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| 3GPP TR 23.700-25 V0.2.0 (2022-04) |
| Technical Report |
| 3rd Generation Partnership Project;Technical Specification Group Services and System Aspects;Study on timing resiliency and TSC and URLLC enhancements(Release 18) |
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# Foreword

This Technical Report has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

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where:

x the first digit:

1 presented to TSG for information;

2 presented to TSG for approval;

3 or greater indicates TSG approved document under change control.

y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

z the third digit is incremented when editorial only changes have been incorporated in the document.

In the present document, modal verbs have the following meanings:

**shall** indicates a mandatory requirement to do something

**shall not** indicates an interdiction (prohibition) to do something

The constructions "shall" and "shall not" are confined to the context of normative provisions, and do not appear in Technical Reports.

The constructions "must" and "must not" are not used as substitutes for "shall" and "shall not". Their use is avoided insofar as possible, and they are not used in a normative context except in a direct citation from an external, referenced, non-3GPP document, or so as to maintain continuity of style when extending or modifying the provisions of such a referenced document.

**should** indicates a recommendation to do something

**should not** indicates a recommendation not to do something

**may** indicates permission to do something

**need not** indicates permission not to do something

The construction "may not" is ambiguous and is not used in normative elements. The unambiguous constructions "might not" or "shall not" are used instead, depending upon the meaning intended.

**can** indicates that something is possible

**cannot** indicates that something is impossible

The constructions "can" and "cannot" are not substitutes for "may" and "need not".

**will** indicates that something is certain or expected to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

**will not** indicates that something is certain or expected not to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

**might** indicates a likelihood that something will happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

**might not** indicates a likelihood that something will not happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

In addition:

**is** (or any other verb in the indicative mood) indicates a statement of fact

**is not** (or any other negative verb in the indicative mood) indicates a statement of fact

The constructions "is" and "is not" do not indicate requirements.

# 1 Scope

The objective of this Technical Report is to study and perform an evaluation of potential architecture enhancements for supporting 5G Timing Resiliency and TSC & URLLC enhancements for 5G System (5GS). The following aspects are covered:

- Study how to report 5GS network timing synchronization status (such as divergence from UTC and 5GS network timing source degradation) to UEs and 3rd party applications (AFs):

- Study how RAN and 5GC learn about network 5GS network timing synchronization status to be able to inform UEs and AFs.

- Study if additional information needs to be provided to UEs and AFs to inform about 5GS network timing synchronization status.

- Study how to enable AFs to request time synchronization service in a specific coverage area and how to enforce the coverage area.

- Study how to control 5G time synchronization service based on subscription (i.e. introducing subscription parameter for time synchronization and enforcing it).

- Study how to enable an AF to explicitly provide PER to NEF/PCF.

- Study mechanisms for interworking with TSN transport networks. Study interworking mechanisms with TSN networks deployed in the transport network in order to support of E2E determinism and low latency communication and efficient N3 transmission.

- Study if there is a need for applications to adapt downstream scheduling in order for 5GS to meet really low latency (e.g. 2msecs) requirement and if there is a need to have feedback from RAN (e.g. for application to consider DL packet transmission time slots to avoid buffering in the RAN) for this purpose.

# 2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non‑specific.

- For a specific reference, subsequent revisions do not apply.

- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] 3GPP TS 23.501: "System Architecture for the 5G System (5GS); Stage 2".

[3] 3GPP TS 23.502: "Procedures for the 5G System; Stage 2".

[4] 3GPP TS 23.503: "Policy and charging control framework for the 5G System (5GS); Stage 2".

[5] 3GPP TS 38.331: "NR; Radio Resource Control (RRC); Protocol specification".

[6] IEEE 802.1Qcc: "IEEE Standard for Local and Metropolitan Area Networks--Bridges and Bridged Networks -- Amendment 31: Stream Reservation Protocol (SRP) Enhancements and Performance Improvements".

[7] IEEE Std 802.1AS: "IEEE Standard for Local and Metropolitan Area Networks-Timing and Synchronization for Time-Sensitive Applications".

[8] IEEE Std 1588: "Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems".

[9] 3GPP TR 22.878: "Feasibility Study on 5G Timing Resiliency System".

[10] IEEE P802.1Qdj d0.2: "Configuration Enhancements for Time-Sensitive Networking".

[11] 3GPP TS 38.321: "Medium Access Control (MAC) protocol specification".

# 3 Definitions of terms, symbols and abbreviations

## 3.1 Terms

For the purposes of the present document, the terms given in TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in TR 21.905 [1].

**example:** text used to clarify abstract rules by applying them literally.

## 3.2 Symbols

For the purposes of the present document, the following symbols apply:

<symbol> <Explanation>

## 3.3 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [1].

<ABBREVIATION> <Expansion>

# 4 Architectural Assumptions and Requirements

## 4.1 Architectural Assumptions

The following architectural assumptions apply:

- The architecture defined in clause 4.4.8 of TS 23.501 [2] is as a baseline for the study.

- The TSN network deployed in the transport network supports the fully centralised model defined in IEEE 802.1 Qcc [6].

NOTE: The transport network and 5GS may belong to the same operator or different operator.

- Configuration and operation of the external synchronization network (i.e. timing synchronization provided by network external to 5GS network) and mitigation actions when time source fails or degrades are assumed to be outside the scope of 3GPP.

- This study is assumed to inherit the time synchronization architecture, methods, and exposure framework as defined in Rel-17 for 5G System in TS 23.501 [2]. This includes the support for time synchronization service based on 5G Access Stratum timing distribution, (g)PTP time sync based on IEEE Std 802.1AS [7] with 5GS acting as grand-master or PTP time sync with 5GS acting as grand-master based on IEEE Std 1588 [8], along with support for DS-TT, NW-TT and TSCTSF in the time synchronization architecture.

- How the 5GS network is time synchronized is assumed to be deployment specific thus outside the scope of this study (e.g., 5GS may use local GNSS server, may be time synchronized with an external clock using transport network synchronization protocols, etc.).

## 4.2 Architectural Requirements

The following architectural requirements apply:

- Solutions for timing resilience and time synchronization shall support the already defined time synchronization distribution methods as defined in clause 4.1.

Editor's note: In case of PTP-based time sync, for which IEEE Std 1588 [y] profile(s) to support timing resilience is FFS.

- Solutions for main 5G time resiliency use cases shall at least support that the UEs are static to address financial and power grid scenarios, see TR 22.878 [9]), but may also support the scenarios where the UEs may not be static.

# 5 Key Issues

## 5.1 Key Issue #1: 5GS network timing synchronization status and reporting

### 5.1.1 Description

The objective of this Key Issue is to study the monitoring and reporting for timing synchronization status in 5GS.

For this Key Issue the following areas should be studied:

- Study how RAN and 5GC learn about 5GS network timing synchronization status to be able to inform UEs (e.g. application running in the UE), devices attached to the UE (i.e. that receive time information from 5GS) and AFs.

- Study how to report 5GS network timing synchronization status (such as divergence from UTC and 5GS network timing source degradation) to UEs (e.g. application running in the UE), devices attached to the UE (i.e. that receive time information from 5GS) and 3rd party applications (AFs).

- Study if additional information needs to be provided to UEs and AFs to inform about 5GS network timing synchronization status.

## 5.2 Key Issue #2: Time synchronization service enhancements

### 5.2.1 Description

The objective of this Key Issue is to study enhancements for 5GS time synchronization considering the coverage area where the service is configured.

For this Key Issue the following areas should be studied:

- How to enable AFs to request time synchronization service in a specific coverage area and whether and how to enforce the coverage area.

## 5.3 Key Issue #3: Support for controlling 5G time synchronization service based on subscription

### 5.3.1 Description

Control of time synchronization service based on UE subscription is important for the operator in managing time critical services such as smart grid or financial services.

This key issue aims at studying how to control 5G time synchronization service based on subscription (i.e. introducing subscription parameter for time synchronization and enforcing it).

The following technical issues will be studied:

- How to authorize time synchronization service based on UE subscription.

- How to enforce time synchronization service on a per UE basis based on subscription.

- What parts of time synchronization service require a separate UE subscription (and authorization), if any.

## 5.4 Key Issue #4: How to enable an AF to explicitly provide PER to NEF/PCF

5.4.1 Description

For this Key Issue the following areas should be studied:

1. Enable an AF to explicitly provide the required PER to the NEF/PCF for QoS and Alt-QoS.

## 5.5 Key Issue #5: Interworking with TSN network deployed in the transport network

### 5.5.1 Description

The objective of this Key Issue is to study interworking mechanisms with TSN networks deployed in the transport network in order to support of E2E determinism and low latency communication and efficient N3 transmission.

This Key Issues applies only to 3GPP layer traffic flows that fall in the category of "periodic deterministic communication" as defined in clause 5.27.1a of TS 23.501 [2], i.e. for 3GPP layer traffic flows that can be associated with the TSCAI parameters - namely, burst arrival time, periodicity and flow direction.

For this Key Issue the following areas should be studied:

a) The architecture enhancement to support the interworking between 5GS and TSN networks deployed in the transport network.

b) What information are needed and how to collect these information from 5GS (e.g. NG-RAN, 5GC NF), so that the 5GS can interact with TSN network. Also, determine which 5GS entity is responsible to provide it to the TSN network deployed in the transport network.

NOTE: In the context of interworking with a TSN-based transport network, 5GS is assumed to take the role of the CUC towards the CNC of the TSN transport network. It is assumed to rely on on-going work in IEEE for the interaction between CUC and CNC (P802.1Qdj), i.e. no new interface to the CNC will be specified as part of this work.

## 5.6 Key Issue #6: Adapting downstream scheduling based on RAN feedback for low latency communication

### 5.6.1 Description

This key issue is targeting how for applications to adapt downstream scheduling in order for 5GS to meet really low latency (e.g. 2msecs) requirement.

For this key issue, the following areas should be studied:

- Need for application transmission schedule adaptation and the ability to meet extremely low PDB for a QoS Flow from the 5GS perspective for periodic traffic streams (based on feedback from RAN WGs).

- How to enable the RAN to provide feedback to application for low latency communication (e.g. for application to consider DL packet transmission time slots to avoid buffering in the RAN) for this purpose.

NOTE 1: The key issue needs to consider also the downlink scheduling in N3 transport network as studied under the Key Issue #x: Interworking with TSN network deployed in the transport network.

NOTE 2: Although the focus is on downstream scheduling, any optimization on upstream scheduling should not be precluded if similar enhancement as for downstream scheduling applies.

# 6 Solutions

## 6.0 Mapping of Solutions to Key Issues

Table 6.0-1: Mapping of Solutions to Key Issues

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Key Issue #1 | Key Issue #2 | Key Issue #3 | Key Issue #4 | Key Issue #5 | Key Issue #6 |
| Solutions |  |  |  |  |  |  |
| #1 | X |  |  |  |  |  |
| #2 |  |  |  |  |  | X |
| #3 | X |  |  |  |  |  |
| #4 | X |  |  |  |  |  |
| #5 | X |  |  |  |  |  |
| #6 |  | X |  |  |  |  |
| #7 |  | X |  |  |  |  |
| #8 |  |  |  | X |  |  |
| #9 |  |  |  |  | X |  |
| #10 |  |  |  |  | X |  |
| #11 |  |  |  |  | X |  |
| #12 |  |  |  |  |  | X |
| #13 |  |  |  |  |  | X |
| #14 | X |  |  |  |  |  |
| #15 |  |  |  |  |  | X |
| #16 |  |  |  |  |  | X |

## 6.1 Solution #1: Inform UE and AF about network timing synchronization status

### 6.1.1 Introduction

This solution enables UE and AF to learn about network timing synchronization status, addressing KI #1.

