL signal transmission is delayed in the analysis of the calculated receiving time. The same effect that the DL signal transmission is delayed should also be imposed on the analysis of the actual time.  That is the reason why we gets ‘-errorUE, DL, RX’ in the equation, which is different from the other companies. |
| Intel | Option 2 or Option 3 both can be fine with clarification on Q 2.2-1.  Furthermore, the component of BS frame timing error does not seem to be dominating the total error, and thus could be taken as a worst-case assumption. |
| HW/HiSi | Support |
| LG | Support |
| Ericsson | Support FL Proposal 3.1-1. |
| ETRI | We prefer option 1, as we read the specification, conceptually appears in the equation but its value is already captured in . |
| Qualcomm | To move forward, we can remove the parameter Te from the equation. i. e., just keep the original three errors as it is and not apply the approximation of . As a result, majority of the total error equation will be aligned as  – |

#### Summary of the status for proposal 3.1-1 based on first round email discussion

* ***Support proposal 3.1-1:*** *Vivo, Intel, Huawei/HiSilicon, LG, Ericsson*
* Downlink frame timing error should not be included 
  + *CATT, MediaTek, Samsung, ETRI*
* Downlink frame timing error should be applied to the signaling to indicate the reference time also 
  + *OPPO, ZTE*
* BS transmit timing error should be considered also for propagation delay estimation error 
  + *OPPO*
* **Feature lead**: It seems the question raised by OPPO and ZTE is correct, we need to consider downlink frame timing error also for receiving the signal with reference timing. In addition, the BS transmit timing error seems also contribute the error for .More views are needed from other companies though.

### Second round email discussion

Based on the views in the first round email discussion and summary above, the following questions and proposals are made for further discussion:

**Question 3.1-1: Do you think that downlink frame timing error should also be used to capture the timing error at the UE side to receive the indicated reference timing information, i.e. the following equation should be used for overall synchronization error where and reflect the error related to receiving the indicated reference timing:**

**Note that for original proposal 3.1-1 (i.e. option 2) only is considered for the error to receive the indicated reference timing information.**

|  |  |
| --- | --- |
| *Company* | *View* |
| OPPO | Yes, both and should be included in the equation as above.   * For gNB Tx, gNB may send a clock of t1 at time (t1+). This timing imperfectness never gets a chance to be compensated in the later processing. So it should remain as a contribution to the very-last total error. * For UE Rx, the actual one-way propagation delay terminates at time t2 but the UE gets it wrongly as (t2+), then the UE uses (t2+) instead of t2 in the delay compensation. This error also remains to the very last.   We think the total error equation in Q3.1-1 above is correct. |
| CATT | We would like to modify above equation as follows  because is already reflected to . |
| Qualcomm | Support. It is exact same as our proposal. . In addition, I think we can remove the Te and majority of the equations proposed by different companies will be the same.  Below is the detailed description.    Assuming , the downlink propagation delay is calculated as:  Then the error of the downlink propagation delay is:  As shown in the Figure 1, the error of 1st TA estimation is calculated as  The error of regular TA estimation is  Based on above section, the total error with 1st TA estimation is  The total error with regular TA estimation is |
| Nokia, NSB | We don’t think adding another error parameter (*errorPD*)here – that is only the sum of some of the parameters is not really helping and will lead to some confusion here.  As this will create even more confusion in the end (i.e. we move now all the discussion to *errorPD*. At least the same error cannot increase overall to 1.5 times (see answer to Question 3.1-3 below) |
| ZTE | We are fine with the proposal. For errorPD, it would be better to clarify the assumption for the analysis because we think other two errors in the equation may affect the errorPD. |
| Vivo | We agree the intention of the proposal. It needs further clarify whether other two terms in the equation can affect the . |
| Samsung | We are also confused by *errorPD*. Some clarification is needed. |
| Huawei, HiSilicon | We think *errorPD* needs to be clarified since it is determined based on multiple error components. |
| OPPO-2 | Appreciate Qualcomm for sharing the detailed derivation. It definitely helps the discussion. Here comes ours.  Assume following math notation:     * : the actual time instance for DL Tx on gNB side. * : the gNB-measurable time instance for DL Tx. * : the actual time instance for DL Rx on UE side. * : the UE-measurable time instance for DL Rx. * : the actual time instance for UL Tx on UE side. * : the UE-measurable time instance for UL Tx. * : the actual time instance for UL Rx on gNB side. * : the gNB-measurable time instance for UL Rx. * The errors between the actual Tx/Rx time and measurable Tx/Rx time:   Where x can be {DL, UL} and y can be {TX, RX}   * : the Rx-to-Tx time interval measured at gNB, between the measurable UL Rx and measurable DL Tx, i.e., . For TA-based PD estimation performed by UE, subject to an error , whose absolute value is up to half TA granularity. Because due to this TA granularity, gNB may never get the DL-Tx and UL-Rx perfectly aligned. * : the Tx-to-Rx time interval measured at UE, between the measurable UL Tx and measurable DL Rx, i.e., . * : the actual one-way propagation delay, which is assumed the same between DL and UL, i.e., * : the estimated one-way propagation delay.   1). In step of TA-based one-way propagation delay estimation at UE:  Therefore,  Note this error equation confirms FL’s question in Q3.1-2.  2). In step of PD compensation:  Assume gNB intends to send clock value of at its local time of , but the actual DL Tx transmission happens at . The clock value is received by the UE at actual time of but UE believes the reception time is at . With PDC, the UE would set its clock for received clock of at its local time given by:  Then the total clock sync error is equal to  Note this equation become identical to the one given by FL in Q3.1-1 if all “-“ signs flip to “+”.  Now when bringing from delay estimation step into delay compensation step, the trick is upon the fact that, both and contribute twice to the total error, one time inside as caused by delay estimation, and another time outside of as caused by delay compensation. However, these two contributions happen at the different times, i.e., the two contributions come from the same error source but very-likely with the independent real-time error values. Therefore, is brought into total error formula only after all “-“ signs are flip to “+”, which gives the exact one shown in Q3.1-3.  where . |
|  |  |

#### Summary of the status for question 3.1-1 based on the first and second round email discussion

* Downlink frame timing error should also be used to capture the timing error at the UE side to receive the indicated reference timing information
  + *OPPO, Qualcomm, ZTE*
* No
  + *CATT, Nokia/NSB*
* Some other companies feel clarification needed

**Question 3.1-2: Do you think that BS transmit timing error should be considered also for propagation delay estimation error (i.e. )? If your answer is yes, do you agree that /2 should be included for ?** Note that the original proposal (i.e. option 2) doesn’t consider **for**

|  |  |
| --- | --- |
| *Company* | *View* |
| OPPO | Yes. should be an error component with coefficient 1/2 in . This should be obvious for RTT-based estimation (given is one end of errors in gNB Rx-to-Tx interval measurement) but not so straightforward for TA-based estimation (which is built on Rx-to-Tx interval on UE side). The fact is, the timing relation in TA-based estimation actually translates the UE-side Rx-to-Tx interval (which is already subject to timing error at UE-Tx and UE-Rx) into the one-way propagation delay (equally on DL and UL) plus the gNB-side Rx-to-Tx interval, which is eventually subject to the timing errors at gNB-Tx and gNB-Rx as well as TA-granularity error (gNB may never get ideal alignment between DL-Tx and UL-Rx). |
| CATT | No, BS transmit timing error is already independently considered and it needn’t be considered in propagation delay estimation error again. |
| Qualcomm | No. Please see the detailed description in Question 3.1-1, especially the Figure. |
| Nokia, NSB | No. Agree with CATT & QC. Also see the comment above, unclear why we need to introduce this. |
| ZTE | Yes. We think it can be considered. But we also can accept the view of the majority companies. |
| Samsung | Clarification of Error PD is needed. |
| Huawei, HiSilicon | We prefer not to consider twice |

#### Summary of the status for question 3.1-2 based on the first and second round email discussion

* **BS transmit timing error should be considered also for propagation delay estimation error with coefficient 1/2**
  + *OPPO (for RTT based), ZTE (can accept no)*
* **No**
  + *CATT, Qualcomm, Nokia/NSB*

**Question 3.1-3: If your answer to the above two questions are yes, do you agree with the following equation for evaluation of the overall time synchronization error for TA based propagation delay compensation?**

|  |  |
| --- | --- |
| *Company* | *View* |
| OPPO | Agree. Key point here:  contributes to the total compensation error twice. One is in the form shown in Q3.1-1 with coefficient equal to 1, and another is in the formula of one-way propagation delay estimation shown in Q3.1-2, with coefficient equal to 1/2 (actually the math derivation for the actual error shows coefficient equal to -1/2). Some companies seem to simply combine the two terms to land on **/2** inside **TOTAL** compensation error. We do not think this is correct, because the in the one-way estimation delay estimation step (which happens at time x) may not be the same as the one in the delay compensation step (which happens at time y). They are just two error terms sharing the same math notation in analysis. To find the max error impact, should have coefficient 3/2 in the total compensation error, as shown above in Q3.1-3. The same logic applies to |
| CATT | We prefer below equation |
| Qualcomm | . To move forward, we remove Te. |
| Nokia, NSB | No  Now the and are even considered more than 1x (1.5 times). So really the additional introduction of the parameter seems to be not really helping. |
| ZTE | In fact, we don’t understand how to obtain this equation. We cannot add all the components as the overall error simply. As we explained above, the components highlighted in red should carefully studied. A figure should be better to illustrate this. |
| Samsung | If we considering the TA based method is based on current PRACH, we think the following is correct:  For some new signaling in connected mode (option 1c, where we allowing additional adjustment), we think Qc’s proposal can be a startng point: |
| Huawei, HiSilicon | If is not considered, then it should be 0. And we would like to know the value of if we remove Te. Please note that based on the agreements in the appendix, we have not defined the value of yet. |

