3GPP TSG-RAN WG2 Meeting #112e R2-20xxxxx

Online, 2-13 November 2020

**Agenda item: X.X.X**

**Source: Nokia, Nokia Shanghai Bell**

**Title: [DRAFT] E-mail discussion: [Post111-e][924][R17 URLLC/IIoT] Propagation delay for TSN (Nokia)**

**WID/SID: NR\_IIOT\_URLLC\_enh**

**Document for: Discussion and Decision**

# 1 Introduction

This document aims to collect views from companies for the following email discussion agreed during RAN2 #111e:

* [Post111-e][924][R17 URLLC/IIoT] Propagation delay for TSN (Nokia)

1st phase: Agree on baseline scenarios and then for each scenario the high-level breakdown on the delay components and agree on assumptions. Identify the aspects that RAN1 should investigate

2nd phase: Identify the set of possible options to continue investigating and how they address each component

Intended outcome: report to next meeting

Deadline: Long

For the first phase, we aim to agree on baseline scenarios that will be examined in this WI. Furthermore, for each scenario, we should reach a consensus on the assumption of the Uu interface time synchronization error budget from a high-level E2E time synchronization error budget breakdown. This can form the basis for identifying any aspect that would require further investigation by RAN1. These would serve as a foundation for work relating to potential propagation delay compensation enhancement. Remarkably, the scope of the first phase coincides with a latest LS from RAN1 (R1-2007446), which indicates that RAN1 already identified two use cases from TS 22.104:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **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 |

Besides, the LS R1-2007446 also request RAN2 to provide feedback on Uu interface error budget for each of the two use cases, this fits the objectives of this email discussion. Hence, the first phase of this email discussion will use RAN1 agreements as the basis.

For the second phase, we should identify the options of propagation delay compensation that we will further investigate.

# 2 Phase-1 Discussion: Use Cases, Scenarios, and Assumptions on Synchronization Error Budget

## 2.1 Use Cases and Scenarios

The scenarios for accurate time synchronizations are provided in TS 22.104 Table 5.6.2-1, and are copied below. As aforementioned, RAN1 has already agreed two of the use cases for further study, which are highlighted in the table below:

**Table 1 - C****lock 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. | | | | |

**Question 1: In addition to use cases identified by RAN1 (Highlighted in Table 1), do you think RAN2 should further study any other use cases listed in TS 22.104? If so, please provide the additional use cases you consider should be studied and arguments why.**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Nokia | No  We think the use cases identified by RAN1 are sufficient for Rel-17. |
| Ericsson | No |
| Qualcomm | No. These use cases are sufficient for assessment. |
| CATT | No |
| Samsung | No |
| Fujitsu | No |
| OPPO | No |
| Huawei | No  RAN1 has already made analysis about the use cases, and finally chosen the two use cases for further study. Other use cases listed in the above table are somewhat less stringent than the two identified use cases. |
| ZTE | No |
| LG | No |
| Intel | No. Use-cases identified by RAN1 are sufficient. |
| vivo | No |
| CMCC | No |
| Apple | No |
| MediaTek | No |
| Sequans | Use case 1 could be considered as well, as a small service area may ease synchronization requirements. |
| NTTDOCOMO | No |
| Xiaomi | No |

***Summary of Question 1:***

*All companies agree that RAN2 should only consider the use cases identified by RAN1. One company has proposed to consider use case 1 additionally.*

Aligned with the agreed assumptions on one Uu (smart grid) and two Uu interfaces (control-to-control) as listed in LS R1-2007446, we can consider two placements of the 5G GM for the control-to-control use case. These are illustrated in Figure 1. In one case, the TSC GM is connected to a device behind the 5GS CN and the E2E accuracy budget would apply from the time-stamping entity at the NW-TT to the time-stamping entity at the DS-TT. The other placement is that the TSC GM is connected to a device behind the UE, where the 5GS E2E budget applies from DS-TT timestamping entity at the source UE to the DS-TT timestamping entity at the target UE. The smart grid use-cases is different as the TSC GM is the 5G GM (or similar TD), so in this case the 5GS E2E accuracy is from the 5G GM to the DS-TT at a UE, as illustrated in Figure 2. These 5G GM placements for different use cases could be considered as the baseline scenarios.

**A close up of a map

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Figure 1. Illustration of the control-to-control use case with two possible scenarios (Scenario 1 and 2) to consider.

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Figure 2. Illustration of the smart grid use case and a corresponding scenario (Scenario 3).

**Question 2: Based on the two use cases identified by RAN1, which of the following scenarios should be considered as the baseline?**

* **Scenario 1: In the control-to-control communication use case, where TSC devices behind a target UE are synchronized to any TD, from a GM behind the CN. The 5GS introduced error is caused by the relative time-stamping inaccuracy at the NW-TT and the DS-TTs.**
* **Scenario 2: In the control-to-control communication use case, where TSC devices behind a target UE are synchronized to any TD, from a GM behind the UE. The 5GS introduced error is caused by the relative time-stamping inaccuracies at the involved DS-TTs.**
* **Scenario 3: In the smart grid use case, where the TSC devices behind a target UE are synchronized to the 5G GM TD. The 5GS introduced error is caused by the synchronization of the 5G clock to the DS-TT.**
* **Scenario 4: Other**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Company** | **Scenario** | | | | **Comments** |
| **1** | **2** | **3** | **4** |
| Nokia | V | V | V |  | We think Scenario 1, 2 and 3 should be considered as baseline. |
| Ericsson |  | Y | Y |  | Scenario 1 and scenario 2 belong to the same use case, but scenario 1 has a looser Uu requirement than scenario 2. Thus, it is not necessary to separately consider scenario 1. Note that RAN1 has agreed (see LS R1-2007446):   * Two Uu interfaces are assumed for control-to-control. |
| Qualcomm | Y | Y | Y |  | Agree with Nokia |
| CATT |  | Y | Y |  | Similar view as Ericsson: solutions we will specify to cope with scenario 2 will enable scenario 1 as well.  For scenario 2 it could be clarified that this is “**from a GM behind ~~the~~ another UE**”. |
| Samsung | V | V | V |  | We think all those scenarios should considered. |
| Fujitsu | Y | Y | Y |  | All scenarios seem to be valid per the RAN1 agreement. |
| OPPO |  | Y | Y |  | Agree with Ericsson. Scenario 1 seems no difference to what we have done in R16. |
| Huawei | Y but | Y | Y |  | We are fine to take Scenario 1, 2 and 3 as the baseline. Since Scenario 1 is less stringent than Scenario 2 w.r.t sync error requirements, and RAN1 agreed that two Uu interfaces are assumed for control-to-control, we shall focus on Scenario 2 and 3. |
| ZTE | Y | Y | Y |  | We agree with Ericsson that scenario 1 has a looser Uu requirement than scenario 2. But as scenario 1 may be also regular in the control-to-control use case, we still think the analysis of Scenario 1 is required, at least from a completeness point of view.  We agree that two Uu interfaces can be assumed, but we think one Uu interface is also possible for control-to-control case.  Both scenario 1 and scenario 3 can be assumed with one Uu interface, but a difference between them is that scenario 1 is a global time domain scenario so it requires in general a precision of 1 µs between the sync master and any device of the clock domain while scenario 3 can be seen as a “partial” scenario, e.g., 5G system within the global time domain, in which the synchronicity budget shall not exceed 900 ns.  Here we also assume the budget difference of 100ns (1us <-> 900ns) between the scenario of global time domain (scenario 1 and 2) and the scenario of 5G system (scenario 3) accounts for the time synchronization errors in those peripheral components, e.g., error between the robotic arms and UEs or error between UPF and the TSC GM. |
| LG |  | Y | Y |  | Scenario 1 looks covered by Rel-16. Scenario 2 has two Uu interfaces and is more difficult to satisfy the requirement than scenario 1. |
| Intel | Y | Y | Y |  | Scenarios 1,2,3 can serve as baseline scenarios. We are also okay with considering only 2 and 3 as Ericsson notes from RAN1 agreement. |
| vivo |  | Y | Y |  | Based on the agreement from RAN1 that *“For two Uu interfaces are assumed for control-to-control”*, no need to take scenario 1 into account. |
| CMCC | Y | Y | Y |  | We think all those scenarios should considered. |
| Apple | Y | Y | Y |  | All scenarios are valid. It is okay if scenario 1 is considered with lower significance than scenario 2 and 3. |
| MediaTek |  | Y | Y |  | Agree with others that Scenario 2 is more stringent than Scenario 1, and therefore our focus could be on Scenario 2. |
| Sequans |  | Y | Y | Y (?) | We agree with Ericsson regarding scenario 1.  Regarding smart grid use case, we are not sure why we have the restriction “the TSC GM is the 5G GM”. We assume we could have a TSC GM external to 5GS, and TSC devices behind a target UE are synchronized to that TSC GM (that would be scenario 4). |
| NTTDOCOMO | Y | Y | Y |  | All scenarios should be considered. |
| Xiaomi | Y | Y | Y |  | We should consider all potential deployment scenarios. |

**Summary of Question 2:**

*All companies think both Scenario 2 and 3 should be considered, and 10 out of the 17 companies think Scenario 1 should be considered as well. In particular, opponents of Scenario 1 essentially think Scenario 1 definitely has looser requirement than Scenario 2, so RAN2 does not have to consider it separately. However, companies also generally think Scenario 1 represents a typical setting for control-to-control use cases, so it should be included for the sake of completeness. Furthermore, one company has considered another scenario. From the rapporteur point of view, RAN2 will consider Scenario 2 and 3 in the evaluation of enhancements for propagation delay compensation, without precluding Scenario 1 for now.*

## 2.2 High-level 5GS E2E Synchronization Budget Breakdown

In the LS R1-2007446. RAN1 has requested RAN2 to provide some information on the error budget in the Uu interface. The budget for the Uu interface depends on how much error could be consumed in other segments of the E2E path, as also mentioned in e.g. [7], [8], [16], [5], [16] and [3]. In particular, on top of the network-side error, it has also been mentioned that the UE-side would introduce an error and hence needs to be taken into account as a part of the E2E path error budget. Taking [3] as a starting point, the E2E path could be broken into three components, as illustrated in Figure 1, which could include:

* **RAN / Uu interface** – Account for the time synchronization errors introduced by the Uu interface i.e. between the UE and the gNB. This includes the aspects of antenna alignment errors, ReferenceTimeInfo delivery, SFN estimation including the impact on propagation delay (PD) compensation. Here we also include errors introduced by the gNB architecture splits (e.g. use of gNB-CU and gNB-DU).
* **Network** – Accounts for the time synchronization errors caused between the GM and the gNB. When the 5G GM source is shared between the UPF and the gNB, the synchronization error involved in this, should also be accounted for here. In case of split architecture, the gNB is a gNB-CU.
* **Device** – Accounts for the time synchronization errors introduced by the device implementation for maintaining the 5G clock at the DS-TT and potentially also the device output interface to the TSC devices connected to the device.

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Figure 3. Possible breakdown of the 5GS E2E path