This solution makes the following assumptions:

- NG-RAN is time synchronized with an external clock using transport network synchronization protocols or using a local GNSS receiver.

- NG-RAN can detect network timing synchronization degradation/improvement or timing synchronization failures locally, e.g. based on information provided by the transport network time synchronization protocols or based on information provided by the local GNSS receiver. The details of how NG-RAN detects timing synchronization degradation/improvement or timing synchronization failures are beyond the scope of 3GPP.

- If UPF/NW-TT is involved in providing timing information to UEs, UPF/NW-TT is time synchronized e.g., using transport network-based time synchronization protocols.

- UPF can detect network timing synchronization degradation/improvement or timing synchronization failures locally, e.g., based on information provided by the transport network time synchronization protocols. The details of how the UPF detects timing synchronization degradation/improvement or timing synchronization failures are beyond the scope of 3GPP.

This solution addresses the following scenarios for 5G internal timing distribution:

- 5GS distributes timing information to UEs using access stratum signaling.

- 5GS is acting as GM and distributes timing information to UEs using PTP or gPTP.

### 6.1.2 Functional Description

The solution is based on the following principles:

- Informing 5GC and AFs about network timing synchronization status:

- Informing 5GC about RAN and UPF time synchronization status:

- TSCTSF subscribes for receiving RAN time synchronization status on a per RAN node level from NWDAF:

- NWDAF subscribes for RAN time synchronization status information from OAM. RAN time synchronization internal status information includes e.g. synchronization state, primary source information (e.g. type, quality, lock state), relevant PTP dataset members such as clock class (if PTP applies), the more general UTC traceability information, stability and clock accuracy.

- As an alternative option, TSCTSF subscribes for RAN time synchronization status information from OAM. RAN time synchronization status information includes e.g. synchronization state, primary source information (e.g. type, quality, lock state), relevant PTP dataset members such clock class (if PTP applies), the more general UTC traceability, stability and clock accuracy information.

- If UPF/NW-TT is involved in providing time information to DS-TT, TSCTSF subscribes for receiving time synchronization status from UPF (i.e. the status of the synchronization of the UPF with the transport network timing):

- Based on this, UPF reports transport network time synch status (e.g. relevant PTP dataset members such as clock class (if PTP applies), UTC traceability information and clock accuracy and stability) to TSCTSF.

NOTE 1: UPF time synchronization status is only needed for the option when UPF/NW-TT is generating and timestamping messages for the DS-TT, which are forwarded from DS-TT adding residence time

- Determining UEs impacted by RAN time synchronization status degradation or improvement:

- TSCTSF subscribes to receive location information (RAN node granularity) from AMF for UEs that AF requested time synchronization for.

- TSCTSF requests UEs for which an AF requested time synchronization to perform a Registration Update if the UE is in CM-IDLE and detects a change in the RAN time synchronization status information (see below) for the current cell or when re-selecting to a different cell. This ensures that the CN is made aware of the location of a UE in case the RAN time synchronization status changes while a UE that has been configured to receive time information is in CM-IDLE.

- Determining UEs impacted by UPF time synchronization status degradation or improvement (only for the case when UPF/NW-TT is involved in providing time information to DS-TT):

- If TSCTSF receives time synchronization status information for NG-RAN nodes from NWDAF (or from OAM directly) indicating time synchronization status degradation or improvement, then TSCTSF determines the UEs served by those NG-RAN nodes based on location information received from AMF.

- If TSCTSF receives time synchronization status information from UPF indicating time synchronization status degradation or improvement, then the TSCTSF determines the UEs for which the UPF/NW-TT or the DS-TT co-located with those UEs is configured to send (g)PTP messages.

- Inform AFs about network timing synchronization status degradation or improvement:

- If TSCTSF has determined UEs impacted by RAN or UPF time synchronization status degradation or improvement then TSCTSF informs the AF about the network timing synchronization status for those UEs as follows:

- For UEs impacted by RAN time synchronization status degradation or improvement for which the AF has requested 5G access stratum time distribution, TSCTSF determines if the Time synchronization error budget provided by the AF can be met given the change of clock accuracy for the RAN node serving the UE:

- If the sum of the clock accuracy of the RAN node serving a UE and the Uu time synchronization error budget previously calculated for the UE (see TS 23.501 [2] clause 5.27.1.9) exceeds the Time synchronization error budget provided by the AF, then the TSCTSF informs the AF that the time synchronization request cannot be fulfilled for the impacted UE.

- Otherwise, the TSCTSF informs the AF that the time synchronization request can be fulfilled again for the impacted UE.

- For UEs for which the AF has requested (g)PTP based time distribution and which are impacted by RAN and/or UPF time synchronization status degradation or improvement, TSCTSF determines if the Time synchronization error budget provided by the AF can be met given the change of clock accuracy for the RAN node serving the UE and/or the change of clock accuracy reported by the UPF:

- If the sum of

- the clock accuracy of the RAN node serving a UE,

 the Uu time synchronization error budget previously calculated for the UE (see TS 23.501 [2] clause 5.27.1.9), and,

- (in case NW-TT is configured to act as Grandmaster on behalf of the UE/DS-TT) the clock accuracy reported by the UPF

- exceeds the Time synchronization error budget provided by the AF, the TSCTSF informs the AF that the time synchronization request cannot be fulfilled for the impacted UE.

- Otherwise, the TSCTSF informs the AF that the time synchronization request can be fulfilled again for the impacted UE.

Editor's note: Whether and how to provide network timing synchronization status for the case that an AF requested time synchronization service in a specific coverage area depends on the progress of the related key issue.

- Informing UEs and devices attached to UE/DS-TT about network timing synchronization status:

- NG-RAN detects network timing synchronization degradation or failure based on implementation-specific means.

- NG-RAN informs UEs about the time synchronization status by providing additional time synchronization status information (e.g. synchronization state, primary source description (e.g. typequality, lock state), clock class and information about traceability to UTC, clock accuracy and stability) to UEs in SIB or using dedicated RRC.

NOTE 2: Time synchronization status information provided to the UE using RRC is assumed to be used by the UE, e.g., for applications running on the UE or to provide time information to devices attached to the UE using implementation specific means. Time synchronization status information provided to UE/DS-TT by 5GC in (g)PTP (e.g. clock class, clock accuracy) is assumed to be consumed by devices attached to the UE to which UE/DS-TT forwards the (g)PTP frames/packets.

- If TSCTSF has determined UEs impacted by RAN or UPF time synchronization status degradation or improvement (see above) for which the AF has requested (g)PTP based time distribution and for which the the Time synchronization error budget provided by the AF cannot be met (see above) then TSCTSF temporarily removes the UE/DS-TT from the PTP instance:

- If the DS-TT is configured to send Sync, Follow\_Up and Announce messages for the related PTP instance, then TSCTSF deactivates the Grandmaster functionality in the DS-TT using PMIC (see also TS 23.501 [2] clause K.2.2.4) and removes the DS-TT from the PTP instance (see also TS 23.501 [2] clause K.2.2.1).

- If NW-TT is configured to send Sync, Follow\_Up and Announce messages on behalf of the DS-TT, then TSCTSF deactivates the Grandmaster functionality on behalf of the DS-TT in NW-TT using UMIC (see also TS 23.501 [2] clause K.2.2.4) and removes the DS-TT from the PTP instance (see also TS 23.501 [2] clause K.2.2.1).

Editor's note: Whether instead of removing the DS-TT from the PTP instance TSCTSF can put the DS-TT's PTP port into Faulty state (see also IEEE 1588 [Z] clause 7.6.2) is FFS.

Editor's note: Whether the scenario exists (and if so, how to support it for (g)PTP) that RAN or UPF time synchronization status has degraded but the Time synchronization error budget provided by the AF can still be satisfied is FFS.

### 6.1.3 Procedures

### 6.1.4 Impacts on services, entities and interfaces

- NG-RAN:

- Indicate RAN network timing synchronization status to UEs in RRC signaling or SIB9.

- UE:

- Support receiving RAN network timing synchronization status information.

- Support performing a Registration request when RAN network timing synchronization status information changes while the UE is in CM-IDLE, if requested by TSCTSF.

- NWDAF:

- Support subscribing for RAN time synchronization status information from OAM and providing RAN time synchronization status information to TSCTSF.

- TSCTSF:

- Receive time synchronization status information from NWDAF (or OAM) and UPF.

- Subscribe for receiving location information from AMF.

- Support for requesting UEs to perform a Registration request if the UE detects a change in RAN network timing synchronization status information and the UE is in CM-IDLE.

- Inform AFs about time synchronization status.

- Discover serving AMF for a UE.

- Configuration of NG-RAN node to notify UEs via RRC or SIB9.

- UPF:

- Report transport network time synch status (e.g., primary source information and status, clock class UTC traceability and clock accuracy and stability) to TSCTSF in case NW-TT is configured to generate (g)PTP messages (see case (a) in TS 23.501 [2], clause 5.27.1.7.

## 6.2 Solution #2: Burst arrival time adaptation

### 6.2.1 Introduction

This solution enables the network to adjust the burst arrival time by signaling positive or negative offset values (e.g. +3 ms) to the AF so that the AF can adjust the burst sending time accordingly.

Providing a burst arrival time offset value to an AF does not require 5GS and AF to be time synchronized.

The solution builds on top of the QoS notification control mechanism (TS 23.501 [Y] clause 5.7.2.4.1a (without Alternative QoS Profiles) or clause 5.7.2.4.1b (with Alternative QoS Profiles)). In line with the assumptions for the existing QoS notification control mechanism, also this solution applies only if the application traffic is able to adapt to the change in QoS, i.e., if an application can tolerate that the PDB target is temporarily not met.

### 6.2.2 Functional Description

This solution is based on the following principles:

- When requesting QoS for a flow as defined in TS 23.503 [X] clause 6.1.3.22, AF may also indicate support of Burst arrival time adaptation to5GS. AF also subscribes to receive notifications for successful resource allocation and when the QoS targets can no longer (or can again) be fulfilled as described in TS 23.503 [X] clause 6.1.3.18

- PCF forwards the support of Burst arrival time adaptation indication to SMF together with a PCC rule and other parameters (burst size, flow direction, burst periodicity), BAT (optional)), if provided by the AF. PCF enables QoS Notification Control in the PCC rule.

NOTE 1: If AF and 5GS are time synchronized, then the AF may additionally include BAT.

- SMF creates TSCAI based on the received periodicity , flow direction and BAT (if provided by PCF). If PCF indicated support of Burst arrival adaptation, SMF includes support of Burst arrival time adaptation indication in TSCAI and signals TSCAI to NG-RAN as described in clause 4.3.3.2 of TS 23.501 [2]. As part of this, SMF also activates QoS notification control.

- At any time after the flow has started, if NG-RAN has received the indication of support of Burst arrival time adaptation in TSCAI for the given QoS Flow and NG-RAN determines that the PDB of the QoS profile cannot be fulfilled in DL direction, then NG-RAN sends a notification to SMF as defined in TS 23.501 [Y] clause 5.7.2.4.1a (if no Alternative QoS parameters have been provided) or as defined in TS 23.501 [Y] clause 5.7.2.4.1b (if Alternative QoS parameters have been provided). As part of the notification to SMF, NG-RAN may include a burst arrival time offset value. The burst arrival offset can take positive or negative values.