### Third round email discussion

Based on the views in the first and second round email discussion, it would be good for us 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. I made some draft steps as below as the starting point for further checking:

**Step 1**: Discuss and determine **high level** error component(s) for signaling the reference time clock from gNB to UE

* 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**
* DL propagation delay estimation error (details for this component as step 2 below)



**Question 3.1.2-1:** **Do you agree with the high-level error components in step 1 above? If your answer is NO, please explain which part is wrong and why it is wrong. If you feel that it depends on details of , please explain why the error components for transmission of RRC signaling containing the reference time would be relevant to DL propagation delay estimation error.**

|  |  |
| --- | --- |
| *Company* | *View* |
| OPPO | The final equation is not the error modeling given it does not show what the total error is. But our answer would be YES (agree) if the equation above yields the same total error equation as in Q3.1-1, which we guess it does.  Note that this error equation does not depend on whether is part of Te or not. |
| Ericsson | Do not understand the point of the question 3.1.2-1. All companies have been providing equations for , although exact expression varies.  If the question is about: “if should be included as an explicit component as ”, then: we can agree this is to be included if UE is the entity to perform PD compensation. |
| Intel | Yes. In addition, we don’t like to include the granularity of providing reference timing information since RAN2-provided budget values include that already. |
| Nokia | Agree.  Our understanding on is that it reflects the mismatch between the SFN boundary timestamp provided in referenceTimeInfo and the actual air interface frame timing. This could be caused by e.g. a DU and RU split. |

**Step 2**: Discuss and determine error component(s) for DL propagation delay estimation (i.e. )



Assuming , the downlink propagation delay is calculated as:



Then the error of the downlink propagation delay is:



* study the following two options:
  + **Option 1:**  <= Te
  + **Option 2:**  = Te and considered separately

**Question 3.1.2-2:** **Do you agree with the above equation for DL propagation delay estimation (i.e. )? If your answer is NO, please explain which part is wrong and why it is wrong.**

|  |  |
| --- | --- |
| *Company* | *View* |
| OPPO | NO. The equation for has missing. This equation actually draws a strange logic: no matter how large the BS DL Tx timing error is (say X times larger than 32.5ns, where X is arbitrary), the one way propagation delay estimation error is not impacted. Then which TA-based estimation method does proponents suppose to have this property? We just do not see it.   * If TA-based estimation is done in gNB, gNB needs to measure time interval between DL-Tx and UL-Rx. Any DL-Tx timing error counts. * If TA-based estimation is done in UE, UE needs to assume that gNB perfectly aligns DL-Tx timing and UL-Rx timing. Any DL-Tx timing error (which makes the alignment not “perfect”) would contribute to final one-way estimation error. |
| Samsung | Regarding on UE transmission error, I see there are two cases, for both TA-based and RTT-based method:  Case 1: UE wake up from IDL, potentially with data transmission: Te defined in RAN4 spec can be used. However, we can ask RAN 4 whether smaller value can be achieve, if no data or assuming some particular channel, e.g. PRACH/SRS  Case 2: UE tries the best to transmit an uplink in connect mode. Some particular case:  Case 2-1: UE transmit a PDCCH ordered PRACH with pre-defined TA  Case 2-2: UE transmit a UL channel on a pre-known time location (UE reports this time location to base station for RTT-based method)  In our view, the error is about:  **gNB transmission error**: limited by hardware  **UE detection error:** limited by UE detection performance (May or may not be covered by UE tranmsisison error )  **UE transmission error:** limited by hardware  **gNB receiver error:** limited by gNB detection performance  and indication error:  gNB to UE  UE to gNB  For both RTT based and TA based method, there is no fundamental difference on the hardware limited part. However, we might need to ask a proper question to RAN 4, seeking for an answer with a correct assumption.  We can discuss the equation later, after we understand the parameters and assumption. |
| Intel | Yes |
| Nokia | Agree  With Option 2, as has already been discussed. |

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

**Proposal 3.1.2-1:Take the follow equation for evaluation of the overall time synchronization error for TA based propagation delay compensation:**

* study the following two options:
  + **Option 1:**  <= Te
  + **Option 2:**  = Te and is considered separately

|  |  |
| --- | --- |
| *Company* | *View* |
| Feature lead | Note that if is agreed to be introduced for receiving the RRC signaling containing the reference time, it doesn’t matter whether it is “” or “” in terms of calculating the overall error, since if “” is used, then -100 ns would be used here. |
| OPPO | Agree the summation components except that /2 is missing from part (the 2nd term on right side of inequality). Please see our comments above Proposal 3.1.2-1. |
| Samsung | Same as comment above, we suggest to ask RAN 4 first, to clarify the definition of each parameter. |
| Intel | In our understanding, sign does matter since there are two entries of that component (should be ‘-‘ for the red one). Therefore, we need to collapse those entries into one first using proper signs, and then take modulo as a worst case. |
| Nokia, NSB | Agree.  On the comment from the FL, we would argue that when determining DL frame timing for TA and for SFN boundary would be strongly correlated (if not equal – i.e. the frame timing is done once and is equally “wrong” for DL PD estimation and to interpret referenceTimeInfo), and hence the + or – does matter. If the original equation is followed the expression becomes:    And then you end up with -0.5 instead of 1.5. |

## Overall time synchronization error over Uu interface

Once we achieve consensus on the equation to be used for calculating the overall time synchronization, we can get the overall time synchronization error achievable based on Rel-16 scheme based on the following assumption we agreed in RAN1#102-e.

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

In addition, 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 in section 3.1, 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 | 490 | 360 | 490 | 360 |
| Intel | 491 | 360 | 491 | 360 |
| Ericsson | 490 |  | 490 |  |
| 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 |

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.**

|  |  |
| --- | --- |
| *Company* | *View* |
| CATT | We support observation 1 from our evaluation results. |
| OPPO | Ok. |
| Samsung | OK |
| Nokia, NSB | Agree |
| vivo | We support observation 1. |
| MediaTek | Agree with the observation. |
| ZTE | We have the same observation |
| Intel | Agree |
| HW/HiSi | Support |
| LG | Support. |
| Ericsson | Agree with the observation.  However, we caution that this does not mean that smart grid case should stop at the TA-based method. If an enhanced method is adopted for control-to-control case, then smart grid case can benefit from the enhanced method also. One method should be standardized in Rel-17 to cover all TSN use cases. |
| ETRI | Support the observation. |

#### Summary of the status for observation 1 based on first round email discussion

* ***Support observation 1:*** *Vivo, Intel, Huawei/HiSilicon, LG, Ericsson, CATT, OPPO, Samsung, Nokia/NSB, Vivo, MTK, ZTE, ETRI*
* ***Feature lead: Observation 1 is agreeable.***

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

|  |  |
| --- | --- |
| *Company* | *View* |
| CATT | We support observation 2 from our evaluation results. |
| OPPO | In our timing error analysis, the error budget for control-to-control scenario cannot be met even if TA command granularity (for TA-based estimation) and Tx-Rx interval indication granularity (for RTT-based estimation) go down to zero; even further, the error budget for 15kHz SCS cannot be met even if Te becomes zero as well. Therefore, our observation is that NO enhancement from RAN1/RAN4 perspective can help to meet the RAN2 error budget for control-to-control scenario. |
| Samsung | Ok with the observation |
| Nokia | Agree  RAN1 should further evaluate the pros and cons of Option 1b and Option 2 as supplementary procedures to legacy timing advance. Option 1b may be used to satisfy the accuracy of the control-to-control scenario with 15kHz SCS with enhanced Te by at least 122ns. This includes RAN1 to ask RAN4 on the feasible enhancement of Te. |
| Vivo | We support observation 2. |
| MediaTek | In our evaluation [R1-2100578], we don’t see a need for PDC in the control-to-control scenario. .  Hence, we don’t see a need for observations for TA-based method in the control-to-control scenario given that there is no need for PDC. |
| ZTE | Yes. We have the same observation. |
| Intel | Agree |
| HW/HiSi | Support |
| LG | Support. |
| Ericsson | Agree with the observation.  However, we emphasize again that one method should be standardized in Rel-17 for all TSN use cases. The enhanced method developed to satisfy control-to-control requirements can be used for smart grid case and many other TSN use cases. |
| ETRI | Support the observation. |

#### Summary of the status for observation 2 based on first round email discussion

* ***Support observation 2:*** *CATT, OPPO, 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.*
* ***Feature lead:*** *More clarification needed how ISD will have impact on the estimated timing error here.*

|  |  |
| --- | --- |
| *Company* | *View* |
| OPPO | It seems our 1st-round feedback was misunderstood. Our view is that “NO enhancement from RAN1/RAN4 perspective can help to meet the RAN2 error budget for control-to-control scenario”. Anyhow this observation2 should be re-evaluated based on conclusions on questions 3.1-x. |
| CATT | Why ISD will have impact on the estimated timing error is not clear to us.  We still think enhancement for propagation delay compensation is necessary for control-to-control scenario. |
| Qualcomm | Support. |

# 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).

## TA-based propagation delay compensation

This section will discuss details of TA-based propagation delay.