**Question 3: Do you agree that the 5GS E2E synchronization budget could be split into three parts namely Device, Uu interface and Network? If the answer is No, please provide proposals for alternative approach.**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Nokia | Yes  We think this is a sensible way to evaluate the budget in different segments of the E2E path, and hence determine the propagation delay compensation scheme to be introduced. |
| Ericsson | Partially  On a high-level, Ericsson is fine to have such a split, but some further clarifications are needed:   * Network component includes the delivery of the 5G reference time **from the 5G GM to** **one gNB radio transmission unit**. RAN2 should simplify the analysis with the assumption that one gNB radio transmission unit covers one cell, the same as in RAN1. In our view, RAN2 should not mandate one particular network architecture as it is the choice of the network vendor and the deployment. In other words, RAN2 has to consider a network architecture without CU/DU split.   + If CU/DU split deployment is preferred by some companies, its budget should be considered here rather than in RAN/Uu interface. As a matter of fact, there will be inaccuracies for reference time delivery between CU and DU and one may approximate the accuracy deterioration as similar to one gPTP hop. * RAN/Uu interface component includes the delivery of the 5G reference time on the Uu interface **from one gNB radio transmission unit to one UE.** The transmission timing error at gNB in included, as it has been considered in the RAN1 analysis.   Since in the worst case more than one gNB might be involved in time sync, it is reasonable to assume that 5G GM may be placed at the UPF.  Additionally, RAN2 needs to further make clear that   * If synchronization GM is at the network side (e.g., smart grid, scenario 3), the E2E path includes one device component, one RAN/Uu interface component and one network component. * If synchronization GM is at the device side (e.g., control-to-control with TSN uplink time synchronization, scenario 2), the E2E path includes **two** device components, **two** RAN/Uu interface components and **two** network components. The 5GM GM is assumed to be placed at the UPF.   One goal of this email discussion should be to provide feedback on the synchronicity budget for Uu interface, as requested in the RAN1 LS. As a summary of the below answers from Ericsson (100 ns for device component, 160 ns for the network component, 5 ns for the granularity of the reference time), the Uu interface synchronicity budget is:   * If synchronization GM is at the network side (e.g., smart grid, scenario 3), then it is 1000 ns – 100 ns – 160 ns – 5 ns = 735 ns * If synchronization GM is at the device side (e.g., control-to-control with TSN uplink time synchronization, scenario 2), then it is (900 ns – 100 ns \* 2– 160 ns \* 2 – 5 ns \* 2) / 2 = 185 ns   Note that implementation-related inaccuracies (see answers to question 13) are not considered yet, such as the channel variations between when the reference time delivery is provided and when the propagation delay is compensated, etc. |
| Qualcomm | Yes. |
| CATT | Yes we agree with these three components, but some clarifications are needed on what they include.  Indeed, for the control-to-control use-case, it is discussed further in following questions the associated deployments to consider. Deployments assumed in RAN1 so far (TS38.324, TS38.901) indeed involve multiple gNBs to cover an indoor factory scenario with 20m and 50m ISDs for small and big hall respectively. It is questionable though whether these are different gNBs or different TRPs or DUs associated with one gNB.  1) Multi-gNB: we don’t think the multi-gNB deployment would be the most cost effective or efficient approach for such small area and would rather favor a single gNB with multiple TRPs (RRHs) or DUs, as below.  2) Multi-DUs deployment: we agree with Ericsson here that the DU should be modeled as an additional gPTP hop resulting, per RAN3 LS in R3-187252, in an additional absolute timing error TE<|40ns|, and this component should be part of the Network timing error budget.  3) Multi-TRPs (RRH) deployment: the transport of the I/Q antenna samples from the gNB BBU to the radio units is typically eCPRI based, which takes its timing accuracy requirements [*CPRI: Requirements for the eCPRI Transport Network, Table 2*] from the 3GPP TAE (relative timing error between TRPs) requirements discussed in Q12. But we think the TAE is in the RAN1 domain and RAN1 is indeed currently assessing how it contributes to the total Uu synchronization error (R1-2007068), in order to check if it fits in the Uu budget RAN2 will provide as an outcome of this discussion. So we don’t think RAN2 should take into account the radio units (and distributed deployments thereof) in the timing error budget which should stop at the gNB (or DU) BBU output. This can be made clear when we reply to the RAN1 LS. |
| Samsung | Yes |
| Fujitsu | Yes  Fujitsu are fine with the proposed components from the high-level perspective. For the CU/DU split, there are many CU/DU split architectures which can be deployed in IIoT networks e.g. the split point. The details of the CU/DU split architectures should be left to implementations and not the scope of discussions. Then, the synchronicity budget of RAN/Uu should be abstractly (i.e. network topology agnostic) defined as timing error (TE) budget between “egress point of gNB” and “ingress point of UE” i.e.  Uu budget = |TE| between “egress point of gNB” and “ingress point of UE”.  As for the Network component, the definition should be defined in RAN3 but it can be similarly defined as follow:  NW budget = |TE| between “egress point of NW-TT” and “ingress point of gNB”. |
| OPPO | Yes |
| Huawei | Yes.  For CU-DU split architecture, Rel-16 has already considered such deployment for DL synchronization scenario. For 5G timing through dedicated RRC signaling, RAN3 specified that DU can deliver *referenceTimeInfo* to CU periodically or upon CU’s request. For Rel-17, CU-DU split architecture shall also be taken into account. The sync error caused by CU-DU split can be included in the error budget for network components. |
| ZTE | Partially Yes.  We also fine to have kind of split, but some clarifications from our side are as following:   * We are generally fine with following Ericsson’s clarification on Network component and RAN/Uu interface component (we think the “egress/ingress” wording in CATT comments may be not so common in 5GS):   + It is reasonable to assume that 5G GM may be placed at the UPF.   + Network component includes the delivery of the 5G reference time from the 5G GM (UPF/NW-TT) to one gNB radio transmission unit.   + RAN/Uu interface component includes the delivery of the 5G reference time on the Uu interface from one gNB radio transmission unit to one UE. * For the deployment, as we don’t think it’s always small area scenario in IIoT, we agree multi gNBs deployment needs to be considered. We are also fine to consider both deployment with CU/DU split and without CU/DU split and assume the analysis for multi DUs deployment would be similar as multi gNBs deployment. We are not crystal clear about why and how multi-TRPs deployment would have impacts on evaluation on synchronicity budget on Uu interface, we don’t think it needs to be considered, at least not in RAN2. * We are also not crystal clear about here the concept of “device” and motivation about listing this as a separate component in 5GS E2E. With the below comments and referring to the Figure 3, we suggest to separate 5GS E2E into only two parts, e.g., RAN/Uu interface component and Network component (as shown in the following figure):      * + As mentioned in the comments for Q1, we have a high-level understanding that there would be 100ns synchronization errors in those peripheral components in that scenario of global time domain. We understand maybe this part can be seen as a “device” part. This would have no impacts on the evaluation for synchronicity budget on Uu interface in 5GS E2E.   + For the pure 5GS E2E, we don’t think there would be synchronicity error between DS-TT and UE. AS mentioned in TS 24.535, “*Upon reception of a gPTP message over the user plane, the UE shall forward the gPTP message to the DS-TT. The DS-TT shall create an egress timestamping (TSe) for every gPTP event (Sync) message. The DS-TT shall use TSi from the Suffix field of the gPTP message (Sync message for one-step operation or Follow\_up message for two-step operation) to calculate the residence time spent within the 5G system for the gPTP event (Sync) message expressed in 5GS time as specified in 3GPP TS 23.501 [2] for the corresponding TSN working domain*”, if there is time synchronization error at the DS-TT, it may be infeasible for the DS-TT to calculate the residence time spent within the 5G system. So we think the DT-TT would be completely synchronized with the UE. Similarly, we assume NW-TT would be completely synchronized with the UPF. |
| LG | Yes. But device part is relatively a minor portion. |
| Intel | Yes, we are fine with this split at higher level. Eventually we can also analyse specific error components as Ericsson has presented above. How DU is synchronized to 5GS GM is not specified in 3GPP, so we may not simply assume DU is synchronized via CU, therefore one more hop is needed. However, we agree with other companies that this should be a part of the network interface error, and therefore the ±100ns bound on synchronization error for network side should hold irrespective of the assumptions on CU/DU split etc. |
| vivo | Yes.  We also agree to consider the network architecture with/without CU/DU split. For network architecture with CU/DU split, the DU should be modeled as an additional gPTP hop and the synchronization error between CU and DU should be considered in NETWORK part. Besides, we think that no matter which network architecture is deployed, the error budget for NETWORK part can be modeled as |TE|<N\*40ns, where the maximum value of N is 4. |
| CMCC | Yes  For the deployment, we agree that multi gNBs deployment and CU/DU split are possible in IIOT scenarios. For multi-gNBs deployment, we can take the SA2’s conclusion in TR 23.700 into account “In the case of synchronizing TSN end stations behind other UE(s), UPF then forwards the gPTP messages to the UEs via all PDU sessions terminating in this UPF except for the PDU session of the source ("avoids play back to the source DS-TT port"). The other UE(s) perform the operation as specified in clause 5.27.1.2.2 of TS 23.501 [2].”Based on this, in our understanding, even in multiple gNBs case, the number of hops is same with that in two devices in single gNB, since anyway the E2E synchronization need completed via two PDU session conveyed the Gptp timing stamp. But for network architecture with CU/DU split, the DU should be modeled as an additional gPTP hop and we prefer to take the synchronization error between CU and DU into the network part.  On the other hand, we think the evaluation on synchronicity budget of multi-TRPs deployment can be studied in RAN1. |
| Apple | Yes. The device part ends at the egress point where DS-TT timestamping happens based on the 5GS clock. We also think assumptions on network synchronization error should not link with a single NW architecture (with or without CU/DU split) only. |
| MediaTek | Partially yes. We agree with Fujitsu that the synchronicity budget should be network-topology agnostic. Therefore only delays between the egress point of the gNB and the ingress point of the UE should be part of the Uu budget. Similarly the network budget should be between the egress point of the NW-TT and the ingress point of the gNB. |
| Sequans | Yes. |
| NTTDOCOMO | Yes |
| Xiaomi | Yes |

**Summary of Question 3**:

*The companies are generally agreeing to consider the 5GS in three parts; Device, Uu interface and Network. As per the attention of this email discussion is to derive a Uu interface accuracy budget the focus is on the network and the device budgets. It seems agreeable to capture the error introduced by a CU/DU split in the network part. Two companies have argued for a network agnostic approach; however, from the rapporteur point of view, it is not clear how to determine a network part budget in this case. Details on the assumptions on each parts are covered in the respective sections of the email discussion. Other details which remains to be discussed on each of these components is asked in the follow-up questions in Phase-2.*

All subsequent questions of Phase-1 are based on the above assumption where the 5GS E2E synchronization budget is split into Device, Uu interface and Network parts.

## 2.3 Assumption on Error Budget for Network Part

Several papers have proposed to capture a budget for a network related part of the 5GS E2E budget. For example, [8] and [16] have proposed that at least 100ns inaccuracy should be assumed for the network part, whereas some other papers (e.g. [7] and [5]) have mentioned the importance of network part budget. In [3], for example, two separate network part inaccuracies are proposed, one for each use case. There could be at least two options for the network part budget, as described below.

In the first option, particularly for the control-to-control use case, a single 5G GM clock source (e.g. from a GNSS receiver or a TSC GM) is distributed to the gNB and UPF (NW-TT) with a (g)PTP framework. It is assumed 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 a maximum error of TE<|4 ∙40ns|, corresponding to an error within ±80ns.

In the second option, specifically for the smart grid use case, multiple 5G GM clock instances (of the same time-domain, e.g. from multiple GNSS receivers) are distributed in the service area (e.g. one at each gNB and one at the UPF). With the multiple 5G GM clock sources (of the same reference), 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, according to R3-187252 the maximum error between the GNSS receivers is 200ns, which translates to a time synchronization error range of maximum ±100ns.

**Question 4: Do you agree to use the above two options as the network part budget, i.e. ±100ns for the smart grid and ±80ns for the control-to-control use case related scenarios respectively? If not, please provide your views on the network part budget for the considered use cases and scenarios. Please also indicate if any additional error components to be considered.**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Nokia | Yes  We are fine with having two network budgets for the two use cases. For simplicity we can also assume ±100ns for both use cases. Per scenario this means that:  Scenario 1 is the control-to-control use case, where the time synchronization error is between DS-TT and the NW-TT. Here the network budget of e.g. ±80ns applied.  Scenario 2 is the control-to-control use case, where the time synchronization error is between a DS-TT and another DS-TT. We assume only a single gNB is involved, which means that the network budget could be kept at ±80ns.  Scenario 3 is the smart grid use case where the time synchronization error is between a gNB and the DS-TT. Here the network budget of ±100ns applied. |
| Ericsson | No  It is okay to use RAN3 LS R3-187252 as reference and to have separate network budgets for the two use cases. On the other hand, Ericsson has different understandings on the exact budget for the control-to-control use case.  Smart grid:   * It is written in R3-187252 that “|TE| = 100 ns absolute, 200ns relative between nodes.”. This means a budget of ±100ns.   Control-to-Control:   * It is written in R3-187252 that “|TE| ~N\*40ns, where N is number of PTP hops.” Note that the absolute symbol is around TE and one PTP hop introduces ±40ns inaccuracy. Ericsson is okay to assume that a maximum four (g)PTP capable hops or equivalent is needed to deliver the 5G GM to the gNB. For the delivery from the 5G GM to **one** gNB, the maximum inaccuracy is then |TE| ~N\*40ns where N = 4 and so the budget is ±160ns. However, the service area is indoor with size of 1000 meters by 100 meters. Multiple gNBs are needed to cover this service area and so the inaccuracy between two gNBs should be considered, and so the total budget on the network component is ±320ns.   In summary, the synchronization budget of the network interface component is ±320ns for control-to-control use case and ±160ns for smart grid use case. |
| Qualcomm | Yes. Agree with Nokia on assuming ±100ns across different cases. |
| CATT | Partly. We agree with Nokia for the smart grid use case, but for the control-to-control use-case we have the same interpretation of R3-187252 as Ericsson that the budget for 4 hops is +/- 160ns. And as elaborated in Q3, we think it is not reasonable to model the deployments assumed so far in TS38.324 and TS38.901 as multi-gNB deployment but rather as a single gNB (CU) with multiple DUs, where each DU is an additional g-PTP capable network hop. Thus we think the worst-case synchronicity budget of the indoor factory scenario is |TE| ~N\*40ns where N = **5** and so the budget is ±200ns. |
| Samsung | Yes for smart grid.  For control-to-control, small cell size should be considered, so we think multiple gNBs should be considered. |
| Fujitsu | No for control-to-control (Scenarios 1 and 2); Yes for smart grid (Scenario 3)  As Ericsson stated, it says in RAN3 LS that |TE| ~N\*40ns. This means that |TE| ~160ns in case of N=4 i.e. ±160ns inaccuracy. Then, the summary is provided below.  Scenario 1: the network budget of ±160ns is applied.  Scenario 2: the network budget of ±160ns is applied.  Scenario 3: the network budget of ±100ns is applied. |
| OPPO | OK for smart grid scenario.  For control-to-control scenario, we think there are two possible deployment possibilities.   * Multi-gNB:   Suppose the two DS-TTs are in the coverage of different gNB, then according to the RAN3 LS R3-187252 as the reference, totally, there could be up to 8\*40ns = 320ns timing synchronization error.   * CU-DU architecture:   Suppose the two DS-TTs are in the coverage of different DUs under one particular gNB-CU, the timing synchronization error over F1 could not be ignored, which accounts for 2\*40ns\* No. of PTP hops over F1 for a pair of DU and CU. We think the number of PTP hops over F1 for a pair of DU and CU should be further analyzed by RAN3 |
| Huawei | No  For Scenario 1, based on RAN3’s LS R3-187252, if a maximum error of |TE|<N∙40ns, the corresponding maximum error shall be counted as ±N∙40ns. It is fine to assume that maximum N is four. The error budget for network part is then ±160ns.  For Scenario 2, the specific network part budget needs to be carefully analysed for different deployment cases. If a single gNB is involved, the network budget can be ignored. While if multiple gNBs are involved and gNB is synchronized to 5GM (behind an UE) through maximum four PTP capable hops, the error budget for network part is ±320ns.  For Scenario 3, there exists a sync error ±100ns between gNB and GNSS. We are not sure whether or not this sync error should be included within 5GS synchronicity budget (900ns). If this sync error is not included within 5GS synchronicity budget but only counted against the total TSN synchronicity budget 1us, it should be ignored here. However if a local on-site GNSS receiver is regarded as part of 5GS, the error budget for network part is then ±100ns. |
| ZTE | As mentioned in the comments for Q3, we agree Ericsson that network component includes the delivery of the 5G reference time from the 5G GM to one gNB radio transmission unit, so we understand network part budget accounts for one-way synchronization budget between **5G GM (or NW-TT/UPF) to one gNB**.  Moreover, we see in some above companies’ comments, only synchronization based on gPTP message is assumed for control-to-control case and the maximum inaccuracy of |TE| ~N\*40ns is assumed. But different companies have different assumption on N, e.g., N=2, N=4 or N=5. We are not sure whether there is concrete reason to only assume synchronization based on gPTP message for control-to-control and which N is the most suitable value? So we tend to think all these use cases can have common assumption of having local on-site GNSS receiver.  We agree with some comments that one gNB covering the whole service area is a too strict restriction for NW deployment. So we also think the scenario that two UEs are connected to two different gNBs (or DUs) needs to be considered.  Then we have the following assumption for the network budget:   * If with synchronization based on GPS time source:   + For the scenario 1 and scenario 3, one network budget, e.g., network budget of ±200ns is applied (here we assume a budget of ±100ns between each node (UPF or gNB) and GPS time source, then the final network budget between UPF and gNB would be ±200ns).   + For the scenario 2, if two UEs are connected to single gNB (or DU), we assume the network budget would be 0 as the two of one-way network budgets can cancel each other.   + For the scenario 2, if two UEs are connected to different gNBs (or DUs), we assume the final network budget is still ±200ns (here we don’t assume **two** network budgets. As it’s still a budget of ±100ns between each node (the gNB connected to source device and the gNB connected to the target device) and GPS time source, so the total budget between these two gNBs is still ±200ns). * If with synchronization based on gPTP message:   + For the scenario 1 and scenario 3, one network budget, e.g., network budget of ±200ns is applied (here we assume a maximum N = 5 with CU/DU split).   + For the scenario 2, if two UEs are connected to single gNB (or DU), we also assume the network budget would be 0 as the two of one-way network budgets can cancel each other.   + For the scenario 2, if two UEs are connected to different gNBs (or DUs), **two** network budgets should be assumed, then the final network budget of ±400nss applied. |
| LG | Yes. We assumed that case of local on-site GNSS receiver (GPS is TSN GM clock) is applied or number of PTP hops (N) is in controlled situation. It’s based on RAN3’s LS R3-187252. However if a number of companies share different views, we can reconsider it. |
| Intel | For simplicity, we prefer to assume ±100ns for network part budget. |
| vivo | We are fine with the smart grid scenario.  For scenario 2, we prefer to model the error budget for NW part as |TE|<2\*N\*40ns under the network architecture with/without CU/DC split. We agree with the majority view that the maximum value of N is four, which accounts for a total error budget of ±320ns for the network part. |
| CMCC | Yes  For scenario 2 for control-to-control application, the service area may be up to 1000m x 100m, which is possible to be covered by multiple gNBs. Hence, it is not reasonable to take such a strict restriction on network deployment. |
| Apple | To rely on the assessment done by RAN3 for the network error budget in R3-187252 appears reasonable to us. |
| MediaTek | No.  Control to control:  We don’t follow the reasoning provided by the rapporteur. The control to control use case applies to a local area (1000m x 100m) and the rapporteur states that the assumption is that ‘***the 5G GM clock source, UPF and gNB are located within the same facility and potentially within the same rack***’.  RAN3 indicated in R3-187252 that ***in case of local on-site GM, the TE is negligible***.  Therefore, why is the assumption for the error budget of the network part (i.e. 4 x 40ns) based on RAN3’s evaluation of a remote GM clock entity and not one that is on-site? The assumption should be that the synchronicity error budget for the network component is negligible for the control to control use case.  Smart grid:  Agree with the rapporteur that the error budget for the network part is ±100ns for this use case, based on RAN3’s earlier feedback. |
| Sequans | No strong view on NW side budget. |
| NTTDOCOMO | Agree with Ericsson’s view. |
| Xiaomi | Agree with Ericsson |