NOTE 2: NG-RAN determines a relative burst arrival time offset value in reference to the current Burst Arrival Time experienced by RAN (i.e. in reference to when RAN currently receives bursts). Since it is a relative offset it can also be applied by the AF for adapting when it sends bursts, i.e. for the AF to adapt the burst sending time (see further below).

NOTE 3: Since NG-RAN is aware of the radio resource situation NG-RAN can determine whether it would be possible to support the PDB of the QoS profile again if the burst was shifted in the time domain and calculate the required offset value.

NOTE 4: The QoS notification procedure, which is reused by this solution already avoids too frequent signaling to the SMF (see NOTE 2 in TS 23.501 [Y] clause 5.7.2.4.1b).

- The burst arrival time offset value is signaled from SMF to AF via PCF/TSCTSF/NEF using existing Notification control signaling.

- For downlink flows AF adapts the burst sending time based on the received offset.

### 6.2.3 Procedures

Existing procedures are reused (PDU session modification to signal support of Burst arrival time adaptation indication in TSCAI to NG-RAN; Notification control as defined in clause 5.7.2.4.1a or clause 5.7.2.4.1b of TS 23.501 [2]. to signal burst arrival time offset value to PCF/TSCTSF/NEF/AF).

### 6.2.4 Impacts on services, entities and interfaces

- AF: Support of sending burst arrival time adaptation indication and receiving burst arrival time offset.

- NEF, PCF, TSCTSF, SMF: Support of signalling burst arrival time adaptation indication and burst arrival time offset.

- NG-RAN: Support of receiving burst time arrival adaptation indication, determining and signalling burst arrival time offset.

## 6.3 Solution #3: Timing synchronization resiliency and status reporting

### 6.3.1 Introduction

This solution aims to address Key issue #1: 5GS network timing synchronization status and reporting. When 5GS provides timing resiliency service e.g. in the smart grid or financial sector, the timing synchronization status (such as divergence from UTC, timing source degradation) needs to be able to inform UEs (e.g. application running in the UE), devices attached to the UE (i.e. that receive time information from 5GS) and AFs. The AF can configure 5GS with the requirements about the timing resiliency service to meet when timing synchronization event happens.

This solution makes the following assumptions:

- UEs are consuming (g)PTP timing synchronization service from UPF/NW-TT that acts as grand-master based on IEEE Std 802.1AS [7] or IEEE Std 1588 [8];

- 5G GM may have different sources of time/frequency like GNSS signal, Synchronous Ethernet (SyncE), PTP transport network, PPS input, etc. It is assumed that the 5G GM is collocated with UPF or UPF is synchronized with 5G GM by PTP compatible transport, etc.

- When UPF detects 5GS networking timing synchronization status for original timing source, it sends the reporting to 5GC. Additionally, the UPF activates the timing synchronization configuration for PTP GM functionality as configured by TSCTSF in case of degradation for original timing source, so as to provide seamless time synchronization service for the UEs; or the UPF de-activates the timing synchronization configuration for PTP GM functionality as configured by TSCTSF in case of recovery for original timing source.

Editor's note: Reporting of 5GS network timing synchronization status to UE is FFS.

Editor's note: It is FFS how to address the case where time synchronization service is offered based on 5G Access Stratum timing distribution.

### 6.3.2 Functional Description

This solution uses the following principles:

- TSCTSF collects timing synchronization capability of UPF via PMIC or UMIC:

- The timing synchronization capability can indicate holdover time or traceability capability information. For example, clock class, synchronization accuracy, holdover time parameters for the smart grid scenario, or UTC divergence scale and synchronization accuracy parameters for financial scenario;

- TSCTSF creates timing synchronization configuration on the UPF upon reception of AF request:

- TSCTSF receives timing synchronization requirement from AFs. The timing synchronization requirement includes timing resiliency service KPIs that 5GS needs to meet, e.g. AF requests for holdover time for 1h for ms sync accuracy for the smart grid scenario, or AF requests for 1ms maximum divergence from UTC for financial scenario;

Editor's note: It is FFS whether and what additional information is needed in AF request for time synchronization service and subscription for 5GS networking timing synchronization status.

- TSCTSF confirms that the 5GS can meet the requirement based on UPF reported timing synchronization capability;

- TSCTSF creates a timing synchronization configuration on UPF;

- With the timing synchronization configuration, the UPF detects and reports the networking timing synchronization status, and (de)activates the timing synchronization configuration for PTP GM functionality accordingly.

- UEs are consuming (g)PTP timing synchronization service from UPF/NW-TT that acts as grand-master based on IEEE Std 802.1AS [7] or IEEE Std 1588 [8];

- When UPF detects networking timing synchronization status for original timing source, it sends the status reporting to TSCTSF, and the TSCTSF forwards the reporting to AFs

- When UPF detects degradation or unavailable for original timing source, the UPF activates the timing synchronization configuration for PTP GM functionality as configured by TSCTSF, and the status reporting contains original timing source disabled status: 5GS timing synchronization enabled status, the timing source clock class, time validity;

- When UPF detects recovery for original timing source, the UPF de-activates the timing synchronization configuration for PTP GM functionality, and status reporting contains original timing source enabled status: 5GS timing synchronization disabled status, the timing source clock class, time validity

### 6.3.3 Procedures

Existing PDU Session establishment procedures are reused in timing synchronization capability configuration. Existing timing distribution procedures are reused for UEs using (g)PTP messages

### 6.3.4 Impacts on services, entities and interfaces

UPF:

Support of signaling the timing synchronization capability to TSCTSF

Support of reporting time synchronization status (e.g., holdover time or UTC divergence status) to TSCTSF

TSCTSF:

Support of receiving timing synchronization requirement from AFs

Support of timing synchronization capability configuration

Support of timing synchronization status report to AFs

AF:

Support of providing timing synchronization requirement (e.g. holdover time and UTC divergence requirement) to TSCTSF, and receiving status reporting from TSCTSF

## 6.4 Solution #4: 5GC learning and reporting network timing synchronization status

### 6.4.1 Introduction

This solution is proposed to solve Key Issue #1: 5GS network timing synchronization status and reporting.

In this key issue, the 5GS has a synchronization plane that synchronizes the 5G network functions (e.g., UPFs and RAN nodes) to a common time reference. The synchronization plane may have different sources of time/frequency like GNSS signal, Synchronous Ethernet (SyncE), PTP transport network, PPS input, etc. Thus, the following assumptions are considered for the synchronization plane:

- NG-RAN is time synchronized with an external clock using transport network synchronization protocols or using a local GNSS receiver.

- NG-RAN is frequency synchronized (i.e., synchronization) with an external clock using transport network syntonization methods or using a local GNSS receiver.

NOTE: The syntonization aspect is included in the assumptions because it may have an important role when the primary time reference source is lost but still the base station has a frequency reference (e.g., SyncE), then the holdover period can be longer. This is taking for example the long interruption failure scenarios considered in ITU-T G.8271.1 Appendix V

- NG-RAN can detect network timing synchronization degradation/improvement or timing synchronization failures locally, e.g., based on information provided by the transport network time or frequency synchronization methods or based on information provided by the local GNSS receiver. The details of how NG-RAN detects timing synchronization degradation/improvement or timing synchronization failures are beyond the scope of 3GPP.

- UPF/NW-TT is time synchronized with an external clock using transport network-based time synchronization protocols if UPF/NW-TT is involved in providing time information to UEs/DS-TTs.

- UPF can detect network timing synchronization degradation/improvement or timing synchronization failures locally, e.g., based on information provided by the transport network time synchronization protocols. The details of how the UPF detects timing synchronization degradation/improvement or timing synchronization failures are beyond the scope of 3GPP.

This solution addresses the following scenarios:

- 5GS distributes time information to UEs using access stratum signaling.

- 5GS distributes time information to UEs using PTP or gPTP messages. If the 5GS is acting as a GM for the PTP instance, the network timing synchronization status reporting to UE/DS-TT or AF can complement the description of the GM the PTP messages already include (e.g., Announce messages) and detail the status of the 5G clock distributed via u-plane messages.

Editor's note: Whether external gPTP clock is in scope is FFS. How to determine the relative error between the 5G clock realizations at the DS-TT side and the NW-TT side used for (g)PTP timestamping operation is FFS.

From UE/DS-TT perspective, the 5GS time information received can be the primary time source the UE/DS-TT is consuming or can be a back-up time source alternative to a time source already present at the UE/DS-TT side. For both cases, this solution proposes enablers to allow the 5GC to retrieve 5GS network timing synchronization status from NG-RAN nodes and UPF/NW-TT (if needed) and report this information to subscribed UEs and AFs.

### 6.4.2 Functional Description

#### 6.4.2.1 Functional Description for 5GC learning network timing synchronization status

The following principles are proposed to enable the 5GC to learn the network timing synchronization status at the NG-RAN and UPF/NW-TT:

- The TSCTSF can retrieve and store timing synchronization status from NG-RAN and UPF/NW-TT.

- The NG-RAN timing synchronization status and the UPF/NW-TT timing synchronization status provide information for different time synchronization processes the UE/DS-TT(s) may have configured. The TSCTSF checks the time synchronization distribution method the target UE(s) have configured and determines the network functions to subscribe:

- The NG-RAN timing synchronization status informs the synchronization performance of the time distribution process the gNB and UE execute at Uu interface using access stratum signaling.

- On top of the access stratum time distribution method, if the UE/DS-TT receives 5G clock via (g)PTP (with the GM behind UPF/NW-TT) or the UPF/NW-TT performs timestamping operation of (g)PTP messages, the UPF/NW-TT timing synchronization status informs the synchronization performance of the time distribution process between the UPF/NW-TT and the UE/DS-TT.

Editor’s Note: It is FFS in case when UPF/NW-TT acts as PTP GM, GM quality attributes (e.g., clockClass, offsetScaledLogVariance, and ClockAccuracy) already present in PTP Announce messages may be enough and the TSCTSF can avoid subscribing to UPF/NW-TT timing synchronization status.

Editor's note: How TSCTSF can learn the UPF/NW-TT time synch status is FFS.

- For TSCTSF subscription to NG-RAN timing synchronization status, two reporting alternatives via AMF are possible as follows:

- Alternative 1 for NG-RAN Time Sync Status reporting: The TSCTSF is responsible for determining the impacted UE(s) based on their location and the NG-RAN timing synchronization status reports received from AMF.

- Alternative 2 for NG-RAN Time Sync Status reporting: The AMF is responsible for determining the impacted UE(s) based on their location and the NG-RAN timing synchronization status reports received. Per impacted UE, the AMF forwards the notification to the TSCTSF subscribed to it.

- For TSCTSF subscription to UPF/NW-TT timing synchronization status, three reporting alternatives are possible as follows:

- Alternative 1 for UPF/NW-TT Time Sync Status reporting: Using UPF event exposure service operation. The TSCTSF can be a new consumer of the service and node level signalling is used between UPF and TSCTSF.

- Alternative 2 for UPF/NW-TT Time Sync Status reporting: Using N4 Node Level procedures between the UPF and the SMF to report the update from the UPF. The TSCTSF subscribes to this information at the SMF on a per UE level or node level (between UPF and SMF or between SMF and TSCTSF). If UE level signalling is preferred, the SMF is responsible for determining the impacted UE(s) and notify the TSCTSF per UE level basis using PDU Session information available.

- Alternative 3 for UPF/NW-TT Time Sync Status reporting: Using UMIC to forward the status update from the UPF to the TSCTSF. Node level signalling is used between UPF and TSCTSF.

- The TSCTSF can determine time source degradation/failure/recovery events using the event flags and/or comparing numeric attributes included within the network timing synchronization status update received from NG-RAN and UPF/NW-TT.