### Option 1a: Propagation delay estimation based on legacy Timing advance (potentially with enhanced TA indication granularity)

For option 1a, TA indication error needs to be improved. Nokia (R1-2100730) proposes to take the Timing Delta MAC CE introduced in Release 16 for IAB as the baseline for TA-based propagation delay compensation enhancements.

|  |  |
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| *Nokia R1-2100730*  It has been discussed how to enhance the time synchronization accuracy error caused by the NTA granularity (e.g. carried in the timing advance command). This is also partly the motivation behind PD estimation Option 1a, where a new MAC CE, could optionally be introduced to be used to supplement the current timing advance command.  Alternatively, to introducing a new MAC CE, existing work in Release-16 may be used instead. In the context of IAB, a Timing Delta MAC CE has been introduced [TS 38.213 Section 14, TS 38.321 which serves the purpose of enhancing DL PD estimation accuracy and hence also the NTA signaling granularity. The description of the Timing Delta MAC CE is copied in below from TS 38.213 Section 14:   |  | | --- | | If an IAB-node is provided an index in a Timing Delta MAC CE [11, TS 38.321] from a serving cell, the IAB-node may assume that is a time difference between a DU transmission of a signal from the serving cell and a reception of the signal by the IAB-MT when , where is obtained as for a "UE" in Clause 4.2 for the TAG containing the serving cell and and are determined as  - and , if the serving cell providing the Timing Delta MAC CE operates in FR1,  - and , if the serving cell providing the Timing Delta MAC CE operates in FR2  The IAB-node may use the time difference to determine a DU transmission time. |   Utilizing this Timing Delta MAC CE will supplement NTA e.g. provided in the Timing Advance MAC CE, hence the UE. Based on our understanding this should be understood as the downlink air interface propagation delay even with the split between a DU and RU in IAB terminology. The signaling granularity of is given by , where for FR1 operation. This corresponds to 32ns and is 16 times smaller than NTA for 15kHz SCS, and 8 times smaller than NTA for 30kHz SCS. The drawback is that when NTA needs to be updated, Timing Delta MAC CE update might also be needed.  **Observation 2: For Option 1 schemes, using the Timing Delta MAC CE introduced in Release 16 for IAB may reduce the error from NTA granularity by 16 and 8 times.**  **Proposal 7: RAN1 should use Release-16 as baseline for PD estimation accuracy enhancement evaluations, which includes the Timing Delta MAC CE introduced in Release 16 for IAB.** |

**Feature lead**: It seems make sense to take the R16 mechanism as the starting point. However, since not much details in the contributions on how to enhance the TA granularity, more views are needed from companies before making any way forward.

**Question 4.1-1: How to enhance the TA indication granularity in option 1a? Please also indicate the enhanced TA indication granularity that your solution can achieve.**

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| --- | --- |
| *Company* | *View* |
| CATT | If the TA indication granularity is only enhanced, TA-based PDC can’t meet Uu interface budget from RAN2. |
| OPPO | In our understanding, the Rel-16 IAB mechanism of using indication of T\_delta belongs to the RTT-based one-way delay estimation, not TA-based. For Opt 1a, it seems the only way to enhance is to reduce TA command granularity, which means quite some changes in RAN4 UE Tx timing requirements. As mentioned in section 3.2, it is better for RAN1 to firstly prove the feasibility and effectiveness of such enhancements before digging the solution – we do not see the feasibility of reducing TA command granularity down to zero, which still cannot meet the overall error budget. |
| Samsung | First of all, we need to ensure gNB estimation can provide finer TA estimation. Then we can discuss how to indicate. |
| Nokia | Only a very minor (≤±16ns) enhancement is feasible with PD estimation Option 1a compared to legacy timing advance supplemented by the Release-16 Timing Delta MAC CE. Following option 1a, even having TA indication granularity of 0ns, we cannot meet the requirements for the control-to-control scenario. |
| vivo | Improvement of TA indication granularity error is beneficial for satisfying the synchronization requirements. However, for Single Uu interface Budget for control-to-control scenario, option 1a cannot meet the requirement. |
| MediaTek | We don’t see a need for enhanced TA indication granularity. We first need to justify the necessity for such enhancement before discussing the solutions. |
| ZTE | For the enhanced TA indication granularity, it may be easy to get the value if the consensus is achieved in section 3. From our understanding, a small enhancement is sufficient as long as the accuracy is less than 275ns for control to control. |
| Intel | TA indication granularity is not the only limiting factor, and it should be supported by new RAN4 requirements, which may also demand new signals for estimation. |
| HW/HiSi | Option 1c.  No impact on legacy procedures. Granularity needs to be decided. |
| LG | Enhanced TA indication would be start line for enhancement on TA-based scheme. For example, finer TA estimation and L3 signaling. However, enhanced TA indication is not sufficient in order to meet the requirement. |
| Ericsson | Do not agree that RAN1 should waste time on enhancing TA based method.  Enhancing TA indication granularity does not satisfy the requirements as shown in our contribution. In our evaluation, both Te and TAG error need to be reduced by 75% to reach the high end of RAN2 requirements for control-to-control. This is very difficult to achieve. |
| ETRI | If only granularity is enhanced, then the error bound may be larger in the control scenario requirement. We think at least option 1b or 1c can be considered. |

However, it can be expected that the gain that can be achieved by option 1a would be limited. If we only rely on option 1a, it is impossible to meet the synchronization budget. However, it might be possible to combine with other method, e.g. option 1b.

#### Summary of the status for question 4.1-1 based on first round email discussion

* ***Need to check the feasibility of finer TA indication granularity, including feasibility for gNB to provide finer TA estimation:*** *OPPO, Samsung,*
* ***Whether Release-16 Timing Delta MAC CE can be used for enhanced TA indication granularity?***
  + ***Yes:*** *Nokia*
  + ***No:*** *OPPO*
* ***Feature lead:*** *The key question is whether we can combine option 1a with option 1b, if yes then we can further study whether we can improve the 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)

For option 1b, TA indication error , TA adjustment accuracy and Te should be improved compared to legacy UEs. In RAN1#103-e, it was agreed that TA adjustment accuracy is not considered for the evaluation of time synchronization error, thus we would mainly focus on enhance Te. However, since Te is specified by RAN4, we need RAN4 to evaluate the feasibility to define a new enhanced Te.

**Proposal 4.1-1:Send a LS to RAN4 to ask for feedback on the following two questions:**

* **Question 1:** Is it feasible to define a new enhanced initial transmit timing error Te?
* **Question 2:** If the answer to question 1 is yes, what the enhanced value(s) for Te?

**Please provide your views on the above proposal 4.1-1.**

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| --- | --- |
| *Company* | *View* |
| *CATT* | We support Option 1b because TA-based PDC can meet Uu interface budget from RAN2 if both TA indication error and Te can be enhanced simultaneously.  For example, if TA indication error can be reduced by 8 times and Te can be reduced by 4 times.  one Uu interface time synchronization error based on TA-based estimation for 15Hz SCS is [-147.5ns, 147.5ns] with BS transmit timing error(±32.5 ns) and the formula with option1. |
| OPPO | By following our error analysis given earlier, no non-negative value for Te can make the total error meet RAN2 error budget for 15kHz SCS in control-to-control scenario. It seems useless to consult RAN4 with Q1 and Q2. We would rather suggest to send LS to RAN2 to simply report the difficulty in meeting RAN2 error budget for control-to-control scenario. |
| Samsung | Although we don’t think TA adjustment error needs to be considered for the calculation, it doesn’t mean we don’t need to introduce a finer TA. With 1b, propagation delay estimation requires to trigger a new PRACH for gNB to estimate propagation delay. Otherwise, UE need to calculate TA from the last RACH procedure.  Therefore, we think it is not enough to only support 1b. |
| Nokia, NSB | Yes, RAN1 should further evaluate the pros and cons of Option 1b as supplementary procedures to legacy timing advance. This includes RAN1 to ask RAN4 on the feasible enhancement of Te.  Based on the analysis in our TDoc, Te should be enhanced by at least 122ns to satisfy the accuracy of the control-to-control scenario with 15kHz SCS |
| vivo | According to our evaluation, for single Uu interface budget with ±145ns for Control-to-Control use case, only 12.5ns is left for the sum of Te and TA granularity error assuming BS transmit timing error(±32.5 ns). It is difficult for meeting clock synchronization requirements. |
| MediaTek | No need to send an LS to RAN4.  Based on our evaluations, there is no need for PDC in the C2C scenario, and the exiting errors are within the smart-grid scenario budget. |
| ZTE | We think the LS can be sent if RAN1 finally determine that Te should be reduced. |
| Intel | We need to be careful with bothering RAN4 with such requests unless we don’t find other ways forward.  If companies still think the LS is necessary, we need to provide more context, e.g. whether it is possible to change Te without changing other procedures and signals. |
| HW/HiSi | We would be fine with a LS to RAN4. The answer would give valuable information for the work in RAN1. |
| LG | We also think it would be right way to go to draft LS to RAN4. |
| Ericsson | Do not support.  In our view, it’s useless to send an LS to RAN4, since the TA-based method is too far from satisfying the design target. It simply wastes time both for RAN1 and RAN4. |
| ETRI | We think the LS can help us discussing all of option 1a/1b/1c. |

#### Summary of the status for proposal 4.1-1 based on first round email discussion

* ***Support:*** *CATT, Nokia/NSB, ZTE, Huawei/HiSilicon, LG, ETRI*
* ***No any enhanced option 1b can meet the RAN2 budget:*** *OPPO, Samsung, Vivo, Ericsson*
* ***Feature lead:*** *The main concern from companies who prefer not to send the LS is that they think option 1b cannot meet the RAN2 budget, however in my understanding it would depend on whether and how much we can reduce Te and TA indication granularity, which needs inputs from RAN4. Without inputs from RAN4, it is expected difficult to achieve consensus in RAN1.*

#### Second round email discussion

Based on the views in the first round email discussion and summary above, the following proposal are made for further discussion:

**Revised proposal 4.1-1:Send a LS to RAN4 to ask for feedback on the following two questions:**

* **Question 1:** Is it feasible to define a new enhanced initial transmit timing error Te?
  + If it is feasible, whether any new procedure/signal needed?
* **Question 2:** If the answer to question 1 is yes, what is the enhanced value(s) for Te?

|  |  |
| --- | --- |
| *Company* | *View* |
| OPPO | It is better for RAN1 to firstly ensure the meaningfullness of such LS before sending it to RAN4. If RAN1 can expect that the required improvement on Te (even already under the condition of super-small TA granularity) is too stringent to be practically feasible for UE vendor implementation, such LS should not be sent. Anyhow the decision on 4.1-1 should be based on conclusions from 3.1-x. |
| CATT | We support FL proposal 4.1-1 |
| Qualcomm | Support. |
| Nokia, NSB | Support. |
| ZTE | We support the proposal. |
| Samsung | We’d like to clarify that whether the definition of Te is changed or not? i.e., from DRX idle  Feature lead>> My assumption is not to change the definition of Te. |
| Huawei, HiSilicon | If a LS needs to be sent to RAN4, we would prefer to also ask whether Te includes the downlink frame timing error, considering that the main divergence in section 2.1 is due to the understanding of the RAN4 spec. |

#### Summary of the status for revised proposal 4.1-1 based on first and second round email discussion

* ***Support:*** *CATT, Qualcomm, Nokia/NSB, ZTE, Huawei/HiSilicon, LG, ETRI*
* ***No any enhanced option 1b can meet the RAN2 budget:*** *OPPO, Samsung (first round), Vivo, Ericsson*

***Feature lead:*** *The main concern from companies who prefer not to send the LS is that they think option 1b cannot meet the RAN2 budget, while some other companies think it is possible to meet the budget with enhanced Te. Since whether option 1b can meet the budget does depend on whether and how much we can reduce Te, which needs inputs from RAN4, it seems useful to ask for RAN4 on the feasibility. Without inputs from RAN4, it is expected difficult to achieve consensus in RAN1.*

#### Third round email discussion

Based on the views in the first and second round email discussion and summary above, the proposal 4.1-1 are kept for further check if any strong concern:

**Revised proposal 4.1-1:Send a LS to RAN4 to ask for feedback on the following two questions:**

* **Question 1:** Is it feasible to define a new enhanced initial transmit timing error Te?
  + If it is feasible, whether any new procedure/signal needed?
* **Question 2:** If the answer to question 1 is yes, what is the enhanced value(s) for Te?

**Please comment if any strong concern.** If you support or can accept this proposal no need to fill in the table to save your time.

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| *Company* | *View* |
| OPPO | We oppose this proposal. With following reasons.   1. We do not think it is a good idea for RAN to tighten RAN4 requirements (which is generally applicable in PHY layer) just for certain single specific higher layer application. 2. As UE vendor, we do not support the change of UE hardware requirements that already stays stable since Rel-15. 3. The way the Question 2 is asked seems to suggest RAN4 to reduce Te to as small as they can, which would restrict the hardware implementation choices. What RAN4 requirements target to is “what is sufficient or tolerable”, but now what Q2 asks is “what you can do best”. 4. It is not clear to us what “any new procedure/signal needed” means given RAN4 is not the WG to study new procedure/signal. |
| Samsung | We might not need to change the definition of Te, however, we need to ask Ran 4 on “UE transmission error assuming connect mode”, as we pointed out in previous question.  Case 1: UE wake up from IDL, potentially with data transmission: Te defined in RAN4 spec can be used. However, we can ask RAN 4 whether smaller value can be achieve, if no data or assuming some particular channel, e.g. PRACH/SRS  Case 2: UE tries the best to transmit an uplink in connect mode. Some particular case:  Case 2-1: UE transmit a PDCCH ordered PRACH with pre-defined TA  Case 2-2: UE transmit a UL channel on a pre-known time location (UE reports this time location to base station for RTT-based method) |
| Ericsson | Do not support.  First, without providing design targets to RAN4, RAN4 wouldn’t know how much reduction to work towards. For example, if RAN4 replies that “existing Te=12\*64\*Tc=768\*Tc can be reduced to 765\*Tc”, nothing is changed as far as what RAN1 should do next for TA-based method. Even if an LS is to be sent, RAN1 should ask questions, where the response tells RAN1 what the next step to take.  Second, reducing Te is not sufficient to make TA-based method satisfy control-to-control requirement. TA granularity needs to be reduced at the same time. If RAN1 is to send RAN4 an LS, then a question on TA granularity should be included. How small TA granularity can go depends on gNB hardware, and RAN1 cannot arbitrarily reduce it. |
| Intel | Suggest to wait asking RAN4 unless it is clear that Te reduction is the way forward. |
| Nokia | Agree.  Clearly Te as is already specified and used since Rel-15 should not be changed, but an enhanced Te could be specified and associated with a UE capability. It is clear that an enhanced Te is not sufficient to make Option 1b a viable solution for the most challenging scenario, but along with an enhanced TA granularity (e.g. by using the IAB introduced Timing Delta MAC CE – which in the species is not bound to any special procedure other than TA with the purpose of DL PD estimation) – Option 1b can also be used to meet the most challenging scenarios. |
| Hw/HiSi | Agree |

### 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)

This option relies on the gNB to estimate DL PD, and then use an additional signal to indicate the PD from gNB to UE. Since a separate signaling is used, it has no impact on TA procedure. However, based on the contributions, it seems there are different understanding whether gNB needs to estimate the DL PD based on TA or some other dedicated reference signal (e.g. Samsung proposes to use SRS, UL DMRS or PUSCH with predefined TA for propagation delay estimation). Nokia (R1-210037) mentioned that if the estimation is based on TA, then gNB may have to track all relative TA adjustments, and if the UE applies an autonomous adjustment to its timing advance value, the gNB cannot reliably determine the applied timing advance value at the UE.

**Question 4.1-2: Do you think that gNB will estimate the DL PD based on TA for option 1c? If your answer is NO, please provide your detailed solution.**

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| --- | --- |
| *Company* | *View* |
| CATT | Option1c is one of the enhanced methods on TA-based PDC but signaling of current TA-based PDC is quite complete. So it isn’t necessary to introduce new signaling. |
| OPPO | Same comments as for 4.1-1. Besides, it is a general assumption that the gNB cannot reliably track the NTA value which is the accumulation of series TA commands due to possible missing of HARQ-ACK for PDSCH containing the TA command MAC-CE. |
| Samsung | Yes. We think gNB will estimate the DL PD based on a uplink transmission.  Another motivation to separate the propagation delay estimation and indication from TA is that, there is no need to require to use finer TA for all the TA adjustment, and no need to change TA procedure when there is no need to compensate the propagation delay. |
| Nokia, NSB | Yes. |
| vivo | Yes. gNB need estimate the DL PD based on TA for option 1c. |
| ZTE | Yes. We think gNB should estimate the DL PD based on TA because this estimation is based on the uplink signal detection at gNB, where the uplink signal signal transmission is controlled by the TA. |
| Intel | Yes |
| HW/HiSi | Yes |
| LG | Yes. |
| Ericsson | Do not understand the question. Is the intention of the question to clarify RRC/MAC signaling aspect? But the RRC/MAC signaling question should be handled mainly by RAN2.  In our view, RAN1 should focus on methods (TA-based or RTT-based) and associated physical layer signaling (e.g., better DL RS and/or better UL RS).  RAN4 handles measurement accuracy requirements.  Considering that existing description of 1a/1b/1c is indeed confusing, we are fine with improved description, e.g., clarify RAN1 design aspects. However, this may not be the best use of RAN1 time, as we do not think any of the TA-based method can satisfy the control-to-control requirements. |
| ETRI | Yes |

#### Summary of the status for question 4.1-2 based on first round email discussion

**Question 4.1-2: Do you think that gNB will estimate the DL PD based on TA for option 1c? If your answer is NO, please provide your detailed solution.**

* ***Yes:*** *CATT, Yes, Vivo, ZTE, Intel, Huawei/HiSilicon, ETRI*
* ***Use uplink signal (e.***g. SRS, UL DMRS or PUSCH with predefined TA): *Samsung*
* ***Feature lead:*** *The question was raised because it was observed not all companies think that option 1c needs to be based on TA. Since most companies would like to be still based on TA, we can further discuss the potential issue as raised by Nokia if TA is used.*

**Question 4.1-3: Do you have any other views on TA-based propagation delay compensation?**

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| *Company* | *View* |
| CATT | From our point of view, TA-based propagation delay compensation can be considered for enhancement for propagation delay compensation with high priority because compared with RTT-based propagation delay compensation method, TA-based propagation delay compensation method already has the complete ignaling/mechanism of air interface. |
| Samsung | In our view, the total error is from UE/gNB estimation, as well as UE/gNB transmission. For transmission error, it is limited by hardware. But for estimation, we can improve the accuracy. For example, we need to ensure that gNB can estimate TA with current PRACH, and UE can achieve a certain error for DL timing. In addition. If we jump out from PRACH, Te is not necessary to be used when we calculate the error, since Te is the minimal requirement for the UE when waking up from DRX idle.  In some sense, we think option 1c might be closer to option 2. We only need to care about DL and UL signal for UE and gNB detection, and signaling/pre-defined rule for UE to use for DL timing. |
| Nokia, NSB | Legacy timing advance (Release-16) or Option 1a, the benefit of Option 1c seems to be limited as the options are potentially enhancing the same error source (i.e. signaling granularity). |
| ZTE | We share the same view with CATT that TA-based method should be considered first. |
| HW/HiSi | Agree with CATT, we should investigate the TA with high priority. |
| Ericsson | Based on our analysis, we do not think the TA-based options can satisfy the control-to-control requirements. We recommend RAN1 focus on RTT-based method directly. |

#### Second round email discussion

Based on the views in the first round email discussion and summary above, it seems many companies prefer that gNB will estimate the DL PD based on TA. In this case, it seems the issue mentioned by Nokia (R1-210037) below is valid.