***Summary of Question 4****:*

*The opinions relating network budget from the companies can summarized per scenario;*

* *Scenario 1:* 
  + *±100ns (QC, Nokia, CMCC, Intel),*
  + *±160ns (N=4 PTP hops) (Ericsson, Fujitsu, OPPO, Huawei, NTTDOCOMO, Xiaomi),*
  + *±200ns (CATT (N=5 PTP hops), ZTE (if GNSS at UPF)))*
  + *Negligible (MediaTek (in case of local on-site GM), Sequans)*

*For scenario 1 the views seem to be quite diverse, with the majority ranging from ±100ns to ±200ns. It is also questioned by one company why an assumption of (g)PTP synchronization path is used to propagate the 5GM to UPF and gNB. One company thinks the network budget in this scenario is negligible. As a possible way forward on the network budget for scenario 1 is to use a network accuracy part budget range from ±160 to ±200ns which covers the views from the majority of companies.*

* *Scenario 2:* 
  + *2x100ns (Nokia, LG, CMCC, Intel)*
  + *2x160ns=320ns (Ericsson, Fujitsu, OPPO(multi-gNB), vivo, Huawei (assuming multi-gNB), NTTDOCOMO, Xiaomi),*
  + *Twice the network budget for Scenario1 (Samsung)*
  + *2x40x#PTPhopOnF1 (OPPO (assuming multi-DU))*
  + *Can be ignored if a single gNB is involved (Huawei, ZTE)*
  + *As scenario 1 (200ns) (ZTE (for GNSS only one interface))*

*For scenario 2 most companies have assumed that the network budget is twice the budget of Scenario 1, while some companies think it depends on if GNSS is assumed to be present at all gNBs. It is proposed that the number of hops are maintained equal, even if a CU/DU split is assumed, which the rapporteur considered as a reasonable way forward for both multi-gNB and multi-DU/TRP hops are then treated similarly from a budget point of view. The assumption on the GM location at the UPF (or co-located) seems reasonable. A possible way-forward on the network accuracy budget part for Scenario 2 is to assume 2x Scenario 1.*

* *Scenario 3:* 
  + *±100ns (Nokia, Fujitsu, Samsung, CATT, OPPO, Huawei (if GNSS is to be included in 5GS budget), vivo, CMCC, MediaTek, Intel),*
  + *±160ns (Ericsson, NTTDOCOMO, Xiaomi)*

*For scenario 3 (smart grid), all companies agree the network budget should be ±100ns, except for one company which proposes to assume a network part accuracy budget of ±160ns.*

As per Section 2.1, scenario 2 states time synchronization error between two DS-TT in control-to-control use case, where UEs can belong to same or different cell, and might have a different realization of the 5G clock, e.g. because the number of hops to synchronize the gNB with the 5G GM can be different.

**Question 5: Can it be assumed that the involved UEs in scenario 2, will be connected to different gNBs and if so, what can we expect of relative 5G GM synchronization error between two gNBs?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Nokia | No  We consider it likely that a single gNB with multiple gNB-DU is deployed if synchronization accuracy is the priority. As the termination point of the network budget would then be the gNB-CU, the network part is irrelevant for this scenario. However, the relative inaccuracy between the involved gNB-DU should be accounted for in the Uu interface assumptions (see Question 13). |
| Ericsson | Yes  As answered in Question 3, RAN2 should not mandate a network deployment with CU/DU split. The service area is 1000 meters by 100 meters and hence very unlikely covered by one gNB. Even with CU/DU split architecture, it is much easier to analyze this in the network interface component, as all these falls into the expertise of RAN3. This approach also clarifies that the RAN/Uu interface component is related with one gNB to one UE which falls exactly in the scope of RAN1.  The relative 5G GM synchronization error between two gNBs is the sum of the synchronization error between each gNB and the common reference point (i.e., 5G GM clock), and thus in this case doubled (i.e., ±320ns). |
| Qualcomm | We think that the ±100ns bound on synchronization error holds irrespective of the assumptions on same/different gNBs or gNB splits. This is true as long as assumptions in R3-187218 for network interface error to be negligible hold, which we can assume in the IIoT studied use cases. |
| CATT | Same answer as for Q4: multi-gNB deployment may be overkill and a single gNB with multiple TRPs or DUs can be more cost-effective and efficient resulting in a maximum timing inaccuracy of ±200ns (assuming DU hop is accounted for in network part). |
| Samsung | Yes. We agree with Ericsson’s observation that one DU covering the whole service area is a too strict restriction to NW deployment. When two UEs are connected to two different gNBs, the synchronization error could be doubled. |
| Fujitsu | “Can be connected to different gNBs”  As in Q3, the details of the CU/DU split architectures should be left to implementations and not the scope of discussions. Given that the NW synchronicity budget should be defined as follow,  NW budget = |TE| between “egress point of NW-TT” and “ingress point of gNB”  the relative 5G GM synchronization error between two gNBs can be defined as follow.  Relative 5G GM sync error = 2 \* NW budget = 2\*160ns = 320ns |
| OPPO | Yes, agree with Ericsson. In addition, for the CU/DU architecture, we also do not know how many PTP hops should be assumed for F1 interface between one pair of CU and DU. In our opinion, that could be equal to the number of PTP hops we assume for the NG interface, 4. |
| Huawei | Yes  For control-to-control scenario, the service area may be up to 1000m x 100m, which is difficult to be covered by a single gNB. Especially for certain coverage challenging environments, it is not reasonable to assume such a restriction that the involved UEs are connected to the same gNB.  If each gNB is synchronized to 5GM through maximum four PTP capable hops, the error budget for network part is ±320ns. |
| ZTE | We agree with some above comments that one gNB covering the whole service area is a too strict restriction for NW deployment. So we also think the scenario that two UEs are connected to two different gNBs (or DUs) needs to be considered.  Other analysis related to two different gNBs can be found in our comments for Q4. |
| LG | Yes.  The involved UEs in scenario2, can be connected to different gNBs. If intra 5G synchronization is to use PTP, the network part error is sum of the error between gNB for TSC GM and 5G GM, and the error between 5G GM and gNB for TSC device. The NW part budget is around ±160ns when referring to the value (±80ns) in Q4. |
| Intel | We are fine with considering different gNB case. Connection of UEs to different TRP is likely. Whether a pair of TRPs is connected to same gNB or not would be two different assumptions. However, we agree with Qualcomm, that the ±100ns bound on synchronization error holds irrespective of the assumptions on same/different gNBs or gNB splits. |
| vivo | For the scenario with 1000m x 100m, the deployment of a single gNB is not able to cover the service area. Based on this understanding, the involved UEs in scenario 2 may connect to different gNBs. The relative 5G GM synchronization error between two gNBs is (±2\*N\*40ns). ( i.e., ±320ns when N=4). |
| CMCC | Error budget for device part is a kind of implementation, we think it is valuable to take the input from device vendors for budget evaluation into consideration. |
| Apple | Scenario 2 can appear with the same or different gNBs. For evaluation and error budget dimensioning it is better to assume different gNBs which is also more general. |
| MediaTek | For Scenario 2, i.e. control to control use-case, we see no real impact on the error budget due to same/different gNBs or CU/DU split, assuming RAN3’s evaluation that the error budget is negligible still holds true for deployments with a local GM clock. |
| Sequans | If we consider 100m x 100m use case as well, single gNB might more easily be considered (see question 1). Otherwise multiple gNBs might be needed. |
| NTTDOCOMO | Yes. Agree with Ericsson’ view. Involvement of multiple DU is possible in control-to-control communication use case (assuming the service area is larger than 100m\*100m). |
| Xiaomi | Yes. Agree with Ericsson. |

***Summary of Question 5****:*

*It is observed that the majority of companies do see the need of using more than one gNB/DU/TRP to cover the areas of the corresponding scenarios.*

## 2.4 Assumption on Error Budget for Device Part

The device part is intended to capture the device introduced time synchronization errors. Such errors could be the DS-TT clock instance maintenance or at the DS-TT output interfaces.

**Question 6: What error component do you see should be accounted for in the device part and what assumptions can be made on the required device budget?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Nokia | Input from device vendors would be appreciated. |
| Ericsson | Inputs/confirmations from the UE/device vendors are appreciated. A value of 0 ns, of course, would be strange. See Ericsson’s estimate in the answer to the Question 7 below. |
| Qualcomm | We think 50-100ns would be a reasonable assumption. This should be taken for study purposes but not as a performance requirement. |
| CATT | See Q7 |
| Samsung | We think the source of device error is just an inaccuracy inside the user device. Fine with Qualcomm’s suggestion |
| Fujitsu | The device can be considered as (g)PTP capable switches and likely to implement function of be Boundary Clock (BC) or Transparent Clock (TC). In case of BC, there is |TE| requirement in ITU-T recommendation G.8273.2 that the maximum |TE| for BC with Class C which assumes to be used for 5G mobile telecommunication is 30ns. Note that BC with Class D will have strict budget compared to Class C (e.g. below 30ns), but the exact value is still studied and not decided yet in ITU-T.  Now, given that |TE| of BC with Class C is 30ns in G.8273.2 and the one hop |TE| is 40ns in RAN3, Fujitsu can accept to assume that the required device budget is simply ±40ns to have alignment with the RAN3 assumption. The 10ns margin can also be good for “accuracy budget buffer” since the device may implement TC where there is no requirement.  Having provided that, |TE| for BC with Class A is 100ns and |TE| for BC with Class B is 70ns. Such “looser” |TE| could be also acceptable as a study purpose. Fujitsu appreciate more input from companies. |
| OPPO | OK with Qualcomm’s comments |
| Huawei | Error budget for device part can be assumed as ±50ns. |
| ZTE | As mentioned in our comments for Q3, we think it’s no need to consider this part if we take 5GS E2E as the total budget for analysis. |
| LG | It’s about synchronization error inside a device. If error of 40ns per PTP hop can be assumed for PTP capable transport network connections, error of device part also can be assumed around 40 ns for study purposes. |
| Intel | The time synchronization error between the DS-TT and UE modem, and UE internal error should be accounted for. The device error budget would typically be less than the network error budget. Network error is mainly due to the timing sync error of 5GS GM to gNB, which can be physically separated by several hops. But in case of device error, the related components are typically very close physically. |
| vivo | When DS-TT is not integrated into UE, e.g., as a peripheral component of UE, it can be assumed that the error budget for device part is counted as one PTP hop (i.e., ±40ns). Considering the device may have lower sync accuracy ability than NW node, we prefer to leave a more tolerable error budget of ±50ns for the device part. |
| CMCC | We agree with Nokia that assume in scenario of DL synchronization defined in SA2 that a value of ±40 ns would be a reasonable starting point, while in scenario of UL synchronization defined in SA2 that a value of ±80 ns would be a reasonable starting point. |
| Apple | The device error budget needs to account for DS-TT functions up to and including the timestamping. In addition, a margin needs to be considered for detection and distribution of reference time in the UE. |
| MediaTek | Agree with Qualcomm that 50-100ns can be taken as a reasonable assumption for study purposes. |
| Sequans | This error is due to clock instance maintenance, as well as timestamping accuracy at DS-TT (exact budget TBD). |
| NTTDOCOMO | Agree with Qualcomm’s view. |
| Xiaomi | Agee with Qualcomm. |

