**3GPP TSG RAN WG1 Meeting #102-e R1-xxxxxx**

**E-meeting, August 17-28, 2020**

**Agenda Item: 8.3.4**

**Source: Moderator (Huawei)**

**Title:** **Feature lead summary#1 on propagation delay compensation enhancements**

**Document for: Discussion and Decision**

# Introduction

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

|  |
| --- |
| 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], and aims to identify and discuss some high-level issues in RAN1#102-e.

# Requirements for time synchronization

The timing synchronization requirements between the clock grand master and the TSN end station are given in [10] and copied below. Please note that these requirements on the overall system level. The toughest numbers have to be achieved is 900 ns for motion control and control-to-control.

Table 1 - Clock synchronization service performance requirements for the 5G System

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| User-specific clock synchronicity accuracy level | Number of devices in one Communication group for clock synchronisation | 5GS synchronicity budget requirement  (note) | Service area | Scenario |
| 1 | Up to 300 UEs | ≤900 ns | ≤ 100 m x 100 m | * Motion control * Control-to-control communication for industrial controller |
| 2 | Up to 300 UEs | ≤900 ns | ≤ 1000 m x 100 m | * Control-to-control communication for industrial controller |
| 3 | Up to 10 UEs | < 10 µs | ≤ 2500 m2 | * High data rate video streaming |
| 3a | Up to 100 UEs | <1 µs | ≤10 km2 | * AVProd synchronisation and packet timing |
| 4 | Up to 100 UEs | <1 µs | < 20 km2 | * Smart Grid: synchronicity between PMUs |
| 5 | Up to 10 UEs | < 50 µs | 400 km | * Telesurgery and telediagnosis |
| NOTE: The clock synchronicity requirement refers to the clock synchronicity budget for the 5G system, as described in Clause 5.6.1. | | | | |

**Feature lead view**: From Table 1, there are different requirements for different use case. In order to make the discussion more focus, it would be good to select some representative use case for further discussion. Considering both the requirements and the difference of potential deployments, it seems use case 2 and use case 4 in Table 1 can be the representative use cases.

***Proposal 2-1****: 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 |

**Please provide your views on the above proposal 2-1, especially if you have different views on the selected representative use case.**

|  |  |
| --- | --- |
| *Company* | *View* |
| Nokia, NSB | Support the view.  It could be good to be aligned on the assumptions of the SA2 work on these two representative use cases. Regarding the “Control-to-control” use case, it is out understanding that both a 5GS towards a single UE and the case where a TSC GM is connected to a device behind a UE also applied. But for the “smart grid” use case, it is our understanding that the TSC GM is the 5G GM and hence NOTE 6 from 22.104 does not apply. This means that the 1µs does only apply for one link (one Uu interface). |
| *Samsung* | *OK* |
| *vivo* | We are fine with FL’s proposal 2-1. |
| ZTE | Support the FL proposal |
| Intel | In general, fine. However, we are not sure if the target scenarios / use cases need to be determined in RAN1 given that it is a RAN2-led objective. Clarifications on work split between RAN1 and RAN2 in this regard are appreciated.  Feature lead: Agree would be good if both RAN1 and RAN2 take the same representative use cases for further discussion. If necessary we can even consider to send an LS to RAN2 to inform them, or RAN1 colleagues for each company can let their RAN2 colleagues know. |
| HW/HiSi | We support the proposal. |
| Ericsson | Support the proposal.  We also agree with Nokia that it is good to clarify that the two use cases put different demands on the Uu interface. That is,   1. Use case 2: two Uu interfaces with two gNBs, and 2. Use case 4: one Uu interface.   Feature lead: Agree it would be good for us to clarify this also. I made a corresponding proposal below accordingly. |

#### Summary of the status for proposal 2-1

* ***Support****: Nokia, NSB, Samsung, Vivo, ZTE, Intel, Huawei, Ericsson*
* ***Feature lead:*** *All companies who provided feedback support the proposal in principle.*

***Proposal 2-1a****: For 5GS synchronicity budget requirement,*

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

**Please provide your views on the above proposal 2-1a if you have concern.**

|  |  |
| --- | --- |
| *Company* | *View* |
| Feature lead | *During the discussion or proposal 2-1 above, Nokia and Ericsson mentioned it would be good to clarify whether one or two Uu interface involved for a certain representative use case, I agree it would be good to clarify* |
| Nokia, NSB | Agree with the proposal. |
| Qualcomm | We are fine with this simplification. |
| ZTE | Agree with the proposal |
| Samsung | OK |

## Design target on synchronicity budget for Uu interface

The requirement for the representative use cases as show in proposal 2-1 above is the overall synchronicity budget. In order to decide whether any enhancements needed or what compensation methods needed in RAN, we need the design target on synchronicity budget for Uu interface. However, we may need some input from other working groups in order to achieve this value. Companies are encouraged to share views on this also.

**Question 2-1: What design target on synchronicity budget for Uu interface to assume in RAN for the representative use cases in proposal 2-1 above? Please provide your views and your reasons if any.**

|  |  |
| --- | --- |
| *Company* | *View* |
| *vivo* | Synchronicity budget for Uu interface: 450ns for single link including maximum 100ns synchronization error between gNB and 5G GM. |
| ZTE | We share the same view with FL. The overall synchronicity budget includes the budgets for Uu interface and the budgets for the network. We need some inputs from the other working groups to get the value of the latter. Then, the design target can be determined according to the synchronicity budget for Uu interface. |
| HW/HiSi | Difficult to say at this stage. If RAN2 can provide input it would be very good.  But regardless the design target, we can progress to align the other parameters and methods how to calculate the estimation accuracy. |
| Ericsson | We agree that it is necessary to set a design target for Uu interface for both use case 2 and use case 4. Error budget should be set aside for network interface sync error, 5GS reference time delivery error, DS-TT to UE error, and UE internal error. Also see our comment to Section 3.2.5. |
| Qualcomm | The overall synchronicity budget can be assumed as 450ns in total including additional 100ns - 200ns loss for implementation errors. We can use a fixed value for this loss for simplification. Therefore, the synchronicity budget for Uu interface is around 250-350ns. |

#### Summary of the status for question 2-1

* ***Feature lead:*** *Based on the views above, it seems common understanding that we need inputs from other working groups first before making decision on the design target on synchronicity budget for Uu interface for each representative use case.*

# Evaluation on the necessity of enhancements in RAN1 in Rel-17

In order to evaluate whether any enhancements needed in Rel-17 in order to meet the requirement discussed in section 2, we need the check the performance that can be achieved by Rel-16 mechanisms first.

## Summary of the evaluation and conclusion in Rel-16

ZTE gives a good summary of Rel-16 discussion. In Rel-16, RAN1 has analyzed the time synchronization accuracy of Uu interface for two cases, i.e. synchronization accuracy with and without UE propagation delay compensation. The maximum timing synchronization error results with UE propagation delay compensation are summarized in Table 2 below.

Table 2 – Summary of maximum timing synchronization error results with UE propagation delay compensation given in Rel-16

|  |  |  |  |
| --- | --- | --- | --- |
|  | 15kHz SCS | 30kHz SCS | 60kHz SCS |
| Source R1-1900156 | 488ns | 357.5ns | 276.5ns |
| Source R1-1901334 | 505ns | 371ns | 287.5ns |
| Source R1-1900935 | 472.5ns | 338.5ns |  |
| Source R1-1901252 | 536ns | 438ns | 357ns |

**Conclusion from the evaluation in RAN1 in Rel-16**:

|  |
| --- |
| RAN1 has performed analysis on the achievable time synchronization accuracy over Uu interface. A timing synchronization error between a gNB and a UE no worse than 540ns is achievable based on the RAN1 agreed evaluation assumptions for Rel-15 NR with 15kHz SCS. It is RAN1´s conclusion, that the synchronization accuracy is improved when using higher SCS. For small service areas with dense small cell deployments a propagation delay compensation by the UE would not be required. The propagation delay compensation needs to be applied by the TSN UEs for larger service areas with more sparse cell deployments (e.g. for inter-site distances >200m the gNB-to-UE timing synchronization accuracy without propagation delay compensation may be worse than 1us). |

In Rel-16, there is no any RAN1 specification work, and RAN2 has agreed that the reference timing information can be sent by SIB9 and dedicated RRC signaling with a granularity of 10ns was introduced to deliver the accurate reference time from the gNB to the UE in RAN2. More details can be found in TR 38.825.

**Feature lead view**: Although we already have the evaluation in Rel-16, some companies pointed out that different companies were estimating the accuracy differently in Rel-16, which can be seen from the values from different source as shown in Table 2 above. In Rel-16, it didn’t matter since the requirements were always fulfilled regardless which method was used. However, the situation is different in Rel-17, since different assumption would result in different conclusion on the necessity of the enhancements in Rel-17. Therefore, it is recommended to further evaluate the achievable time synchronization accuracy over Uu interface.

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

There are several aspects which have impact on the timing accuracy between UE and gNB. In order to do the evaluation, it would be good for us to discuss one by one. Note that there is commonality on the potential factors. However, it seems different companies use different name and/or different denotation in the contributions. Therefore, you might find that the name used here different with what you used in your own paper.

The time synchronization between UE and gNB can be obtained basically through three steps, the first step is the reference time information (denoted by ) delivery, the second step is the downlink frame timing applied by UE, denoted by , and the third step is the estimation of downlink propagation delay, denoted by . The basic mechanism of time synchronization between UE and gNB can be expressed as the equation below. That is, the time clock of UE is equal to the received time clock of gNB plus the downlink propagation delay. A simple illustration of the basic mechanism can be found in Figure 1.

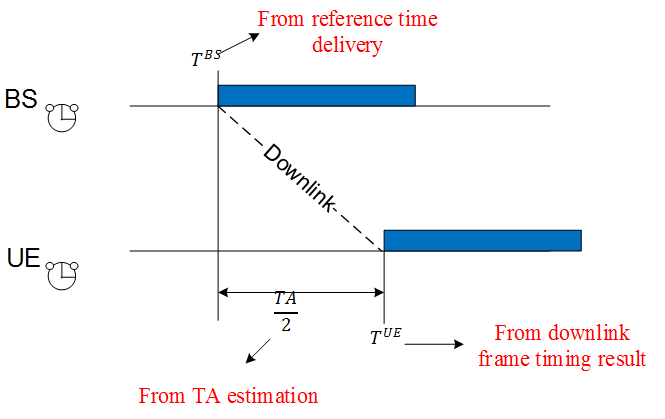


Figure 1: Illustration of time synchronization mechanism

### Error related to BS timing

The accuracy of is mainly impacted by two factors, i.e. one is the frame timing accuracy of BS transmitter and another is the indicating error associated to the indicating granularity of .

The frame timing accuracy of the gNB transmitter can refer to the Time Alignment Error (TAE) which is defined in TS38.104 as a requirement for the base station. This requirement applies to the frame timing in TX diversity, MIMO transmission, carrier aggregation and their combinations. And this requirement is defined due to the frames of the NR signals present at the BS transmitter antenna connectors or TAB connectors are not perfectly aligned in time, and the RF signals present at the BS transmitter antenna connectors or transceiver array boundary may experience certain timing differences in relation to each other. In a sense, the inaccurate frame timing of BS is caused by the misalignment of the BS transmitter timing in different antenna connectors or transceiver array boundary in different transmitting occasions. So the frame timing accuracy can be seen as same as the TAE.