- The TSCTSF can use the primary source quality attributes included within the NG-RAN and UPF/NW-TT timing synchronization status update to compute a new 5GS error budget for the time synchronization service offered to UE(s) to assist time synchronization enforcement.

Editor's note: It is FFS what this means because the 5GS error budget comes from the AF and cannot be changed unilaterally by the TSCTSF.

This depends on the progress of the related key issue #3.

#### 6.4.2.2 Functional Description for network timing synchronization status information

Editor's note: What type of information is needed and how it is used is FFS.

#### 6.4.2.3 Functional Description for AF requested network timing synchronization status

The following capabilities are proposed for AF requesting network timing synchronization status:

- The AF requests network timing synchronization status monitoring from the NEF or TSCTSF (if it is a trusted AF). The request may contain:

- Targets of the monitoring and filtering information (e.g., UE IDs, spatial validity, DNN/S-NSSAI).

- The subscription events or information elements it wants to be notified.

- Request for UE side reporting (i.e., the UE(s) that are targets of the monitoring receive also the network timing synchronization status report) and reporting criterion (e.g., as soon as new information is available, when the UE is reachable).

- AF Identification.

Editor's note: Whether a new request for network timing synchronization status monitoring is needed or whether the existing request for time synchronization is reused is FFS.

- To determine the targets of the monitoring, AF request for network timing synchronization status provides the filter information. Four criteria to determine the targets of the network timing synchronization status exposure framework can be considered as summarized in Table 6.x.2.3 based on UE identities, known location, or connectivity.

Table 6.4.2.3: Criteria alternatives for network timing synchronization status exposure

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Criteria | Spatial validity | All UEs within the spatial validity | All UEs connected to the DNN/S-NSSAI | A UE or group of UEs |
| Target of Monitoring Reporting | an optional SUPI or any UE | any UE | any UE | one or more SUPI(s) or Internal Group Identifier(s) |
| Monitoring Filter information | spatial validity; | Spatial validity | DNN;S-NSSAI; |  |

- If AF’s request includes geographical area filter(s), the AF can provide them in spatial validity format (e.g., a civic address or shapes), or area(s) of interest. If the AF provides spatial validity, the NEF/TSCTSF maps the spatial validity to validity area(s) (based on pre-configuration). Later, the TSCTSF or PCF determines the area(s) of interest based on validity area(s). The TSCTSF or AMF subscriptions use area of interest that may be the same as spatial validity condition or may be a subset of the spatial validity condition (e.g., a list of TAs) based on the latest known UE location.

- AMF or TSCTSF uses Location reports or UE presence in Area of Interest services at the AMF to identify the UE(s) to which the AF request with geographical area filter(s) applies, following the description of clause 6.4.2.1.

- If AF’s request includes DNN/S-NSSAI filters, service events related to PDU Sessions (e.g., establishment or release) can be used at the SMF or TSCTSF to identify the UE(s) to which the request applies.

#### 6.4.2.4 Functional Description for network timing synchronization status reporting to UE(s)

The following capabilities are proposed for UE(s) receiving network timing synchronization status:

- Based on TSCTSF policies or the received AF’s network timing synchronization status request as described in clause 6.4.2.3 and the time synchronization service the UE has configured, the TSCTSF is responsible for subscribing to network timing synchronization status as described in clause 6.4.2.1 (i.e., to the serving NG-RAN via AMF and if needed to the UPF/NW-TT via SMF or UPF directly).

- The TSCTSF gathers the status from the network functions and generates the network timing synchronization status report to be forwarded to the UE/DS-TT(s). Depending on the time distribution method the UE has configured, the TSCTSF may need to compound a report using the input received from the serving NG-RAN node and the UPF/NW-TT or group the information coming from the NG-RAN node and UPF/NW-TT node into one report to indicate to the UE/DS-TT the performance of the gNB and the UPF/NW-TT related to the 5G clock.

Editor's note: How the TSCTSF can create a single report based on RAN and UPF time synch status and what the report would contain is FFS.

- When access stratum time distribution method is configured for the UE, the TSCTSF could configure the NG-RAN node (via AMF) to generate and send the NG-RAN timing synchronization status report to the UE(s) via SIB9/RRC signalling. The report shall be made available to DS-TT by the UE.

- When (g)PTP time distribution method is configured for the UE/DS-TT, the DS-TT is the receptor of the network timing synchronization status report. TSCTSF could provide network timing synchronization status reports to the DS-TT via the UE using NAS signalling to transport the report, e.g., extending Port Management Information Container (PMIC).

Editor's note: Whether there is a need for additional information to be signalled to DS-TT in case of (g)PTP based time distribution (and how the DS-TT should use it) or if the PTP information that can already be signalled to DS-TT is sufficient is FFS.

- If the DS-TT is the last recipient of the network timing synchronization status reports (if only access stratum time distribution method is configured), it is up to the DS-TT implementation the determination of how the time source status update impacts the total degradation of the timing service the DS-TT is running.

### 6.4.3 Procedures

#### 6.4.3.1 Procedure for AF requested network timing synchronization status

An overall procedure for AF requested network timing synchronization status is illustrated in Figure 6.4.3.1-1.



Figure 6.4.3.1-1: Procedure for AF requested network timing synchronization status

1. The AF sends network timing synchronization status request to the NEF or TSCTSF. The request may include targets of the monitoring and filtering information (as described in Table 6.x.2.3), the subscription events or information elements it wants to be notified, request for UE side reporting and reporting criterion, AF Identification.

2. If the request is received at the NEF, it checks whether the AF is authorized to send the request and forwards the request to the TSCTSF.

If spatial validity is included in AF’s request, NEF or TSCTSF may determine the validity area(s).

Based on the filters the request contains, the TSCTSF determines the target(s) UE(s) for the request.

3. The TSCTSF determines the AMF(s) and the UPF/NW-TT nodes (if applicable) that needs to initiate network timing synchronization status subscription considering the time synchronization service the target UE(s) have configured in the 5GS.

To determine the serving AMF(s), the TSCTSF can use different methods such as:

- Method 1: NRF services (Nnrf\_NFDiscovery) or UDM UE Context Management services (Nudm\_UECM\_Get) to discover the AMF of the target TAI(s) or UE(s). This method enables the TSCTSF to directly interact with the AMF to retrieve NG-RAN Time Sync Status reports at UE or NG-RAN node level.

- Method 2: AM policy procedures via PCF. The TSCTSF can discover the PCF for the UE using the BSF and interact with the AMF via PCF AM Policy services. This method only enables the TSCTSF to retrieve NG-RAN Time Sync Status reports at UE level.

To determine the serving UPF/NW-TT(s) the TSCTSF can use the PTP instance information already configured for the (g)PTP service provided to the UE(s). That is, the TSCTSF can reuse the time synchronization capability exchange via UMIC with the UPF/NW-TT (e.g., attribute List of UEs associated with the User-Plane Node ID in 23.502 Table 5.2.6.25.8-1).

4. The TSCTSF request NG-RAN timing synchronization status subscription to the AMF. Two alternatives are possible (as described in 6.4.2.1):

 - Alternative 1 for NG-RAN Time Sync Status reporting: TSCTSF subscribes for receiving NG-RAN timing synchronization status at the AMF on a per RAN node level. The AMF forwards the received status report from the NG-RAN node to the TSCTSF. The TSCTSF is responsible for determining the impacted UE(s) based on their location.

- Alternative 2 for NG-RAN Time Sync Status reporting: TSCTSF subscribes for receiving NG-RAN timing synchronization status at the AMF on a per UE level. The AMF is responsible for determining the impacted UE(s) based on the NG-RAN node level report received and UE(s) location. Per impacted UE, the AMF forwards the NG-RAN time synchronization status report to the TSCTSF subscribed to it.

 If (g)PTP time distribution is configured for a UE, the TSCTSF request UPF/NW-TT timing synchronization status subscription to the SMF (at UE level or node level) or directly at the UPF/NW-TT (node level), as described in 6.4.2.1.

5. If AF’s request contains a spatial validity filter and the TSCTSF subscribes to node level information at the AMF in step 4, the TSCTSF is responsible for determining if a NG-RAN timing synchronization status update received at node level signalling impacts the UE(s) matching AF’s request condition. To support this, the TSCTSF subscribes to location services at the AMF (e.g., Namf\_EventExposure service for events like Location Report (TAI, Cell ID) or UE moving in or out of a subscribed "Area Of Interest").

If AF’s request contains a spatial validity filter and (g)PTP time distribution is configured for a UE, the TSCTSF is responsible of determining the UE(s) matching AF’s request condition based in their location and the serving UPF/NW-TT for the PTP instance.

6. The TSCTSF responds the AF.

7. The AMF request network timing synchronization status subscription to the NG-RAN node.

8. The AMF subscribes to UE(s) location services reporting from NG-RAN node.

9. The NG-RAN node detects a primary source event (e.g., degradation, failure, recovery).

10. The NG-RAN node notifies the AMF providing a NG-RAN timing synchronization status report. The report message may include, for example, the gNB node information, time status information, relevant UE information. The gNB node information indicates which 5G access stratum time distribution is impacted. The time status information might include the clock status in gNB node, and it can refer to the time service indication (disabled, enabled and holdover status). The relevant UE info represents those UE using the involved gNB access stratum time.

Editor’s Note: The actual details of the parameters to be provided by AF and to NG-RAN are FFS.

11. The AMF forwards the NG-RAN timing synchronization status report to the TSCTSF. If TSCTSF subscription is at NG-RAN node level (alternative 1 for NG-RAN Time Sync Status reporting), the AMF can directly forward the report received from NG-RAN node. If TSCTSF subscription is at UE level (alternative 2 for NG-RAN Time Sync Status reporting), the AMF determines the UE(s) impacted by the status update received from NG-RAN before notifying the TSCTSF (e.g., based on UE locations or UE identities).

12. The TSCTSF stores the network timing synchronization status update received and notifies the subscribed AF via exposure framework. If the notification from gNB provides the time status information (e.g. disabled, enabled and holdover status, actual status information values is FFS), TSCTSF stores the time status information locally.

Figure 6.4.3.1-1 illustrates the NG-RAN timing synchronization status subscription example, if the TSCTSF requires UPF/NW-TT timing synchronization status (determined in step 3), a similar signalling exchange between UPF/NW-TT, SMF, and TSCTSF is required to subscribe to UPF/NW-TT updates (directly or via the SMF), as described in 6.4.2.1.

#### 6.4.3.2 Procedure for UE provisioning network timing synchronization status

An overall procedure for UE provisioned network timing synchronization status is illustrated in Figure 6.x.3.2-1.



Figure 6.4.3.2-1: Procedure for UE provisioning network timing synchronization status

1. The AF sends network timing synchronization status request to the NEF or TSCTSF. The subscription configuration of NG-RAN nodes and UPF/NW-TT (if applicable) is performed as described in clause 6.4.3.1.

2. The NG-RAN node detects a primary source event (e.g., degradation, failure, recovery).

3. The NG-RAN node notifies the AMF providing a NG-RAN timing synchronization status report. The TSCTSF may have already configured the NG-RAN node to provide updates to the UE directly via SIB9/RRC signalling, in that case, steps 5 and 6 can be skipped.

4. The AMF forwards the NG-RAN timing synchronization status report to the TSCTSF. If TSCTSF subscription is at NG-RAN node level (alternative 1 for NG-RAN Time Sync Status reporting), the AMF can directly forward the report received from NG-RAN node. If TSCTSF subscription is at UE level (alternative 2 for NG-RAN Time Sync Status reporting), the AMF determines the UE(s) impacted by the status update received from NG-RAN before notifying the TSCTSF (e.g., based on UE locations or UE identities).