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| --- |
| *Nokia R1-210037*  **Option 1c**  This option relies on the gNB to estimate DL PD based on timing advance with the arguments that the gNB will be able to estimate a DL PD more accurately than the UE. The gNB is capable of determining when an updated NTA is needed, by measuring the timing offset (TO) by comparing the received uplink reception time with the gNB frame timing (illustration available in Figure 2). Signaling the changed NTA value to the UE currently implies an error of 32ns when using the described legacy timing advance (Release-16), which can be avoided if the gNB acquires the PD estimation. However, it does require the gNB to track all relative TA adjustments to the absolute TA signaling during PRACH.  **Observation 4: Considering legacy timing advance (Release-16) or Option 1a, the benefit of Option 1c seems to be limited as the options are potentially enhancing the same error source (i.e. signaling granularity).**  However, if the UE applies an autonomous adjustment to its timing advance value, the gNB cannot reliably determine the applied timing advance value at the UE. There could be at least three options to handle this issue:   * Alt. 1. Relying on gNB implementation. The gNB may signal an updated Timing Advanced Command MAC CE, which will force the UE to discard its autonomous adjustments. * Alt. 2. The gNB may ask the UE for its applied timing advance. * Alt. 3. It is specified that DL PD when based on timing advance, is done not considering UE autonomous adjustments.   While Alt. 1 does not need any additional standardization effort, as we rely on gNB implementation, Alt. 2 and Alt. 3 does. Alt. 3 does not introduce any additional over the air signaling compared to Opt. 2. The introduction of any of these enhancements should be weighed against the benefit of Option 1c compared to the others.  **Proposal 8: The alternatives below for the handling of UE autonomous TA adjustment should be studied, if significant benefits are identified with Option 1c compared to Option 1a and Option 1b, to ensure consistency of TA at the gNB and UE:**   * **Alt. 1. Relying on gNB implementation. The gNB may signal an updated Timing Advanced Command MAC CE, which will force the UE to discard its autonomous adjustments.** * **Alt. 2. The gNB may ask the UE for its applied timing advance.** * **Alt. 3. It is specified that DL PD when based on timing advance, is done not considering UE autonomous adjustments.** |

**Question 4.1-4: If gNB will estimate the DL PD based on TA for option 1c, do you agree that the gNB cannot reliably determine the applied timing advance value at the UE if the UE applies an autonomous adjustment to its timing advance value?**

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| *Company* | *View* |
| OPPO | Yes. gNB cannot reliably determine the TA on UE side even if the autonomous adjustment (defined in RAN4 spec) is NOT taken in to account. Two reasons:   1. . UE sends HARQ-ACK/NACK for the PDSCH containing the TA command MAC-CE. gNB may misinterpret the ACK as NACK, and then gNB does not think the TA command in the previous MAC\_CE was applied on UE side, but actually the UE did. Then the TA history as well as the NTA for the UE on gNB side is easily wrong. 2. According to 38.213, the UE may “modify” TA command without knowledge of gNB. Please refer to 38.213 text saying “The applicable NTA\_new value for an UL BWP with lower SCS ***may be rounded*** to align …” , where the wording “may be” suggests an UE implementation based behavior. |
| CATT | Whether significant benefits of Option 1c are identified with Option 1c compared to Option 1a and Option 1b or not need be further studied. In addition, first of all, we need focus on Option 1b. |
| Qualcomm | We shall discuss which option will be taken first. |
| Nokia, NSB | Agree.  At least we found three different alternatives on how to solved this with more or less specification impact. But clearly, if other alternatives can achieve the intended accuracy, then Option 1c may not be considered with highest priority. |
| ZTE | After the UE receives the TA command, it should adjust the UL frame transmitting timing according to the TA. Anyway, the error should not exceeds Te defined by RAN4. However, the Te has already been considered in the analysis. We don’t see any issue.  " When the transmission timing error between the UE and the reference timing exceeds ±Te then the UE is required to adjust its timing to within ±Te. The reference timing shall be cid:image002.png@01D6F5AD.02632E50 before the downlink timing of the reference cell." |
| Samsung | We don’t think option 1c is for gNB to estimate DL PD. Our intention is be able to use a proper DL reference timing (reduce DL frame error), a better UL transmission (other than PRACH, assuming waking up from IDLE). gNB still estimate UL PD. |
| Huawei, HiSilicon | In our view, the UE autonomous timing adjustment is because the DL timing has changed, so the UE needs to adjust its uplink timing within Te regardless of which option is adopted. It seems this is valid for all options. |
| Ericsson | We do not see the issue.  We also do not see Option 1c as designating gNB to acquire the PD estimation. In our view, Option 1c allows tracking DL timing and/or UL timing more accurately by providing better DL RS and/or UL RS for timing measurement. Sending TA with better granularity via a new MAC CE (for example) is the same between Option 1a and 1c. |

#### Summary of the status for question 4.1-4 based on second round email discussion

**Question 4.1-4: If gNB will estimate the DL PD based on TA for option 1c, do you agree that the gNB cannot reliably determine the applied timing advance value at the UE if the UE applies an autonomous adjustment to its timing advance value?**

* ***Yes:*** *OPPO, Nokia/NSB*
* ***Feature lead:*** *Not many companies show view here. 2 companies think the issue exists for all TA-based solutions. However, in my understanding, it is only applied to option 1c, since for option 1c gNB will compensate the propagation delay directly in the RRC signaling to indicate the reference time, while other options will do the compensate at the UE side. However, not many inputs. Companies are encouraged to think more and proponents are encouraged to provided details and the motivation gain it can bring in future meetings.*

**Question 4.1-5: If your answer to the above question 4.1-4 is yes, do you have any preference on the following alternatives for the handling of UE autonomous TA adjustment? If you have other solutions, please indicate here also.**

* **Alt. 1. Relying on gNB implementation. The gNB may signal an updated Timing Advanced Command MAC CE, which will force the UE to discard its autonomous adjustments.**
* **Alt. 2. The gNB may ask the UE for its applied timing advance.**
* **Alt. 3. It is specified that DL PD when based on timing advance, is done not considering UE autonomous adjustments.**

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| *Company* | *View* |
| OPPO | With our two reasons mentioned in 4.1-4, Alt-1 does not work.  It is also not clear to us how Alt-3 can work because UE autonomous adjustment is a behavior in long term, and its effectiveness is accumulative. Then what does “not considering autonomous adjustments” mean?  For Alt-2, it logically works, but it seem to have no advantage over sending Tdelta MAC\_CE to UE (similar to IAB logic) and letting UE do the PD compensation. Further, to let one entity signal its Rx-to-Tx interval to the peer entity would make the solution more like a RTT-based, not TA-based. So Alt-2 (as a solution categorized as TA-based) is actually an RTT-based solution. |
| Qualcomm | We shall discuss which option will be taken first. |
| Nokia, NSB | We are open for discussions. But at least Alt. 1 would not require any additional specification effort. |
| Samsung | Clarification of the option is needed.  Alt 3 is something in our mind.  The signaling of propagation delay is only for propagation delay compensation, it doesn’t force UE to apply it for TA as well, since this TA adjustment error is limited by hardware. So finer TA is not needed for TA adjustment but for propagation delay compensation. |
| Huawei, HiSilicon | We would like to point out that RAN4 defines the rules for this UE autonomous timing adjustment. Our understanding is that before we discuss solutions here, we need to first identify whether/how much impact there is to the accuracy. |
| Ericsson | Do not see any reason to continue discussion on UE autonomous adjustment. Shouldn’t we first pick Option 1 vs Option 2 first? |

#### Summary of the status for question 4.1-5 based on second round email discussion

* ***Alt.1:***
  + ***Not work:*** *OPPO*
  + ***Support:*** *Nokia/NSB (Open)*
    - ***No specification impact***
* ***Alt.2:*** *OPPO*
  + ***May work:*** *OPPO*
* ***Alt.3:*** *Samsung* 
  + ***Not work:*** *OPPO*
* ***Feature lead:*** *Inputs not sufficient for making any way forward. Some companies mentioned that need to decide which option to choose first, however without understanding the details of the options, it is difficult to understand whether it can work or how much gain it can bring.*

In addition, Samsung also proposes to estimate the DL PD based on other uplink signal, e.g. SRS, UL DMRS or PUSCH with predefined TA, since no view shown in the contribution on this solution from other companies, the following question is set to understand the situation a little bit better.

**Question 4.1-6: Do you have any view/question on estimating DL PD based on uplink transmission with predefined TA, e.g. SRS, UL DMRS or PUSCH?**

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| --- | --- |
| *Company* | *View* |
| CATT | We need consider whether significant benefits based on other UL signals are identified with PRACH. |
| Qualcomm | We prefer a separated mechanism for PDC without touching legacy TA mechanism to make the design clean and tidy. |
| Samsung | Agree with Qc. |
| Huawei, HiSilicon | Share similar view as QC and Samsung |
| Ericsson | The purpose of this question is to clarify the meaning of Option 1c?  In our view, Option 1c allows tracking DL timing and/or UL timing more accurately by providing better DL RS and/or UL RS for timing measurement. |
|  |  |

#### Summary of the status for question 4.1-6 based on second round email discussion

**Question 4.1-6: Do you have any view/question on estimating DL PD based on uplink transmission with predefined TA, e.g. SRS, UL DMRS or PUSCH?**

* ***CATT****: The motivation needs to be justified first.*
* ***Qualcomm, Samsung, Huawei/HiSilicon****: Enable a separated mechanism for PDC without touching legacy TA mechanism to make the design clean and tidy*
* ***Feature lead:*** *Not many inputs. Companies are encouraged to think more and proponents are encouraged to provided details and the motivation gain it can bring in future meetings.*

## 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.

Based on the views in the contributions, several companies expressed that RTT-based method is introduced only if TA-based propagation delay compensation enhancements are not sufficient. Before sufficient discussion is done on TA-based propagation delay compensation enhancements, it might be difficult to justify whether it is sufficient or not.