**Question 7: What can we assume of device part budget for each scenario described in Question 2?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Nokia | Scenario 1 and 3, only one device is involved in the E2E path. One option is to consider the device as a boundary clock with e.g. an uncertainty of ±40ns.  Scenario 2 two devices are involved in the E2E path and the device budget should be accounted twice. That is assuming that both the source and target device introduce a similar time synchronization magnitude. One option is to consider the device as a boundary clock with e.g. an uncertainty of ±40ns, so a total device budget of ±80ns. |
| Ericsson | It is not clear the difference between this question and the above Question 6.  Ericsson tends to agree with Nokia that a value of ±40 ns would be a reasonable starting point, but to leave place for UE/device implementation, a value of ±100ns would be acceptable, which should be more than enough.  In summary, the synchronization budget of the device interface component is ±200ns for control-to-control use case and ±100ns for smart gird use case. |
| Qualcomm | For each device, 50-100ns of uncertainty should be accounted for in Uu interface budget (per Scenario breakdown). |
| CATT | We agree with Nokia. The DS-TT to UE total implementation error should be expected very small and should not exceed the RAN3 budget (R3-187252) for one (g)PTP capable device hop, ±40ns per UE. |
| Samsung | Considering some error margin to UE implementation, 100ns for each UE can be ok. |
| Fujitsu | It depends on the answer to Question 6, but if the device budget is assumed to be ±40ns, then the consequence mentioned by Nokia is reasonable.  Without loss of generality, if the device budget is assumed to be ±X [ns], then the device part of budget can be defined as follows:  Device budget for Scenario 1 = X [ns], where X= ±40ns can be the baseline  Device budget for Scenario 2 = 2\*X [ns], where X= ±40ns can be the baseline  Device budget for Scenario 3 = X [ns], where X= ±40ns can be the baseline |
| OPPO | Suppose ±100 ns is assumed for each UE, then for the control-to-control case where two UEs are involved, in sum ±200 ns should be accounted for, while for the smart grid case where only 1 UE is involved, ±100 ns is enough. |
| Huawei | For Scenario 1 and 3, single device is involved, then the total error budget for device is ±50ns.  For Scenario 2, since two devices are involved in the E2E path, the total device part budget can be assumed as ±100ns. |
| ZTE | As mentioned in our comments for Q3, we think it’s no need to consider this part if we take 5GS E2E as the total budget for analysis. |
| LG | Time synchronization error between a TSC device part and a 5G access part in a device is considered. The device part budget can be assumed around 40ns as explained in Q6. In case of scenario 2, two device are involved and the total device budget is around twice of 40ns. |
| Intel | Agree with other companies that for two Uu interfaces in control-to-control scenario, the device error should be considered twice. We are okay to consider the RAN3 value of |TE| = N\*40 ns assuming a single hop (N = 1) as given in R3-187252. So device error budget of ±80ns for control-to-control use case and ±40ns for smart gird use case seems reasonable. |
| vivo | We assume an error budget of ±50 ns for each UE.  Thus, for scenario 1 and 3, the total error budget for device is ±50ns.  For scenario 2, the total error budget for devices is ±100ns. |
| CMCC | We agree with Nokia that assume in scenario of DL synchronization defined in SA2 that a value of ±40 ns would be a reasonable starting point, while in scenario of UL synchronization defined in SA2 that a value of ±80 ns would be a reasonable starting point. |
| Apple | In scenario 2 the device budget needs to be accounted for twice. In scenarios 1 and 3, where there is only one Uu interface, the device budget counts only once. |
| MediaTek | For Scenario 2, the device error budget should be double that used for scenarios 1 and 3, as two devices are involved in the E2E scenario. |
| Sequans | Agree with Mediatek. |
| NTTDCOMO | Agree with MediaTek’s view. |
| Xiaomi | Agree with MediaTek. |

***Summary of Question 6 and 7****:*

*It is observed that companies view on the device part budget can be summarized as following:*

* *≤40ns (Nokia, CATT, LG (2x40 for scenario 2), CMCC)*
* *±100ns (Samsung, Ericsson)*
* *±50-±100 (QC, OPPO (±200 for scenario 2), MediaTek, NTTDOCOMO, Xiaomi)*
* *±50 (Huawei (±100 for scenario 2), vivo)*
* *No need to include (ZTE)*
* *Typically be less than the network, 40ns for single Uu interface and 80 ns for two Uu interfaces (Intel)*

*The proposed UE budget value from majority of companies lie in the range of ±50-±100ns, with two companies arguing that the device budget should be very small or could be neglected. A possible way forward is to assume a device part accuracy budget range of ±50-±100ns. Further it is observed that all companies agree that the device budget should be accounted twice for scenario 2 and once for scenario 1 and 3.*

## 2.5 Assumption on Error Budget for Uu Interface

According to TS 22.104 Table 5.6.2-1, the service area defined for control to control and smart grid use case is ≤ 1000 m x 100 m and < 20 km2 respectively. However, the assumption on the deployment of BS in the service area will impact the maximum propagation delay to be expected and hence agreeing on this will be helpful in the continued discussions. Companies are requested to provide their views on the number of BS, the maximum cell size and eventually the maximum expected propagation delay to be expected in each use case.

**Question 8: For each use case, how many BS can be expected to be needed, what is the maximum cell size to be expected and eventually what is the maximum propagation delay to be expected?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Nokia | For the control-to-control, it is reasonable to use the deployment layout described in TS 38.901 Table 7.8-7 for indoor factory (copied in for convenience). In fact, two big halls each with a hall size of L=300m x W=150m could be used as a starting point.  A picture containing large  Description automatically generated  In this deployment the distance between BS are D=50m would give an expected maximum direct path between a UE and the nearest BS of 35m and hence the maximum expected propagation delay would be ~120ns. The corresponding calibration exercises in R1-1909704 reveals that even with this number of BS, the experienced coupling gain can in some cases give challenging signal conditions, so we would consider this number of BS to be a minimum.  A close up of a map  Description automatically generated  For the smart grid scenarios, we propose that any cell sizes supported by NR should also be supported for the smart grid use case. Hence we consider it reasonable to assume a standard hexagonal cellular grid with 1732m ISD. This would give an expected cell radius of about 1200m and hence a corresponding direct propagation path delay of about 4000ns. |
| Ericsson | These are indeed RAN1 questions and should be studied in RAN1. For example, in the TR 38.825, RAN1 has provided simulation results for different ISDs.  What RAN2 can provide is the synchronization accuracy budget of the Uu interface under different (reasonable) scenarios. The bottom line is whether the end-to-end synchronization path involves multiple gNBs, and consequently the network interface accuracy budget and whether the propagation delay compensation should be applied or not.  For smart grid,   * One gNB with a large cell size is assumed. Thus, the delay compensation is needed.   For control-to-control, RAN1 has assumed in Rel-16 a small cell size (e.g., in TR 38.824, system simulation assumption for factory automation assume ISD of 20 m for factory floor size of 120 m x 50 m) and no delay compensation is needed. In Rel-17, the service area is 1000 meters by 100 meters and the exact deployment needs to be discussed.   * With a large (1000 m x 100 m) service area, to re-use the same cell size of 20m would result in a very dense gNB deployments. Thus, the cell size would need to be sufficiently large and so a propagation delay compensation is needed. Note that in RAN1, 15 kHz SCS is agreed to be considered (see question 9 below) since it is assumed that the cell size can be sufficiently large. * Multiple gNBs are needed since it is difficult to cover 1000 meters in indoor environment by one gNB, and then the network interface synchronization budget should consider between two gNBs (i.e., ±320ns in Ericsson’s analysis). |
| Qualcomm | Following RAN1 agreement, the service area defined for control to control and smart grid use case is ≤ 1000 m x 100 m and < 20 km2 respectively. If we assume the service area of the cell is circle, the corresponding radius of the cell will be 178.4m and 2.5km respectively, and propagation delay is 594.7ns and 8.4μs respectively |
| CATT | For smart grid: we agree with Nokia and Ericsson: large cell size involving PDC.  For control-to-control: we agree with Nokia that the expected TRP/DU density (ISDs ~50m) removes the need for PDC. |
| Samsung | Large size, e.g., 1732m for smart grid and small size for control-to-control can be considered as a reasonable baseline. No strong view on exact values. |
| Fujitsu | The questions (the number of BSs, the maximum cell size, and the maximum propagation delay) are more about RAN1 study topic, so that Fujitsu will wait for RAN1 progress.  Fujitsu think what’s important from RAN2 perspective is to decide synchronicity budget for RAN/Uu component for two use cases. With the above-mentioned analysis in Section 2.1 – 2.4, the RAN/Uu part of budget can be derived as follows:  Uu budget in Scenario 1 = 900ns – 160ns (NW) – 40ns (Device) – 5ns (granularity)  = 695ns  Uu budget in Scenario 2 = (900ns – 2\*160ns (NW) – 2\*40ns (Device) – 2\*5ns (ranularity))/2  = 245ns  Uu budget in Scenario 3 = 1000ns – 100ns (NW) – 40ns (Device) – 5ns (granularity)  = 855ns |
| OPPO | For smart grid, with large cell size, the PDC is needed. For the control-to-control use case, only when the cell radius size is larger than 80m (corresponding to 1 TA granularity for 15KHz) and 40m (corresponding to 30KHz), PDC is required. |
| Huawei | The actual synchronization error for Uu interface is affected by many factors, e.g. SCS and corresponding TEUE-DL-RX, TA adjustment error, Te, and so on, which shall be evaluated by RAN1(and RAN4). Besides, the Uu sync error budget is also affected by how the propagation delay compensation is performed, and with what accuracy. We don’t think that the error budget for Uu interface can be just based on the maximum cell size and the expected maximum propagation delay value.  Since it is much easier to determine the error budget for network part as well as for device part, we think error budget of Uu interface can be determined as the result of the 5GS synchronicity budget minus the error budget for network part as well as for device part.  Based on the above consideration, for Scenario 1, the error budget for Uu interface can be ±(900ns - 160ns- 50ns)= ±690ns.  For Scenario 2, the total error budget for two Uu interfaces can be ±(900ns - 320ns -100ns)= ±480ns, assuming maximum 4 gPTP capable hops are used between gNB and 5GM. The sync error budget for each Uu interface is then ±240ns.  For Scenario 3, the error budget for Uu interface can be ±(1000ns - 50ns)= ±950ns or ±(900ns - 50ns)= ±850ns. |
| ZTE | We agree with some of above comments that the assumption of number of BS, the maximum cell size can be decided by RAN1. We just don’t want any unnecessary restriction on the deployments. Our brief comments are as following:   * For smart grid, both one gNB or multi gNBs should be possible. Anyway, PDC is needed. * For control-to-control: With a large (1000 m x 100 m) service area, multiple gNBs are also possible.   Moreover, from RAN2 perspective, we have the following assumption on RAN/Uu part of budget:   * If with synchronization based on GPS time source and with multi gNBs (DUs):   + One-way Uu budget in Scenario 1 = 1000ns - 100ns (peripheral components) - 200ns (NW) - 5ns (granularity) = 695ns.   + One-way Uu budget in Scenario 2 = (1000ns - 100ns (peripheral components) - 200ns (NW) - 2\*5ns (granularity)) / 2 = 345 ns.   + One-way Uu budget in Scenario 3 = 900ns - 200ns (NW) - 5ns (granularity) = 695ns. * If with synchronization based on gPTP message and with multi gNBs (DUs):   + One-way Uu budget in Scenario 1 = 1000ns - 100ns (peripheral components) - 200ns (NW) - 5ns (granularity) = 695ns.   + One-way Uu budget in Scenario 2 = (1000ns - 100ns (peripheral components) - 2\*200ns (NW) - 2 \* 5ns (granularity)) / 2 = 245 ns   + One-way Uu budget in Scenario 3 = 900ns - 200ns (NW) - 5ns (granularity) = 695ns |
| LG | The maximum propagation delay is obtained when use cases are served by a single gNB,  For use case of 1000m by 100m, we assume the maximum distance between a UE and gNB is 500m and the maximum propagation delay is 1.6 us.  For use case of < 20 km2, we assume a circle and the maximum distance is around 2.5 km. The maximum propagation delay is around 8.4 us. |
| Intel | This may require RAN1 input.  For Control-to-control, ~50 m inter-BS distance may be a reasonable assumption based on Indoor Factory channel model studies and calibration in TR 38.901.  For Smart grid, a typical cellular hexagonal deployment can be assumed. Both 500 m and 1732 m typical values can be assumed: 500 m was previously used by RAN1 for Smart Grid and power distribution analysis in TR 38.824, while 1732 m can provide an additional worst-case assumption. |
| vivo | In R16, RAN1 is responsible for determining network deployment (e.g. the number of BS and maximum cell size) and providing simulation results for different ISDs (which can refer to TR 38.825). In R17, we can also ask RAN1 for the maximum cell size. |
| CMCC | This is indeed RAN1 issue and we can followRAN1 agreement that the service area for control to control and smart grid use case is ≤ 1000 m x 100 m and < 20 km2 respectively. If we assume the service area of the cell is circle, the corresponding radius of the cell will be 178.4m and 2.5km respectively, and propagation delay is 594.7ns and 8.4μs respectively |
| Apple | Agree with vivo |
| MediaTek | Agree with comments above that assumptions on number of BS and max cell size should be discussed in RAN1. It is however clear that to fit within the available error budget for the Uu interface in the smart grid scenario, propagation delay compensation will be required. As a next step, for each propagation delay compensation mechanism that is proposed, we should evaluate whether its associated error fits within the available budget (after having accounted for Network and Device errors). |
| Sequans | RAN2 agreed to introduce PDC “for the improved synchronisation accuracy requirement **in case of in UL Time Synchronization**”  However none of use cases proposed seems to match:  - control to control: no PDC needed given small ISD  - smart grid: no UL Time Synchronization (PDC could be left as in Rel-16).  In our understanding, control to control with small service area (e.g. 100x100m) and/or large cell size might be considered as well. |
| NTTDOCOMO | It’s dependent on RAN1 analysis. We agree with Fujitsu’s analysis. |
| Xiaomi | This should be discussed in RAN1, and we agree with the views from Ericsson. |

***Summary of Question 8****:*

*Many companies have highlighted that this discussion is beyond the scope of RAN2. The rapporteur also agrees so we probably do not have to consider this aspect in RAN2.*

Another important assumption when evaluating the Uu interface time synchronization accuracy is the assumption on the sub-carrier spacing. In the LS R1-2007446 it has been agreed to evaluate both 15 and 30 kHz for both use cases.

**Question 9: Do you agree to use 15 kHz and 30 kHz sub-carrier spacing in the evaluations of the Uu interface time synchronization accuracy for all scenarios?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Nokia | Yes  We are fine by using the RAN1 agreement as a baseline for the evaluations for time synchronization budgets. |
| Ericsson | Yes. No reason to discuss again RAN1 agreement |
| Qualcomm | Yes. This conforms to the RAN1 agreement. |
| CATT | Yes |
| Samsung | Yes. |
| Fujitsu | Yes. |
| OPPO | Yes |
| Huawei | Yes. It has been agreed by RAN1. |
| ZTE | Yes |
| LG | Yes |
| Intel | Yes |
| vivo | Yes |
| CMCC | Yes |
| Apple | Yes |
| MediaTek | While we see 15kHz SCS as a less important scenario for evaluation, we are fine to use RAN1’s agreement as the baseline for calculating the synchronization error budget. |
| Sequans | Yes – we should follow RAN1 agreements. |
| NTTDOCOMO | Yes |
| Xiaomi | Yes |

***Summary of Question 9****:*

*All companies agree with the RAN1 assumption on sub-carrier spacing.*

Moreover, according to RAN1 agreements, one and two Uu interfaces are considered for the control-to-control and smart grid use cases respectively.

|  |
| --- |
| Agreements:   * For 5GS synchronicity budget requirement,   + One Uu interface is assumed for smart grid.   + Two Uu interfaces are assumed for control-to-control. |

**Question 10: Do you agree on the assumptions on the involved number of Uu interfaces in the considered scenarios?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Nokia | Yes |
| Ericsson | Yes. No reason to discuss again RAN1 agreement |
| Qualcomm | Yes |
| CATT | Yes |
| Samsung | Yes |
| Fujitsu | Yes |
| OPPO | Yes |
| Huawei | Yes |
| ZTE | Yes.  For control-to control, we agree two Uu interfaces can be assumed but one Uu interface is also possible. |
| LG | Yes |
| Intel | Yes |
| vivo | Yes |
| CMCC | Yes |
| Apple | Yes |
| MediaTek | Yes |
| Sequans | Yes |
| NTTDOCOMO | Yes |
| Xiaomi | Yes |

***Summary of Question 10****:*

*All companies agree with the RAN1 assumption on the number of Uu interfaces in different scenarios.*

While discussing the scenario where two Uu interfaces are involved, it should be considered if the involved Uu interfaces require a similar time synchronization accuracy budget. For instance, the UE deployment can cause different propagation delays, or even that propagation delay compensation is only applies for one or none of the Uu interfaces.