5. The TSCTSF determines the UE(s) to notify and the method to use to forward the network timing synchronization status notification.

 If UE is using (g)PTP time distribution and there is an available UPF/NW-TT timing synchronization status report, the TSCTSF may include this information when determining the content to send to the UE.

Editor's note: Need to inform the UE about UPF time synch issues and how a UE could make use of this information is FFS.

Editor's note: Need to remove a UE from the PTP instance in case of time synchronization degradation is FFS.

6. The TSCTSF can initiate a network triggered procedure to forward the notification to the UE via AMF or can command the serving NG-RAN node to notify the UE via SIB9/RRC messages.

7. The serving NG-RAN node forwards the network timing synchronization status to the UE.

Figure 6.4.3.2-1 illustrates the NG-RAN timing synchronization status notification example, for UPF/NW-TT timing synchronization status notification, a similar signaling exchange is required between UPF/NW-TT, SMF, and TSCTSF to retrieve the timing synchronization. For reporting UPF/NW-TT timing synchronization status report to the UE/DS-TT, the TSCTSF may use PMIC.

### 6.4.4 Impacts on services, entities and interfaces

- UE:

- Support receiving network timing synchronization status information.

- Support performing a registration request when RAN network timing synchronization status information changes while the UE is in CM-IDLE, if requested by TSCTSF or AMF.

- DS-TT:

- Support receiving network timing synchronization status information.

- NG-RAN:

- Indicate NG-RAN network timing synchronization status to UEs via SIB9 or RRC signalling.

- Report NG-RAN network timing synchronization status to AMF.

- AMF:

- Subscribe for network timing synchronization status reports from NG-RAN nodes.

- Report NG-RAN timing synchronization status to the TSCTSF (at UE level or NG-RAN node level).

- SMF:

- If SMF is involved in UPF/NW-TT timing sync status reporting, subscribe for network timing synchronization status reports from UPF/NW-TT nodes.

- Report UPF/NW-TT timing synchronization status to the TSCTSF (at UE level or UPF node level).

- TSCTSF:

- Receive network timing synchronization status information from NG-RAN (via AMF) and UPF/NW-TT (via SMF or directly).

- Discover serving AMF for a UE.

- Subscribe for receiving UE’s location, UE’s presence in Area of Interest, and reachability information from AMF.

- Subscribe for receiving UE’s PDU Session events from SMF.

- Support for requesting UEs to perform a Registration request if the UE detects a change in RAN network timing synchronization status information and the UE is in CM-IDLE.

- Mapping from spatial validity to validity area(s) (based on pre-configuration).

- Determination of area of interest based on the validity area(s).

- Inform AFs about network timing synchronization status.

- Initiate network-triggered procedures to reach the UE if is in CM-IDLE.

- Inform UE(s) about network timing synchronization status using PMIC or configuration of NG-RAN node to notify the UE via RRC.

- UPF:

- Report transport network timing synchronization status to TSCTSF (directly or via SMF).

- AF:

- Request for network timing synchronization status.

- Support receiving network timing synchronization status information.

## 6.5 Solution #5: Inform UE and AF about 5GS network timing synchronization status for PTP

### 6.5.1 Introduction

The solution is proposed to solve Key Issue #1: 5GS network timing synchronization status and reporting.

This solution addresses the following scenarios:

- 5GS is acting as Bridge to distribute time information to UEs using PTP or gPTP, as defined in 23.501 [2] clause 5.27.1.7.

This solution makes the following assumptions:

- The UE/DS-TT, NG-RAN, UPF/NW-TT are synchronized with the 5G GM (i.e. the 5G internal system clock) as specified in the TS 23.501 [2] and TS 38.331 [5].

- The UE/DS-TT and UPF/NW-TT handle the (g)PTP message as TS 23.501 [2].

### 6.5.2 Functional Description

Editor's note: how RAN time synch issues are detected and handled by this solution

The solution is based on the following principles:

- The AF/NEF subscribes the time synchronization status with TSCTSF.

- TSCTSF subscribes for receiving time synchronization status from UPF/NW-TT via PMIC/UMIC (i.e. the status of the synchronization of the UPF/NW-TT with the 5G GM and PTP GM):

- According to the status subscription, the UPF/NW-TT reports 5G GM and PTP GM (e.g. clock class and traceability) to TSCTSF/TSN AF via PMIC/UMIC.

- When TSCTSF receives the time synchronization status, it determines the impacted PTP ports and related UE (i.e. AF sessions.)

- TSCTSF inform the synchronization status to impacted UE/DS-TT via PMIC.

Editor's note: Which information needs to be signaled to UE/DS-TT and what DS-TT is supposed to do with this information is FFS.

- The TSCTSF notify the AF with the time synchronization status

### 6.5.3 Procedures

The exchange of PMIC/UMIC between TSCTSF and UE/DS-TT and between TSCTSF and UPF/NW-TT is specified in the TS 23.501 [2] clause 5.28.3.

### 6.5.4 Impacts on services, entities and interfaces

- UE/DS-TT:

- Support receiving the timing synchronization status information via PMIC.

- TSCTSF:

- Receive time synchronization status from UPF/NW-TT.

- Indicating time synchronization status to UE/DS-TT.

- Inform AFs about time synchronization status.

- UPF/NW-TT:

- Report 5G GM or PTP GM time sync status (e.g., clock class and UTC traceability) to TSCTSF via PMIC/UMIC.

## 6.6 Solution #6: Support for 5G Timing Exposure Enhancement.

### 6.6.1 Introduction

The solution enables AF to request time synchronization service in a specific coverage area. 5GS enforces the time synchronization service according to the requested coverage area.

### 6.6.2 General description

* The AF requested time synchronization service is for one UE or a group of UE.
* UEs get time synchronization service by receiving 5GS access stratum time or time-synchronized UPF/NW-TT.

The general idea of the solution is structured as follows:

- AF requests time synchronization service for targeted UE(s), and the coverage area info is included in the request.

- NEF authorizes the AF request and sends it to TSCSTF.

- TSCTSF determines the time source for the requested AF.

- AMF reports UE location information to PCF when the PCF initiates the AM policy association modification.

Editor’s Note: The coverage information in FFS. It may be per cell or a geographical area. For instance, in smart grid, the coverage area might be an industrial park. It is assumed the requested coverage information can be interpreted by NEF to 3GPP defined location information. This will be addressed in the associated KI solution.

### 6.6.3 Procedures

Flow chart for the AF requested time synchronization service in a specific area is illustrated as following.

（ UE location info）

（UE location info needed）

AMF

PCF

TSCTSF

NEF

AF

BSF

2.Nnef\_TimeSynchronization\_ASTICreate/Update/Delete

1. AM Policy Association Establishment

3.Ntsctsf\_TimeSynchronization\_ASTICreate/Update/Delete request

（ coverage area info）

4.Nbsf\_Managemet\_Subscribe/Notify

6.AM Policy Association Modification initiated by the PCF

(UE location information)

8.Ntsctsf\_TimeSynchronization\_ASTICreate/Update/Delete Response

9.Nnef\_TimeSynchronization\_ASTICreate/Update/Delete Response

5.Npcf\_AMPolicyAuthorization\_Create/Update request

7.Npcf\_AMPolicyAuthorization\_Create/Update response

 **Figure 6.6.3-1 AF requesting time synchronization service in a specific area**

1. AM policy association establishment is finalized during UE registration procedure.
2. The procedure is triggered by the AF request to influence the 5G time distribution. The coverage area information is added in step 2 when the AF requests the service in a specific area.
3. The NEF authorizes the request and invokes the operation with the corresponding TSCTSF. TSCTSF calculates the Uu time synchronization error budget if the AF provides the error budget requirements. The coverage area information is considered together with the 5G access stratum time distribution indication by the TSCSTF. If 5G access stratum time distribution is enabled in the coverage area, it can meet the request. If another gNB not in the coverage area or time-synchronized UPF/NW-TT can meet the request requirements, it provides reference time to the targeted UE in the area to enforce AF request if possible.

Editor’s Note: It is FFS if targeted UE(s) moves out of the coverage area.

Editor’s Note: It is FFS if TSCTSF can communicate with AMF directly, then step 4-7 are skipped.

1. If the 5G access stratum time distribution parameters in UDR are associated with a DNN/S-NSSAI for the PCF for the UE may discover the PCF for the PDU Session using SUPI and (DNN, S-NSSAI) as parameters.
2. TSCTSF selects for the PCF that handles the AM Policy Association of the targeted UE with SUPI (step 4) as an input parameter and informs the PCF to consider UE location information when determining AM policy.
3. If the TSCTSF sends multiple time synchronization error budgets for a given UE, the PCF would pick the most stringent budget. The PCF takes a policy decision and then it may initiate an AM Policy Association Modification procedure. In the step, the AMF is responsible for reporting UE location information to PCF. When PCF receives UE location information, it determines to provide which 5GS access stratum time information to UE based on time synchronization date sent by TSCTSF. As part of this, the 5G access stratum time distribution indication and the Uu time synchronization error budget are provided to NG-RAN. Based on this, NG-RAN provides the 5GS access stratum time to the UE according to the Uu time synchronization error budget as provided by the TSCTSF (if supported by UE and NG-RAN).
4. The PCF of the UE replies to the TSCTSF with the result of Npcf\_AMPolicyAuthenorization operation.
5. The TSCTSF responds to the NEF request in step 3.
6. The NEF informs the AF about the result of the operation in step 2.

### 6.6.4 Impacts on services, entities and interfaces

* AF

- Support to include the coverage area information in the time synchronization service request.

* TSCTSF

- Support to include the coverage area information in the time synchronization service request.

- Update the 5G access stratum time distribution indication based on coverage area information

- Inform the PCF to consider UE location information.

* PCF

## - Combine UE location information when AM policy decision.6.7 Solution #7: RequestedCoverage area filters for time synchronization service

### 6.7.1 Introduction

This solution is proposed to solve Key Issue #2: Time synchronization service enhancements. In this Key Issue, the coverage area is taken into account for the configuration of the time synchronization service. Therefore, this solution addresses the time synchronization service scenarios already supported in 5G Release-17 based on access stratum or (g)PTP time distribution methods.

This solution proposes to use Tracking Areas (TAs) identified by a list of Tracking Area Identities (TAI) or Cell list to describe a specific geographical area (a so-called Requested Coverage Area) where an AF requests to enable a time synchronization (TS) service. Furthermore, in order to enforce that the requested TS service is enabled for UEs (a specific UE or a group of UEs) only in that Requested Coverage Area, the proposed solution exploits the 5GS functionality (provided by the AMF) of tracking and reporting “UE mobility on Area of Interest” events (clause 5.3.4.4 of TS 23.501). An Area of Interest for each AMF is represented by the TA(s) or Cell list, wherein the Area of Interest is identical to the Requested Coverage Area or the Area of Interest is a TA or cell subset of the Requested Coverage Area.

### 6.7.2 Functional Description

The existing time synchronization exposure procedures (clause 4.15.9 of TS 23.502 [3]) are enhanced.

The following principles are proposed to enable the use of coverage area for time synchronization service operation:

- An AF may optionally include spatial validity condition (i.e., Requested Coverage Area within the timing synchronization service request.

- The AF may provide as spatial validity condition (e.g., a civic address or shapes), or area(s) of interest (AoI), or a TAI/Cell list (if it is an AF within the operator’s domain, it will have TA(s) or Cell(s) configured).