According to the description in the TS38.104 as shown below, there is various requirement for the TAE under different cases.

|  |
| --- |
| 6.5.3.2 Minimum requirement for *BS type 1-C* and *BS type* 1-H For MIMO transmission, at each carrier frequency, TAE shall not exceed 65 ns.  For *intra-band contiguous carrier aggregation*, with or without MIMO, TAE shall not exceed 260ns.  For *intra-band non-contiguous carrier aggregation*, with or without MIMO, TAE shall not exceed 3µs.  For inter-band *carrier aggregation*, with or without MIMO, TAE shall not exceed 3µs.  The time alignment error requirements for NB-IoT are specified in TS 36.104 [13] clause 6.5.3. |

**Question 3-1: What value should we assume for TAE for different representative use cases as given in section 2 (i.e. control-to-control and smart grid)?**

|  |  |
| --- | --- |
| *Company* | *View* |
| Nokia, NSB | TAE only applies if the respective feature is supported. We may assume that in the indoor scenario MIMO from different gNBs/TRPs or intra-band CA is supported and hence we have an inter-gNB error bounded by TAE of <65ns or <260ns. However, as we see it there are no TAE applicable for the smart grid scenario (unless we assume TDD band operation (<3µs). Therefore, we have to make an assumption on the maximum error between gNBs or at a single gNB. Our internal analysis suggests 400ns between gNB.  This translates to a single gNB error between the time-stamping entity and the air interface SFN timing of: ±130ns for the indoor scenario and ±200ns for the smart grid scenario. |
| *Samsung* | *65ns* |
| *vivo* | We think single carrier can be baseline. For a single carrier, the maximum error is to be within ±65ns, i.e., TAE=65 ns can be assumed. |
| ZTE | 65 ns is preferred since the time accuracy between one cell and one UE is analyzed |
| HW/HiSi | For TSN, we think the requirement for MIMO transmission should apply, i.e. 65 ns. |
| Ericsson | First of all, it should be clarified that TAE as defined in TS 38.104 is very different from the BS transmit frame timing. See below definition from TS 38.104, i.e., TAE refers to time difference between two antenna connectors, not the difference between gNB transmit time and reference frame time at baseband.   |  | | --- | | TS 38.104,  6.5.3      Time alignment error  6.5.3.1          General  Frames of the NR signals present at the BS transmitter *antenna connectors* or *TAB connectors* are not perfectly aligned in time. The RF signals present at the BS transmitter *antenna connectors* or *transceiver array boundary* may experience certain timing differences in relation to each other.  The TAE is specified for a specific set of signals/transmitter configuration/transmission mode.  For *BS type 1-C*, the TAE is defined as the largest timing difference between any two signals belonging to different *antenna connectors* for a specific set of signals/transmitter configuration/transmission mode.  For *BS type 1-H*, the TAE is defined as the largest timing difference between any two signals belonging to *TAB connectors* belonging to different transmitter groups at the *transceiver array boundary*, |   Our estimate for the BS transmit frame timing error is: **50+65/2 = 82.5 (ns)**. Here 50ns for baseband internal error and 65/2 for error from baseband to one antenna connector. Note that the error component of NW-TT and gNB input is not counted, and it should be included when analyzing the network interface errors. |

#### Summary of the status for question 3-1: What value should we assume for TAE for different representative use cases as given in section 2 (i.e. control-to-control and smart grid)?

* ***65 ns:*** *Samsung, Vivo, ZTE, Huawei/HiSilicon*
* *Reasons*
  + *Single carrier case can be the baseline and it is 65 us if following what defined in TS 38.104.*
* ***±130ns for the indoor scenario and ±200ns for the smart grid scenario:*** *Nokia, NSB*
* *Reasons*
  + *In the indoor scenario MIMO from different gNBs/TRPs or intra-band CA is supported and hence we have an inter-gNB error bounded by TAE of <65ns or <260ns. There are no TAE applicable for the smart grid scenario, we have to make an assumption on the maximum error between gNBs or at a single gNB, assuming 400ns between gNB.*
* ***82.5 ns:*** *Ericsson*
* *Reasons*
  + *TAE as defined in TS 38.104 is very different from the BS transmit frame timing. Our estimate for the BS transmit frame timing error is: 50+65/2 = 82.5 (ns). Here 50ns for baseband internal error and 65/2 for error from baseband to one antenna connector.*
* ***Feature lead:*** *The majority view is 65 ns. However, the difference on the proposed values are big, therefore further discussion is needed. Companies are encouraged to check the reasons given by companies, and provide further views on the preferred values.*

***Proposal 3-1****: 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*

In order to fasten the discussion on the above proposal 3-1, the following further questions are made to collect the views.

**Question 3-1-1: Can TAE represent BS transmit frame timing?**

|  |  |
| --- | --- |
| *Company* | *View* |
| Feature lead | Companies can provide your views here. In addition, I have some question for better understanding the comment from some companies.  @ Ericsson   1. Can you clarify how to get 50 ns for baseband internal error? And why we need to consider baseband internal error? 2. Can you clarify why 65/2 for error from baseband to one antenna connector?   @ Nokia   1. Can you elaborate a little bit more on the comment that “there are no TAE applicable for the smart grid scenario (unless we assume TDD band operation (<3µs)”? |
| Nokia, NSB | Our understanding on TAE is that it applies when one of the five cases described in 6.5.3.2 is supported. We are fine by assuming that MIMO for a single carrier (TAE<65ns) and/or Intra-band contiguous CA is supported between cells (TAE<260ns/2 per cell) in the control-to-control use case.  For the smart grid we do not see any of the TAE cases (smaller than 3µs) accurately bounding the timing error between antenna ports at different base-stations. Therefore, other means to evaluate the corresponding TAE for the smart grid case is needed. We considered that the air interface transmission timing between two cells, will be subject to the gNB architecture. Our internal studies has identified that +-200 is a worst case for this case. Note that this does not include the impact of GM to gNB, but only the gNB to its antenna port. |
| Qualcomm | This is highly related to gNB implementation. We can use the value in Option 3 as a starting point. |
| ZTE | Yes. |
| Samsung | Support further study based on the 3 options summarized by FL.  Agree with Ericsson’s analysis that 65ns is not the error of BS timing (comparing to what gNB intended to transmit) |

**Question 3-1-2: Do we need to consider gNB-to-gNB error for BS transmit frame timing?**

|  |  |
| --- | --- |
| *Company* | *View* |
| Feature lead | It seems the proposed value from Nokia is big because they consider gNB-to-gNB error. |
| Nokia, NSB | We used the gNB-to-gNB transmission error (which applies for TAE) simply to derive a per gNB error. It is not something that needs to be considered in general in all cases.  When we consider a UE-UE case, we might need to consider the relative synchronization accuracy between two gNB or gNB-DUs. Either by two different GM realizations (different PTP paths or two separate GNSS receivers), or as part of the RAN (inter-gNB synchronization (e.g. bounded by TAE (if applicable). |
| Qualcomm | Yes. We need. |
| ZTE | In our understanding, we only consider one gNB for time accuracy analysis. There is no need to consider gNB-to-gNB error. |
| Samsung | We think this part of error was provided by RAN 3 in Rel-16 SI. And this is not part of RAN 1 evaluation. |

**Question 3-1-3: Is it sufficient to only consider single carrier case for BS transmit frame timing?**

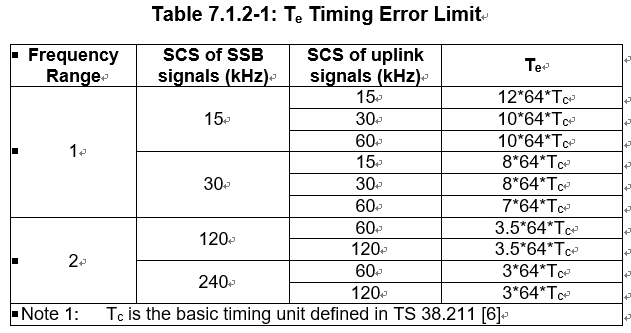
|  |  |
| --- | --- |
| *Company* | *View* |
| Feature lead | More companies prefer 65 ns, it seems the main reason is that they think single carrier case is sufficient. |
| Nokia, NSB | Yes, for the control-to-control case this is OK, as per our comment in 3-1-1. |
| Qualcomm | Yes for the control-to-control case. |
| ZTE | Yes, it is sufficient. |
| Samsung | Yes for control-to-control case |

It seems the indicating error would be associated to the indicating granularity of . According to what agreed in RAN2 in Rel-16, the granularity is 10 ns here.

### Error related to UE timing

The downlink frame timing at the UE receiver represents the arrival time of the downlink signal, and is obtained via detecting the downlink signal of the reference cell. The requirement of UE initial transmit timing error has been defined in TS 38.133 which is denoted by Te, and it represents the uplink transmission timing error of UE in a DRX cycle for PUCCH, PUSCH and SRS or it is the PRACH transmission. It mainly includes the detecting error of downlink signal by UE, and also includes the implementation error of UE due to the internal processing jitter. Both of these factors have impact on the final timing accuracy between UE and gNB. So basically the time error related to UE timing can be seen as same as Te.

According to the description in TS 38.133, Te has various values under different scenarios.



**Feature lead**: For the UE transmit timing error here, it seems we can take whatever defined in the RAN4 specification, and there should be no controversial views.

**Question 3-2: Do you agree that the value defined in TS 38.133 can be used directly for all the representative use cases?**

|  |  |
| --- | --- |
| *Company* | *View* |
| Nokia, NSB | Not agree.  We do not agree that Te is applicable for this analysis as it only reflects the initial timing error. If we studied the worst cases, then OK, but here we have devices, which are not power limited and could be in RRC-CONNECTED all the time to receive (g)PTP messages. Instead we need to model the TA mechanism with the errors of the UE detection inaccuracy of the DL reference signal, applying the latest TA-C (noted TA-err or TA-adj). It is further our understanding that the UE transmitter chain is sufficiently simple, that that no mismatch exists between the UE timing understanding and the actual transmission on the air interface (hence no additional error (apart from a single sample maybe) at the UE transmitter chain. |
| *Samsung* | *OK. And we want to clarify that this error includes DL time estimation error and UL transmission error.* |
| *vivo* | Agree the value defined in TS 38.133. |
| ZTE | Yes, agree |
| HW/HiSi | Yes |
| Ericsson | We agree to use Te for existing Rel-16 analysis.  Regarding meaning of Te: we do not agree that Te includes DL time estimation error. See 38.214 below. That is, ±Te is tx timing error with reference to DL reception time, but DL reception time error is not accounted for.  38.214 section 7.1:  “*The uplink frame transmission takes place before the reception of the first detected path (in time) of the corresponding downlink frame from the reference cell.*”  “*When the transmission timing error between the UE and the reference timing exceeds ±Te, the UE is required to adjust its timing to within ±Te. The reference timing shall be  before the downlink timing of the reference cell.*” |

#### Summary of the status for question 3-2

* ***The value defined in TS 38.133 can be used for error related to UE timing:*** *Samsung, Vivo, ZTE, Huawei/HiSilicon, Ericsson*
* ***No:*** *Nokia, NSB*
  + *Te is not applicable for this analysis as it only reflects the initial timing error. The UE transmitter chain is sufficiently simple, that that no mismatch exists between the UE timing understanding and the actual transmission on the air interface (hence no additional error (apart from a single sample maybe) at the UE transmitter chain*
* ***Feature lead:*** *The majority view is that the value defined in TS 38.133 for UE initial transmit error should be considered for evaluation of the time synchronization. It is recommended to consider it.*

***Proposal 3-2****: 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.*

**Please comment if you have strong concern on the above proposal 3-2.**

|  |  |
| --- | --- |
| *Company* | *View* |
| Feature lead | @ Nokia   1. Can you check if you are ok with it? |
| Nokia, NSB | We are OK with proposal 3-2.  Our understanding of Te is that it is defined as the maximum uplink transmission timing offset relative to the reference time defined as the downlink reception time minus the applied TA value. As the uplink transmission time is always relative to the DL reception timing, Te includes the DL reception error in the TA procedure already (DL reception timing should still be applied for the SFN estimation though).  The description of Te in TS 38.133 describes that it applies for the first transmission in a DRX cycle, and use the DL timing from at least one SSB (i.e. no TA command to allow for adjustments has been present).  TS 38.133 Section 7.1.2:   |  | | --- | | 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. |   So when we use Te in the analysis, we should not include the TA adjustment error as well. |
| Qualcomm | The value in the table is the requirement of initial transmit timing error, not exactly the requirement of transmit timing error. However, we think it is feasible to use this value for evaluation since it is difficult to find the suitable value for this purpose. |
| Samsung | We also think Te is initial transmission error when TA adjustment is not applied.  TA adjustment error is not for calculate for TSN but for UE to adjust the transmission time. And at UE side, it is more about UE implementation on when/how to adjust the TA, as long as the UE can meet the requirement on TA adjustment. |

### Error related to DL propagation delay estimation

UE decides the downlink propagation delay according to the TA value obtained from TA command sent by gNB. According to the current TA mechanism, the TA command delivery is realized by implementation. That is, gNB decides, by realization, when to deliver the TA command to UE, and UE may re-obtain the TA value after the TA-alignment timer expires according to the specification. At worst case, the TA accuracy can be seen as about half of CP length since gNB may trigger the TA command delivery after one or several uplink demodulation failures. At best case, it can be assumed that gNB can deliver the TA command to UE in time and the accuracy relies on the detailed TA processing which is analyzed as follows. Since the TA command delivery belongs to the behavior which gNB has ability to control, **it is assumed that gNB can deliver the TA command in time at least to the UEs which have requirement of high accuracy time synchronization**.