**Question 11: When two Uu interfaces are involved, do you agree that the two Uu interfaces should be assumed to use the same time synchronization accuracy budget?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Nokia | Yes,  In this case, we would have to assume the worst case assumption.  One worst case assumption is if propagation delay compensation is needed for both Uu interfaces.  Another one, if propagation delay compensation is not needed for both Uu interfaces, the worst case is that one UE is located very close to a TRP, and the other is located furthest away possible from a TRP. |
| Ericsson | Yes.  The same budget is the easiest approach and indeed it is the optimal allocation of the budget. Assuming there is a fixed total budget for the two Uu interfaces, an uneven split would result in one of them with a tighter requirement. |
| Qualcomm | Yes. Equal split between Uu interfaces should be the baseline. |
| CATT | Yes, especially considering we assume in Q8 no PDC is required in control-to-control scenario which involves two Uu interfaces. |
| Samsung | Yes. We don’t have a reason to have different accuracies for different UEs. Same accuracy can be a simple baseline. |
| Fujitsu | Yes. |
| OPPO | Yes |
| Huawei | Yes |
| ZTE | Yes |
| LG | Yes |
| Intel | Yes, our understanding is that the two Uu interfaces scenario is where there is UE-UE timing synchronization case, so it would be appropriate to use the same time synchronization accuracy budget. |
| vivo | Yes |
| CMCC | Yes |
| Apple | Yes |
| MediaTek | Yes |
| Sequans | Yes |
| NTTDOCOMO | Yes |
| Xiaomi | Yes |

***Summary of Question 11****:*

*All companies agree to assume the same accuracy budget for Scenario 2, where two Uu interfaces are involved.*

Related to Question 5 and 6 on the network part budget, the Uu interface budget part could account for a relative error between TRPs (assuming that between gNBs are accounted for in the network part).

**Question 12: Should the Uu interface part account for an error between TRPs? And if so, what can be assumed on the maximum time synchronization error between TRPs?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Nokia | Yes  Here we would assume that the TAE requirement given in 38.104 bounds the maximum synchronization error between any two any two antenna-connectors. |
| Ericsson | No  Multiple TRPs are part of the €MIMO scheme which is not considered in the IioT/eURLLC WI. If the intention of the question is about the Base Station transmit timing error (inferred from the above Nokia answer), RAN1 has considered this, see below agreements  Agreements:  For BS transmit timing error, further study the following three options:   * **Option 1**:65 ns * **Option 2**: ±130ns for the indoor scenario and ±200ns for the smart grid scenario * **Option 3**: 82.5 ns |
| Qualcomm | Possible error between TRPs is more into the RAN1 scope. Thus, RAN2 need not make assumptions about possible errors between TRPs. It is better to wait for RAN1 to conclude their discussions on the different error components on the Uu interface including possible TRP errors. |
| CATT | No. As elaborated in Q3, we think the TAE is in the RAN1 domain and RAN2 should not take into account the radio units (and distributed deployments thereof) when dimensioning the Uu timing error budget which should stop at the gNB (or DU) BBU output. |
| Samsung | Yes. Agree with Nokia. |
| Fujitsu | Yes  We also think that TAE requirement for TRPs should be given in TS38.104. |
| OPPO | Agree with Ericsson |
| Huawei | We think this is within RAN1 or RAN4 scope. |
| ZTE | No, we tend to agree with QC. |
| LG | This is in RAN1 scope. |
| Intel | The definition of TAE may also apply to different antenna connectors in single gNB, thus should be considered in control-to-control use case. Question should be updated to whether TAE should be considered instead of timing synchronization between TRPs. What value should be assumed for TAE for the different representative use cases (i.e. control-to-control and smart grid) is already under discussion in RAN1 and RAN2 should wait for their discussion to conclude. |
| CMCC | We think this is within RAN1 scope. |
| Apple | We consider the error between TRPs is in RAN1 and RAN4 domain. RAN2 should wait for RAN1 to conclude on the discussion of possible errors. |
| MediaTek | No, agree with QC |
| Sequans | No strong view. |
| NTTDOCOMO | Agree with Qualcomm’s view. |
| Xiaomi | This should be decided in RAN1, but we agree that the errors between TRPs should be considered. |

**Summary of Question 12**:

*It is observed that most companies consider discussions on TAE should be conducted in RAN1/RAN4 other than RAN2. As there is a relevant on-going discussion in RAN1 regarding the use of TAE requirement, a possible way forward is to wait until RAN1 has made further conclusions.*

Finally, please indicate if anything is missing or should be considered in this Phase-1 of the email discussion and if RAN2 thinks there are any additional aspects which RAN1 should consider.

**Question 13: Please indicate if anything additional should be considered in Phase-1 discussion.**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Ericsson | The granularity of the reference time delivery from gNB to UE should be considered, which is ±5ns and included in the TR 38.825. Note that this has not been considered by RAN1 in Rel-16 and the assumption is that this will not be considered in Rel-17 by RAN1 either.  In addition, some accuracy budget buffer should be allocated to account for implementation related aspects. One example is related with the 5G reference time delivery and the information for propagation delay compensation. It is important to signal the information needed by a UE to determine a downlink propagation delay value and a 5G system clock value in close time proximity. The closer these two events are in time the more accurate the UE acquires the 5G reference time. However, network cannot guarantee it is fulfilled all the time, as some messages on the Uu interface might have HARQ retransmissions.  Lastly, RAN2 agreed in RAN2#110-e that   * UE can calculate/predict the reference timing based on DL timing information after receiving the eferenceTimeInfo from gNB once. (No spec impact)   In other words, there is no UE clock drift issue in relation to the 5G reference time and RAN2 can consider a sufficiently stable UE clock so that it is not of a concern in propagation delay compensation context. It is good to confirm this baseline conclusion in the Rel-17 work. |
| Qualcomm | It is our understanding that section 2.5 covers RAN1 analysis of the different uncertainty sources on the Uu interface, in particular Questions 8 and 12, and also possible errors stemming from UE detection timing. It would be better to wait for conclusion of RAN1 analysis and input on these before discussing them in RAN2.  We think in conclusion of this phase of email discussions, RAN2 should develop a table for different error components for scenario1, scenario2, and scenario 3. |

***Summary of Question 13:***

*Two issues have been brought up, namely (1) the timing accuracy error introduced by the rounding error in referenceTimeInfo, and (2) the timeliness of PD estimation and PD compensation. These issues can be further discussed in the Phase-2.*

**Question 14: Any aspects that RAN1 has not yet considered that RAN2 thinks that RAN1 should consider?**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Nokia | No |
| Qualcomm | No |
| Huawei | No |
| Intel | No |
| vivo | Agree with QC. |
| CMCC | We think this is within RAN1 scope. |
| Xiaomi | At least for the control-to-control communication, the movement of the UE may also have impacts on the reception accuracy of the reference time. Considering that this is in the industrial deployment scenarios, the speed of the machine will not be fast. Then a maximum speed of 30Km/H might be needed in the evaluation. |

***Summary of Question 14****:*

*No additional input to RAN1 have been mentioned.*

# 3 Phase-2 Discussion: Further Clarification on Time Budget and Options for Propagation Delay Compensation

The second phase of this email discussions will start with open issues from Phase-1, and then moving to discussions on the propagation delay estimation and compensation options from a RAN2 perspective.

## 3.1 Follow-up questions from Phase-1

This section contains follow-up questions raised from Phase-1. The intention with these questions is to bring us a bit closer to consensus on the Uu interface budget, and if needed, a discussion on the background for the budget determination methodology.

Based on the summary of Phase-1 it is agreeable to consider the 5GS E2E time synchronization budget to be split into three parts for the considered Scenarios 1, 2, and 3. The intended outcome of Phase 1 is a Uu interface budget, and given that multiple companies has given their input to a budget calculation, we may try to agree on the expression used to determine the single Uu interface budget. The next question covers Scenario 1 and 3, and the proceeding question covers Scenario 2. Note that, for the following questions the E2E 5GS accuracy requirement from 22.104 (illustrated in Table 1) is used, although in Phase-1 a few companies have proposed to use a 5GS E2E accuracy requirement <1µs for scenario 3 (e.g. 900ns) as defined for Scenario 1 and 2. From the rapporteur point of view, it is not easy to agree a number below 1µs, so it is proposed to use the 1µs as given in 22.104.

**Question 15: Do companies agree to calculate Uu interface budget for Scenario 1 and 3 as per;**

* **Scenario 1: Uu budget = 900ns – Device – Network scenario1**
* **Scenario 3: Uu budget = 1000ns – Device – Networkscenario3**

|  |  |  |
| --- | --- | --- |
| **Company** | **Yes/No** | **Comments** |
| Nokia | Yes |  |
| Fujitsu | Yes |  |
| Xiaomi | Yes |  |
| Intel | Yes |  |
| Huawei | Yes |  |
| NTTDOCOMO | Yes |  |
| OPPO | Yes |  |
| CATT | Yes |  |
| Samsung | Yes |  |
| LG | Yes |  |
| vivo | Yes |  |
| MediaTek | Yes |  |
| Ericsson | Yes | The Uu interface budget for Scenario 1 is larger than that for Scenario 2 while they both target the same control-to-control use case. Also, RAN1 has agreed (see LS R1-2007446) to focus only on Scenario 2 and Scenario 1 is not considered:   * Two Uu interfaces are assumed for control-to-control.   Thus, Scenario 1 must be removed in the reply LS to RAN1 to avoid unnecessary works in RAN1. |

As companies agree to assume an equal split of the between Uu interfaces, and multiple gNBs are involved in Scenario 2, then one method to calculate the Uu interface budget can be as below.

**Question 16: Do companies agree to calculate the single Uu interface budget for Scenario 2 as;**

* **Scenario 2: Uu budget = (900ns – 2xDevice – 2xNetwork scenario2)/2**

|  |  |  |
| --- | --- | --- |
| **Company** | **Yes/No** | **Comments** |
| Nokia | Yes | We note that Network scenario1 and Network scenario2 can be assumed to be equal. |
| Fujitsu | Yes |  |
| Xiaomi | Yes |  |
| Intel | Yes |  |
| Huawei | Yes |  |
| NTTDOCOMO | Yes |  |
| OPPO | Yes |  |
| CATT | Yes | … which assumes accounting twice the Network budget in the equation which, for the case of a synchronization based on gPTP messages is very pessimistic since it assumes the network paths to both UEs are totally different with no common g-PTP capable node (as also commented by Nokia in Q20). |
| Samsung | Yes |  |
| LG | Yes | We think it is assumed that the synchronization in 5GS is based on PTP. |
| vivo | Yes |  |
| MediaTek | Yes | We also agree with CATT that assuming twice the Network budget is very pessimistic |
| Ericsson | Yes | Network scenario1 and Network scenario2 are equal.  The network deployment (e.g., the cell size) should be independent of where the GM is located and depend more on the coverage area. Thus, the network deployment is assumed to be the same in Scenario 1 and Scenario 2. The only reason for a different expression is that the TSN GM clock is at the UE side for Scenario 2.  Since Network scenario1 and Network scenario2 are the same and the network deployment is assumed to be the same, Scenario 1 must be removed (whose Uu budget is larger) in the reply LS to RAN1. |

These expressions leave us to agree on what is being assumed as network and device accuracy budgets. The next 6 questions capture the main issues to be follow-up from Phase-1, related to determining the budget for the device and network parts.

**Question 17: Do you agree that RAN2 assumes a device time synchronization accuracy budget range from ±50 to ±100ns?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Yes/No** | **Comments** |
| Nokia | Yes | This is a reasonable compromise capturing the majority of companies views from Phase-1. |
| Fujitsu | Yes |  |
| Xiaomi | Yes |  |
| Intel | Yes |  |
| Huawei | Yes |  |
| NTTDOCOMO | Yes |  |
| OPPO | Yes |  |
| CATT | Partly | Could it be acceptable to take a lower bound at ±40ns? As mentioned in Q7, we wonder why the DS-TT to UE total implementation error should be larger than the RAN3 budget (R3-187252) for one (g)PTP capable device hop (±40ns). |
| Samsung | Yes |  |
| LG | Yes |  |
| vivo | Yes |  |
| MediaTek | Yes |  |
| Ericsson | Yes | This is a reasonable compromise given the inputs from the device/UE vendors and the analysis therein. |

In Phase-1 a company has raised an issue in Question 13 on whether the time synchronization error from the granularity of referenceTimeInfo-r16 IE should be included in the budget calculations.

**Question 18: Should we consider the referenceTimeInfo-r16 IE granularity in the network budget? If you agree, please indicate the time synchronization error to be added to the network budget (e.g. ±5ns).**

|  |  |  |
| --- | --- | --- |
| **Company** | **Yes/No** | **Comments** |
| Nokia | Yes | The time synchronization error from the finite granularity of referenceTimeInfo-r16 IE should be captured in the network part and added on top of the network part budgets in the Uu interface budget calculations. The error to be added to the network budget can be ±5ns. |
| Fujitsu | Yes | The value of ±5ns can be used. |
| Xiaomi | Yes |  |
| Intel | Yes | Yes, referenceTimeInfo-r16 IE granularity should be considered in the network budget. ±5ns is reasonable. |
| Huawei | Yes | Since this error component has not been considered by RAN1 for the evaluation of Uu interface budget, we can consider it within the network budget. This synchronization error is ±5ns. |
| NTTDOCOMO | Yes |  |
| OPPO | Yes |  |
| CATT | Yes |  |
| Samsung | Yes | ±5ns error should be considered |
| LG | No | Inaccuracy caused by referenceTimeInfo IE granularity can be considered in the Uu interface budget because the related operation is performed between UE and gNB. A UE uses it to obtain the synchronization together with the boundary of the system frame. The error caused by referenceTimeInfo IE granularity is ±5ns. |
| vivo | Yes |  |
| MediaTek | Yes |  |
| Ericsson | Yes | RAN1 has not considered this in the Rel-16 Uu interface performance analysis and this part is added by RAN2 in the TR 38.825. It is okay to split like this in Rel-17. |

Based on the summary of Phase-1, it seems to be reasonable to assume a range between ±160ns and ±200ns for Scenario 1 as the network part time synchronization accuracy budget.