- If the AF provides spatial validity, the NEF/TSCTSF maps the spatial validity to validity area(s) (based on pre-configuration). Later, the TSCTSF or PCF determines the area(s) of interest based on validity area(s). The TSCTSF or AMF subscriptions use area of interest that may be the same as spatial validity condition or may be a subset of the spatial validity condition (e.g., a list of TAs, or Cell list) based on the latest known UE location.

- If the AF provides a AoI, the NEF/TSCTSF/trusted AF maps the information to a list of TAs or Cell list.

Editor’s Note: Whether TSCTSF also needs to provide mapping is FFS.

- TSCTSF uses Location or UE presence in Area of Interest services at the AMF Event Exposure service (Namf\_EventExposure operations) to identify the UE(s) to which the AF request with a Requested Coverage Area applies. The TSCTSF subscribes to this information at the AMF(s) and stores it.

- Requested Coverage Area will be used at the TSCTSF for triggering time synchronization service activation/modification/deactivation with the following differences: (1) the TSCTSF discovers the AMF(s) serving in the Tracking Areas (TAs) comprising the Requested Coverage Area; (2) the TSCTSF subscribes (using the Namf\_EventExposure\_Subscribe service operation specified in clause 5.2.2.3.2 of TS 23.502 [3]) to the UE mobility on Area of Interest event notification service from the AMF(s) to be notified the UE(s) presence in an Area of Interest for each AMF (e.g. UE location is IN or OUT an Area of Interest); (3) the TSCTSF determines (based on the notification from the AMF(s)) whether or not the targeted UE(s) are inside the Requested Coverage Area; and (4) the TSCTSF proceeds with the time synchronization service activation/deactivation only after the TSCTSF has determined which of the targeted UE(s) are in or out of the Requested Coverage Area. The subscription to reports of UE presence in the Area of Interest procedure is described in clause 5.3.4.4 of TS 23.501 [2].

- For access stratum distribution activation/deactivation, the TSCTSF will enable/disable ReferenceTimeInformation delivery to the UE at the serving NG-RAN node. For (g)PTP distribution activation/deactivation, the TSCTSF will modify the PTP instance configuration by means of sending a PMIC to the impacted UE/DS-TT and UMIC to the UPF/NW-TT, as described in clause K.2.2 of TS 23.501 [2].

Editor's note: Whether to enable/disable 5G access stratum time distribution for UE(s) based on RAN report of AoI is FFS.

### 6.7.3 Procedures

#### 6.7.3.1 Procedure for AF requested (g)PTP timing synchronization with Requested Coverage Area

An overall procedure for AF providing coverage area filter(s) for (g)PTP based time synchronization service is illustrated in Figure 6.7.3.1-1.



Figure 6.7.3.1-1: (g)PTP time distribution configuration with Requested Coverage Area

1. The AF creates a time synchronization service configuration for a PTP instance by invoking Nnef\_TimeSynchronization\_ConfigCreate service operation. The request includes the parameters as described in table 4.15.9.3.1 in TS 23.502 [3] and optionally a spatial validity condition (i.e., Requested Coverage Area) in the format of spatial validity, or area(s) of interest, or list of TA(s), or Cell list.

2. The NEF authorizes the request. After successful authorization, the NEF invokes the Ntsctsf\_TimeSynchronization\_ConfigCreate service operation with the corresponding TSCTSF, with the parameters as received from the AF.

 The AF that is part of operator's trust domain may invoke the services directly with TSCTSF.

3. If the AF provided spatial validity, the TSCTSF maps the information to areas of validity based on pre-configuration, then the TSCTSF determines area(s) of interest based on validity area(s) and the corresponding list of TA(s) or Cell list.

Editor’s Note: Whether TSCTSF or trusted AF provides the mapping is FFS.

4. The TSCTSF discovers the AMF(s), serving in the Tracking Areas (TAs) that comprise the spatial validity condition, using the NRF discovery service (Nnrf\_NFDiscovery\_Request) with the TAs.

5. The spatial validity condition (or the area(s) of interest condition) for the UE(s) is resolved at the TSCTSF. In order to do that, the TSCTSF subscribes to the AMF(s) to receive notifications about the UE presence in an area of interest (or UE location) using Namf\_EventExposure operation. The subscribed area of interest may be the same as the spatial validity condition (i.e., Requested Coverage Area) or may be a subset of the Requested Coverage Area (e.g., a list of TAs, or cell list) based on the latest known UE location.

The AMF(s) track the UE’s location to determine the UE’s presence in an Area of Interest as described in clause 4.15.4.2 of TS 23.502 [3]. Further, the AMF(s) notify the TSCTSF about the UE(s) presence (IN, OUT, or UNKNOWN) in the Area of Interest(s).

6. According to the UE location of each UE that is targeted by the request and spatial validity condition in step 1, the TSCTSF determines whether to active time synchronization service for this UE:

 - If the UE location is in an Area of Interest, the TSCTSF determines to active time synchronization service;

- If the UE location is out of Requested Coverage Area, the TSCTSF determines not to active time synchronization service, or determines to hold a while according to Temporal Validity Condition (if this parameter is available, and current time is within validity time period);

7. The TSCTSF responds with the Ntsctsf\_TimeSynchronization\_ConfigCreate response.

8. The NEF responds with the Nnef\_TimeSynchronization\_ConfigCreate response.

9. The TSCTSF uses the procedures described in clause K.2.2 of TS 23.501 [2] to configure and initialize the PTP instance in the DS-TT(s) and NW-TT.

10. The TSCTSF uses the procedure in clause 4.15.9.4 of TS 23.502 [3] to manage the 5G access stratum time distribution for the UEs that are part of the impacted PTP instance.

11. UE moves in/out of the determined area of interest (i.e., Requested Coverage Area).

12. NG-RAN determines the UE presence in the area of interest has changed and notifies the AMF.

13. The AMF detects the subscription change related event occurs and it sends the event report by means of Namf\_EventExposure\_Notify message to the TSCTSF.

14. If the TSCTSF receives the UE location change notification for AoI. The TSCTSF may update to activate or deactivate the time synchronization service for the given UE.

- If the UE moves out of Requested Coverage Area, TSCTSF determines to deactivate time synchronization service and proceeds as Ntsctsf\_TimeSynchronization\_ConfigUpdate was received that indicated this UE is removed from the PTP instance as described in clause 4.15.9.3.3 TS 23.502 [3];

- If the UE moves into an Area of Interest, and according to Temporal Validity Condition (if this parameter is available, and current time is within validity time period), the TSCTSF determines to activate time synchronization service;

- The TSCTSF keeps the requested TS service unchanged (i.e., active/inactive) when the UE presence in the Requested Coverage Area becomes UNKNOWN until the TSCSTF determines that the UE is inside/outside the Requested Coverage Area.

15. The TSCTSF updates the state of the time synchronization configuration and may notify the NEF (or AF) with the Ntsctsf\_TimeSynchronization\_ConfigUpdateNotify service operation. The notification indicates the identities of the UEs currently within the area of spatial validity.

16. The NEF notifies the AF with the Nnef\_TimeSynchronization\_ConfigUpdateNotify service operation.

#### 6.7.3.2 Procedure for AF requested access stratum timing synchronization with Requested Coverage Area

An overall procedure for AF providing coverage area filter(s) for access stratum based time synchronization service (refer TS 23.502) is illustrated in Figure 6.7.3.2-1 .



Figure 6.7.3.2-1: 5G access stratum time distribution configuration with Requested Coverage Area

1. The AF request to influence the 5G access stratum time distribution providing access stratum time distribution parameters to the NEF (together with the AF identifier and potentially further inputs as specified in table 4.15.9.4-1 in TS 23.502 [3]) and optionally a spatial validity condition (i.e., Requested Coverage Area) in the format of spatial validity, or area(s) of interest, or list of TA(s), or Cell list.

2. The NEF authorizes the request. After successful authorization, the NEF invokes the Ntsctsf\_ ASTI\_Create service operation with the corresponding TSCTSF.

3. If the AF provided spatial validity, the TSCTSF maps the information to areas of validity based on pre-configuration, then the TSCTSF determines area(s) of interest based on validity area(s) and the corresponding list of TA(s) or cell list.

4. The TSCTSF discovers the AMF(s), serving in the Tracking Areas (TAs) that comprise the spatial validity condition, using the NRF discovery service (Nnrf\_NFDiscovery\_Request) with the TAs.

5. The spatial validity condition (or the area(s) of interest condition) is resolved at the TSCTSF. In order to do that, the TSCTSF subscribes to the AMF to receive notifications about change of UE location in an area of interest using Namf\_EventExposure operation. The subscribed area of interest may be the same as spatial validity condition or may be a subset of the spatial validity condition (e.g., a list of TAs) based on the latest known UE location.

The AMF(s) track the UE’s location to determine the UE’s presence in an Area of Interest as described in clause 4.15.4.2 of TS 23.502 [3]. Further, the AMF(s) notify the TSCTSF about the UE(s) presence (IN, OUT, or UNKNOWN) in the Area of Interest(s).

6. According to the UE location and spatial validity condition, the TSCTSF determines whether to active time synchronization service:

 - If the UE location is in an Area of Interest, the TSCTSF determines to active time synchronization service;

- If the UE location is out of Requested Coverage Area, the TSCTSF determines not to active time synchronization service, or determines to hold a while according to Temporal Validity Condition (if this parameter is available, and current time is within validity time period);

7. The TSCTSF responds the AF with the Ntsctsf\_ASTI\_Create service operation response.

8. The NEF informs the AF about the result of the Nnef\_ASTI\_Create service operation performed in step 1.

9. The TSCTSF uses the procedures described in clause 4.15.9.4 of TS 23.502 [3] to configure ReferenceTimeInformation delivery to the UE(s) at the serving NG-RAN nodes.

10. UE moves in/out of the configured area of interest.

11. NG-RAN determines the change of the UE presence in the area of interest has changed and notifies the AMF.

12. The AMF detects the subscription change related event occurs and it sends the event report by means of Namf\_EventExposure\_Notify message to the TSCTSF.

13. If the TSCTSF receives the UE location change notification for AoI. The TSCTSF may update to activate or deactivate the time synchronization service.

- If the UE moves out of Requested Coverage Area, TSCTSF determines to deactivate ASTI time synchronization service as described in clause 4.15.9.4 TS 23.502 [3];

- If the UE moves into an Area of Interest, and according to Temporal Validity Condition (if this parameter is available, and current time is within validity time period), the TSCTSF determines to activate ASTI time synchronization service as described in clause 4.15.9.4 TS 23.502 [3];

- The TSCTSF keeps the requested TS service unchanged (i.e., active/inactive) when the UE presence in the Requested Coverage Area becomes UNKNOWN until the TSCSTF determines that the UE is inside/outside the Requested Coverage Area.

14. The TSCTSF updates the state of the time synchronization configuration and may notify the NEF (or AF) with the Ntsctsf\_ASTI\_UpdateNotify service operation.

15. The NEF notifies the AF with the Nnef\_ASTI\_UpdateNotify service operation.

### 6.7.4 Impacts on services, entities and interfaces

- TSCTSF:

- Subscribe for receiving UE’s presence in Area of Interest from AMF.

- Mapping from spatial validity to validity area(s) (based on pre-configuration).

- Determination of area of interest based on the validity area(s).

- Support for time synchronization service configuration conditioned to geographical area filter(s) received from AF.

- Discovers the related AMF(s) using the NRF’s service operation Nnrf\_NFDiscovery\_Request.