If TA-based propagation delay is necessary to be introduced, the following issues are raised by companies to further study:

* **Whether DL reference signals other than PRS could be used for DL time estimation at UE side, such as CSI-RS.**
* **Whether to leave the signaling design for RTT based delay compensation method to RAN2? E.g. how the UE reports the measurement to the gNB (e.g. via RRC) and what the report should contain (can be left for RAN2).**
* **What equation to use for evaluating the overall time synchronization error?**

In case we will need to introduce RTT based delay compensation enhancements, the following questions are set to collect the views from the proponents.

**Question 4.2-1: Whether DL reference signals other than PRS could be used for DL time estimation at UE side?**

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| --- | --- |
| *Company* | *View* |
| CATT | PRS is enough for RTT-based PDC and it isn’t necessary to introduce other new DL signals. |
| OPPO | Yes. It seems a UE implementation issue to use what DL RS or RS combination for timing detection. |
| Samsung | Other DL reference signals other than PRS can be considered. We think RAN 1 or RAN 4 can further study it. For example, we can estimate a range for DL sync and then make sure UE can achieve such requirement. However, this can be further discussion whether this is up to UE implementation |
| Nokia, NSB | Yes 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. Additionally, 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. Therefore, these options need to be further studies for discussion. |
| Vivo | DL reference signals other than PRS used for DL time estimation can be further investigated. On the other hand, the required bandwidth of reference signals should be studied. For example, if the larger bandwidth of reference signal is required to meet the timing accuracy, the potential overhead should be considered, especially for URLLC service with small payload size. |
| ZTE | We believe the DL RS may affect the synchronization accuracy. The DL RS other than PRS could be used. However, the impact and the corresponding assumption for synchronization accuracy should be analyzed carefully. |
| Intel | Agree that non DL PRS can be used since the accuracy requirement is different, and a UE may easier reuse its existing hardware without supporting positioning framework, e.g. if CSI-RS is utilized. |
| HW/HiSi | The accuracy of DL time estimation at the UE side may be different among different reference signals due to e.g. bandwidth. If based on other than PRS, the accuracy may be decreased. Thus, it depends on how much accuracy we need to satisfy the budget. |
| LG | We think it should be possible to use DL RS other than PRS for PD compensation. In order to guarantee accuracy, we can define UE behavior on how UE measure and report based on RS. |
| Ericsson | Agree that DL RS other than PRS can be used to measure UE Rx – Tx time difference, as long RS bandwidth and time domain density are adequate.  It is noted that in 38.215 v16.4.0, the definition of UE Rx – Tx time difference is updated such that the Rx timing and Tx timing are for a Transmission Point (TP), not positioning node. Thus, UE Rx – Tx time difference has been generalized already. |
| ETRI | The accuracy will be affected by the DL RS and DL PRS can be sufficient. |

#### Summary of the status for question 4.2-1 based on first round email discussion

**Question 4.2-1: 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.*
* ***Feature lead****: It seems most companies think other DL RS can be used.*

**Question 4.2-2: Whether to leave the signaling design for RTT based delay compensation method to RAN2, e.g. how the UE reports the measurement to the gNB (e.g. via RRC) and what the report should contain (can be left for RAN2)?**

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| *Company* | *View* |
| CATT | We agree to leave the signaling design for RTT based delay compensation method to RAN2. |
| OPPO | It seems too early to decide for now. |
| Samsung | We need to provide analysis on the error and assumption, e.g., what kind of assumption we used to achieve such result, including what parameters UE/gNB need to know. But we agree that, signaling/procedure design can up to RAN 2. |
| Nokia, NSB | Agree with Samsung. The signaling details can be left up to RAN2  But on the signaling content (e.g. granularity etc.), at least RAN1 should be involved. |
| Vivo | The details for RTT-based delay compensation method should be clarified firstly. |
| ZTE | We think the signaling should be designed by RAN2. We share the same view with Samsung and Nokia. |
| Intel | In case of UE-based compensation, a UE needs to know gNB Rx-Tx time difference reported from gNB. Such signaling may be designed different ways: L1 or MAC or RRC. Thus, RAN1 can discuss first which type of indication to pursue and which group then need to implement.  In case of gNB-based compensation, a gNB needs to know UE Rx-Tx time difference. This signaling can be similar to other measurement reports and can be handled by RAN2. |
| HW/HiSi | Leave the signaling to RAN2. Agree with the view from Nokia, e.g. that for the determination of the granularity, RAN1 should be involved. |
| LG | It should be left to RAN2. Similar to Nokia, for a required value range of signaling, RAN1 can involve and help. |
| Ericsson | For both TA-based method and RTT-based method, there is the RRC/MAC signaling aspect, and this should be handled by RAN2. |
| ETRI | We think it is up to RAN2. |

#### Summary of the status for question 4.2-2 based on first round email discussion

**Question 4.2-2: Whether to leave the signaling design for RTT based delay compensation method to RAN2, e.g. how the UE reports the measurement to the gNB (e.g. via RRC) and what the report should contain (can be left for RAN2)?**

* **Leave it to RAN2:** *CATT, Intel (only for gNB-based compensation), ETRI*
* **Leave signaling design to RAN2 but RAN1 should be involved at least for signaling content:** *Samsung, Nokia/NSB, ZTE, Huawei/HiSilicon, LG, Ericsson*
* **Too early to make decision now***: OPPO, Vivo*
* **Feature lead:** Agree it seems better understating of RTT-based solution needed first, therefore we can make decision later once the details are clearer.

As to what equation to use for evaluating the overall time synchronization error for RTT based propagation delay compensation enhancements, the following options are proposed from companies:

**Option 1:**

* + is to reflect the error due to report granularity of Rx-Tx time difference
  + ***Support:*** *ETRI, Intel*

**Option 2:**

* + ***Support:*** *Qualcomm*

**Option 3:**

* + ***Support:*** *CATT*

**Option 4:**

* + ***Support:*** *LG*

**Option 5:**

* + 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.
  + ***Support:*** *Ericsson*

**Option 6:**

* + ***Support:*** *Nokia, vivo*

**Option 7:**

* + is to reflect the error due to report granularity of Rx-Tx time difference
  + is to reflect the error due to the granularity of propagation delay indication
  + ***Propagation delay indication granularity error ()****: gNB eventually need to signaling to UE about the propagation delay. Therefore, an additionally signaling to indicate propagation delay cannot be avoided. The granularity of propagation delay indication will also affect the total error.*
  + ***Support:*** *Samsung*

The views are very divergent, maybe once we achieve consensus on the equation for TA-based method, some aspects can be straightforward, e.g. whether or should be included, whether should be considered, etc.

**Question 4.2-3: Do you have any suggestion on how to move forward on the equation to use for evaluating the overall time synchronization error for RTT based propagation delay compensation enhancements?**

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| *Company* | *View* |
| CATT | From our perspective, common components in all of formula options can be made as baseline and then discuss about whether differential components is necessary or not one by one. |
| OPPO | Agree with FL that RAN1 should firstly try to converge on TA-based formula. In addition, option-4 above is just our formula to calculate the error in one-way propagation delay estimation, not the overall error. Our current observation is that, the error terms that are common to TA-based and RTT-based methods already make the RTT-based method fail to meet the error budget for control-to-control scenario. Our comments under 4.1-1 also apply here. |
| Samsung | Support CATT’s suggestion |
| Nokia, NSB | Agree with CATT & Samsung here. On the error of – if using half or not depends also here on the outcome of Sec. 1 discussions (65ns vs +-32.5ns) |
| vivo | We share the similar view with CATT. |
| ZTE | CATT’s suggestion seems feasible. |
| HW/HiSi | Agree with CATT. |
| LG | Agree with CATT. |
| Ericsson | We understand RTT-based method as using “UE Rx – Tx time difference” and “gNB Rx – Tx time difference”, which have definition in 38.215, and accuracy requirements in RAN4 spec (under development). Hence measurement accuracy and reporting accuracy of these quantities should be used in the equation. We don’t see the reason to translate these to variables used in the TA formula. |
| ETRI | Agree with CATT. |

#### Summary of the status for question 4.2-3 based on first round email discussion

**Question 4.2-2: Whether to leave the signaling design for RTT based delay compensation method to RAN2, e.g. how the UE reports the measurement to the gNB (e.g. via RRC) and what the report should contain (can be left for RAN2)?**

* **Common part among the options as baseline:** *CATT, Samsung, Nokia, Vivo, ZTE, LG, ETRI*
* ***Feature lead****: Agree that the common part among the options can be taken as baseline. However, I guess it is not controversial for the common part and controversial part is more critical. Since the controversial part has some relationship with TA-based equation also, let’s focus on there first.*