#### Asymmetry between downlink and uplink channel

UE estimates the downlink propagation delay as half of the TA value obtained from gNB, which introduces error due to the asymmetry between downlink and uplink propagation delay. In TDD system, the downlink and uplink channel fading can be seen strongly correlated with each other while the time gap between them is short enough. And the asymmetry between downlink and uplink propagation delay is mainly due to the change of small scale fading. In FDD system, the situation is a little worse since the downlink and uplink signal are transmitted at different carrier frequencies. In general, devices in factory or electric system have low mobility, so it can be assumed that the downlink and uplink channel with time gap of dozens of milliseconds have the same large scale fading. Then the asymmetry is mainly caused by the change of multi-path distribution.

**Feature lead**: Based on the views in the contribution, it seems some companies assume there is no asymmetry between DL and UL. More views are needed.

**Question 3-3: Do we need to consider asymmetry between downlink and uplink channel? If yes, what value should we assume?**

|  |  |
| --- | --- |
| *Company* | *View* |
| Nokia, NSB | No, we don’t need to consider asymmetry.  The error introduced by asymmetry can be assumed to be quite small (if present). Asymmetry is only present if the second path is stronger and of a certain longer PD. In that case asymmetry is also only contributing by half to the inaccuracy introduced by PD estimation using TA. |
| *Samsung* | *No need.* |
| *Vivo* | Asymmetry between downlink and uplink channel is more related to the ability of UE & gNB receiver to identify the earliest signal path, which is impacted by small-scale fading.  In our contribution, ‘asymmetry’ part is counted in the Error related to UE timing/Downlink frame timing error as well as the BS detecting error. Thus, no explicit value is considered. We are open to consider ‘Asymmetry’ term in the error of propagation delay. |
| ZTE | We admit that it is difficult to define a representative value for the asymmetry between downlink and uplink propagation delay for the analysis although we think this factor should be considered. We want to hear views from other companies. We can also accept that asymmetry is not considered if majority of companies support it. |
| Ericsson | * For indoor (e.g., use case 2), we are OK to assume DL-UL asymmetry equal to zero for analysis. * For outdoor (e.g., use case 4), the DL-UL asymmetry is set to ±160ns. |

#### Summary of the status for question 3-3: Do we need to consider asymmetry between downlink and uplink channel? If yes, what value should we assume?

* ***No:*** *Nokia, NSB, Samsung, Vivo (open), ZTE (can accept), Ericsson (for control-to-control)* 
  + *Nokia: The error introduced by asymmetry can be assumed to be quite small (if present).*
  + *Vivo: ‘asymmetry’ part is counted in the Error related to UE timing/Downlink frame timing error as well as the BS detecting error.*
* ***Yes****:* *Ericsson ( ±160ns for smart grid), Huawei*
* ***Feature lead****:* *It seems reasonable to assume 0 for indoor scenario. However, more views needed before making the decision at least for smart grid.*

***Proposal 3-3****: Asymmetry between downlink and uplink channel for control-to-control scenario is not considered.*

**Please comment if you have different views on the above proposal 3-3.**

|  |  |
| --- | --- |
| *Company* | *View* |
| Nokia, NSB | Agree with the proposal. |
| Qualcomm | Agree |
| Samsung | OK |

It seems we need more discussion for smart grid case.

**Question 3-3-1: Do we need to consider asymmetry between downlink and uplink channel for smart grid? Please provide your reasons.**

|  |  |
| --- | --- |
| *Company* | *View* |
| Feature lead | 1. The value provided by E// and Huawei seems not small. |
| Nokia, NSB | No, we don’t think that is needed.  In our analysis we have defined the asymmetry component to be an actual difference in propagation delay. The UE and gNB receiver’s capability to detect the CIR peak is impacted by small scale fading, is therefore not affecting asymmetry in this definition. That said, we do agree that the likelihood of a propagation delay difference (assuming errors in the detection of the first identified path) in UL and DL in the smart grid case is larger than in the control-to-control use case. |
| Qualcomm | Yes. It will cause not accurate result if we do not take into account the Asymmetry between DL and UL. |
|  |  |

#### BS detecting error

BS decides the value of the TA for a certain UE by detecting the reference signal (e.g. SRS) sent by the UE, so the detecting error impacts the final accuracy of the time synchronization. However, it was observed in the contributions that the performance here would be impacted by some other factors also, e.g. the bandwidth of the signal.

**Question 3-4: What value should we assume here? Please provide your detailed analysis on how you achieve your value also.**

|  |  |
| --- | --- |
| *Company* | *View* |
| Nokia, NSB | Based on simulations we have found that a value of 100ns for 15kHz and 92ns for 30kHz can be assumed. |
| *Samsung* | *~100ns can be assumed. But we might need to clarify on which channel/RS for BS detection.* |
| *Vivo* | A maximum error of about 100ns for 15kHz SCS and 92ns for 30kHz SCS are assumed. |
| ZTE | 100ns which is used in our analysis in Rel-16 |
| HW/HiSi | Based on simulation from Rel-16, 130 ns for 15 kHz is an upper bound. We think 100ns is a reasonable number to assume. |
| Ericsson | 100 ns is reasonable |

#### Summary of the status for question 3-4: What value should we assume for BS detecting error?

* ***100 ns for 15 kHz and 92 ns for 30 kHz:*** *Nokia, NSB, Vivo*
* ***~100 ns:*** *Samsung, ZTE, Huawei, HiSilicon, Ericsson*
* ***Feature lead:*** *It seems majority view is ~100 ns and the different for 15 kHz and 30 kHz is minor. It is recommended to take 100 ns for all SCS for simplicity.*

***Proposal 3-4****: 100 ns is assumed for BS detecting error.*

**Please comment if you have different views on the above proposal 3-4.**

|  |  |
| --- | --- |
| *Company* | *View* |
| Nokia, NSB | Agree. |
| Qualcomm | Agree |
| Samsung | Agree |

#### TA Indicating error

The indicating granularity of TA command causes additional error, i.e. the error can be as large as half of the indicating granularity. According to 38.213, the TA indicating granularity is , so the indicating error can be assumed as .

for 15kHz

for 60kHz

**Question 3-5: Do you agree with using**  **as the TA indicating error in the evaluation of the baseline performance? If you don’t agree, please provide your value and the corresponding analysis here also.**

|  |  |
| --- | --- |
| *Company* | *View* |
| Nokia, NSB | Agree |
| *Samsung* | *OK.* |
| vivo | Yes. |
| ZTE | Yes, agree |
| HW/HiSi | Yes |
| Ericsson | Agree |

#### Summary of the status for question 3-5: Do you agree with using as the TA indicating error in the evaluation of the baseline performance? If you don’t agree, please provide your value and the corresponding analysis here also?

* ***Yes:*** *Nokia, NSB, Samsung, Vivo, ZTE, Huawei, HiSilicon, Ericsson*
* ***Feature lead:*** *It seems majority view is yes.*

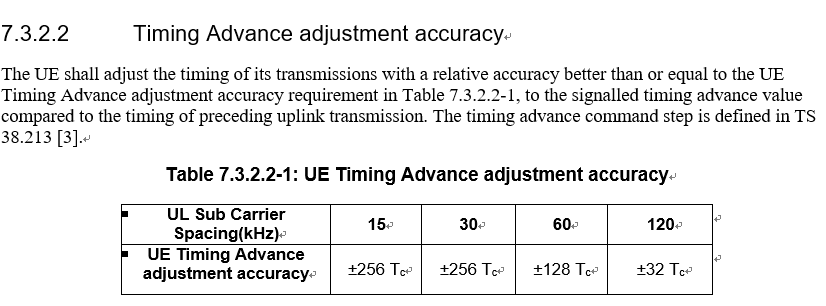
***Proposal 3-5****: as the TA indicating error is assumed in the evaluation.*

**Please comment if you have different views on the above proposal 3-5.**

|  |  |
| --- | --- |
| *Company* | *View* |
| Nokia, NSB | Agree. |
| Qualcomm | Agree |
|  |  |

#### TA adjustment accuracy

TA adjustment accuracy is also one aspect to consider and the values defined in TS 38.133 can be used.



***Proposal 3-6****: Timing advance adjustment accuracy defined in Table 7.3.2.2-1 in TS 38.133 is assumed for evaluation of the time synchronization.*

**Please comment if you have different views on the above proposal 3-6.**

|  |  |
| --- | --- |
| *Company* | *View* |
| Nokia, NSB | Agree - this is fine to include. But this should not be included together with Te, as Te already includes the TA adjustment error. |
| Qualcomm | Agree |
| Samsung | We think if there is no TA adjustment, we shall not consider TA adjustment error, even for option 1, since this is not for time estimation but for TA adjustment.  If the reference time for time estimation considered any TA command, this error need to be considered, but only once.  OK for the table for evaluation if the reference time is related to any TA command. |

#### Downlink frame timing error

The downlink frame timing error also impacts the accuracy of the estimation for downlink propagation delay . As shown in Figure 2, the estimated TA equals to correct TA plus Te without regard to other factors.

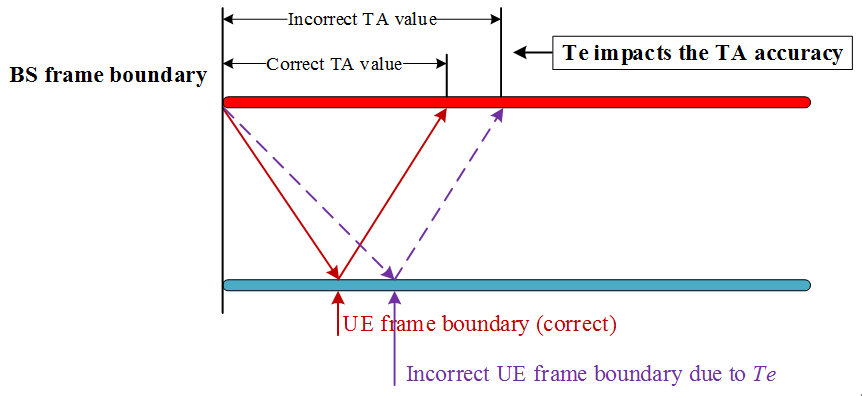


Figure 2: Te impacts the TA estimating accuracy

**Question 3-6: Do you have any other views on downlink frame timing error?**

|  |  |
| --- | --- |
| *Company* | *View* |
| Nokia, NSB | This assumption only applies when Te applies (i.e. the UE has been in DRX). We do not think this assumption applies for the scenarios related to this analysis. |
| *Samsung* | *No. we think this will be covered by propagation delay estimation.* |
| ZTE | We agree that downlink frame timing error may affect the TA accuracy |
| HW/HiSi | No other views. |
| Ericsson | This error is essentially DL detection error. This error should be accounted for. Also, as explained earlier, this is not part of Te. |

#### Summary of the status for question 3-6: The estimated TA equals to correct TA plus Te. Do you have any other views on downlink frame timing error?