**Question 19: Do you agree that RAN2 should assume a network time synchronization accuracy budget range between ±160ns and ±200ns for scenario 1 (control-to-control)?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Yes/No** | **Comments** |
| Nokia | Yes | This is a reasonable compromise capturing the majority of companies views from Phase-1. |
| Fujitsu | Yes |  |
| Xiaomi | Yes |  |
| Intel | See comment | We think **±**200 ns is a very high value for scenario 1. For Question 4 in phase 1, we see that our opinion was not included in the summary. We have added our name in the summary above for ±100ns network budget for scenario 1. We propose the range **±** [100 - 160] ns to be considered instead of **±** [160 - 200] ns as a compromise. |
| Huawei | Yes | Agree with Nokia |
| NTTDOCOMO | Yes |  |
| OPPO | Partially yes | In our opinion, network time synchronization accuracy budget only has two possibilities: either 160ns or 200 ns (two discrete values). Note that according to majority of companies replies in phase-1 discussion, 4/5 PTP hops is accounted for aggregated/disaggregated network deployment choice. |
| CATT | Yes | It corresponds to N=4 or 5 gPTP hops between 5GM on network side and the Uu. |
| Samsung | Yes | Agree with Nokia |
| LG | Yes, but | It is fine to consider it as a starting point, but it needs to be open to re-evaluate it in case that it is required in RAN1 response. The range between ±160ns and ±200ns for scenario 1 is understood when synchronization is based on PTP and N=4 or 5 is assumed. However, it is not sure to allocate accuracy budget enough to the Uu interface, particularly for scenario 2, after applying the above-mentioned range. |
| vivo | See comment | Agree with Intel, ±200 ns is relatively high. We prefer to assume 4 gPTP hops between the GM and the gNB, i.e., ±160ns . |
| MediaTek | Should be evaluated by RAN3 before being agreed | As mentioned in our earlier response, the LS from RAN3 indicated that in case of a ‘local on-site gNB’, the error should be negligible. Given that scenario 1 (control-to-control) falls within this scenario, it is strange that RAN2 are disagreeing with RAN3’s evaluation on the NW budget.  Given this discrepancy between RAN2 and RAN3’s estimation of NW budget, we suggest getting RAN3’s opinion on this topic. |
| Ericsson | Yes | If the TSN GM clock is co-located with a gNB, the synchronization inaccuracy from the TSN GM clock to this gNB is negligible according to RAN3. However, the service area is as large as 1000m x 100m. This cannot be covered by a single gNB in indoor environment. |

Based on the summary of Phase-1, it seems to be reasonable to assume that the network part time synchronization accuracy budget for Scenario 2 is twice the budget for Scenario 1.

**Question 20: Do you agree to assume a network budget of 2x Scenario 1 for scenario 2 (control-to-control, with GM connected to a node behind a UE)? If you do not agree, please indicate the budget to be assumed for scenario 2 (e.g. the maximum number of hops between the 5GM and any two gNBs).**

|  |  |  |
| --- | --- | --- |
| **Company** | **Yes/No** | **Comments** |
| Nokia | Yes | This is a reasonable compromise of companies views expressed in Phase-1.  We do consider this to be a pessimistic (too high) accuracy budget as the time synchronization accuracy of the two network budget can be semi-correlated by either sharing some PTP hops or by being served by the same gNB. |
| Fujitsu | Yes |  |
| Xiaomi | Yes |  |
| Intel | Yes |  |
| Huawei | Yes | Agree with Nokia that we need not to be too pessimistic assuming maximum four hops on the network side. The network error budget can be reduced through proper deployment. |
| NTTDOCOMO | Yes |  |
| OPPO | Yes | Considering that UE with GM connected and UE in need of time synchronization service could be served by different gNB, it is a reasonable assumption. |
| CATT | Yes | Agree with Nokia though that it is a very pessimistic assumption, especially for a small area, assuming a deployment without aggregating node. |
| Samsung | Yes |  |
| LG | Yes | We agree to Nokia’s comment about that this is the worst case and PTP hops can be shared. |
| vivo | Yes |  |
| MediaTek | Yes | We also agree with Nokia that this is a highly pessimistic assumption |
| Ericsson | Yes | This is to capture the worst-case scenario among all possible network deployments. Note that, this question seems to be covered already by Question 16. |

Based on the summary of Phase-1, it seems to be reasonable to assume ±100ns for Scenario 3 as the network part time synchronization accuracy budget.

**Question 21: Do you agree that RAN2 should assume ±100ns as network time synchronization accuracy budget for scenario 3 (smart grid).**

|  |  |  |
| --- | --- | --- |
| **Company** | **Yes/No** | **Comments** |
| Nokia | Yes |  |
| Fujitsu | Yes |  |
| Xiaomi |  | No strong view. But it seems that the ±160ns assumption from Ericsson is reasonable. |
| Intel | Yes |  |
| Huawei | Yes |  |
| NTTDOCOMO | Yes |  |
| OPPO | Yes |  |
| CATT | Yes |  |
| Samsung | Yes | No strong view on exact number. |
| LG | Yes |  |
| vivo | Yes |  |
| MediaTek | Yes |  |
| Ericsson | Yes | Ericsson is fine to use the value of 100 ns for Scenario 3. The proposed value of 160 ns in the phase 1 from Ericsson is an attempt to harmonize the network interface part for all scenarios to have one common value to capture the worst case. |

Moreover, we would like to check company’s views on the timeliness issue raised in Question 13 during Phase-1.

**Question 22: Do companies agree with the issue raised by one company in Question 13: “*It is important to signal the information needed by a UE to determine a downlink propagation delay value and a 5G system clock value in close time proximity. The closer these two events are in time the more accurate the UE acquires the 5G reference time*” ?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Yes/No** | **Comments** |
| Nokia | No | We do acknowledge that the closer these two events are in time, the smaller is the likelihood for a mismatch between the PD estimation when used for PD compensation. If needed, this can be handled by the gNB implementation. |
| Fujitsu | No, but… | Fujitsu want to understand what kind of solution Q13 is proposing. In case when some information is likely to be erroneous in Uu interface sent from NW to UE, the NW can take properly action by e.g. selecting proper transmission power and coding rate. |
| Xiaomi | Yes | The UE could be moving around. If the time point of the propagation delay compensation is far away from the time point of the provisioning of the reference time message, the propagation delay calculated by the UE might be different from the propagation delay of sending the reference time message. But we would also agree that more evaluation is probably needed on the extra errors caused by the too-late propagation delay calculation. |
| Intel | No | We agree with Nokia that while this point can be acknowledged, we do not need to consider this detail at this point. |
| Huawei | No | It should be up to network implementation to solve if there is such problem. It shall be noted that the periodicity of downlink propagation delay update and the periodicity of 5G system clock update could be different. It is then not clear what it means by signaling the two values in close time proximity (?). Assuming normal hardware (no UE clock drifting issue) and network implementation, we don’t see issues caused by e.g. HARQ retransmission of 5G reference time or propagation delay update. |
| NTTDOCOMO | No | Agree with Nokia’s view. |
| OPPO | No | Agree with Nokia this is up to network implementation. |
| CATT | No | Agree with Nokia’s view. |
| Samsung | No | Agree with Nokia |
| LG | Yes | We think that it increases accuracy of synchronization at the beginning to signal the reference time and PD value at the same time. The PD changes after the first synchronization can be compensated using following PD update values. |
| vivo | No | Agree with Nokia’s view this is up to network implementation.  According to the description in TS 22.104, UE speed in scenario 1/2/3 is stationary. Thus, no need to consider the resulting impact caused by UE mobility. |
| MediaTek | Yes | Given that the Uu budget is quite limited from the discussions above, any solution we choose should avoid new/further sources of error such as the one raised in this question. |
| Ericsson | Yes | This is the proposal from Ericsson. During the phase 1 discussion on high-level budget breakdown, the point is to highlight that there are implementation aspects that further introduce inaccuracy.  We agree that the inaccuracy there can be mitigated to some extent by gNB implementations (without spec enhancements), as mentioned above by Nokia and examples pointed out by Fujitsu. In addition, it might be difficult to agree to a common value. For the purpose of the evaluation and study, we can compromise and accept that the inaccuracy is considered to be zero in the evaluation and study. |

## 3.2 Robust propagation delay compensation

As indicated by the email discussion scope, the main goal of Phase-2 is intended to discuss the various options for propagation delay estimation and compensation, as well as the framework around these. Prior to delving into the details, we would like to start with confirmations relating to which node should conduct PD estimation and which node should conduct PD compensation.

**Question 23: Please provide your comments on which node should conduct PD estimation (e.g. gNB or UE), and which node should conduct PD compensation, as well as highlighting the RAN2 impact in your reply.**

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| **Company** | **Comments** |
| Nokia | We prefer that the UE conducts PD compensation, while the PD estimation is fully conducted by the UE or conducted by the UE but assisted by the gNB.  There would be RAN2 impact by at least (referring to options agreed by RAN1):   * PD estimation framework;   + Specific for Option 1 (TA-based PD estimation).     - UL transmission configurations.     - Possible TA-C with enhanced granularity.   + Specific for Option 2 (Rx-Tx based PD estimation)     - UL and DL reference signal configuration to be used for Rx-Tx measurements (not restricted to SRS and PRS as in the R16 positioning procedures).     - Configured relation between UL and DL reference signals used for Rx-Tx measurements.   + A UE trigger for PD estimation procedure.   We also foresee the signaling that allows the UE to determine when to conduct PD compensation. From the studies conducted in Rel-16 it is clear that PDC is only improving the time synchronization accuracy when the PD is sufficiently large. Therefore, the best time synchronization accuracy is achieved when PDC is used above a PD threshold. This threshold depends on several factors, such as the used BW, and hence is gNB configured and determined by gNB implementation. |
| Fujitsu | UE should conduct PD compensation. RAN1 is carrying on the discussion on the details of PD as in the LS R1-2007446. Fujitsu want to wait for the RAN1 progress. |
| Xiaomi | We should focus on the UE-based propagation delay compensation. RAN1 can probably provide more inputs after evaluating the performance of different solutions. |
| Intel | gNB may have the option for PD compensation, in which case RAN2 impact would be to introduce new RRC indication from the gNB to the UE whenever it has performed pre-compensation at the network side to avoid double compensation. Legacy option of PD compensation at the UE side should also be supported. |
| Huawei | PD estimation can be conducted by the gNB, and the gNB can construct TA command (potentially with enhanced TA indication granularity) or a new dedicated signaling with finer delay compensation granularity, as Option 1 agreed by RAN1. PD compensation shall be conducted by the UE after obtaining the propagation delay value indicated by the gNB.  An alternative solution is network pre-compensation. In this solution, PD estimation as well as PD compensation can be conducted by the gNB, and the pre-compensation is indicated to the UE.  Potential RAN2 impacts:  • New TA command with enhanced TA indication granularity, or new dedicated signaling with finer delay compensation granularity;   * Dedicated signaling to indicate UE whether PD compensation shall be conducted by the UE. |
| NTTDOCOMO | Either UE or network based PD compensation is fine to us. The point is to avoid double compensation and when to conduct the PD compensation. We agree with Nokia that threshold based PD compensation by UE is prefereable to determine the timing for conducting the PD compensation, which is also helpful for signaling reduction (i.e. No explicit PDC indication from network is need). |
| OPPO | We are open to both choices. Please note that PD compensation at UE only works when the distance between UE and gNB has reached a certain level and there is always residual error after PDC. Bearing this in mind, PDC at gNB could be a better choice. The only concern is that gNB might need to pre-compensate propagation delay for numerous UEs simultaneously, which might bring additional burden to gNB.  In our mind, the RAN2 impacts are indicated as follows:   * For option1, i.e. TA-based solution   1. PDC at gNB:      + Potential UL reference signal configuration      + Up to gNB implementation to pre-compensate for the PD, i.e., tune the ReferecetimeInfo IE transmitted to UE.   2. PDC at UE (TA-based):      + UL transmission configuration      + Potential finer PDC accuracy * For option2, i.e. RX-TX based solution   1. PDC at gNB(assuming the PDC is also calculated at gNB):      + UL/DL RS configuration and relationship configuration.      + The calculation of RX-TX time difference at UE/gNB.      + The mechanism on UE report of UE RX-TX time difference.      + Up to gNB implementation to pre-compensate for the PD, i.e., tune the ReferecetimeInfo IE transmitted to UE.   2. PDC at UE (assuming the PDC is also calculated at UE)      + UL/DL RS configuration and relationship configuration.      + The calculation of RX-TX time difference at UE/gNB.   The mechanism on gNB RX-TX time difference indication. |
| CATT | We share Nokia’s view that, when needed, the PDC estimation and compensation should be performed in the UE. However, for cases where it is not needed (e.g. in some deployments of the control-to-control scenario) gNB should indicate the UE not to do PDC for TSN time-sync purpose. |
| Samsung | UE should perform PDC. gNB should indicate a proper value to be used for PDC, e.g. TA or other message.  Considering reference time broadcast by SIB, UE side compensation is necessary. gNB’s compensation could be additional thing. But we think duplicate functionality is not necessary. |
| LG | We think PD is estimated at gNB and PD is compensated at UE. In addition, UE can send a PD update request. |
| vivo | In R16, it has been agreed that UE can perform PDC-based on implementation. It is better to adopt UE-based PDC to align with R16. Moreover, considering that the NW based propagation delay compensation is not feasible for providing the *ReferecetimeInfo* IE to UE by broadcast, we prefer the UE-based PDC solution.  As RAN1 is studying the details of PD, RAN2 can wait for more inputs from RAN1. |
| MediaTek | RAN1 are evaluating PDC options over the Uu, and this discussion should be taking place there.  From an accuracy perspective, the ideal node to perform PDC is the gNB. If the UE is to perform PDC, it can only do so after being provided PD estimations from the gNB (such as an enhanced TA, or from new RX/TX signaling). The provision of the PD estimate to the UE introduces another source of error, both from its signaling accuracy as well as from the delay between 5GS time provision and PD estimate provision. Performing PDC at the gNB avoids these issues leading to a significantly more accurate PDC method.  The expected RAN2 impact would be new signaling to prevent UE from performing R16 PDC. This would have a minor RAN2 impact, as it would be one-shot signaling as listed out under Q29 (Options 2/3). |
| Ericsson | On PD estimation: Both UE and gNB shall be involved in the estimation.   1. TA-based solutions: UE tracks DL transmissions and adjusts UL transmission timing based on received TA commands. gNB tracks UL transmissions and issues TA commands. 2. RTT-based solutions: Both UE and gNB calculate Rx-Tx time difference.   On PD compensation:   1. For TA-based solutions, gNB sends TA commands and UE has all relevant information to compensate on its own and so it should be that UE compensate. From the received TA commands, UE knows the time difference between DL frame and UL frame. The half of the time difference is the propagation delay. 2. For RTT-based solutions, neither node can perform the compensation on its own since the Rx-Tx time difference needs to be transmitted from one node to the other. More technical discussions are needed on the pros/cons for compensating at UE or gNB, but it should happen after RAN1 agrees to go with this solution based on the Uu interface budget provided by RAN2.   RAN2 impacts:   1. TA-based methods:    1. RRC configuration related (provided by RAN1): specific reference signals (such as SRS) to assist gNB to estimate the uplink timing more accurately.    2. MAC procedure related: Fine tune the timing advance command (in RAR and in MAC CE) to cater PD compensation purpose, e.g., a finer command granularity and only TA commands PCell are considered, and etc. 2. RTT-based methods:    1. RRC configuration related (provided by RAN1): Reference signals (such as SRS for UL, CSI-RS for DL) to assist Rx-Tx measurements. 3. Switch on/off PD compensation at UE: Network can explicitly indicate so in RRC. It can also be implicitly switched-on if network provides specific PD compensation-oriented reference signals or sends new TA commands (e.g., a finer granularity TA MAC CE)   On “UE triggers”:  RAN2 agreed in RAN2#110-e that   * UE can calculate/predict the reference timing based on DL timing information after receiving the referenceTimeInfo from gNB once. (No spec impact)   The PD compensation is needed when gNB provides a reference time and after that, UE can track the reference timing. In other words, there is no need for UE to trigger. |

