3GPP TSG-RAN WG2 #113-e Tdoc R2-210xxxx

**Electronic meeting, Jan 25th – Feb 5th, 2021**

Agenda Item: 8.5.2

Source: Ericsson

Title: Summary on Enhancements for support of time synchronization (8.5.2)

Document for: Discussion, Decision

# 1 Introduction

This paper presents a summary of the submitted papers in the Agenda Item 8.5.2, see the list of the papers in the section 4 references. The agreements from the previous meetings can be found in the section 5.

# 2 Discussion

## 2.1 Mobility issue

### 2.1.1 On the need to transfer reference time between gNBs

[5][12][18][21] propose to transfer the reference time between the source gNB and the target gNB, more specifically the reference time is delivered from the target gNB to the source gNB and the source gNB transmits it in the handover command. The assumption is that the source gNB and the target gNB shares a different clock or there are significant timing errors between the two clocks:

* [5] states that the maximum absolute time error between the TSN GM clock and the gNB can be with an absolute of 100 ns and the worse-case timing difference between different gNBs is 200 ns and thus not negligible.
* [21] states that the gNBs involved in TSN are not synchronized with each other in terms of system frame number (SFN) and timing of system frame boundary, and thus in the target cell, UE needs the reference time information indicating the time at the system frame boundary of the target cell and the PD information from the target cell to the UE.

On the other hand, [2][3][4][8][9][16] do not think there is a need, mainly based on the below observations:

* There is no UE clock drift issue.
* The source gNB and the target gNB clock are tightly synchronized to the same master clock.

Assumption #1: UE clock drift

At RAN2#110-e the following was agreed in Rel-16 discussion:

|  |
| --- |
| * UE can calculate/predict the reference timing based on DL timing information after receiving the referenceTimeInfo from gNB once. (No spec impact)
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In addition, [2][8][16] mention that, as a RAN4 requirement specified in TS 38.101, UE clock is locked to DL frequency with at least ±0.1 PPM precision, which means (from these submitted paper) e.g., +/- 1ns timing drift over 10ms, a refresh time of 1s is sufficient to remain within the 1 µs accuracy, network needs to deliver the reference time at most every 5s. Moreover, [9] assumes a clock drift from 0.3 to 0.8 ppm / second and an interruption time up-to 88 ms, and concludes that the inaccuracy is below 50 ns (i.e., not of a concern for the Uu sync target).

Assumption #2: Clock synchronization between gNBs

[3][16] state that all gNBs are synchronized to the same master clock as it is specified in RRC spec (i.e., the IE ReferenceTimeInfo contains timing information for 5G internal system clock and not an arbitrary clock), and thus there is no difference regarding whether the 5G reference time is delivered from the source gNB or from the target gNB. [4] expresses a similar view but with the argument that the case when it is not synchronized may be out of the WI scope.

From the submitted papers, rapporteur believe that the differences among the proposals lie in the two above assumptions. They were discussed in Rel-16 with some common understandings, but no formal agreements were documented. Rapporteur proposes to discuss the two proposals first to have a common understanding:

1. RAN2 to discuss if there is a UE clock drift issue.
2. RAN2 to discuss if the source and the target gNB are tightly synchronized to the same master clock.

Once the above proposals are discussed, RAN2 can further discuss the below proposal:

1. RAN2 to discuss the need to transfer reference time between gNBs.

Another relevant issue is the need to indicate the reference time delivery periodicity to the gNB via the UEAssistanceInformation message from the UE [5][9]. The reasoning is that the UE may not choose to track DL frame timing and since the clock drift performance may be different for different UEs, it’s hard for network to select a suitable periodicity value for all the UEs. Recall that this issue was discussed in Rel-16 but not agreed. In addition, this is related with the above discussion on UE clock drift and rapporteur proposes to discuss the below proposal after a conclusion is reached on Proposal 1 and Proposal 2:

1. RAN2 to discuss the need for a UE to indicate the reference time delivery periodicity to the gNB

### 2.1.2 On the need to transfer UE’s need for reference time between gNBs

These papers [1][3][7][8][9][11] have discussed this issue.