* ***Nokia:*** *Downlink frame timing error is not needed to be considered because the assumption only applies when Te applies (i.e. the UE has been in DRX).*
* ***Samsung:*** *Downlink frame timing error is not needed to be considered since it will be covered by propagation delay estimation.*
* ***ZTE:*** *downlink frame timing error may affect the TA accuracy.*
* ***Ericsson:*** *This error is essentially DL detection error. This error should be accounted for. Also, as explained earlier, this is not part of Te.*

**Please continue provide your views here.**

|  |  |
| --- | --- |
| *Company* | *View* |
| Feature lead | @ Ericsson   1. By “this is not part of Te”, you mean we cannot use Te as the downlink frame timing error here? Then what value we should use?   @ Samsung   1. Yes in the end it will be counted as part of propagation delay as shown in section 3.2.3.5.   @ Nokia   1. Do we need to consider it for the worst case? e.g. UE is in DRX? |
| Nokia, NSB | No, we do not need to consider the worst case.  As mentioned earlier, if we use Te in our assumptions, this would correspond to the worst performance one can get with TA (i.e. the worst case). In our analysis in R1-2006341 we have not used Te, but focused identifying the expected performance. We believe that a gNB providing accurate time 1asynchronization to a UE, which are capable of using this, will have a performance with TA for PD compensation which is much better than the worst case TA assumptions. |

#### Overall error of the downlink propagation delay

In general, the error of TA estimation is composed of BS detecting error, TA indicating error and the downlink frame timing error. And the total error of TA estimation is calculated as:

Since the downlink propagation delay is gotten from the following equation sets:

So the downlink propagation delay is calculated as:

.

Then the error of the downlink propagation delay is:

**Question 3-7: Do you agree with the above method to calculate the error of downlink propagation delay? If your answer is No, please provide your suggestion here also.**

|  |  |
| --- | --- |
| *Company* | *View* |
| Nokia, NSB | We find the model insufficient as it does not capture the UE detection inaccuracy or the application error of timing advance. To estimate the PD the UE will use based on TA, the estimation will be as following (excluding TAE and TI as these error sources apply to the SFN timing (compared to R1-2006341)):  tUE-SFN-TX-Timing = tUE-RX – ½TA1  = tUE-RX – (TO1 + TETA-C + TA0).  The error then related to PD estimation becomes:  TERAN-PD-estimation = ½TEUE-DL-RX + ½(dPD-DL - dPD-UL) - ½TEgNB-UL-RX - ½TETA-err - ½ TETA-C |
| *Samsung* | *OK if we assume the reference signal for BS detection has no TA apply (starting from DRX or for PRACH as defined for Te), there is no need to take into account the TA adjustment error.*  *If we assume the propagation delay compensation is performed on top of TA adjustment, Timing Advance adjustment error needs to be considered. Since UE may have different understanding on what it actually did for TA adjustment.* |
| *vivo* | In principle we are fine with the equation for the error of the downlink propagation delay. |
| ZTE | Principally, we agree the calculation method. But for the TA estimation error, we think BS transmitting timing error, and TA adjustment error should also be taken into account.  BS transmitting timing error is the time offset between the time at which the BS wants to transmit a signal and the time at which the signal is transmitted actually. The UE transmits the UL signal based on the actually transmitted DL signal. It means UL transmission is affected by the actual time. However, the TA is estimated by the BS according to the ideal time. Therefore, the BS transmitting timing error should be considered.  TA adjustment error may affect the UL signal transmission, which is unknown to the BS. So it cannot be mitigated by the BS when estimating TA. Therefore, it should be considered |
| Ericsson | The method is not right. It does not account for several errors, e.g., BS transmit time error () in our formula below.  We suggest this formula (see R1-2005517): |

#### Summary of the status for question 3-7: What’s the method to calculate the error of downlink propagation delay?

* ***Feature lead:*** *The intention of this section is only for the error of downlink propagation delay. However, it seems people feel the principle here is similar as what we have in section 3.2.6, and we can focus on section 3.2.6.*

### 5GS Network time synchronization error budget

Nokia (R1-2006341) provides views on Network time synchronization error also.

|  |
| --- |
| **Network (NW) part** accounts for the time synchronization error caused by distributing the 5G GM to the gNB through the NW. When the 5G GM source is shared between the UPF and the gNB, the synchronization error involved in this, is also included in the network part. For the UE-UE synchronization scenario, the network part accounts for the relative synchronization error between the gNB providing the involved UEs with the 5G GM. 5GS Network time synchronization error budget Based on the description above on the network part, we consider two general options for deployment of the 5G GM clock;   1. A single 5G GM clock source (e.g. from aGNSS receiver or a TSC GM) is distributed to the gNB and UPF (NW-TT) with a (g)PTP framework. 2. Multiple 5G GM clock instances (of the same time-domain, e.g. from multiple GNSS receivers) are distributed in the scenario (e.g. one at each gNB and UPF).   We consider that Option A is relevant for the indoor factory scenario, where we assume that the 5G GM clock source, UPF and gNB are located within the same facility and potentially within the same rack. The connection between UPF (NW-TT) and gNB is assumed to span over maximum four (g)PTP capable hops relative to the 5G GM. According to The RAN3 LS in R3-187252 this can introduce an maximum error of TE<|4 ∙40ns|, corresponding to an error within ±80ns.  For Option B, when multiple 5G GM clock sources (of the same reference) are provided throughout the scenario, the NW accuracy does not depend on the path between the 5GS components, but on the synchronization error between two 5G GM clock instances (e.g. GNSS receivers). Considering the 5G GM instance is provided by GNSS receivers, the maximum error between the GNSS receivers are 200ns according to R3-187252, which translates to a time synchronization error range of maximum ±100ns. |

**Question 3-8: Do you have any different views on Network time synchronization error?**

|  |  |
| --- | --- |
| *Company* | *View* |
| ZTE | We believe the network time synchronization error should be considered. We think the assumed values provided by Nokia are reasonable. In addition, more detailed values are provided in TR38.825 in Rel-16. For the analysis in Rel-17, there may be some enhancements on the network. So we think RAN1 can ask RAN2/RAN3 to provide more exact values for our analysis by sending an LS. At this stage, RAN1 can just make a conclusion whether the network time synchronization error is considered. |
| HW/HiSi | Similar to the Uu design target, also this synchronization error could be provided from RAN2? |
| Ericsson | Network interface error should be accounted for. Unless RAN2/RAN3 provides updated values, our analysis is similar to Nokia’s, that is:   * For use case 2 (factory automation), cascaded PTP is assumed for synchronization source. According to TR38.825 Table 6.3.4.1-1, “|TE| ~N\*40ns, where N is the number of PTP hops.” * For use case 4 (power grid), local on-site GNSS receiver is assumed. According to TR38.825 Table 6.3.4.1-1, “|TE| = 100 ns.” |
| Qualcomm | 100ns is reasonable for network time synchronization error. |

#### Summary of the status for question 3-8: Do you have any different views on Network time synchronization error given in R1-2006341?

* ***Feature lead:*** *Based on the views from companies, it seems the value to be used may depend some discussion in RAN2/RAN3. Therefore, we may wait for the inputs first before making any decision here.*

### Any other aspect that will have impact on the time synchronization?

If companies have some suggestion on additional factor that will have impact on the time synchronization, please indicate it here.

**Question 3-9: Any other aspect we need to consider also?**

|  |  |
| --- | --- |
| *Company* | *View* |
| Nokia, NSB | Input from UE vendors on potential UE introduced timing errors would be good to get on the table now. |
| ZTE | See our view in question 3-7.  BS transmitting timing error, and TA adjustment error should also be considered. |
| HW/HiSI | Timing Advance adjustment accuracy could also be included |
| Ericsson | TA adjust accuracy should be included, and make it a sub-section under 3.2.3.  Outside of Uu interface, several error components are still missing:   * Error due to RRC 5GS time signaling granularity. This is granularity/2 = 10/2 =5(ns) for Rel-16.   Chengyan: This is already mentioned in section 3.2.1, but I can highlight it more   * UE internal error * DS-TT to UE error   A general comment is, section 3.2.4 and 3.2.5 (error components outside of air interface) belong to section 2.1 Uu interface design target analysis. That is, Uu interface error target is obtained by subtracting errors outside of Uu from 5GS total error budget (e.g., 900ns for use case 2), also taking into account if one pair of gNB-UE or two pairs of gNB-UE are involved.  Either of following is fine with us:   1. RAN1 wait for RAN2 input on Uu interface design target. In this case, RAN1 does not need to discuss section 3.2.4 and 3.2.5. 2. RAN1 estimates Uu interface design target without waiting for RAN2 input. In this case, RAN1 try to align views for section 3.2.4 and 3.2.5. |
| Samsung \* | We need to further clarify TA adjustment error. In our understanding, it only needs to be considered if the reference time is calculated based on previous TA. |

#### Summary of the status for question 3-9: Any other aspect that will have impact on the time synchronization?

* ***TA adjustment error:*** *ZTE, Huawei, HiSilicon, Ericsson*
* ***Other parameters:*** *UE internal error, DS-TT to UE error*
* ***Feature lead:*** *TA adjustment error will be added under section 3.2.3.*

### Overall error of the time synchronization

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. It would be good if companies can provide some views here also.

One example is show as below (network time synchronization is not considered here):







It can be seen from the equation that the total error of the time synchronization is:

**Question 3-10: How to calculate the overall error of the time synchronization?**

|  |  |
| --- | --- |
| *Company* | *View* |
| Nokia, NSB | We agree with the principle of the analysis above, but on the use of Te and would like to highlight that TAE and TI is not accounted for. The text below is copied from our t-doc [R1-2006341]:  Starting at the air interface, (i.e. between two antennas), a reference signal is subject to propagation delay and detection errors at the receiver. The latter is subject to the bandwidth (fading conditions) and receivers sampling capabilities. So we may denote the antenna reception time at the UE to be  tSFN-UE-RX = tSFN-UE-TX + dPD-DL+ TEUE-DL-RX.  As we use the SFN timing (tSFN-UE-RX) at the UE as our reference time for the timestamp received in referenceTimeInfo-r16, we need to account for the gNB introduced error for the transmission time and timestamp recording. This time error is denoted TETAE in this analysis and represents the gNB antenna port timing to the gNB timestamp used in referenceTimeInfo-r16 (providing the SFN timestamp. As mentioned in [4], there are no requirements on this in the specifications, but they can be derived from the RAN4 specifications of gNB TAE which captures the timing inaccuracy between two antenna ports. Further, there is a rounding error from the resolution of the referenceTimeInfo-r16 IE. Eventually, from an 5GS E2E perspective, the distribution of the 5G clock from the source of the clock to the gNB generating the timestamping, is also subject to errors denoted here as TETI. So we need to add the errors TETAE and TETI. The total accuracy error for cases without propagation delay compensation then becomes  TERAN-Not-PD-Compensated = TEUE-DL-RX + dPD-DL + TETAE + TETI .  We then consider the case where timing advance is applied for PD compensation. The UE UL transmission time is based on the UE’s DL reference timing, the latest TA command and the TA application error which is bounded by RAN4 (TETA-err) The expression becomes, assuming that TA is a positive number  tUE-TX = tUE-RX – TA0 + TETA-err .  The gNB measures and compares the received signal time from the UE with the expected time and calculates the timing offset (TO). Again, the UL transmission is subject to air interface introduced errors such as propagation delay and receiver detection errors. The gNB may issue a new TA command to the UE, instructing it to adjust its UL transmission time with TO. This adjustment is subject to rounding error due to a limited TA adjustment granularity, which we denote TETA-C. The UE will add the new TA command adjustment to its previously applied TA and obtain the new and updated TA value. The applied TA by the UE can then be expressed as  TA1 = TO1 + TETA-C + TA0 ,  where we note that the TETA-err is only considered when the UE adjusts its TA. So to not include it twice, it is not visible in this expression.  We can then express the UEs best estimation of the transmission time of the SFN boundary by the DL reception time minus half the applied TA value  tgNB-UE-Estimate = tUE-RX – ½TA1 .  Putting it all together we get the following expression for the total time synchronization error when the TA procedure is used for PD compensation  TERAN-PD-Compensated = ½TEUE-DL-RX + ½(dPD-DL - dPD-UL) - ½TEgNB-UL-RX - ½TETA-err - ½ TETA-C - TETAE + TETI .  When, lets consider the case where the 5G clock timestamping entity is both a DS-TT, we need to consider the relative time difference at two UEs, which we express as  TEUE0-UE1 = |tUE0 – tUE1| , where  tUE0 = tgNB0 + TEUE0-DL-RX + dPD-DL-gNB0-UE0 and tUE1 = tgNB1 + TEUE1-DL-RX + dPD-DL-gNB1-UE1  The difference between transmission timing on the air interface on gNB0 gNB1, depends on the functional and hardware in the gNB architecture and whether components are shared in the synchronization chain to each UE. In this analysis we assume that the UEs are connected to two separate DUs but the same CU. |
| *Samsung* | *Might need to consider TA adjustment error in some assumption. See the answer to above* |
| *vivo* | In principle we are fine with the equation. |
| ZTE | We think something more should be considered. For example, the positive or negative time error factors and the factors that should be considered in two steps.  In our understanding, all the time error factors can be positive or negative. It depends on the actually situation. In addition, some factors should be considered twice. It means these factors can occur in two steps. For example, the BS transmitting timing error considered in the first step also affect the accuracy of downlink propagation delay analyzed in the third step. The downlink frame timing error at UE receiver considered in the second step also affect the accuracy of downlink propagation delay analyzed in the third step. Therefore, we need to analysis the accuracy by some detailed assumption, e.g. assuming the positive factors or the negative factors.  We suggest our detailed illustrations in R1-2005435 can be used as a starting point. The maximum overall error could be: 1/2\*(e1+e2+e3+e4+e5+e6) |
| HW/HiSi | Timing advance accuracy needs to be considered here. |
| Ericsson | It’s a bit confusing to me why two separate sections, 3.2.3.5 and 3.2.6, are needed? They are essentially the same, aren’t they? Only difference is BS transmit timing?  Chengyan> Yes section 3.2.3.5 is mainly only for propagation delay error, while here is for the overall error of the time synchronization  In any case, repeat the same response we provided earlier, we suggest this formula (see R1-2005517): |
| Qualcomm | Timing Advance adjustment accuracy should be included in the equation. This parameter is related to TA based solution and not related to RTT based solution. |