- AMF:

- Tracks a UE’s location to determine the UE’s presence in an Area of Interest using the existing event reporting type, i.e., UE mobility on Area of Interest.

- Notifies the subscribed TSCTSF about the change of UE’s status (IN, OUT, or UNKNOWN) in the Area of Interest using the (existing) Namf\_EventExposure\_Notify service operation.

- AF:

- Includes the Spatial Validity Condition in AF request for time synchronization service configuration.

## 6.8 Solution #8: AF Request of PER for QoS and Alt-QoS

### 6.8.1 Introduction

This solution is proposed to solve Key Issue #4: Enable an AF to explicitly provide the required PER to the NEF/PCF for QoS and Alt-QoS.

In Release 17, the “Setting up an AF session with required QoS” procedure (TS 23.502[3] clause 4.15.6.6) and the “AF Session with required QoS update” procedure (TS 23.502[3] clause 4.15.6.6a) were revised so the AF can provide individual parameters for QoS and Alt-QoS. Inclusion of PER as an individual parameter requested by the AF was postponed to Release18. PER is a QoS Characteristic as defined in TS 23.501[2] clause 5.7.3.1, similar to PDB which was included as an individual parameter. PER is also currently part of the Alternative QoS Profile, along with PDB and GFBR. PDB and GFBR as individual parameters for Alt-QoS were addressed in Release 17.

This solution adds Requested PER to the AF request for QoS and Alternative QoS

### 6.8.2 Functional Description

When there is a single PDU session anchor for the UE, an AF request for QoS specifying a Requested PER value can sent to the PCF where it is mapped to a PCC rule with a 5QI that reflects the Requested PER. Similarly, a Requested PER value can be added to each Alternative-QoS Related parameter set (currently comprising Requested Delay and Requested GBR) in the Alternative QoS Requirements. Requested PER in the Alternative QoS requirements is mapped to the corresponding parameters in the Alternative QoS Profile (as defined in TS23.501[2] clause 5.7.1.2a), in the same manner as was done for PDB and GFBR in Release 17. PCF selects the appropriate 5QI considering the requested PER and Requested 5GS Delay as in TS 23.503[3].

### 6.8.3 Procedures

Following are the steps needed for the AF requested PER to be considered either using single or redundant user plane paths:

1. The AF provides Requested PER for QoS and Alternative QoS. If it is a trusted AF, it may provide it directly to the TSCTSF. If not, it provides it via the NEF which eventually forwards it to the TSCTSF.
2. The TSCTSF forwards the parameters to the PCF.
3. The PCF selects the appropriate 5QI considering the requested PER and the individual QoS Parameters as specified in TS 23.503[3] clause 6.1.3.22.
4. The PCF determines a PCC rule using the Requested PERs received from the AF/NEF.
5. The response to the AF (Nnef\_AFsessionWithQoS\_Create/Update response) indicates whether the PER request was achieved.

### 6.8.4 Impacts on services, entities and interfaces

- SMF:

- Map Requested PER to QoS Profile for QoS and Alternative QoS

- PCF:

- Map Requested PER to PCC Rule for QoS and Alternative QoS

- TSCTSF:

- Support receiving Requested PER from NEF and sending to PCF

- NEF:

- Include Requested PER in Nnef\_AFSessionWithQoS service and send Requested PER to TSCTSF

- AF:

- Request PER for QoS and Alternative QoS.

## 6.9 Solution #9: Interworking with TSN network deployed in the transport network

### 6.9.1 Introduction

This solution enables enhancement to support TSN transport network for N3.

This solution addresses the following areas:

a) The architecture enhancement to support the interworking between 5GS and TSN networks deployed in the transport network.

b) The information from 5GS to interact with TSN network.

6.9.2 Functional Description

5GC will act as CUC to interact with the TN CNC. RAN and UPF will act as Talker or Listener. It is proposed to introduce Access Network TSN Translator (AN-TT) and N3 interface TSN Translator (N3-TT) as network termination point for the N3 interface. AN-TT and N3-TT support the functionality of Talker and Listener (End Station).

The architecture is as Figure 1:

 

Figure 6.9.2-1 Architecture on interworking with TSN transport network

NOTE: The TN CNC in transport network (TN) is independent from the CNC in the DN.

As CUC needs to interact with the End Station, it is proposed the SMF will act as the CUC or the CUC functionality is collocated with SMF. SMF/CUC provides merged stream requirements (i.e. translated Talker group and Listener group information) as specified in clause 45.1.7 of IEEE P802.1Qdj [10] via the User/Network-Interface (UNI) to the TN CNC. TN CNC uses the merged stream requirements as input to select respective path(s) and calculate schedules in TN. Based on the results, the TN CNC provides merged end station communication-configuration back to the SMF/CUC. The SMF may further adjust the transmit time of the stream in UPF and RAN.

In particular, the details of providing End Station related information to generate the merged stream requirements by the SMF/CUC are as following:

For the Talker group:

* Stream ID and Stream Rank can be generated by the SMF/CUC based on pre-configuration.
* EndStationInterfaces and Interface Capabilities can be pre-configured in the SMF/CUC or the SMF/CUC can collect them during PDU Session Establishment from AN-TT and N3-TT.

Editor’s Note: DataFrameSpecification is optional and its usage is FFS.

* In TrafficSpecification elements, there are several parameters related to the TSC traffic within 5GS
	+ MaxFrameSize, SMF/CUC could generate it from the Burst Size of the TSC traffic. PCF needs to transfer the Burst Size to the SMF. SMF also needs to consider the framing bits which is not used for transferring in 5GS, e.g. CRC.
	+ MaxFramesPerInterval, SMF could set it as 1.
	+ Interval, SMF could generate it from the Periodicity of the traffic.
	+ TSpecTimeAware group
		- EarliestTransmitOffset, SMF could generate it from the Burst Arrive Time (BAT) of the traffic (i.e. the BAT in TSC Assistance Container as described in clause 5.27.2 of TS 23.501 [2]) and jitter. For uplink, the BAT in AN-TT should be the BAT in UL plus the sum of UE-DS-TT Residence Time and 5G-AN PDB. EarliestTransmitOffset could be set as the sum of the BAT in AN-TT and jitter. For downlink, the BAT in N3-TT should be the sum of the BAT in DL and UPF Residence Time. EarliestTransmitOffset could be set as the sum of the BAT in N3-TT and jitter.
		- LatestTransmitOffset, the last chance within an interval should leave enough time to transfer a packet with MaxFrameSize. Thus, the SMF could generate it from the BAT in AN-TT/N3-TT subtracting the sum of jitter and the time to transfer a packet with MaxFrameSize.
		- Jitter, SMF could generate it based on local configuration.
* UserToNetworkRequirements.MaxLatency
	+ NumSeamlessTrees, SMF/CUC could set it as 0 if no redundancy is needed, otherwise it could use other values.
	+ MaxLatency, SMF/CUC could generate it based on CN PDB and UPF Residence Time, i.e. it should be CN PDB minus UPF Residence Time.

The Listener group contains Stream ID, EndStationInterfaces, UserToNetworkRequirements, and Interface Capabilities. The SMF could generate the corresponding information in the same way as defined for the Talker group.

Editor’s Note: It is assumed that the merged stream requirements will contain at least the same information as defined for the User/network configuration information (i.e. Talker group and Listener group).

The merged end station communication-configuration provided by TN CNC to the SMF/CUC includes:

* Stream ID
* StatusInfo
* AccumulatedLatency
* InterfaceConfiguration
	+ MAC Address
	+ VLAN Tag
	+ IPv4/IPv6 Tuples
	+ TimeAwareOffset
* FailedInterfaces

The details of the above information are described in IEEE Std 802.1Qcc [6]. When the SMF/CUC receives the merged end station communication-configuration, the SMF/CUC should configure the AN-TT and N3-TT based on the TimeAwareOffset. The AN-TT and N3-TT should set the sending time of the traffic (e.g. AdminBaseTime and OperBaseTime) accordingly.

Editor’s Note: It is assumed that the merged end station communication-configuration will contain at least the same information as defined for the status.

### 6.9.3 Procedures

Figure 6.9.3-1 shows the procedure for this solution:

RAN/AN-TT

SMF/CUC

UE

PCF

2. PCC rules with TSC Assistance Container

3. Parameter Mapping

UPF/N3-TT

TN CNC

4. Merged Stream Requirements

5. Merged End Station Communication-Configuration

6a. End Station configuration

6b. End Station configuration

1. **PDU Session Establishment procedure**

Figure 6.9.3-1: Procedure for interworking with TSN transport network

1. UE triggers the PDU Session Establishment procedure as described in clause 4.3.2 in TS 23.502 [3]. The RAN and UPF report AN-TT/N3-TT port information to the SMF/CUC.
2. During PDU Session Modification, the SMF received PCC rules with TSC Assistance Container from the PCF. The PCF needs to send Burst Size of the TSC traffic as described in clause 6.x.3.
3. The SMF/CUC generates merged stream requirements as described in clause 6.x.3.
4. The SMF/CUC sends the merged stream requirements to the TN CNC.
5. The TN CNC returns the merged end station communication-configuration to the SMF/CUC.
6. The SMF/CUC configures the Talker and Listener based on the merged end station communication-configuration returned by the TN CNC. The SMF/CUC could send the TimeAwareOffset to the N3-TT. The N3-TT should adjust the sending time of the traffic (e.g. AdminBaseTime and OperBaseTime) accordingly.

### 6.9.4 Impacts on services, entities and interfaces

SMF: support the collocation with CUC, i.e.

* + - * Provide input related to the Talker/Listener Group based on the above description.
			* Transfer received merged end station communication-configuration from the TN CNC to the Talker/Listener accordingly

PCF: sends the TSCAC including Burst Size of the TSC traffic to the SMF.

RAN: support the functionality of Listener/Talker as described above.

UPF: support the functionality of Talker/Listener as described above.

## 6.10 Solution #10: 5GC acting as a CUC for CNC in TN

### 6.10.1 Introduction

This solution enables the 5GC to act as a TSN CUC (Centralized User Configuration).

This solution makes the following assumptions:

- The underlay transport network for N3 and N9 tunnels support TSN features and deploys a CNC.

- 5GC implements the UNI as defined in IEEE P802.1Qdj [10] towards the CNC in Transport Network.

- The solution can be used with both Ethernet and IP type PDU Sessions.

- The solution can be used when 5GS is integrated with external IEEE TSN networks as specified in TS 23.501 [2]. In this case the CNC in external TSN network controls the 5GS as an IEEE 802.1Q bridge via TSN AF.

- The solution can be used when integration with external IEEE TSN networks does not apply as specified in TS 23.501 [2]. In this case the AF uses the 3GPP QoS-service to indicate the QoS requirements and traffic characteristics to the TSCTSF.

- A dynamic value for the CN PDB of a Delay-critical GBR 5QI is determined by the SMF as described in clause 5.3.7.4 in TS 23.501 [2].

### 6.10.2 Functional Description

The solution is based on the architecture in Figure 6.10.2-1:



Figure 6.10.2-1: Architecture to support the control of TSN features in TN

- The solution supports deployments with and without external TSN network:

a) When integration with IEEE TSN applies: CNC in external TSN network provides bridge configuration to the TSN AF. TSN AF uses the PSFP (IEEE 802.1Qci) information as provided by the CNC to derive the TSC Assistance Container (TSCAC). TSCAC is provided to the SMF (via PCF), and SMF determines the TSC Assistance Information (TSCAI) as specified in TS 23.501 [2].

b) When integration with IEEE TSN does not apply: The AF provides a Ntsctsf\_QoSandTSCAssistance service request to the TSCTSF (directly or via NEF). The request contains the flow description and may contain one or more of the Requested 5GS delay, Burst Size, Burst Arrival Time, Periodicity, and Time Domain as specified in clause 4.15.6.6 in TS 23.502 [3]. TSCTSF determines the TSCAC and provides it to the SMF (via PCF), and SMF determines the TSCAI. DS-TT and NW-TT are optional as in Release 17.