The options on how to estimate and compensate PDC are multifold. In RAN2 #111e, we have identified a list of options:

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| *The follows are the main approaches need to be re-evaluated and down-selected in R17:*  *- Option 1a: Leave this up to UE implementation and do not specify any enhancements.*  *- Option 1b: Leave this up to UE implementation but specify finer granularity of TA command to assist the UE calculation.*  *- Option 2a: Specify in the specifications propagation delay compensation based on TA command (no TA granularity enhancements).*  *- Option 2b: Specify in the specifications propagation delay compensation based on TA command and enhance TA granularity.*  *- Option 3: Perform pre-compensation on the network side (up to network implementation) and add the indication in the network to UE signalling that the time information was pre-compensated.*  *- Option 4: reuse some aspects of the positioning framework timing difference measurements for propagation delay compensation* |

Similarly, RAN1 has agreed the following for further evaluations:

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| **Agreements:**  The following options for propagation delay compensation are further studied in RAN1   * **Option 1**: TA-based propagation delay   + **Option 1a**: Propagation delay estimation based on legacy Timing advance (potentially with enhanced TA indication granularity).   + **Option 1b**: Propagation delay estimation based on timing advanced enhanced for time synchronization (as 1a but with updated RAN4 requirements to TA adjustment error and Te)   + **Option 1c:** Propagation delay estimation based on a new dedicated signaling with finer delay compensation granularity (Separated signaling from TA so that TA procedure is not affected) * **Option 2**: RTT based delay compensation:   + Propagation delay estimation based on an RAN managed Rx-Tx procedure intended for time synchronization (FFS to expand or separate procedure/signaling to positioning). |

From the rapporteur point of view, the options provided by RAN1 can pretty much replace the list of options identified in RAN2. Considering that RAN1’s list is officially agreed, it is suggested we proceed our discussions based on the options identified in RAN1 (unless otherwise specified).

**Question 24: Do you agree to use RAN1 agreed options as a basis for further evaluation in RAN2? If not, please indicate which options to further include.**

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| **Company** | **Yes/No** | **Comments** |
| Nokia | Yes |  |
| Fujitsu | Yes |  |
| Xiaomi | Yes |  |
| Intel | Yes, with comment | We agree with the options agreed in RAN1, however, we would like to add the option “*Perform pre-compensation on the network side (up to network implementation) and add the indication in the network to UE signalling that the time information was pre-compensated.*” from RAN2 to the list of options. |
| Huawei | Not really | Network pre-compensation should be included. |
| NTTDOCOMO | Yes, with comment | Agree with Intel. |
| OPPO | Not really | Agree with Intel and Huawei intention. |
| CATT | Yes | We see no need to re-discuss RAN1’s agreements. As for the pre-compensation on the network side, it would be left to NW implementation and in this case the UE would be told not to perform any PDC so we don't see that it contradicts the current RAN1’s options. |
| Samsung | Yes | We don’t see pre-compensation is necessary. Pre-compensation is applicable only for broadcast delivery. We prefer to have a common mechanism for both broadcast and unicast. |
| LG | Yes |  |
| vivo | Yes |  |
| MediaTek | Not really | Agree with others that Option 3 as earlier identified by RAN2, i.e. ‘*Perform pre-compensation on the network side (up to network implementation) and add the indication in the network to UE signalling that the time information was pre-compensated*’ should be included |
| Ericsson | Yes | The options proposed in various RAN2 papers are signalling details to support the two options in RAN1.  What matters now is that RAN2 provides Uu interface budget for RAN1 and RAN1 picks one option to meet the target. Afterwards, RAN2 can work out the signalling details for that option. |

Related to the assumptions on the Uu interface from Phase-1 it was briefly discussed whether propagation delay compensation is needed in all the considered scenario and whether it is needed at all times. It is clear that propagation delay compensation is needed for scenario 3 (smart grid), but it is still questionable if we should do PDC in scenario 1 and 2 as well.

**Question 25: Is propagation delay compensation always needed for scenario 1 and 2?**

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| **Company** | **Yes/No** | **Comments** |
| Nokia | No | As argued by several companies in Phase-1, many different deployment (single-gNB, multi-gNB, multi-DU/TRP) can be considered for scenario 1 and 2. Additionally the need for PDC might be different in different cells if these are having different cell sizes.  For this reason, the propagation delay compensation needs to be a gNB managed on the conditions on when the PDC is executed on the UE.  As mentioned earlier, PDC only improve the time synchronization accuracy when the PD is above a certain (configuration specific threshold). In scenario 2, PDC is only improving the time synchronization accuracy when the respective propagation delay the involved UEs is sufficiently different. |
| Fujitsu | No | As discussed in Q28, PDC control by NW can be considered. However, RAN1 is carrying on the discussion on the details of PD as in the LS R1-2007446. Fujitsu want to wait for the RAN1 progress. |
| Xiaomi | No | Agree with Nokia. |
| Intel | See comment | Detailed analysis is required before concluding this point. It would also depend on the ISD to be agreed upon in RAN1. For now, propagation delay compensation should not be precluded for control-to-control scenario. |
| Huawei | No for scenario 1. Yes for scenario 2 | For small cell deployment, propagation delay compensation may be not needed for scenario 1, e.g. inter-site distance is less than 200m. The gNB can evaluate and control whether propagation delay compensation is needed for a UE.  For scenario 2, the synchronization error budget for Uu interface can be as low as 235ns. Even in quite small cell deployment scenario, the propagation delay compensation is still needed. We think propagation delay compensation is always needed for scenario 2. We understand the main purpose of so called “propagation delay compensation” is to reduce synchronization error between the “master clock” and “client clock”. |
| NTTDOCOMO | No | For scenario1, it depends on the size of service area. (i.e. ISD<200m, no PDC is needed). For scenario2, the requirement (for which no PDC is needed) should be more strict. |
| OPPO | No | Whether or not propagation delay compensation is needed depends on the cell deployment pattern and the synchronization requirements. At lease we can see propagation delay compensation is not always needed for Scenario 1. For scenario 2, further analysis is needed. No need to make conclusion so soon. |
| CATT | No | As discussed in Phase 1, for the control-to-control scenario, deployments would typically involve multiple gNBs/DUs/TRPs to cover an indoor factory scenario with small cell sizes. And below some size, the PDC is not needed. |
| Samsung | No, but | It is clear for some case, PDC may not be necessary. In our view, we don’t need to define when the PDC is necessary. From standardization perspective, we only need to define NW signaling option. Whether to use will be up to NW implementation. |
| LG | Yes | We prefer using PD compensation for scenario 1 and 2 as well.  PD compensation will be designed to satisfy the requirement and it can be used for scenario 1 and 2 in common. It is also considered that manual setting or additional signaling is required to turn PD compensation off if PD compensation is not used for scenario 1 and 2. |
| vivo | No | Agree with Nokia. |
| MediaTek | No | For certain cell sizes, PDC may not be needed.  This is an additional reason why PDC should be done by the NW, as it easily leaves to NW implementation, the deployments and the UEs to which PDC is applied to, before reference time is provided to the UE. |
| Ericsson | Leave for RAN1 and remove Scenario 1 | RAN2 will provide a Uu interface budget to RAN1 and propagation delay compensation is done at the Uu interface. RAN1 will definitely discuss this in detail, along with other evaluation assumptions, such as the cell size and the performance with and without propagation delay compensation, and etc. For the sake of avoiding duplicate work, RAN2 should leave this for RAN1.  Lastly, we want to emphasize again that Scenario 1 must be removed in the reply LS to RAN1. |

The next three questions target to collect views regarding the options that should be considered for each scenario, given the Uu interface budget calculations from Phase-1.

**Question 26: Based on the budget calculations from Phase 1, which options do companies think should be further considered as candidates for PD estimation in Rel-17 for scenario 1? Please also comment on pros and cons among different options.**

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| **Company** | **Preferred Option(s) for Scenario 1** | **Comments** |
| Nokia | Option 1a | Assuming that we use the Uu interface time synchronization budget calculation as proposed in Question 15 and the device and network part budget ranges from Question 17 and 19, we can reach the following Uu interface budget:  Uu budget = 900ns – Device – Network scenario1 = 900ns-[50;100]ns-([160;200]ns+5ns) = [595;685]ns  Given this budget it our analysis suggests that Timing Advance based PD compensation in most cases is still able to provide the desired accuracy, even without enhancements such as a finer TA-C granularity. Obviously the benefit of Option 1a is that minimum specification effort is needed, whereas the drawback if it is the high effort if enhancements are needed in future releases of NR. |
| Fujitsu | Option 1a | With the current TA granularity of TA, Option 1a can work. Specifically, the current TA granularity is about 520ns (SCS=15KHz), 260ns (SCS=30KHz), 130ns (SCS=60KHz) and so on. |
| Xiaomi | Option 1 | We think that all sub-options of Option 1 have similar impacts in RAN2, but the impacts/complexity on RAN1 and RAN4 and the performance might be quite different. We could wait for the further input from RAN1 after RAN1 has done its evaluation of each solution. Not sure that RAN2 should rush to a final decision. |
| Intel | See comment | Timing synchronization analysis needs to be concluded in RAN2 and RAN1 before finalizing the suitable option for this scenario. |
| Huawei | Option 1a | It is noted that scenario 1 is a DL synchronization scenario, which has been evaluated and discussed in Rel-16. In Rel-16, RAN1 evaluates that the Uu synchronization error for DL synchronization scenario is up to 540ns when TA based PD compensation is assumed. As analyzed above by Nokia, the Uu budget for scenario 1 is [595;685]ns, which is larger than 540ns. Thus TA based PD compensation even without enhanced TA indication granularity can fulfil the synchronization requirement of scenario 1.  Based on this, Option 1a is preferred for scenario 1, since it has less specification impacts compared with other options. |
| NTTDOCOMO | Option1a | Option1a is simple, while other options with finer PDC granularity are not excluded. |
| OPPO | Option 1a | The uu time synchronization requirement is not as high as scenario 2. We can just take Option 1a as baseline as it requires the minimum specification effort. |
| CATT | Option 1a / RAN1 | Option 1a seems sufficient for this case although if finer accuracy is needed for scenario 2 and Option 1b is selected, scenario 1 should of course be able to benefit from it. In any case, RAN1 tells us in their LS they are currently studying these options and we should let them conclude their evaluation first, thus avoiding contradicting decisions in RAN1/RAN2. |
| Samsung | Option 1 (a/b/c) | The detail (feasibility) should be discussed in RAN. Also, we prefer to have a common mechanism irrespective of any particular scenario. |
| LG | Option 1c, option 2 | For scenario 1 option 1a (legacy TA) can satisfy the requirement based on the evaluation performed in Rel-16. However, considering scenario 2 and applying a common method, option 1c is preferred and option 2 can be considered for scenario 1. Please refer to our comment of Q27. |
| vivo | Option 1a | As mentioned by Nokia, the Uu budget = 900ns – Device – Network scenario1 = 900ns-[50;100]ns-([160;200]ns+5ns) = [595;685]ns based on the phase1 discussion.  In R16, RAN1 has concluded that a timing synchronization error between a gNB and a UE is no worse than 540ns. Thus Option 1a should be enough for scenario 1. |
| MediaTek | Option 3/RAN1 | NW based PDC, i.e. Option 3, is clearly the ideal solution due to the following advantages of this option over UE-based Options 1 and 2:   * There are no issues related to PD signaling accuracy * No new errors in PDC introduced due to delay between 5GS time delivery and PD estimate delivery * Limited 3GPP impact * NW implementation accurately controls which scenario and UEs PDC applies to   The only disadvantage of Option 3 is that unicast time delivery is needed (i.e. not broadcast). However as both Options 1 and 2 require unicast signaling of a ‘PD estimate’ to each UE, this disadvantage cannot be considered a valid argument.  We also note that RAN1 are evaluating Uu time delivery accuracy and are ok to wait for the conclusion of their deliberations, before deciding on a solution. |
| Ericsson | Option 1c or Option 2 | We agree with Nokia’s calculation on the Uu interface budget of [595;685] ns.  But, we want to emphasize that fragmented solutions are not good for the eco-system and only one needs to be specified. Per the answer to the Question 27 below, either Option 1c or Option 2 is needed, and we prefer to use either of them to address Scenario 1. |

**Question 27: Based on the budget calculations from Phase 1, which options do companies think should be further considered as candidates for PD estimation in Rel-17 for scenario 2? Please also comment on pros and cons among different options.**