#### Summary of the status for question 3-10: How to calculate the overall error of the time synchronization?

* ***Feature lead:*** *It seems companies view are still diverse. Anyway before making decision here on how to calculate the overall error, we need to achieve consensus on the factors that will have impact on the overall error first, it is recommended to delay the discussion here a little bit.*

In addition, it can be expected that the SCS will have impact on the final time synchronization also. To make the discussion more focus, it would be good for us to have some representative SCS for the representative use cases. Nokia pointed that 15 kHz can be considered for smart grid, while 30 kHz can be considered for control-to-control.

**Question 3-11: Do you agree that we can prioritize 15 kHz for smart grid and 30 kHz for control-to-control use case when evaluating the time synchronization?**

|  |  |
| --- | --- |
| *Company* | *View* |
| *Samsung* | *30kHz can be the baseline. Also to have both.* |
| *Vivo* | In our opinion, both 15 KHz and 30 KHz need to be considered for control-to-control. |
| HW/HiSi | We think we could assume 15 kHz and 30 kHz for both cases.  If we agree on the all the parameters in the previous questions, it will be startight forward to obtain results for both SCS. |
| Ericsson | - For use case 2 (factory automation), consider both 15 kHz and 30 kHz. SCS=15 kHz should be considered, since the service area is quite large, 1000 m x 100 m.  - For use case 4 (power grid), consider 15 kHz SCS. |

#### Summary of the status for question 3-11: Do you agree that we can prioritize 15 kHz for smart grid and 30 kHz for control-to-control use case when evaluating the time synchronization?

* ***30 kHz for both control-to-control and smart grid:*** *Samsung,*
* ***15 kHz and 30 kHz for both control-to-control and smart grid:*** *vivo, Huawei, HiSilicon*
* ***30 kHz for control-to-control and 15 kHz for smart grid:*** *Nokia, NSB*
* ***15 kHz and 30 kHz for control-to-control, and 15 kHz for smart grid:*** *Ericsson*
* ***Feature lead:*** *It seems one compromise way is to do analysis for both 15 kHz and 30 kHz for both cases.*

***Proposal 3-7****: Both 15 kHz and 30 kHz are assumed for both control-to-control and smart grid for evaluation of the time synchronization.*

**Please comment if you have different views on the above proposal 3-7.**

|  |  |
| --- | --- |
| *Company* | *View* |
| Nokia, NSB | Agree to 15kHz SCS (& potentially on top 30kHz) for smart grid – but do not agree on 15kHz for contro-to-control  We do not see any immediate need to study 15 kHz SCS for the control-to-control use case as it is indoor and could even a private network. We therefore propose to stick to analyzing 30kHz for the control-to-control use case. |
| Qualcomm | Agree to consider both 15kHz and 30kHz. It is noted that the variable SCS only has impact on performance of TA based solutions while the performance of RTT based solution is impacted by the bandwidth of the signals used for RTT estimations rather than the SCS. |
| Samsung | OK. |

If companies have some other views on how to evaluate the baseline performance here, please provide it here.

**Question 3-12: Any other view on how to evaluate the baseline performance on time synchronization?**

|  |  |
| --- | --- |
| *Company* | *View* |
| ZTE | See our view in question 3-10. We suggest evaluation way in R1-2005435 can be used as a starting point. The maximum overall error could be: 1/2\*(e1+e2+e3+e4+e5+e6) |
| Qualcomm | It seems that all the equations discussed here are for TA based solution. We need baseline performance also for RTT measurement based solution as well. |
| Samsung | We also like to further discuss on RTT measurement based solution. |

# Potential enhancements for propagation delay compensation

At the moment, there is no consensus yet if enhancements are needed. However, it would be good if we in the group can already now get more understanding about the different candidate methods that are on the table. Based on the contribution review, it seems the following methods and their pros and cons are considered.

* **Option 1**: TA-based propagation delay
  + **Option 1a**: Propagation delay estimation based on legacy Timing advance (potentially with enhanced TA-C 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 2**: RTT based delay compensation:
  + **Option 2a**: Propagation delay estimation based on reusing the existing Rx-Tx based procedure from Positioning.
  + **Option 2b**: Propagation delay estimation based on an RAN managed Rx-Tx procedure intended for time synchronization (FFS to expand or separate procedure to positioning).
* **Option 3**: A new dedicated signaling with finer delay compensation granularity (FFS TA-like metric) for propagation delay compensation

**Question 4-1: Do you have any suggestion on the formulation of the above three options? Any other option that need to be list here?**

|  |  |
| --- | --- |
| *Company* | *View* |
| Nokia, Nokia Shanghai Bell | *We propose to split Option 1 into two:*  Option 1a: Propagation delay estimation based on legacy Timing advance (potentially with enhanced TA-C granularity).  Option 1b: Propagation delay estimation based on timing advanced enhanced for time synchronization (as 1a but with updated RAN4 requirements to TA adjustment arror and Te)  *We also propose to split Option 2 into two:*  Option 2a: Propagation delay estimation based on reusing the existing Rx-Tx based procedure from Positioning.  Option 2b: Propagation delay estimation based on an RAN managed Rx-Tx procedure intended for time synchronization (FFS to expand or separate procedure to positioning).  Option 3 is not clear at all. Is would assume that the gNB has a PD estimation acquired and signals this to the UE? But how does the gNB acquire this?  We would like to highlight that if timing advance can be reused for the purpose of time synchronization, this should be preferred, as it will have a minimum of specification effort. Option 1b can quickly become overuse of TA for time synchronization, and have significant larger specification effort than Option 1a, therefore Option 1a should be the baseline method for PD estimation for time synchronization. That said, we believe that the accuracy can be further enhanced with Option 2a and 2b, but it is not in all cases that this is needed, and the corresponding overhead in configuring e.g. PRS and SRS and Rx-Tx measurements and reporting of these measurements, is significantly larger than for Option 1a and 1b. To avoid binding PD estimation together with a positioning UE capability, we prefer Option 2b over 2a.  In summary, we propose to focus on Option 1a, but if time allows, study Option 2b as a supplementary procedure. |
| *Samsung* | *For option 1, we think TA indication with finer granularity can be an optional feature and there should have no impact on legacy UEs. And in our understanding, option 1 means UE need to apply the finer granularity of TA indication for UL transmission similar as legacy behavior for TA adjustment.*   * **Option 1**: TA-based propagation delay (includes finer granularity of TA indication, TA adjustment error improvement, DL synchronization error improvement):   + Pro: Legacy UEs can support TA-based propagation delay (with current TA) when the requirement of time synchronization is not high. Enhanced TA based propagation delay can be supported by Rel-17 UEs to achieve higher time synchronization accuracy.   + Con: Specification effort to support finer granularity. May lead to UE to compensate a finer granularity TA which may not be needed for UL transmission.   *For option 2, we might need further study on whether it can achieve better accuracy than TA based delay compensation.*  *In our understanding, option 3 assumed a new dedicated signaling is introduced only serve for propagation delay compensation purpose. That is, UE doesn’t need to compensate TA with this new signaling with finer granularity. Therefore, we propose the following update:*   * **Option 3**: A new dedicated signaling with finer delay compensation granularity (FFS TA-like metric)for propagation delay compensation:   + Pro: No impact on legacy functions and can achieve the same performance as a finer TA granularity.   + Con: New parameter that would need to be specified. |
| *vivo* | We share the views with Nokia it is not good to bind the PD estimation with a positioning UE capability and additional overhead and UE measurements on the RS are required for option 2a. We also think option 1 can be the baseline and open to discuss option 3. |
| ZTE | We think option 1 should be baseline and the option 2 can be evaluated to investigate the gain. For option 2, the achievable time accuracy should be analysis and the required condition as well. For example, whether PRS is needed for the achievable me accuracy. Further evaluation on whether the required condition is acceptable is needed.  In addition, another issue that should resolved in Rel-17 in our opinion is uplink time clock transmission from a UE to the gNB over Uu interface according to the requirement in Rel-17 that the sync master could be a UE.   |  | | --- | | The 5G system shall provide an interface at the UE to determine and to configure the precision and time scale of the working clock domain.  The 5G system shall be able to support arbitrary placement of sync master functionality and sync device functionality in integrated 5G / non-3GPP TSN networks.  The 5G system shall be able to support clock synchronization through the 5G network if the sync master and the sync devices are served by different UEs. (Flow of clock synchronization messages is in either direction, UL and DL.) | |
| Intel | A general comment about RAN1-RAN2 work split is whether RAN1 should go into the enhancement discussions while not receiving any input from the leading group which is RAN2.  Nevertheless, depending on how the proposal is going to be formulated, we assume there should be an option of “No enhancements”. |
| HW/HiSi | We would like to avoid modifications that have impact on legacy functionality. For example a finer granularity for the TA indication that also is used for UL timing adjustment is not preferred.  Therefore, we would like to look further into Option 2 and Option 3.  It seems that Option 3 sounds simple. A delay with a finer granularity than the TA could be signaled to the UE.  According to the papers from some companies, Option 2 seems to have a potential to achieve higher accuracy, we would like to understand better how much better accuracy can be achieved, and if it is really needed? Some negative parts with option 2 are that UE might need to support positioning as well or at least parts from it. On first sight, it seems like a complicated approach that would need to be justified.  Question for clarification: Is it up to RAN1 or RAN2 to decide which method to adopt? If it is the latter, should then RAN 1, evaluate the performance and PHY of the different options and report to RAN2? |
| Ericsson | Current description of Option 1 and Option 3 are confusing since they are both enhancement of TA based method. It seems that the difference between Option 1 and Option 3 is, for Option 1 the enhanced signaling is also used by TA (i.e., for UL data transmission), while for Option 3 the enhanced signaling is dedicated to delay compensation, and does not affect TA. Is it correct? If so, please add such description to separate Option 1 and Option 3.  For Option 2, suggest removing Option 2a since it requires the positioning server to provide configuration and signaling. For TSN time sync, RAN1 cannot assume the presence of positioning server, in our understanding. |