[3] proposes that it is beneficial for the target gNB to know a UE needs reference time delivery from the source gNB asap, but the detailed signalling (if needed) is handled by RAN3. The reasoning is that the network *periodically* refreshes reference time and there is a non-zero interruption time at handover (e.g., due to implementation-related target cell preparation time) which means DAPS is not feasible when considering RRC-unicast based reference time delivery during handover. Thus, the network needs to increase the priority of reference time refresh upon completing handover and this results in an increased signalling overhead.

[7] acknowledges the need but points out that this is possible already if UE has requested reference time delivery by UEAssistanceInformation which is included in the Handover Request message. This view is mentioned in [1][11], but it is not clear if they acknowledge the need. On the other hand, [3] mentions that this approach is only feasible if UE supports and sends reference time request in UEAssistanceInformation (which is not true for all UEs in all deployments).

Lastly, [8][9] propose that there is no need. [8] proposes that the source gNB can provide reference time information to UE proactively, e.g., when deciding to perform handover, enabling the target gNB to be synchronized to the 5GS within several seconds after handover such that the synchronization requirement can be satisfied. [9] has analysed that even with the worst-case interruption of up-to 100 milliseconds, the inaccuracy is below 50 ns assuming an oscillator clock drift from 0.3 to 0.8 ppm / second.

To sum up, on if it is beneficial to transfer the need between gNBs, some ([3][7]) support, some do not support ([8][9]), and some ([1][11]) are unclear. On the other hand, all papers agree that there are no RAN2 spec impacts. Rapporteur proposes to discuss the need as it may have RAN3 impacts, and confirm that there is no RAN2 spec impact.

1. RAN2 to discuss if it is beneficial to transfer to the target gNB from the source gNB that the UE needs reference time delivery.
2. RAN2 to confirm that there is no RAN2 spec impacts to support the transfer of UE’s need for reference time between gNBs.

### 2.1.3. gPTP message interruption

[2][9][16] discuss the issue on gPTP message, which is transmitted as user plane data on DRBs. Note that the 5G reference time is transmitted on RRC-unicast message and SIB9. [2] proposes to use DAPS, and it is rapporteur’s understanding DAPS is configurable for DRB and applicable for gPTP message. [16] mentions that the gPTP signalling interruption time is internal to the 5GS and will be considered as the part of the maximum residence time requirement. [9][16] also point out that the default sync message periodicity from 802.1AS is 125ms, which is longer than a typical handover interruption time.

Since there were no other companies that have expressed opposite views previously or in the papers submitted to this meeting, rapporteur proposes

1. gPTP message interruption during mobility is not considered in the Rel-17 IIoT WI.

## 2.2 Signalling details for Propagation Delay Compensation (PDC)

The following options for propagation delay compensation are 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).

It is agreed in RAN2 that:

10 It is up to RAN1 to decide which PDC options should be supported for Scenario 1, 2 and 3 in Release-17.

Some papers (e.g., [2][3][8][9][12]) propose to wait for RAN1 progress and afterwards, RAN2 starts to work on the signalling design for the chosen option. However, some papers have already expressed preferences

1. RTT-based: [10] argues that TA method (including enhanced TA) is hardly able to satisfy the synchronization budget requirement and proposes to have a RTT-based method that supports both periodical and event triggered UE Rx-Tx time difference measurements.
2. TA-based: [5][7][19] prefer using TA-based method with the arguments that it is simpler, has less specification efforts and may meet sync the requirement [19]. [5] discusses further signalling details for TA-method, e.g., UE needs to support performing PDC.
3. Non-legacy TA: [4] proposes that RAN2 should not introduce a PDC solution which changes the legacy TA procedure used for timing alignment of uplink.

Due to these diverse views and, more importantly, the agreement in the last meeting that the PDC option is up to RAN1 to decide, rapporteur proposes to not to treat this discussion in the meeting.