**Question 4.2-4: Do you have any other views on RTT-based propagation delay compensation?**

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| *Company* | *View* |
| CATT | From our point of view, TA-based propagation delay compensation can be considered for enhancement for propagation delay compensation with high priority. If the TA-based propagation delay compensation can’t meet the requirements of synchronization budget per Uu Interface, RTT-based propagation delay compensation and the corresponding enhancement method can be considered as the candidate for propagation delay compensation in Rel-17. |
| Samsung | gNB eventually need to signaling to UE about the propagation delay. Therefore, an additionally signaling to indicate propagation delay cannot be avoided. The granularity of propagation delay indication will also affect the total error. |
| Nokia, NSB | RAN1 should further evaluate the pros and cons of Option 2 (RTT). This include on how to consider **the effect of DRX for RTT based methods**? |
| Vivo | For RTT-based solution, some aspects should be clarified.   * Bandwidth of reference signal.   For RTT-based method, the large bandwidth of reference signal may be required to guarantee accuracy. The overhead of reference signal may be an issue, especially for UE specific reference signal.   * The signaling overhead   Obtaining the required precision for external clock may need quite frequent time information updates over Uu interface. Thus, the signaling overhead caused by triggering RTT-based delay measurement may be huge in order to [guarantee](D:/Dict/8.9.4.0/resultui/html/index.html#/javascript:;) the synchronization error is always less than synchronicity budget requirement. |
| Intel | RTT-based solution has two flavors: UE-based (compensation) and gNB-based (pre-compensation). Those may need to be distinguished in the discussion. |
| HW/HiSi | For the RTT-based method, whether to introduce different procedures compared with Rel-16 positioning needs to be clarified. |
| LG | Since we already have RTT-based method for positioning, the discussion would be on how we can bring the design with less effort for TSN. |
| Ericsson | As the estimations submitted by all companies (Table 1) indicate that TA-based method is far from satisfying the control-to-control requirements, RAN1 should spend more time working on the RTT-based method. So far almost all discussion time has been spent on TA-based method, and this is no longer justified. RTT-based method has been shown to give higher accuracy and more future-proof. |

#### Summary of the status for question 4.2-4 based on first round email discussion

**Question 4.2-4: Do you have any other views on RTT-based propagation delay compensation?**

* **TA based high priority and RTT-based can be further studied if TA based is not sufficient:** *CATT,*
* **RAN1 should study how to consider the effect of DRX for RTT based methods:** *Nokia,*
* **RAN1 should study bandwidth of the signal and signaling overhead:** *Vivo,*
* **UE-based RTT and gNB-based RTT needs to be studied:** *Intel,*
* ***More time should be spent on RTT-based method****: Ericsson*
* ***Feature lead****: Though the current discussion focus on TA-based more, the reason is that we need to study the achievable error with R16-TA based solution in order to justify whether any enhancement needed. In addition, many of the discussion would be applied to RTT-based also.*

### Second round email discussion

Based on the views in the first round email discussion and summary above, the following proposal are made for further discussion:

**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 which DL reference signal to be used is UE implementation or not**

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| --- | --- |
| *Company* | *View* |
| OPPO | We do not support this proposal. Two reasons.   1. The current spec does not restrict the UE behavior to use whatever DL RS that UE vendors believe to be helpful for timing determination. 2. If UE happens to be configured with PRS that is sent by its serving cell, the PRS can certainly be used per implementation choice. But the proposal above reads like to exclude PRS. Is there any specific reason for excluding any specific DL-RS *by spec*?   We are not sure the intention here is trying to go more flexible or more restrictive comparing to current spec status. |
| CATT | Based on description of FL proposal 4.2-1, We want to clarify whether PRS can be used for DL time estimation or not. |
| Qualcomm | Same question as CATT. |
| Nokia, NSB | Maybe clarification to CATT & Qualcomm questions would be good to have.  But clearly other existing DL-RS could be used as well – as the PRS overhead just for time synchronization purposes seems to be a bit exorbitant. |
| ZTE |  |
| vivo | In our understanding, PRS can be used for RTT-based propagation delay compensation. It does not exclude DL reference signals other than PRS. |
| Samsung | General OK with the proposal. We also agree on clarification of whether RPS can be used is good.  In addition, if we assuming other DL signaling for DL timing, we need to discuss about the errors, assuming different DL signal(s) |
| Huawei, HiSilicon | A clarification of CATT’s questions may help. And we think another RS can be used, so the RTT-based compensation (if introduced) can be decoupled from Rel-16 positioning. |

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| *Nokia R1-210037*  **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 option 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. 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.  Timeline  Description automatically generated  Figure 1. Timeline example for PD compensation times after DRX, either at time a or time b.  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:   * Opt. 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. * Opt. 2. 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. 1 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. 2 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.  **Proposal 6: RAN1 should discuss the assumptions on when a PD estimation is to be acquired after DRX and align this assumption across PD estimation Options:**   * **Opt. 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.** * **Opt. 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.** |

#### Summary of the status for proposal 4.2-1 based on second round email discussion

* **Clarify whether PRS can be used or not:** *CATT, OPPO, Qualcomm, Samsung, HiSilicon*
* **Feature lead:** My original assumption is that no if we want a separate procedure for propagation delay compensation compared to positioning. But let’s keep it open.

**Question 4.1-5: Which option do you prefer to take as the assumptions on when a PD estimation is to be acquired after DRX for both RTT-based PDC and TA-based PDC?**

* **Opt. 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.**
* **Opt. 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.**

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| *Company* | *View* |
| OPPO | Not sure whether this is an RAN1 discussion topic. In our understanding, RAN1 only needs to work on tools to estimate the one-way propagation delay. How to implement this tool into PDC, including when to invoke the one-way delay estimation for PDC purpose, can be RAN2 issue. Note that RAN2 is the leading WG for this PDC feature. |
| CATT | We prefer Opt.1 because Opt.1 is aligned with the current discussion. |
| Nokia, NSB | We do not have a strong preference. Based on the input by OPPO, we should maybe raise this issue to RAN2, that if they want us to consider the worst case errors when coming back from DRX or if the assumption can be, that there is some time after coming back here. **So maybe a related LS to RAN2 could be usefull**.  But we agree with CATT, that at least for TA based schemes it seems we considered Option 1 there (as taking Te as worst case into account). Having said that, for RTT based methods it seems we assumed Option 2 instead. |
| Samsung | We think both directions can be considered for both TA-based and RTT based methods.  For option 1, we think Te is also applied for RTT-based method. |
| Huawei, HiSilicon | Our understanding is that Te is included in option 1. Both option 1 and option 2 can be considered since it may depend on when the reference time is signaled to the UE. |
| Ericsson | This question is related to higher layer procedure, and is better left for RAN2 discussion. In our understanding, the UE does not have to estimate accurate propagation delay compensation all the time. The TSN clock synchronization is performed periodically. The propagation delay compensation needs to be performed only when TSN clock sync is needed, and UE clock has drifted too much. In between, it is assumed that UE can control its clock drift to reasonable range. |

#### Summary of the status for proposal 4.1-5 based on second round email discussion

* **Opt. 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.**
  + - *CATT, Nokia/NSB, Samsung*
* **Opt. 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.**
  + - *CATT, Nokia/NSB, Samsung*
* **Need to involve RAN2 on this question** 
  + - *OPPO, Nokia/NSB, Ericsson*
* **Feature lead:** No sufficient inputs for making a way forward. Views from other companies are encouraged.

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| *Intel R1-2100653*  **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*. |

**Question 4.1-6: Which option do you prefer for RTT-based PDC, gNB-based or UE-based?**

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| *Company* | *View* |
| OPPO | UE-based. |
| CATT | We prefer both gNB-based and UE-based method for RTT-based PDC and gNB can flexibly configure these two methods based on UE capability. |
| Nokia, NSB | UE-based.  Reasons: Easier for the UE to handle it, as the UE can simply change the timestamp provided in *ReferenceTimeInfo*. Moreover there is no RAN3 impact There is an LS under discussion in RAN3, stating that gNB pre-compensation has RAN3 impact and they will not act unless RAN1/RAN2 would decide to support this (so the work in RAN3 seems to be on hold there). |
| Samsung | We think both can be discussed.  But for gNB based method, this should associated with pre-compensated method. Otherwise, it should be UE-based method. And signaling from gNB on receiving different is needed, as well as the indication error. |
| Ericsson | We are open to consider both at the moment. Slight preference to gNB-based. |

#### Summary of the status for proposal 4.1-6 based on second round email discussion

* **RTT-based UE compensation:** *OPPO, CATT, Nokia/NSB, Samsung,*
  + *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*
* **Feature lead:** No sufficient inputs for making a way forward. Views from other companies are encouraged.