#### Summary of the status for question 4-1:

* ***Feature lead:*** *Based on the inputs above, we can identify the candidate solutions for further study.*

***Proposal 4-1****: One or more of the following options can be considered if enhancements for propagation delay compensation is to be supported*

* ***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 2****: RTT based delay compensation:*
  + ***~~Option 2a~~****~~: Propagation delay estimation based on reusing the existing Rx-Tx based procedure from Positioning.~~*
  + ***Option 2b****: Propagation delay estimation based on an RAN managed Rx-Tx procedure intended for time synchronization (FFS to expand or separate procedure to positioning).*
* ***Option 3****: A new dedicated signaling with finer delay compensation granularity for propagation delay compensation (i.e. no need to rely on TA)*

**Please comment if you have concern on the above proposal 4-1. Further clarification on the comments from companies are welcome also.**

|  |  |
| --- | --- |
| *Company* | *View* |
| Nokia, NSB | We agree with the proposal.  Additional details on how Option 3 is intended to work are needed. |
| Qualcomm | We have discussed a lot for Option 1 in this document. It seems the solution is quite complicated. These errors are almost related to what scheme is implemented at the gNB and the UE. It is not efficient to implement addition functions for gNB/UE in order to reduce the errors. Therefore, we prefer the solution which works using the legacy implementation.  Among the three options, we would like to take Option 2 (2b) as baseline for further evaluation. Since this is joint work between RAN1 and RAN2, RAN1 can focus on performance analysis while RAN2 can make decisions based on the results; this is also the Work Item plan submitted by the WI rapporteur to RAN2 ([R2-2006921](file:///C:\Users\panidx\Documents\RAN2_111-e\Docs\R2-2006921.zip)) |
| Samsung | For option 3, in our view it can cover option 2, which also require a separated procedure/signaling from position. However, we think “TA-like” method can also covered by option3. The different is what kind of signaling needs to be exchanged between gNB and UE. We think either “RTT-based” or “TA-based/propagation delay” signaling is needed between UE and gNB. The most straightforward way is, gNB directly configured to UE the amount of propagation delay that needs to be compensated by UE for time synchronization.  In addition, we also think more detail is needed for RTT-based solution, since TA-based solution already been studied since Rel-16. |

# Summary of the proposals and questions for further discussion

This section summarize the proposals and questions for further discussion, where proposals highlight in blue are stable, while the ones highlight in yellow needs further discussion or more input. More details can be found in the previous sections.

***Proposal 2-1****: 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 |

***Proposal 2-1a****: For 5GS synchronicity budget requirement,*

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

**Please provide your views on the above proposal 2-1a if you have concern.**

|  |  |
| --- | --- |
| *Company* | *View* |
| Feature lead | *During the discussion or proposal 2-1 above, Nokia and Ericsson mentioned it would be good to clarify whether one or two Uu interface involved for a certain representative use case, I agree it would be good to clarify* |
| Qualcomm | Agree |
| ZTE | Agree with the proposal |
| Samsung | OK |

Note: More details please go to section 3.2.1

***Proposal 3-1****: 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*

In order to fasten the discussion on the above proposal 3-1, the following further questions are made to collect the views.

**Question 3-1-1: Can TAE represent BS transmit frame timing?**

|  |  |
| --- | --- |
| *Company* | *View* |
| Feature lead | Companies can provide your views here. In addition, I have some question for better understanding the comment from some companies.  @ Ericsson   1. Can you clarify how to get 50 ns for baseband internal error? And why we need to consider baseband internal error? 2. Can you clarify why 65/2 for error from baseband to one antenna connector?   @ Nokia   1. Can you elaborate a little bit more on the comment that “there are no TAE applicable for the smart grid scenario (unless we assume TDD band operation (<3µs)”? |
| Nokia, NSB | Our understanding on TAE is that it applies when one of the five cases described in 6.5.3.2 is supported. We are fine by assuming that MIMO for a single carrier (TAE<65ns) and/or Intra-band contiguous CA is supported between cells (TAE<260ns/2 per cell) in the control-to-control use case.  For the smart grid we do not see any of the TAE cases (smaller than 3µs) accurately bounding the timing error between antenna ports at different base-stations. Therefore, other means to evaluate the corresponding TAE for the smart grid case is needed. We considered that the air interface transmission timing between two cells, will be subject to the gNB architecture. Our internal studies has identified that +-200 is a worst case for this case. Note that this does not include the impact of GM to gNB, but only the gNB to its antenna port. |
| Qualcomm | This is highly related to gNB implementation. We can use the value in Option 3 as a starting point. |
| ZTE | Yes. |
| Samsung | Support further study based on the 3 options summarized by FL.  Agree with Ericsson’s analysis that 65ns is not the error of BS timing (comparing to what gNB intended to transmit) |

**Question 3-1-2: Do we need to consider gNB-to-gNB error for BS transmit frame timing?**

|  |  |
| --- | --- |
| *Company* | *View* |
| Feature lead | It seems the proposed value from Nokia is big because they consider gNB-to-gNB error. |
| Nokia, NSB | We used the gNB-to-gNB transmission error (which applies for TAE) simply to derive a per gNB error. It is not something that needs to be considered in general in all cases.  When we consider a UE-UE case, we might need to consider the relative synchronization accuracy between two gNB or gNB-DUs. Either by two different GM realizations (different PTP paths or two separate GNSS receivers), or as part of the RAN (inter-gNB synchronization (e.g. bounded by TAE (if applicable). |
| Qualcomm | Yes. |
| ZTE | In our understanding, we only consider one gNB for time accuracy analysis. There is no need to consider gNB-to-gNB error. |
| Samsung | We think this part of error was provided by RAN 3 in Rel-16 SI. And this is not part of RAN 1 evaluation. |

**Question 3-1-3: Is it sufficient to only consider single carrier case for BS transmit frame timing?**

|  |  |
| --- | --- |
| *Company* | *View* |
| Feature lead | More companies prefer 65 ns, it seems the main reason is that they think single carrier case is sufficient. |
| Nokia, NSB | Yes, for the control-to-control case this is OK, as per our comment in 3-1-1. |
| Qualcomm | Yes for control-to-control case |
| ZTE | Yes, it is sufficient. |
| Samsung | Yes for control-to-control case |

#### Summary of the status for question 3-1: What value should we assume for TAE for different representative use cases as given in section 2 (i.e. control-to-control and smart grid)?

* ***65 ns:*** *Samsung, Vivo, ZTE, Huawei/HiSilicon*
* *Reasons*
  + *Single carrier case can be the baseline and it is 65 us if following what defined in TS 38.104.*
* ***±130ns for the indoor scenario and ±200ns for the smart grid scenario:*** *Nokia, NSB*
* *Reasons*
  + *In the indoor scenario MIMO from different gNBs/TRPs or intra-band CA is supported and hence we have an inter-gNB error bounded by TAE of <65ns or <260ns. There are no TAE applicable for the smart grid scenario, we have to make an assumption on the maximum error between gNBs or at a single gNB, assuming 400ns between gNB.*
* ***82.5 ns:*** *Ericsson*
* *Reasons*
  + *TAE as defined in TS 38.104 is very different from the BS transmit frame timing. Our estimate for the BS transmit frame timing error is: 50+65/2 = 82.5 (ns). Here 50ns for baseband internal error and 65/2 for error from baseband to one antenna connector.*
* ***Feature lead:*** *The majority view is 65 ns. However, the difference on the proposed values are big, therefore further discussion is needed. Companies are encouraged to check the reasons given by companies, and provide further views on the preferred values.*

Note: More details please go to section 3.2.2

***Proposal 3-2****: 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.*

**Please comment if you have strong concern on the above proposal 3-2.**

|  |  |
| --- | --- |
| *Company* | *View* |
| Feature lead | @ Nokia   1. Can you check if you are ok with it? |
| Nokia, NSB | We are OK with proposal 3-2.  Our understanding of Te is that it is defined as the maximum uplink transmission timing offset relative to the reference time defined as the downlink reception time minus the applied TA value. As the uplink transmission time is always relative to the DL reception timing, Te includes the DL reception error in the TA procedure already (DL reception timing should still be applied for the SFN estimation though).  The description of Te in TS 38.133 describes that it applies for the first transmission in a DRX cycle, and use the DL timing from at least one SSB (i.e. no TA command to allow for adjustments has been present).  TS 38.133 Section 7.1.2:   |  | | --- | | 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. |   So when we use Te in the analysis, we should not include the TA adjustment error as well. |
| Qualcomm | The value in the table is the requirement of initial transmit timing error, not exactly the requirement of transmit timing error. However, we think it is feasible to use this value for evaluation since it is difficult to find the suitable value for this purpose. |
| Samsung | We also think Te is initial transmission error when TA adjustment is not applied.  TA adjustment error is not for calculate for TSN but for UE to adjust the transmission time. And at UE side, it is more about UE implementation on when/how to adjust the TA, as long as the UE can meet the requirement on TA adjustment. |

#### Summary of the status for question 3-2

* ***The value defined in TS 38.133 can be used for error related to UE timing:*** *Samsung, Vivo, ZTE, Huawei/HiSilicon, Ericsson*
* ***No:*** *Nokia, NSB*
  + *Te is not applicable for this analysis as it only reflects the initial timing error. The UE transmitter chain is sufficiently simple, that that no mismatch exists between the UE timing understanding and the actual transmission on the air interface (hence no additional error (apart from a single sample maybe) at the UE transmitter chain*
* ***Feature lead:*** *The majority view is that the value defined in TS 38.133 for UE initial transmit error should be considered for evaluation of the time synchronization. It is recommended to consider it.*

Note: More details please go to section 3.2.3.1

***Proposal 3-3****: Asymmetry between downlink and uplink channel for control-to-control scenario is not considered.*

**Please comment if you have different views on the above proposal 3-2.**

|  |  |
| --- | --- |
| *Company* | *View* |
| Qualcomm | Agree |
|  |  |

**Question 3-3-1: Do we need to consider asymmetry between downlink and uplink channel for smart grid? Please provide your reasons.**

|  |  |
| --- | --- |
| *Company* | *View* |
| Feature lead | 1. The value provided by E// and Huawei seems not small. |
| Nokia, NSB | No, we don’t think that is needed.  In our analysis we have defined the asymmetry component to be an actual difference in propagation delay. The UE and gNB receiver’s capability to detect the CIR peak is impacted by small scale fading, is therefore not affecting asymmetry in this definition. That said, we do agree that the likelihood of a propagation delay difference (assuming errors in the detection of the first identified path) in UL and DL in the smart grid case is larger than in the control-to-control use case. |
| Qualcomm | Yes. It will cause not accurate result if we do not take the Asymmetry between DL and UL into account. |

#### Summary of the status for question 3-3: Do we need to consider asymmetry between downlink and uplink channel? If yes, what value should we assume?

* ***No:*** *Nokia, NSB, Samsung, Vivo (open), ZTE (can accept), Ericsson (for control-to-control)* 
  + *Nokia: The error introduced by asymmetry can be assumed to be quite small (if present).*
  + *Vivo: ‘asymmetry’ part is counted in the Error related to UE timing/Downlink frame timing error as well as the BS detecting error.*
* ***Yes****:* *Ericsson ( ±160ns for smart grid), Huawei*
* ***Feature lead****:* *It seems reasonable to assume 0 for indoor scenario. However, more views needed before making the decision at least for smart grid.*

Note: More details please go to section 3.2.3.2

***Proposal 3-4****: 100 ns is assumed for BS detecting error.*

**Please comment if you have different views on the above proposal 3-3.**

|  |  |
| --- | --- |
| *Company* | *View* |
| Qualcomm | Agree |
| Samsung | Agree |

#### Summary of the status for question 3-4: What value should we assume for BS detecting error?

* ***100 ns for 15 kHz and 92 ns for 30 kHz:*** *Nokia, NSB, Vivo*
* ***~100 ns:*** *Samsung, ZTE, Huawei, HiSilicon, Ericsson*
* ***Feature lead:*** *It seems majority view is ~100 ns and the different for 15 kHz and 30 kHz is minor. It is recommended to take 100 ns for all SCS for simplicity.*

Note: More details please go to section 3.2.3.3

***Proposal 3-5****: as the TA indicating error is assumed in the evaluation.*

**Please comment if you have different views on the above proposal 3-3.**

|  |  |
| --- | --- |
| *Company* | *View* |
| Qualcomm | Yes |
|  |  |

#### Summary of the status for question 3-5: Do you agree with using as the TA indicating error in the evaluation of the baseline performance? If you don’t agree, please provide your value and the corresponding analysis here also?