1. RAN2 to confirm which PDC option to choose is up-to RAN1 to decide.

[9] states that RAN2 can continue discussions on the signalling framework that is independent of the PD estimation technique. The following options were identified in the email discussion [23]:

|  |
| --- |
| * Option 1: The gNB indicates to the UE whether it has done pre-compensation
* Option 2: The gNB enables/disables UE-side PDC via an indication in unicast-RRC signal
* Option 3: The gNB enables/disables UE-side PDC via an indication in SIB
* 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
* Option 5: The UE requests a PD estimation update
* Option 6: Others
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In what follows, the views that have no particular mentioning of the PDC options are summarized. However, it is rapporteur’s understanding that the technical discussion on the pros/cons may vary depending on which PDC option is adopted.

Here is the summary on the configuration for Rel-17 PDC:

* gNB enables/disables UE-side PDC: [4][5][9][14] propose that RAN2 should support a method to enable/disable UE-side PDC if a UE-side PDC method is specified. Additionally, [9] proposes that for unicast, it is an explicit indication and [5] proposes an explicit enable/disable indication in SIB. On the other hand, [10] mentions that there is an additional delay/overhead in UE applying the PDC.
* UE request a PD estimation update: This is supported by [9][21], with the assumption that another PD compensation using the updated PD values may follow if the propagation delay is changed. In particular, [9] proposes a UE with a decent oscillator clock can detect a change on the DL frame timing and [21] mentions that the maximum propagation delay change during 1 second is about 100ns for UE moving at 108 km/h. On the other hand, [14] indicates that gNB can also estimate UE speed and see no clear benefits of this approach.
* gNB configures the UE with a threshold: [10] proposes that if the estimated PD is larger than the threshold, UE conduct the delay compensation autonomously. This approach is faster and has no additional signaling compared to explicit indication from the network. On the other hand, [14] indicates that if supporting a UE autonomous PDC enabling/disabling, ping-pong effect needs to be avoided and additional schemes are needed.

In Rel-16, RAN2 agreed that PDC may be done by UE implementation (assuming legacy TA-based method). In Rel-17, a new method will be specified to fulfil the more stringent requirements that can be placed on the accuracy/uncertainty of the PD value used to compensate the reference time. [15] proposes that once this new mechanism is agreed upon, it should be obvious that UE must be aware when PDC as defined for Rel-17 is to be used. Rapporteur understands that this is the common understanding from all the above cited papers and propose that:

1. gNB can inform UEs of whether the to-be-adopted PDC option is used or not.

There are followed-up detailed questions, e.g., whether this should be applied for unicast or broadcast message. Another example is whether the gNB can indicate to the UE whether it has done pre-compensation or not. This was controversial in Rel-16 and expected so as well in Rel-17. Only [17] express the view that gNB pre-compensation is not supported, while [13] seems to support that gNB pre-compensation is needed. It is also mentioned in [4] that the change in PD can be large enough to temporarily violate the Uu synchronization accuracy requirement. For instance, the UE can erroneously apply PDC with the PD estimate from the source gNB as it receives the reference time from the target gNB. It is proposed that RAN2 to discuss the procedure of maintaining PDC accuracy during handover. It is rapporteur’s understanding that the technical discussion can be coupled with the PDC option and it would become clearer with the chosen option. Rapporteur proposes to discuss further once the PDC option is chosen.

1. After PDC option is chosen, RAN2 to further discuss the details of the indication and other impacts.

Several papers mention that they prefer explicit indication over implicit indication. It is rapporteur’s understanding that this implicit indication refers to UE request for PD estimation update and UE autonomously compensate. As these questions are more related with the scenarios, requirements, overall approach with respect to the signalling overhead, rapporteur proposes to collect views on these options (the assumption here is that the PDC is supported on the UE-side) and down-select the options if possible:

1. For UE-side PDC (if supported), RAN2 to collect views and down-select the below options:
	* + gNB enable/disable UE-side PDC
		+ UE request a PD estimation update
		+ UE autonomously conduct PDC if a network-configured threshold is met
		+ Other options?