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| **Company** | **Preferred Option(s) for Scenario 2** | **Comments** |
| Nokia | Option 1a and 2 | For scenario 2, assuming yes in Question 15, 17 and 19, we get the following single Uu interface budget:  Uu budget = (900ns – 2xDevice – 2xNetwork scenario2)/2 = (900-2\*[50;100]-2\*([160;200]ns+5ns)) = 0,5\*(900-[430;610]) = [145; 235]ns  With this in mind, it remains to be seen in this can be achieved with Option 1a and in that case we prefer Option 2. However, we note that there will be deployments where the actual single Uu interface achieved accuracy is much better than the budget determined above (e.g. when the involved UEs are served by the same gNB), or the number of hops for the 5GM to the gNB is smaller. Due to this, we suggest that both option 1a and 2 are supported for scenario 2. |
| Fujitsu | Options 1b | The value of [145; 235] ns is finer TA granularity than current TA granularity. Therefore, fine TA granularity seems to be needed. However, Fujitsu want to wait for RAN1 progress. |
| Xiaomi | Option 1 | Same as Question 26. |
| Intel | See comment | Same as Question 26. Timing synchronization analysis needs to be concluded in RAN2 and RAN1 before finalizing the suitable option for this scenario. |
| Huawei | Option 1b (without enhancement for TA indication granularity) + Option 1c | For scenario 2, the error budget for Uu interface, e.g. [145; 235]ns, is much less than that of scenario 1. Propagation delay compensation based on legacy Timing advance without enhanced TA indication granularity cannot satisfy the synchronization error budget for Uu interface of scenario 2. However relying only on option 1a or option 1c may be still difficult to fulfil the Uu error budget, since the error reduction from TA indication granularity enhancement is at most 130ns. With the error from TA indication granularity is completely eliminated, the Uu error budget as low as 235ns is difficult to satisfy.  It is not clear whether option 1b shall always be based on option 1a, e.g. PD estimation shall be based on Timing Advance (with or without TA enhancement for indication granularity). From our perspective, we think option 1b can also be performed without TA enhancement for indication granularity, e.g. based on updated RAN4 requirements to TA adjustment error and Te, as well as PD estimation based on a new dedicated signaling (as in option 1c). Potential solutions for scenario 2 can be option 1a+1b, option 1c+1b, option 2, and network pre-compensation (potentially combined with option 1b updated RAN4 requirement).  For option 1a+1b, legacy TA procedure will be affected. Thus option 1c+1b can be preferred since it doesn’t affect the legacy TA procedure but can avoid the sync error incurred due to a delay compensation indication granularity. The reduction of sync error from option 1b shall still be evaluated by RAN4.  For option 2, propagation delay estimation relies on a reference signaling. For DL, if positioning reference signaling is used, IIoT synchronization service depends on positioning mechanism, which is not preferred since positioning and IIoT may not be supported in the same area simultaneously. If a separate signaling is used, additional reference signaling and related Rx-Tx procedure shall be designed, which may require great specification effort. Such reference signaling may bring also the resource efficiency and power consumption concern for the UE and the gNB.  Based on above consideration, our preferred solution for scenario 2 is option 1b (without enhancement for TA indication granularity) + option 1c. |
| NTTDOCOMO | Option1b/1c | Since the error budget for Uu interface for senario2 is less than scenario1, higher PDC granularity is needed. For Option2, more input from RAN1 is preferable in terms of the positioning accuracy, positioning latency and any extra positioning reference signals needed or not (e.g. PRS, SRS) |
| OPPO | Option 1a as baseline | The strictest requirement is scenario 2: Uu budget = (900ns – 2xDevice – 2xNetwork scenario2)/2 = (900ns-2\*[50:100]ns -2\*({160,200}+5ns))/2 = [185:235] ns or [145:195] ns.  In our opinion, we can take Option 1a as baseline. If analysis demonstrates that Option 1a, even though further optimization of the granularity, cannot satisfy the requirement, then we can apply options 1c or option 2 |
| CATT | Option 1b / RAN1 | The current TA granularity is larger than the Uu timing error budget for scenario 2 which calls for some improved mechanism, e.g. Option 1b. However, similar to Q26, we prefer to let RAN1 complete their evaluations and associated conclusions first. |
| Samsung | Option 1 (a/b/c) | The detail (feasibility) should be discussed in RAN. Also, we prefer to have a common mechanism irrespective of any particular scenario. |
| LG | Option 1c, option 2 | With the legacy TA granularity which contributes 130ns to sync inaccuracy, it seems not to satisfy the requirement considering the above-mentioned network part accuracy budget. UE needs finer PD values to compensate PD precisely and we prefer option 1c (a new dedicated signaling with finer delay compensation granularity). In addition, if PD can be estimated more precisely by option 2, option 2 can be considered to provide more accurate PD update information along with finer PD granularity. |
| vivo | Option 1 | Option 1a is enough for scenario 1, no need to introduce different mechanism (i.e. Option 2) for scenario 2.  From RAN2’ perspective, we prefer a unified solution to handle the propagation delay compensation for all scenarios. Thus, Option 1 is a better choice. However, the final conclusion needs RAN1’ input as they are also working on the same issue. |
| MediaTek | Option 3/RAN 1 | For the same reasons as highlighted in Q26 |
| Ericsson | Option 1c or Option 2 | We agree with Nokia’s calculation on the Uu interface budget of [145; 235] ns.  According to TR 38.825, the legacy TA based method can achieve ±540 ns accuracy with 15 kHz SCS. The inaccuracy due to TA granularity is ± 260ns with 15 kHz SCS. Even if the inaccuracy due to TA is removed (which leads to ± 280ns), the target cannot be met. Additionally, for Option 1a, the current RAN4 requirement targets at data transmission and has not considered synchronization services. It is not reasonable to simply enhance the TA granularity (which was designed for data transmission) without changing the RAN4 requirement to cater for synchronization services.  In Option 1b and Option 1c, a finer TA command granularity is used and RAN4 requirements are expected to be updated. But, Option 1c is one step further compared to option 1b, in the sense that specific reference signals (such as SRS) are configured to assist gNB to estimate the uplink timing more accurately. This is also beneficial to decouple from the legacy TA procedure for data transmission and the synchronization services do not put tighter requirement on other UL transmissions like PUSCH, PUCCH, SRC, RACH and etc.  In summary, among the sub-options in Option 1, Ericsson prefers Option 1c.  Option 2 is also acceptable, if TA-based methods cannot be enhanced to meet the target.  Lastly, we would like to reiterate that the decision should be taken by RAN1. What matters at the moment is to provide the Uu budget to RAN1. |

**Question 28: Based on the budget calculations from Phase 1, which options do companies think should be further considered as candidates for PD estimation in Rel-17 for scenario 3? Please also comment on pros and cons among different options.**

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| **Company** | **Preferred Option(s) for Scenario 3** | **Comments** |
| Nokia | Option 1a and 2 | In scenario 3 is it clear that PDC is needed. Assuming that we use the Uu interface time synchronization budget calculation as proposed in Question 15 and the device and network part budget ranges from Question 17 and 19, we can reach the following Uu interface budget:  Uu budget = 1000ns – Device – Network scenario3 = 1000ns-[50;100]ns-(100ns+5ns) = [795;845]ns  Given this budget, Option 1a will be sufficiently accuracy as a PD estimation technique. However, we are not excluding option 2, as an alternative / supplementary option for PD estimation in this scenario. |
| Fujitsu | Option 1a | With the current TA granularity of TA, Option 1a can work. |
| Xiaomi | Option 1 | Same as Question 26. |
| Intel | See comment | Same as Question 26. Timing synchronization analysis needs to be concluded in RAN2 and RAN1 before finalizing the suitable option for this scenario. |
| Huawei | Option 1a | Scenario 3 is also a DL synchronization scenario, which belongs to the target scenario evaluated and discussed in Rel-16. In Rel-16, RAN1 evaluates that the Uu synchronization error for DL synchronization scenario is up to 540ns when TA based PD compensation is adopted. As analyzed above by Nokia, the Uu budget for scenario 1 is [795;845]ns, which is larger than 540ns. TA based PD compensation even without enhanced TA indication granularity can fulfil the synchronization requirement of scenario 3. Thus, option 1a is preferred for scenario 3 since it has less specification impacts. |
| NTTDOCOMO | Option 1a | Since Option1 is workable with current TA granularity. |
| OPPO | Ooption 1a | Agree with Nokia |
| CATT | Option 1a / RAN1 | Option 1a seems sufficient to meet the Uu timing error budget for scenario 3, but here again, same as Q26/27, we prefer to leave this decision to RAN1, provided that it falls in RAN1 domain and they are already studying it. |
| Samsung | Option 1 (a/b/c) | The detail (feasibility) should be discussed in RAN. Also, we prefer to have a common mechanism irrespective of any particular scenario. |
| LG | Option 1c, option 2 | For scenario 3 option 1a (legacy TA) can satisfy the requirement based on the evaluation performed in Rel-16. However, considering scenario 2 and applying a common method, option 1c is preferred and option 2 can be considered for scenario 3. Please refer to our comment of Q27. |
| vivo | Option 1 | Same comments in Q27. |
| MediaTek | Option 3/RAN 1 | For the same reasons as highlighted in Q26 |
| Ericsson | Option 1c or Option 2 | We agree with Nokia’s calculation that Uu interface budget is [795;845]ns.  We have the same comment as above that fragmented solutions are not good for the eco-system and only one needs to be specified. Per the answer to the Question 27 below, either Option 1c or Option 2 is needed, and we prefer to use either of them to address Scenario 3. |

One essential part of robust propagation delay compensation that has been considered by RAN2 but was not covered by RAN1, is that the compensation should be conducted only once. Based on the papers submitted by companies to RAN2#111e, we may have the following options:

* Option 1: The gNB indicates to the UE whether it has done pre-compensation ([2], [10])
* Option 2: The gNB enables/disables UE-side PDC via an indication in unicast-RRC signal ([3])
* Option 3: The gNB enables/disables UE-side PDC via an indication in SIB ([8])
* Option 4: The gNB configures the UE with a PD threshold. The UE conducts PD compensation when the PD estimation is above the PD threshold ([12])
* Option 5: The UE requests a PD estimation update ([16])
* Option 6: Others

**Question 29: Which option should do you prefer to make sure PDC is only done once ?**

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| **Company** | **Preferred Option(s)** | **Comments** |
| Nokia | Option 4 (and 2).  Both can be benefited from Option 5. | It is clear from studies in Rel-16 that PDC only brings an improvement in time synchronization accuracy, when the PD is sufficiently large. If not taken into account, the achieved time synchronization accuracy will be unnecessarily bad when the UE is close to the gNB, and the note conducting PD compensation is doing an unnecessary job. As mentioned earlier, it is our preference that the UE is the entity which conduct PDC, as we expect the PD to be UE specific, and only this option enables PDC along with a broadcasted referenceTimeInfo-r16 IE.  We would like to note that Option 4 can also resemble Option 2 (by not configuring the threshold or set it very high.  One option to ensure up-to-date PD estimations is to request periodic UL transmissions from the UE. The gNB might fit this periodicity to the UE movement characteristics and UE modem oscillator drift. The drawback is that this is easily resulting in a too frequent updates, to ensure that the target accuracy is met. In some cases, the UE can have a relatively good estimation on the change of PD, and hence it can indicate to the gNB (in e.g. UEAssistanceInformation) when it believes that a PD update is needed (i.e. Option 5), and even indicate the desired periodicity – potentially saving a few unnecessary PD updates.  Therefore, we prefer Option 4 (which can equivalently enable Option 2 as well) along with Option 5. |
| Fujitsu | TBD | RAN1 is carrying on the discussion on the details of PD as in the LS R1-2007446. Fujitsu want to wait for the RAN1 progress. |
| Xiaomi |  | No strong view. We consider that Option 1-4 could be unified as a single solution, as the value of threshold in Option 4 can also include disable/enable PDC and the configuration of Option 4 can be also sent via either SIB/dedicated RRC.  The use cases of Option 5 should be further clarified. |
| Intel | Option 1 | We think Option 2 and Option 1 are similar. For Option 1, default assumption can be that the PDC is enabled at the UE end, however, in the scenario where network has performed PDC, the gNB can indicate to the UE via RRC signaling to avoid double compensation. Therefore, for Option 1, gNB only disables UE-side PDC assuming it is otherwise enabled. |
| Huawei | Option 2 | Option 2 is the most straightforward method to control UE whether PD compensation shall be conducted or not. Option 2 is preferred over option 3, since unicast RRC signal is flexible to implement UE specific control instead of cell level control. |
| NTTDOCOMO | Option 4 | We believe PDC is needed only when PD is large enough, and the timing for PD compensation to be controlled by UE is easier and more flexible (especially considering mobility case), which also can avoid too much explicit PDC indication signaling from the network. |
| OPPO | Option 1,2,3 4 | As already explained before, we are open to both choices: PDC implementation at gNB or UE. If the gNB has already done PDC, it could indicate to UE to avoid excessive PDC job.  Meanwhile, we admit that PDC might be not needed at both UE and gNB, when the distance between UE and gNB is lower than a certain threshold. In such cases, gNB could indicate to UE that PDC at UE side is not needed. |
| CATT | Options 2/3 | Option 3 is the simplest approach for small enough cells not requiring any PDC. Option 2 would allow sending the indication only to UEs requiring TSN time sync and which are far enough from the gNB so that PDC is required. With Option 2, we don’t need Option 4 since we think gNB can estimate by itself at which point a UE needs/does not need to perform PDC. Similarly, Option 5 is not needed as gNB can already estimate how often it needs to refresh its TA estimation for a given UE and configure SRS transmissions accordingly. |
| Samsung | Option 5  TBD for other options | Agree with Xiaomi that Option 1-4 are unified as one option that gNB controls whether UE performs PDC. Also, it is not clear whether Options 1-4 assume gNB’s pre-compensation or not.  We think whether to perform PDCP only once should depend on UE’s mobility. So, at least Option 5 seems necessary. |
| LG | Option 5 | We think that PD compensation needs to be performed when PD changes more than a threshold (e.g. PD granularity) and NW can send PD information to UE for PD compensation properly. UE can assist NW in sending a PD update on time by requesting it. |
| vivo | prefer Option 4 | We prefer Option 4.  As we mentioned earlier, our preference is UE based propagation delay compensation, as NW based propagation delay compensation is not feasible for providing the *ReferecetimeInfo* IE to UE by broadcast. |
| MediaTek | Options 1/2/3 | We prefer options 1, 2, or 3 which we see as equivalent. However it is too early to decide on this aspect before deciding on the PDC solution. |
| Ericsson | Option 2 | As answered in Question 23, network can explicitly indicate so in RRC. It can also be implicitly switched-on if network provides specific PD compensation-oriented reference signals or sends new TA commands (e.g., a finer granularity TA MAC CE). Anyhow, this is more stage-3 details and should be discussed later. |

Lastly, anything else that should be considered?

**Question 30: Anything else to consider in Phase-2?**

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| **Company** | **Comments** |
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# 4 Conclusions

TBD

# References

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[5] R2-2006701 Enhancements for support of time synchronization Ericsson

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[9] R2-2006864 Topics for time synchronization in IIoT Fujitsu

[10] R2-2007141 Consideration of TSN time synchronization enhancements OPPO

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[13] R2-2007475 Considerations on time synchronization enhancement Lenovo, Motorola Mobility

[14] R2-2007611 On propagation delay compensation MediaTek Inc.

[15] R2-2007627 Enhancements for support of time synchronization Sequans Communications

[16] R2-2008033 Discussion on support of time synchronization LG Electronics Inc.

[17] R2-2008059 Enhancements for Timing Synchronization Samsung