* ***Yes:*** *Nokia, NSB, Samsung, Vivo, ZTE, Huawei, HiSilicon, Ericsson*
* ***Feature lead:*** *It seems majority view is yes.*

Note: More details please go to section 3.2.3.4

***Proposal 3-6****: Timing advance adjustment accuracy defined in Table 7.3.2.2-1 in TS 38.133 is assumed for evaluation of the time synchronization.*

**Please comment if you have different views on the above proposal 3-6.**

|  |  |
| --- | --- |
| *Company* | *View* |
| Nokia, NSB | Agree - this is fine to include. But this should not be included together with Te, as Te already includes the TA adjustment error. |
| Qualcomm | Yes |
| Samsung | We think if there is no TA adjustment, we shall not consider TA adjustment error, even for option 1, since this is not for time estimation but for TA adjustment.  If the reference time for time estimation considered any TA command, this error need to be considered, but only once.  OK for the table for evaluation if the reference time is related to any TA command. |

Note: More details please go to section 3.2.6

***Proposal 3-7****: Both 15 kHz and 30 kHz are assumed for both control-to-control and smart grid for evaluation of the time synchronization.*

**Please comment if you have different views on the above proposal 3-7.**

|  |  |
| --- | --- |
| *Company* | *View* |
| Nokia, NSB | Agree to 15kHz SCS (& potentially on top 30kHz) for smart grid – but do not agree on 15kHz for contro-to-control  We do not see any immediate need to study 15 kHz SCS for the control-to-control use case as it is indoor and could even a private network. We therefore propose to stick to analyzing 30kHz for the control-to-control use case. |
| Qualcomm | Agree |
| Samsung | OK. |

#### Summary of the status for question 3-11: Do you agree that we can prioritize 15 kHz for smart grid and 30 kHz for control-to-control use case when evaluating the time synchronization?

* ***30 kHz for both control-to-control and smart grid:*** *Samsung,*
* ***15 kHz and 30 kHz for both control-to-control and smart grid:*** *vivo, Huawei, HiSilicon*
* ***30 kHz for control-to-control and 15 kHz for smart grid:*** *Nokia, NSB*
* ***15 kHz and 30 kHz for control-to-control, and 15 kHz for smart grid:*** *Ericsson*
* ***Feature lead:*** *It seems one compromise way is to do analysis for both 15 kHz and 30 kHz for both cases.*

***Proposal 4-1****: One or more of the following options can be considered if enhancements for propagation delay compensation is to be supported*

* ***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 2****: RTT based delay compensation:*
  + ***~~Option 2a~~****~~: Propagation delay estimation based on reusing the existing Rx-Tx based procedure from Positioning.~~*
  + ***Option 2b****: Propagation delay estimation based on an RAN managed Rx-Tx procedure intended for time synchronization (FFS to expand or separate procedure to positioning).*
* ***Option 3****: A new dedicated signaling with finer delay compensation granularity for propagation delay compensation (i.e. no need to rely on TA)*

**Please comment if you have concern on the above proposal 4-1. Further clarification on the comments from companies are welcome also.**

|  |  |
| --- | --- |
| *Company* | *View* |
| Nokia, NSB | We agree with the proposal.  Additional details on how Option 3 is intended to work are needed. |
| Qualcomm | We have discussed a lot for Option 1 in this document. It seems the solution is quite complicated. These errors are almost related to what scheme is implemented at the gNB and the UE. It is not efficient to implement addition functions for gNB/UE in order to reduce the errors. Therefore, we prefer the solution which works using the legacy implementation.  Among the three options, we would like to take Option 2 (2b) as baseline for further evaluation. Since this is joint work between RAN1 and RAN2, RAN1 can focus on performance analysis while RAN2 can make decisions based on the results; this is also the Work Item plan submitted by the WI rapporteur to RAN2 ([R2-2006921](file:///C:\Users\panidx\Documents\RAN2_111-e\Docs\R2-2006921.zip)) |
| Samsung | For option 3, in our view it can cover option 2, which also require a separated procedure/signaling from position. However, we think “TA-like” method can also covered by option3. The different is what kind of signaling needs to be exchanged between gNB and UE. We think either “RTT-based” or “TA-based/propagation delay” signaling is needed between UE and gNB. The most straightforward way is, gNB directly configured to UE the amount of propagation delay that needs to be compensated by UE for time synchronization.  In addition, we also think more detail is needed for RTT-based solution, since TA-based solution already been studied since Rel-16. |

# References

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4. [R1-2005705](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_102\Docs\R1-2005705.zip) Discussion on propagation delay compensation enhancements CATT
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10. TS 22.104 V17.3.0, “Service requirements for cyber-physical control applications in vertical domains”