## 2.3 Others

gNB knowledge of the synchronization accuracy requirement:

[1][5][17] propose that there is a need for the gNB to know the synchronization accuracy requirement of a UE. The reasoning is that for some UEs the Rel-16 PDC methods (up-to UE implementation) are sufficient, while in some other UEs the Rel-17 PDC methods must be used. The information can be received from the 5GC [1], from higher layer to gNB [5] or be signalled from UE to gNB [17].

From rapporteur’s point of view, this is the first time this issue was brought up and proposes to further discuss.

1. RAN2 to further discuss the need of gNB knowing sync requirement of a UE.

Others:

The below proposals do not fit into any categorizations and RAN2 can discuss them if time allowed.

* [13] proposes that the procedure for determining the value used for PDC should be performed in close time proximity to the reference SFN associated with the indicated reference time. Rapporteur would like to point that in [23] it is agreed that RAN2 does not consider mismatch between PD estimation and PD compensation due to time difference.
* [6] proposes that (g)PTP message delivery be sent in a PTM manner and in RRC\_INACTIVE state as a small data transmission.
* [20] proposes RRC\_IDLE state and RRC\_INACTIVE state to be taken into account.

# 3. Conclusion

**Mobility issue**

Rapporteur believes that the differences among the proposals lie in assumptions for scenarios and thus rapporteur proposes to discuss the first two proposals to get a common understanding.

Proposal 1 RAN2 to discuss if there is a UE clock drift issue.

Proposal 2 RAN2 to discuss if the source and the target gNB are tightly synchronized to the same master clock.

If there are consensus for the above two proposals in the first session, RAN2 can discuss online the below four proposals; otherwise, they can be discussed in the email discussion.

Proposal 3 RAN2 to discuss the need to transfer reference time between gNBs.

Proposal 4 RAN2 to discuss the need for a UE to indicate the reference time delivery periodicity to the gNB

Proposal 5 RAN2 to discuss if it is beneficial to transfer to the target gNB from the source gNB that the UE needs reference time delivery.

Proposal 6 RAN2 to confirm that there is no RAN2 spec impacts to support the transfer of UE’s need for reference time between gNBs.

RAN2 can confirm online if the below proposal can be agreed; otherwise, it is moved to the email discussion.

Proposal 7 gPTP message interruption during mobility is not considered in the Rel-17 IIoT WI.

**Propagation delay compensation (PDC)**

In rapporteur’s understanding, the below proposal is agreed in the last meeting. However, there are numerous papers submitted, and so rapporteur propose to confirm this.

Proposal 8 RAN2 to confirm which PDC option to choose is up-to RAN1 to decide.

Rapporteur then proposes to discuss issues that are independent of the PDC option. The proposal 7 is a baseline and should be agreeable, while the proposal 8 is to confirm that the discussion on the details are postponed till PDC option is chosen.

Proposal 9 gNB can inform UEs of whether the to-be-adopted PDC option is used or not.

Proposal 10 After PDC option is chosen, RAN2 to further discuss the details of the indication and other impacts.

Rapporteur proposes to discuss the proposal 9 in the email discussion.

Proposal 11 For UE-side PDC, RAN2 to collect views and down-select the below options:

* + - gNB enable/disable UE-side PDC
		- UE request a PD estimation update
		- UE autonomously conduct PDC if a network-configured threshold is met
		- Other options?

**Others**

Lastly, rapporteur proposes to discuss the below proposal in the email discussion, as it is the first time the issue was identified. It is good to collect companies views first

Proposal 12 RAN2 to further discuss the need of gNB knowing sync requirement of a UE.

