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:

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

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 | NoWe 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 | NoRAN1 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 |
|  |  |

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.

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

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Figure . 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. |
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## 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.



Figure . 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 | YesWe 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 | PartiallyOn 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 | YesFujitsu 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.
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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.**

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| **Company** | **Comments** |
| Nokia | YesWe 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 | NoIt 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 | NoFor 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 ±400ns is applied.
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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?**

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| **Company** | **Comments** |
| Nokia | NoWe 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 | YesFor 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.  |
|  |  |

## 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?**

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| --- | --- |
| **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. |
|  |  |

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

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| --- | --- |
| **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 baselineDevice budget for Scenario 2 = 2\*X [ns], where X= ±40ns can be the baselineDevice 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. |
|  |  |

## 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?**

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| --- | --- |
| **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 generatedIn 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 generatedFor 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)= 695nsUu budget in Scenario 2 = (900ns – 2\*160ns (NW) – 2\*40ns (Device) – 2\*5ns (ranularity))/2= 245nsUu 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
 |
|  |  |

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?**

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| --- | --- |
| **Company** | **Comments** |
| Nokia | YesWe 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 |
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Moreover, according to RAN1 agreements, one and two Uu interfaces are considered for the control-to-control and smart grid use cases respectively.

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| --- |
| 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?**

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| --- | --- |
| **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. |
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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?**

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| **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 |
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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?**

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| --- | --- |
| **Company** | **Comments** |
| Nokia | YesHere we would assume that the TAE requirement given in 38.104 bounds the maximum synchronization error between any two any two antenna-connectors.  |
| Ericsson | NoMultiple 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 | YesWe 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. |
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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.**

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| --- | --- |
| **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. |

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

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| --- | --- |
| **Company** | **Comments** |
| Nokia | No |
| Qualcomm | No |
| Huawei | No |

# 3 Phase-2 Discussion: Options for Propagation Delay Compensation

TBD

# 4 Conclusions

TBD

# References

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[3] R2-2006922 Discussion on enhancements for support of propagation delay compensation for accurate time synchronization Nokia, Nokia Shanghai Bell

[4] R2-2006906 Propagation Delay Compensation for Reference Timing Delivery Qualcomm

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

[6] R2-2006635 Discussion on Time Synchronization in Rel-17 CATT

[7] R2-2006697 Discussion on enhancements for support of time synchronization Huawei, HiSilicon

[8] R2-2006831 Enhancements for time synchronization in TSN ZTE Corporation, Sanechips, China Southern Power Grid Co., Ltd

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

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

[11] R2-2007145 Discussion on the TSN enhancements vivo

[12] R2-2007294 Discussion on uplink time synchronization for TSN NTT DOCOMO INC.

[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