### Third round email discussion

Based on the views in the second round email discussion and summary above, the following proposal are made for further discussion:

**Revised 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**

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| *Company* | *View* |
| OPPO | We do not support this proposal, because it does not seem to provide any new delta comparing to existing system/spec. For example, in Rel-16 IAB, the IAB-MT (as a type of UE on Uu interface) also needs to perform RTT-based propagation delay estimation and therefore measures DL frame arrival timing. But the RAN1 specification for IAB-MT does not specify which DL reference signal should be used. In general, would existing PSS/SSS/CSI-RS be qualified to be “**DL reference signals other than PRS**”?  Is the intention here to promote “DL RS other than PRS” or to exclude PRS? |
| Samsung | General OK with the proposal.  We like to ensure that it is a common understanding that, the DL detection error is based on the DL reference signaling to use. |
| Ericsson | Do not understand what the proposal is trying to accomplish.  Similar to OPPO, we believe other DL RS can be used, but PRS can be used as well.  We also agree with Samsung point that RxTxTimeDiff measurement accuracy highly depends on the DL reference signal used in the measurement. |
| Intel | Support in principle. We think there are some cases when a UE needs to limit estimation to certain signals, e.g. due to quasi-colocation. |
| Nokia | Support.  We do not see any need to exclude specific DL RS at the moment, but rather to identify which should be supported for the RTT procedure, when it is being specified for the use of DL PD estimation and not only as a part of the Multi-RTT procedure for positioning purposes. |

**Question 4.1-5: Which option do you prefer to take as the assumptions on when a PD estimation is to be acquired after DRX for both RTT-based PDC and TA-based PDC?**

* **Opt. 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.**
* **Opt. 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.**

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| --- | --- |
| *Company* | *View* |
| OPPO | Not sure whether this is an RAN1 discussion topic. In our understanding, RAN1 only needs to work on tools to estimate the one-way propagation delay. How to implement this tool into PDC, including when to invoke the one-way delay estimation for PDC purpose, can be RAN2 issue. Note that RAN2 is the leading WG for this PDC feature. |
| CATT | We prefer Opt.1 because Opt.1 is aligned with the current discussion. |
| Nokia, NSB | We do not have a strong preference. Based on the input by OPPO, we should maybe raise this issue to RAN2, that if they want us to consider the worst case errors when coming back from DRX or if the assumption can be, that there is some time after coming back here. **So maybe a related LS to RAN2 could be usefull**.  But we agree with CATT, that at least for TA based schemes it seems we considered Option 1 there (as taking Te as worst case into account). Having said that, for RTT based methods it seems we assumed Option 2 instead. |
| Samsung | We think both directions can be considered for both TA-based and RTT based methods.  For option 1, we think Te is also applied for RTT-based method. |
| Huawei, HiSilicon | Our understanding is that Te is included in option 1. Both option 1 and option 2 can be considered since it may depend on when the reference time is signaled to the UE. |
| Ericsson | This question is related to higher layer procedure, and is better left for RAN2 discussion. In our understanding, the UE does not have to estimate accurate propagation delay compensation all the time. The TSN clock synchronization is performed periodically. The propagation delay compensation needs to be performed only when TSN clock sync is needed, and UE clock has drifted too much. In between, it is assumed that UE can control its clock drift to reasonable range. |
| Intel | Agree with some comments that this procedural aspect may not be important to RAN1 and relevant for current discussion. |

**Question 4.1-6: Which option do you prefer for RTT-based PDC, gNB-based compensation or UE-based compensation?**

|  |  |
| --- | --- |
| *Company* | *View* |
| OPPO | UE-based. |
| CATT | We prefer both gNB-based and UE-based method for RTT-based PDC and gNB can flexibly configure these two methods based on UE capability. |
| Nokia, NSB | UE-based.  Reasons: Easier for the UE to handle it, as the UE can simply change the timestamp provided in *ReferenceTimeInfo*. Moreover there is no RAN3 impact There is an LS under discussion in RAN3, stating that gNB pre-compensation has RAN3 impact and they will not act unless RAN1/RAN2 would decide to support this (so the work in RAN3 seems to be on hold there). |
| Samsung | We think both can be discussed.  But for gNB based method, this should associated with pre-compensated method. Otherwise, it should be UE-based method. And signaling from gNB on receiving different is needed, as well as the indication error. |
| Ericsson | We are open to consider both at the moment. Slight preference to gNB-based. |
| Intel | We would like to see both, as a toolbox approach.  In terms of spec impact and implementation both have pros and cons. For example, gNB-based may require less spec impact effectively demanding only the UE RxTx time difference measurement report by higher layers + informing UE about already applied compensation. In the same time, UE-based requires other new signaling in DL direction (FFS L1, MAC, RRC). |

## Non-RTT based gNB-based pre-compensation of the reference time information

Intel (R1-200643) proposes to expand the list of propagation delay compensation options with gNB-based pre-compensation (both RTT-based and non-RTT based) in order to match with the latest status of RAN2 discussion.

**Feature lead**: It looks to me that RTT-based gNB-based pre-compensation is same as option 2. Therefore, option 3 here can focus more on non-RTT based gNB-based pre-compensation. However, since there is no more details in the contributions, it would be further clarify the details of this option here.

**Question 4.3-1: Any further details to be provided for gNB-based pre-compensation here?**

|  |  |
| --- | --- |
| *Company* | *View* |
| CATT | RTT-based gNB-based pre-compensation is one of RTT-based PDC methods. The difference between gNB-based pre-compensation and UE compensation is that for gNB-based pre-compensation, UE report s Rx-Tx time difference to gNB and gNB executes PDC while for UE compensation, UE receives from gNB report on the gNB Rx-Tx time difference and executes PDC. |
| Samsung | We think it can be decoupled from option 2.  There were two methods discussed in RAN 2, one is UE to compensate PD, the other is gNB to pre-compensate PD. For UE compensated method, it doesn’t requires unicasted signaling for timing. But it requires UE specific singling for gNB pre-compensate methods. In our understanding, RTT based method can be UE compensate methods or pre-compensated method by gNB. |
| Nokia, NSB | gNB pre-compensation may have some severe RAN3 impact. Therefore, it would be good to involve RAN3 in further clarifications on the gNB-based pre-compensation. |
| ZTE | In our understanding, the propagation delay has been reflected in the reference time indicated by the gNB. The propagation delay can be obtained based on RTT-based method and TA-based method. For TA-based method, additional signaling is not needed since the gNB has already been aware of the TA of the UE. For RTT-based on method, the UE should report the measurement result. |
| Intel | As we discussed in R1-2100653, the main goal of bringing gNB pre-compensation is to match with RAN2 discussions. Note, that RAN2 LS reply suggests RAN1 to lead the decision on PD method, but the RAN1 list does not explicitly include the gNB pre-compensation method which was quite popular in RAN2.  Further, we agree that the description of Option 2 (RTT-based) does not provide details whether the final compensation is performed at a UE or a gNB, thus currently includes both variants. What is missing, is non-RTT pre-compensation at gNB, e.g. using TA measurements, and we would like to include it into the list. |
| HW/HiSi | Share the view from Nokia that gNB pre-compensation may have RAN3 impact, this should also be considered. |
| LG | We think gNB pre-compensation is a solution in different domain from option 1 and 2. We are open to discuss that, however, it seems not feasible to consider as option 3. |
| Ericsson | This aspect is not specific to RTT-based method. Applying gNB pre-compensation or not is possible option to both TA-based method and RTT-based method. Also, this is more of a higher layer signaling issue and should be handled by RAN2. |

#### Summary of the status for question 4.3-1 based on first round email discussion

**Question 4.3-1: Any further details to be provided for gNB-based pre-compensation here?**

* ***Feature lead****: Companies show thinking on different aspects, but it seems one important question is whether gNB pre-compensation would have some severe RAN3 since it would involve other working groups.*

### Second round email discussion

Based on the views in the first round email discussion and summary above, the following question are made for further discussion:

**Question 4.3-2: Do you think that gNB pre-compensation would have some severe RAN3, including RTT based gNB pre-compensation and non-RTT based gNB pre-compensation?**

|  |  |
| --- | --- |
| *Company* | *View* |
| OPPO | This does not seem to be RAN1 discussion point. RAN1 has no base to agree whether some impact to RAN3 is severe or not. If RAN2 (as leading WG) decides to try with gNB pre-compensation, certainly they can no matter what RAN1 concludes on this. What we think RAN1 can discuss is the potential impacts to RAN1 spec. |
| CATT | We need clarify what are the impacts on RAN3 including RTT based gNB pre-compensation and non-RTT based gNB pre-compensation in detail.  This impact means whether the time synchronization between GM (grand master) and gNBs need be supported or not? |
| Nokia, NSB | There is an LS under discussion in RAN3, stating that gNB pre-compensation has RAN3 impact and they will not act unless RAN1/RAN2 would decide to support this (so the work seems to be on hold there). |
| Samsung | We think this can be RAN 2’s work other than RAN 1. RAN 1 can use have some assumption and provide analysis. |
| Huawei, HiSilicon | Our understanding is that RAN3 is discussing this issue, and RAN3’s view gNB pre-compensation would have impact to them. |
| Ericsson | This is a RAN2 topic. No relevance to RAN1 work. |

#### Summary of the status for proposal 4.3-2 based on second round email discussion

* **Not relevant to RAN1:** *OPPO, Ericsson*
* **There is an LS under discussion in RAN3 thus can wait for their LS first** 
  + *Nokia/NSB, Huawei/HiSilicon*
* **Feature lead:** Let’s wait for the outcome from RAN3 on the LS first.

# 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. R1-2100105 Discussion on propagation delay compensation enhancements ZTE
3. R1-2100185 Enhancements for Propagation Delay Compensation OPPO
4. R1-2100272 Propagation Delay Compensation Enhancements for Time Synchronization Ericsson
5. R1-2100380 Discussion on propagation delay compensation enhancements CATT
6. R1-2100440 Discussion on propagation delay compensation enhancements vivo
7. R1-2100578 Discussion on propagation delay compensation for time synchronization MediaTek Inc.
8. R1-2100653 Propagation delay compensation analysis and design considerations Intel Corporation
9. R1-2100730 Discussion on enhancements for propagation delay compensation Nokia, Nokia Shanghai Bell
10. R1-2100884 Discussion on propagation delay compensation enhancements LG Electronics
11. R1-2101078 Propagation delay compensation enhancements ETRI
12. R1-2101205 Discussion for propagation delay compensation enhancements Samsung
13. R1-2101265 Enhancements for support of time synchronization Huawei, BUPT, China Southern Power Grid, HiSilicon
14. R1-2101382 Orphan symbol treatment in unlicensed spectrum access Apple
15. R1-2101463 Enhancements for support of time synchronization for enhanced IIoT and URLLC Qualcomm Incorporated
16. R1-2100024 Reply LS on propagation delay compensation enhancements

# 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