# 4. References

1. R2-2100215, Discussion on the time synchronisation enhancements, Huawei
2. R2-2100221, Discussion on Time Synchronization in Rel-17, CATT
3. R2-2100232, Propagation Delay Compensation Enhancements, Ericsson
4. R2-2100267, Propagation Delay Compensation for TSN, QUALCOMM
5. R2-2100327, Further considerations on time synchronization and PDC, ZTE
6. R2-2100417, Remaining aspect to support time synchronization, Fujitsu
7. R2-2100425, Some considerations on propagation delay compensation, China Telecom
8. R2-2100615, RAN Enhancements for Support of Timing Synchronization, Intel
9. R2-2100716, Time Synchronization Signalling and Mobility Impact Analysis, Nokia
10. R2-2100781, Discussion on uplink time synchronization for TSN, NTT DOCOMO
11. R2-2100829, Discussion on time sync maintenance during mobility, vivo
12. R2-2100844, Consideration of TSN time synchronization in handover scenario, OPPO
13. R2-2100941, Propagation Delay Compensation for TSN, CANON
14. R2-2101119, Discussion on enabling UE side propagation delay compensation, Lenovo
15. R2-2101322, On propagation delay compensation, MediaTek
16. R2-2101490, Mobility aspects of time synchronization, Sequans Communications
17. R2-2101666, Propagation delay compensation and synchronization, Samsung
18. R2-2101671, Mobility issue on time synchronization, Xiaomi
19. R2-2101721, Enhancements for support of time synchronization for TSN, CMCC
20. R2-2101809, Enhancements for support of time synchronization and PDC, TCL
21. R2-2101862, Discussion on enhancements for support of time synchronization, LG
22. R2-2010837, Reply LS on propagation delay compensation enhancements, RAN2
23. R2-2009755, Summary of E-mail discussion: [Post111-e][924][R17 URLLC/IIoT] Propagation delay for TSN (Nokia), RAN2#112e

# 5. Previous Agreements

**RAN2#111:**

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| --- |
| => Discuss by email the delay components and understand the requirements with each component and agree on what needs to be addressed=> Introduce propagation delay compensation for the improved synchronisation accuracy requirement in case of in UL Time Synchronization |

**RAN2#112:**

**Agreements**

1: RAN2 should consider the following three scenarios, with a focus on Scenario 2 and 3:

• 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.

2 RAN2 should evaluate the synchronicity budget by dividing the 5GS E2E path into three parts: Network, Device, and Uu interface. Where the Uu interface is understood as the maximum 5GS time synchronization error between the UE and the gNB-DU (i.e. DU-CU interface error is not included)

3 RAN2 assumes the two Uu interfaces in Scenario 2 have the same time synchronization error budget.

4 The Uu interface budget for Scenario 1, 2 and 3 are respectively calculated as following:

• Scenario 1: Uu budget = 900ns – Device – Network scenario1

• Scenario 2: Uu budget = (900ns – 2xDevice – 2xNetwork scenario2)/2 (assumption is based on GPTP)

• Scenario 3: Uu budget = 1000ns – Device – Networkscenario3 (baseline assumption that this is based on GNSS)

5 The Device part time synchronization accuracy budget is assumed to be in the range ±50 to ±100ns, this applies to all three scenarios

6 The error caused by the limited granularity of referenceTimeInfo-r16 IE (±5ns) is to be included in the network part budget, and RAN1 should be informed not to include this error in Uu interface.

7 The Network part time synchronization accuracy budget for Scenario 1, 2, and 3 are assumed to be the following:

• Scenario 1: ±120 to ±200ns (NetworkScenario1) (*assuming 3-5 hops worst case scenario*

• Scenario 2: ±240 to ±400ns (2xNetworkScenario2) *(assuming 6-10hops worst case scenario)*

• Scenario 3: ±100ns (NetworkScenario3)

8 Based on Proposal 4, 5, 6 and 7, the per Uu interface time synchronization accuracy for Scenario 1, 2 and 3 are as following:

• Scenario 1: ±595ns to ±725ns

• Scenario 2: ±145ns to ±275ns

• Scenario 3: ±795ns to ±845ns

9 LS to RAN1 providing the scenarios and values. Indicate to RAN1 that they should aim to meet the most stringest requirements, but a number within the range is also acceptable

 10 It is up to RAN1 to decide which PDC options should be supported for Scenario 1, 2 and 3 in Release-17.