# Appendix – Selected details from company papers and proposals

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| R1-2005378, vivo | *vivo R1-2005378*  Table 1: Timing error in clock synchronisation   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | **Factors** | **Timing error type** | **Requirement for different SCS (kHz) (unit: ns)** | | | | | 15 | 30 | 60 | 120 | | 1 | Inaccuracy caused by downlink/uplink frame timing alignment | | | | | | 1.1 | Time alignment error of gNB transmitter (TETAE) | 65 | 65 | 65 | 65 | | 1.2 | Inaccuracy caused by UE detection (TEUE-DL-RX) | 260 | 260 | 163 | 98 | | 1.3 | Inaccuracy caused by propagation delay when propagation delay is decided from TA. (1.3.1+1.3.2+1.3.3)/2 | 375 | 245 | 192.5 | 119 | | 1.3.1 | Inaccuracy of UE transmitting (TEUE-DL-to-TX) | 390 | 260 | 228 | 114 | | 1.3.2 | Inaccuracy of gNB detection (TEUL-RX) | 100 | 100 | 92 | 92 | | 1.3.3 | Inaccuracy caused by TA indication (TETA-G) | 260 | 130 | 65 | 32 | | 1.4 | Inaccuracy caused by propagation delay when considering 20km2 service area (TEPD) | 8410 | 8410 | 8410 | 8410 | | 2 | Inaccuracy caused by time reference information delivery from gNB to UE (TERT) | 5 | 5 | 5 | 5 | | 3 | Inaccuracy caused by the synchronisation between the gNB and external clock (TEEC) | 100 | 100 | 100 | 100 | | Total error | Total inaccuracy for 20 km2 service area (with propagation compensation) = (2\*(1.1+1.2+1.3+2+3)) | 1610 | 1350 | 1051 | 774 |   **Proposal 1: NTA/2 is used for the propagation delay compensation of the reference time.**  **Observation 1: After the propagation delay compensation, the inaccuracy of 15/30/60 KHz SCS cannot fulfil the TSN clock synchronization requirements.**  **Proposal 2: RAN1 should discuss the potential enhancements for the propagation delay compensation:**   * **More accurate DL signal detection (1.2)** * **More accurate UL signal transmission (1.3.1)** * **More accurate UL signal detection (1.3.2)** * **Finer granularity of TA indication (1.3.3)** |
| R1-2005435, ZTE | * The gNB wants to transmit DL signal to the UE at t1. In fact, the DL signal is transmitted by the gNB at t2 due to the gNB transmitting time error (e1), where e1 is a negative error. It means that the gNB transmits the signal before the time that the gNB wants to transmits, i.e. t2 is before t1 as shown in Figure 1. * After DL propagation, the DL signal arrives to the UE at t3, where t3-t2 is the DL propagation delay. Due to DL synchronization error (e2), the UE detects that the DL signal is received at t4, where e2 is a negative error so that t4 is before t3 as shown in Figure 1. * When the UE performs UL signal transmission, the TA indicator error (e4) and TA adjustment error (e5) should be taken into account, which leads to the UE transmits UL signal at t6, where e4 and e5 are positive errors so that t6 is after t4 as shown in Figure 1. * After UL propagation, the UL signals arrives to the gNB at t8, where t8-t6 is the UL propagation delay. t8-t7 is the unbalance between the DL and UL (i.e. e6), which is a positive error so that t8 is after t7 as shown in Figure 1. t7 is the time that the UL signals arrives to the gNB if we assume UL propagation delay is equal to the DL propagation delay. * Due to UL synchronization error (e3), the gNB detects that UL signal arrives at t9, where e3 is a positive error so that t9 is after t8 as shown in Figure 1. * In order to adjust the UE transmitting time such that the UL signals is aligned at the gNB, the TA should be 2PDL+e3+e4+e5+e6-e1-e2. Note: all the ex in the equation are the positive time duration value.     Figure 1 An example of time error  The UE detects that DL signals arrives to the UE at t4. According to the UE-based method, the UE thinks t4 is reference timing plus half of the TA, i.e. t1+TA/2=t1+1/2\*(2PDL+e3+e4+e5+e6-e1-e2). However, the correct time of t4 is t1+PDL-e1-e2. Therefore, the timing synchronization error is 1/2\*(e1+e2+e3+e4+e5+e6). Note that the time error for the other cases are also given in the appendix.  ***Observation 1:*** *Propagation delay compensation is performed by UE implementation in Rel-16.*  ***Observation 2:*** *The time accuracy of Uu interface should be improved to meet the requirements in Rel-17.*  ***Proposal 1:*** *It's better to achieve an aligned result on synchronization accuracy of Uu interface by aligning the calculation method and assumption before going further on the enhanced propagation delay compensation.*  ***Proposal 2:*** *The maximum timing synchronization error with UE propagation delay compensation should be 1/2\*(e1+e2+e3+e4+e5+e6), where e1 is the gNB transmitting time error, e2 is the DL synchronization error, e3 is the UL synchronization error, e4 is the TA indicator error, e5 is the TA adjustment error, e6 is the unbalance between the DL and UL.*  ***Proposal 3:*** *Further improvement on the accuracy for some of the factors can be considered.*   * + *TA indicator error is discussed in RAN1*   + *TA adjustment error and DL synchronization error should be discussed in RAN4.*   ***Proposal 4:*** *The clock message transmission in UL link should be resolved in Rel-17.* |
| R1-2005517, Ericsson | **Uncertainties related to UE determination of the downlink PD:**   * (c) : The uncertainty associated with UE downlink frame timing detection. As a worst case, a UE synchronizes to the DL using Sync Signal Block (SSB) received within the last 160 ms, where SSB contains information identifying specific DL frame and slot numbering.   + If there are other DL reference signals available to the UE the uncertainty will be reduced compared to the worst case.   + This uncertainty covers (b) above and therefore (b) need not be considered as a separate source of uncertainty. * (d) : The combined uncertainty associated with UE receive error and UE transmit time error, where a UE performs transmission of UL frames after acquiring DL sync per (c) and applying the most recently received TA information (i.e. this uncertainty = “Te”) * (e) : The uncertainty with which a gNB acquires UL frame timing, which affects how accurately it determines the difference between when an UL sub-frame has been received and when that sub-frame should have been received if the UE was perfectly time aligned (i.e. this uncertainty affects the value the gNB sends within a TA command).   + Currently there is no accuracy requirement defined for (e) in RAN4 specification. It is expected that RAN4 will define some accuracy requirement for "gNB Rx – Tx time difference" (or similar) in in near future. Thus, no definite values are available for the analysis of propagation delay compensation before that. * (f) : The uncertainty due to timing advance (TA) command granularity. Maximum value of this uncertainty is half of TA command granularity, i.e.,     in the existing NR specification where µ represents the applicable SCS.   * (g) : The uncertainty due to “Timing Advance adjustment accuracy” performed by a UE, see section 7.3.2.2 of TS 38.133.   **Determining Overall Uncertainty**  The equation below is then used to determine the overall uncertainty introduced when a UE adjusts the value of the last received 5G reference time to take into account the downlink PD (= ½ the total of all TA adjustments it has made).   * When using this equation it is assumed that no UL-DL RF channel asymmetry exists. Otherwise, UL-DL asymmetry is another error source. * In addition, if using legacy methods to convey 5G reference time and TA information to a UE, it is assumed that the downlink PD applicable to when the UE receives 5G reference time information is the same as when it receives the TA command used to determine the value for downlink PD (i.e. it is assumed that no appreciable change in the downlink radio path occurs between reception of 5G reference time and a TA command).   **Determining Downlink PD Using an Enhanced RTT Method**  An alternate procedure for allowing a UE to determine a value for the downlink PD is to make use of an enhanced RTT method that is based on the timing advance Type-1 measurement definition taken from LTE:   |  | | --- | | TS 36.214:  Type1:  Timing advance (TADV) type 1 is defined as the time difference  TADV = (eNB Rx – Tx time difference) + (UE Rx – Tx time difference),  where the eNB Rx – Tx time difference corresponds to the same UE that reports the UE Rx – Tx time difference. |   **Proposal 1**: RAN1 to adopt a target uncertainty goal of no more than 200ns for each instance of 5G reference time relayed from a gNB to a UE.  **Proposal 2:** Investigate whether the legacy RTT method or an enhanced RTT method is most suitable for determining the downlink propagation delay value, which is then used to adjust the 5G reference time value sent from a gNB to a UE.  **Proposal 3:** For the selected RTT method, identify the sources of uncertainty involved and potentially requiring mitigation to reach the 200ns uncertainty target. |
| CATT, R1-2005705 | With the evaluation results in Rel-16, the gNB-to-UE timing synchronization error can be up to 540ns for 15kHz SCS. So that UE-to-UE timing synchronization error can be up to 1080ns which exceeds the 5GS synchronicity budget requirement of 900ns as shown in Figure 1.  **Observation: 900ns 5GS synchronicity budget requirement may not be met for uplink time synchronization for TSN between two UEs.**  Therefore, RAN1 should further study whether/how to improve UE-to-UE timing synchronization accuracy within 5GS.  **Proposal: RAN1 further study whether/how to improve UE-to-UE timing synchronization accuracy within 5GS.** |
| Oppo, R1-2006062 | ***Observation 1: Propagation delay accuracy requirement cannot be met through current TA indication scheme for SCS=15kHz.***  ***Observation 2: The granularity of RTT could meet accuracy requirement of propagation delay.***  ***Proposal 1: Granularity for TA indication should be improved to satisfy accuracy requirement of propagation delay.***  ***Proposal 2: RTT measurement and positioning could be decoupled and RTT measurement can be configured to compensate propagation delay only.*** |
| Samsung, R1-2006143 | *Samsung R1-2006143*  **Observation #1: For large service area, propagation compensation is needed.**  Based on the study in Rel-16, the estimation errors are related to subcarrier spacing and mainly consist of the following parts:   * **gNB transmit error** **(*Tgte*)**: Based on the definition in TS 38.104, the typical value of BS timing error caused by *Tgte* can be seen as within ± 65ns. * **UE transmit timing error** **(*Te*)**: As defined in TS 38.133 Table 7.1.1-2, this error *Te* is about as ±12\*64\*Tc , ±8\*64\*Tc and ± 7\*64\*Tc for 15KHz, 30KHz and 60KHz respectively. This includes the error on DL timing estimation. * **gNB estimation error (*Tge*)**: This error is introduced when gNB estimates UL channel/signals to obtain propagation delay. PRACH may not able to provide enough accuracy of time estimation. SRS/UL DMRS or PUSCH can be used. The estimation accuracy depends on occupied BW. The error about ~100ns can be assumed with 20MHz bandwidth. * **TA (Propagation delay) granularity (*Tpd*)**: If using current TA granularity, i.e., , and the error is . * **Timing Advance adjustment accuracy (*Tadj*)**: Based on the requirement in TS 38.133, the accuracy of TA adjustment are ±256 Tc/ ±256 Tc/ ±128 Tc / ±32 Tc respectively for SCS 15/30/60/120 kHz.   Since TA is two times of propagation delay, therefore, the error for propagation delay estimation is half of the sum of the above ***Te*** , ***Tge*** , ***Tpd*** and ***Tpd*** . And when UE compensate the propagation delay, the total time synchronization need to add gNB transmit error **(*Tgte*).** Table 1 provide a summary of the above errors. In order to reduce the total error, one easy way is to introduce finer granularity to reduce the error caused by quantization, especial for smaller subcarrier space case, e.g., 15kHz and 30kHz. Other errors are either limited by hardware, or depend on UE or gNB detection performance.  Table 1   |  |  |  |  |  | | --- | --- | --- | --- | --- | |  | 15kHz | 30kHz | 60kHz | 120kHz | | **gNB transmit error** **(*Tgte*)** | 65ns | 65ns | 65ns | 65ns | | **UE transmit timing error** **(*Te*)** | 391ns | 260ns | 228ns | 114ns | | **gNB estimation error (*Tge*)** | 100ns | 100ns | 100ns | 100ns | | **Propagation delay granularity (*Tpd*)** | 260ns | 130ns | 65ns | 32.5ns | | **Timing Advance adjustment accuracy (*Tadj*)** | 130ns | 130ns | 65ns | 16.25ns | | **Total (*Tgte*+1/2\*( *Te*** + ***Tge*** +***Tpd*** +***Tpd*)** | 505.5 ns | 375ns | 294ns | 196.4ns |   **Observation #1: For large service area, propagation compensation is needed.**  **Observation #2: Some other UL channel/signals, e.g., SRS, DMRS, PUSCH occupied larger bandwidth can be used for gNB to estimate propagation delay to increase the accuracy.**  **Observation #3: Finer granularity for propagation delay compensation can help to improve the performance and it is the easiest way to reduce estimation error.**  Based on the observations, the following proposals are made:  **Proposal #1: Introduce a finer granularity for propagation delay compensation.** |
| Nokia, R1-2006341 | Table 1. Summary of 5GS E2E breakdown based on achievable RAN, NW and UE accuracy performance.   |  |  |  |  |  | | --- | --- | --- | --- | --- | | Case | E2E requirement | RAN error (see Appendix 4.2) | NW error (see Appendix 4.1) | Remaining budget (e.g. for the UE) | | Indoor factory, NW-TT to DS-TT, any vertical TD | <900 ns | <465 ns \* | <80 ns | 415 ns | | Indoor factory, DS-TT to DS-TT, any vertical TD | <900 ns | <520 ns \* | <80ns | 380 ns | | Smart grid, 5G TD, | <1000 ns | <580 ns \*\* | <100 ns | 420 ns |   \* No propagation delay compensation is used.  \*\* Using Release-16 Timing Advance procedure as basis for Propagation delay compensation.  From this evaluation of the RAN part time synchronization accuracy in a typical deployment, we first note that the two cases studied in the indoor factory, leaves at least 900ns-520ns=480ns for the NW and UE part. Assuming the NW parts needs **±**100ns, the UEs will have up to 380ns of the E2E time synchronization accuracy budget. We conclude that the configuration used in the RAN part, is sufficiently good to allow the full 5GS E2E to meet the performance requirements set in SA1.  In the smart grid case, it is clear that PD compensation is needed and we find that using TA for PD estimation leaves 1000ns-580ns=420ns of the 5GS E2E time synchronization accuracy budget to the NW and UE parts. Subtracting the NW part of **±**100ns, this leaves 320ns to the UE, which should be plenty. We observe based on our analysis that propagation delay compensation is a strictly necessary feature for the smart grid scenario, and that propagation delay compensation based on Rel-16 timing advance, with a reasonable gNB implementation of the timing advance operation, is sufficient from a 5GS E2E perspective. A reasonable gNB implementation would for example include that the gNB filters out instantaneous errors (e.g. CIR detection changes due to fading) which are not reflecting a change of the propagation delay. It would also include that the gNB objective of timing advance is to minimize the measured UL and DL timing offset (accounting for specified offsets such as TDD offsets obviously) and at the same time keeps the UE up-to-date with the latest PD estimation, when a change of the PD has been determined. We note that this also assumes that the UE is conducting the PD compensation, which is desirable in order to support propagation delay compensation along with broadcasted SIB9. Achievable 5GS RAN time synchronization accuracy Table A1 summarizes the time synchronization errors contributing to the one-shot time synchronization accuracy of the RAN for the two considered scenarios and with and without propagation delay compensation.  Table A1. Achieve one-shot synchronization accuracy performance.   |  |  |  |  | | --- | --- | --- | --- | |  |  | Indoor factory (30kHz SCS) | Smart-grid (15kHz SCS) | | 1 | TEUE-DL-RX | ±130ns | ±260ns | | 2 | TEgNB-UL-RX | ±92ns | ±100ns | | 3 | dPD-DL | <200ns | <4000ns | | 4 | TETA-err | ±130ns | ±130ns | | 5 | TETA-C | ±130ns | ±260ns |   **Observation 1: Propagation delay compensation is needed for Rel-17 to support the smart grid scenario.**  **Observation 2: Propagation delay compensation by the Rel-16 timing advance procedure is sufficient to fulfil the Rel-17 requirements, assuming a reasonable gNB implementation of the timing advance procedure.**  By reusing the Rel-16 timing advance procedure, specification of a propagation delay compensation feature in Rel-17 will not require be any RAN1 involvement.  **Observation 3: No RAN1 involvement for enabling sufficient propagation delay compensation in Release-17 has been identified.** |
| R1-2006803, Qualcomm | Requirement of timing error of UE transmitting is specified in TS 38.133 [4] as explained in the above section. Requirement of timing error of gNB detection is purely implementation and is not specified. Generally, accuracy of gNB detection should be higher than UE detection. For simplicity, it is assumed that inaccuracy caused by gNB detection is the same as or smaller than that of UE detection which is given in the above section. The granularity of TA value is . The inaccuracy caused by TA indication for different SCS is summarized in Table 3-1.  **Table 1 Timing error caused by TA indication**   |  |  |  |  |  | | --- | --- | --- | --- | --- | |  | **Different SCS (kHz)**  **(unit: ns)** | | | | | 15kHZ | 30kHz | 60kHz | 120kHz | | Granularity of TA indication | 520 | 260 | 130 | 65 | | Timing error caused by TA indication | 260 | 130 | 65 | 32 |   **Proposal 1: Propagation delay compensation in Rel-17 should be based on the Rel-16 timing advance procedure, which requires no RAN1 involvement.**  ***Observation 2: Considering in accuracy of UE transmitting, gNB detection and TA indication, TA is not a good way for propagation delay compensation.***  ***Proposal 1: TA-based compensation is not considered for enhancements* for propagation delay compensation.**  **Proposal 2: The scheme based on propagation delay measure in Rel-16 is good candidate for propagation delay compensation.** |
| [R1-2006930](file:///C:\Users\wanshic\OneDrive%20-%20Qualcomm\Documents\Standards\3GPP%20Standards\Meeting%20Documents\TSGR1_102\Docs\R1-2006930.zip), Huawei/HiSi | Huawei R1-2006930  According to the evaluation in TR 38.825, the error is mainly composed by the TAE (Time Alignment Error) defined in TS 38.104 section 6.5.3, the Te (Timing Error Limit) defined in TS 38.133 section 7.1.2, the TA adjustment accuracy defined in TS 38.133 section 7.3.2.2, the TA adjustment granularity of defined in TS 38.213 section 4.2, the asymmetry between downlink and uplink propagation delay and the gNB UL receive timing error. The corresponding spec for some components is shown below.  The TAE is the timing difference of NR signals present at the BS transmitter in e.g. MIMO transmission. It is preferred to keep the TAE the same as the legacy value to avoid the potential impact to the BS transmitter implementation. And for the Te and the TA adjustment accuracy, it is related to the UE uplink timing adjustment, so also here it is preferred to keep it the same as legacy uplink timing adjustment procedures.  **Proposal 1: For any potential propagation delay compensation enhancements considered in Rel-17, keep the TAE, Te and TA adjustment accuracy the same as legacy numbers.** |