- TSN Transport Network (TN) deploys a CNC that communicates witha CUC residing in the 5GC. The SMF is collocated with the CUC and information is exchanged between SMF and CUC by implementation specific means (out of scope of 3GPP). Once the SMF has established a QoS Flow between UPF and NG-RAN, the SMF/CUC determines the merged stream requirementsfor the QoS Flow in the transport network and communicates them to the CNC in TN.

- The CUC implements the UNI as defined in IEEE P802.1Qdj [X] towards the CNC in Transport Network.

- CNC in TN configures the TN according to the merged stream requirements reflecting the required traffic characteristics of the QoS Flow.

Editor’s Note: Stream Aggregation is FFS

### 6.10.3 Procedures

The figure 6.10.3-1 describes the overall procedure how QoS Flows are established with the solution.



Figure 6.10.3-1: Overview of the QoS Flow establishment

1. PCF receives the Policy Authorization service request from the AF/NEF/TSCTSF. The PCF composes the PCC Rules as specified in Release 17. PCF includes the TSCAC in the request when it invokes the SMF.

2. SMF receives the PCC Rules from the PCF. The SMF binds the PCC rule to a QoS Flow.

3. SMF indicates N4 rules for a QoS Flow to the UPF. The UPF assigns the CN tunnel endpoint address. The SMF determines a dynamic value for the CN PDB, based on the UPF and NG-RAN of the PDU Session.

4. The SMF provides the QoS profile for the QoS Flow to the NG-RAN. The SMF signals the dynamic value for the CN PDB for the QoS Flow to NG-RAN. NG-RAN assigns the AN tunnel endpoint address.

SMF provides the TSCAI to the NG-RAN on QoS Flow basis. The TSCAI may contain Burst Arrival Time (BAT) at the UE egress for UL traffic, and BAT at the gNB ingress for DL traffic, as specified in Release 17.

Upon receiving the TSCAI for a QoS Flow from the SMF, if the TSCAI includes a BAT in UL direction, the RAN determines the corresponding BAT offset in UL direction at the gNB egress. The NG-RAN provides the value to the SMF in a response.

BAT offset is relative to the BAT value in UL direction NG-RAN has received from the SMF in TSCAI. BAT offset can take positive or negative values. The NG-RAN estimates the value of BAT offset at the time of QoS Flow establishment or modification. If necessary, the NG-RAN can update the BAT offset to the SMF e.g. if certain threshold is exceeded.

 If (g)PTP time synchronization is used and the TSCAC contains the Burst Arrival Time expressed in external GM time, the SMF adjusts the TSCAI to be expressed in 5GS time based on the clock drifting reports from the UPF as in Release 17. In this case the SMF may update the TSCAI of the QoS Flow to the NG-RAN.

5. After the SMF has setup a QoS Flow between UPF and NG-RAN, the SMF deducts the received BAT offset from the current BAT in UL direction in the TSCAI for the given QoS Flow.

 The SMF provides the corresponding flow identification (AN tunnel end point address/port and CN tunnel endpoint address/port) along with the traffic requirements and characteristic for the QoS Flow (BAT at RAN egress in UL direction, BAT at UPF egress in DL direction, Periodicity, maximum latency, maximum jitter, max number of frames per interval, maximum frame size, etc) While the collocated CUC translates this information to merged stream requirements. The CUC communicates the merged stream requirements to the CNC in the TN. The SMF sets the maximum latency to the value of the CN PDB.

Editor's Note: It is FFS if also the UPF residence time needs to be considered when calculating the maximum latency that is indicated in the stream requirements.

 The CUC and CNC in TN may use the data frame specification for IP to identify at UNI the TN stream on QoS Flow basis, in order to treat the data flow according to the traffic requirements assigned for the QoS Flow. The CNC in TN can then use the provided merged stream requirements to ensure that sufficient resources are reserved in the TN for the TN stream e.g., to select the path(s) and calculate schedules for the traffic that can guarantee the required maximum latency.

NG-RAN and UPF may support the Stream Transformation as described in IEEE 8021.Qdj [x], e.g. Talker uses the Multicast MAC address as assigned by the TN-CNC and indicated to the NG-RAN and UPF from the SMF/CUC. Alternatively, if the NG-RAN and UPF do not support Stream Transformation, two options can be considered for identifying the traffic on QoS Flow basis in the TN:

a) The SMF can instruct the UPF and NG-RAN to assign a separate CN tunnel end point address for each QFI of the N4 Session. This ensures the TN can distinguish the QoS Flows based on the AN and CN tunnel destination IP addresses. It is assumed that IPv6 is used in the CN tunnel addresses to provide sufficient number of addresses.

b) The interface between the CUC and CNC in the TN allows the SMF and CUC to indicate the TEID and QFI of the given QoS Flow to the CNC in the TN. For example, the CUC indicates a Stream Filter including the source/destination IP addresses/ports and QFI and/or TEID, and merged stream requirements that are associated with this Stream Filter. TN can distinguish the QoS Flows based on the TEID and QFI as carried in the GTP-U. This option impacts the IEEE P802.1Qdj [X].

### 6.10.4 Impacts on services, entities and interfaces

- SMF:

- Allows information access with the collocated CUC to support UNI as described in IEEE P802.1Qdj [10].

- Determines the traffic requirements for a QoS Flow and initiates that CUC translates them to merged stream requirements which are then passed to the CNC in Transport Network.

- NG-RAN:

- Determines a BAT offset in UL direction at the gNB egress, based on the BAT in UL direction the NG-RAN receives from the SMF in TSCAI. The NG-RAN provides the BAT offset value to the SMF in a response to the QoS Flow establishment or modification request. If Option a) is used to identify the flows in TN, assigns a separate AN tunnel end point address for each QFI of the PDU Session.

- UPF:

- If Option a) is used to identify the flows in TN, assigns a separate CN tunnel end point address for each QFI of the N4 Session.

## 6.11 Solution #11: Interworking with TSN enabled N3 transport network for deterministic traffic delivery

### 6.11.1 Introduction

The solution is proposed to solve Key Issue #5: Interworking with TSN network deployed in the transport network. In the 3GPP Rel-16 and Rel-17, the 5GS has supported “periodic deterministic communication”, so called TSC communication.

The E2E delay for the service flow in the 5GS (called as PDB) includes AN-PDB between UE and NG-RAN, and CN-PDB between NG-RAN and UPF. The CN-PDB is guaranteed by N3 transport network.

If the TSN is deployed in the N3 transport network, the 5GS can utilize the TSN capability in the N3 to provide the deterministic CN-PDB.

### 6.11.2 Functional Description

In the figure 6.11.2-1, it proposes an enhanced 5GS architecture to utilize the TSN capability in the N3 transport network.



Figure 6.11.2-1: The enhanced 5GS interworking with CNC in transport network

The solution is based on the following principles:

- There is a NG-TT (NG-RAN TSN translator) in the NG-RAN, which act as the TSN end station in the N3 transport network.

- it may support LLDP to report the topology to CNC.

- As the TSN end station, it is Talker when it send to UL packet, and is Listener when it receives the DL packet.

- it support PMIC and UMIC to communicate with TSNCF.

- There is a TNW-TT (Transport NW-TT) in the UPF, which act as the TSN end station in the N3 transport network.

- it may support LLDP to report the topology to CNC.

- As the TSN end station, it is Talker when it send to DL packet, and is Listener when it receives the UL packet.

- it support PMIC and UMIC to communicate with TSNCF.

NOTE: It may reuse the PMIC/UMIC for the NW-TT.

- There TSN CUC Function (TSNCF) in the 5GC. It act as the CUC to communicate with CNC in the N3 transport network.

- The TSNCF may in the TSN AF, or TSCTSF.

- During TSC communication establishment, it collect the Talker/Listener stream requirement as specified in IEEE 802.1 Qcc [6] from NG-TT and TNW-TT via PMIC/UMIC.

- The TSNCF provides the Talker/Listener status to CNC and receives the status of stream configuration from CNC.

- The TSNCF provides the Talker/Listener configuration status to NG-TT and TNW-TT via PMIC/UMIC.

Editor's note: Whether NG-TT and TNW-TT need to perform LLDP is FFS.

Editor's note: The detail on how to use the PMIC/UMIC is FFS.

Editor's note: It is FFS whether additional functionality is needed for the NG-TT, TNW-TT and TSNCF.

Editor's note: It is FFS if UPF can simply act as a TSN capable bridge (interacting directly with the transport NW CNC) and if NG-RAN can simply act as a TSN capable end-point. Related to that it is FFS if NG-TT and TNW-TT are needed.

### 6.11.3 Procedures

The procedure in Figure 6.11.3-1 shows a signalling flow in which the 5GS reserve the resource in the TSN enabled N3 transport network.



Figure 6.11.3-1: Procedure for reserve the resource in TSN transport network

The signalling procedure is similar with the network requested PDU Session Modification specified in TS 23.502 [3] clause 4.3.3.2. The enhancement are:

8. The NG-RAN send the PMIC/UMIC in the N2 request, which carry the stream information needed for CUC. For the UL traffic, the stream information is for the Talker, and for the DL traffic, the stream information is for the Listener. The stream information detail see IEEE 802.1Qcc [6] clause 46.2.3 and 46.2.4.

9. The PMIC/UMIC from NG-TT is sent to SMF.

10. The UPF/TNW-TT send the PMIC/UMIC in the N4 response, which carry the stream information needed for CUC. For the DL traffic, the stream information is for the Talker, and for the UL traffic, the stream information is for the Listener. The stream information detail see IEEE 802.1Qcc [6] clause 46.2.3 and 46.2.4.

11/12. The PMIC/UMIC from NG-TT and TNW-TT is sent to TSNCF via PCF.

13. The TSNCF send the Talker/Listener satus to CNC. The CNC response with stream configuration.

14~18. The TSNCF send the stream configuration to NG-TT and TNW-TT in the PMIC/UMIC.

### 6.11.4 Impacts on services, entities and interfaces

- NG-RAN/NG-TT: it may support LLDP to report the topology to CNC. As the TSN end station, it is Talker when it send to UL packet, and is Listener when it receives the DL packet. It support PMIC and UMIC to communicate with TSNCF.

- UPF/TNW-TT: it may support LLDP to report the topology to CNC. As the TSN end station, it is Talker when it send to DL packet, and is Listener when it receives the UL packet. It support PMIC and UMIC to communicate with TSNCF.

- TSNCF: It collect the Talker/Listener stream requirement as specified in IEEE 802.1 Qcc [6] from NG-TT and TNW-TT via PMIC/UMIC. It provides the Talker/Listener status to CNC and receives the status of stream configuration from CNC. It provides the Talker/Listener configuration status to NG-TT and TNW-TT via PMIC/UMIC.

Editor's note: Additional impact is FFS.

## 6.12 Solution #12: Cross layer scheduling optimization based on RAN feedback

### 6.12.1 Introduction

This solution enables the RAN to provide time offset feedback to AF for low latency communication, and the solution addresses the following scenarios:

* + - * adapting application transmission schedule in DL based on RAN feedback for low latency.
		1. Functional Description

The AF provides the traffic characteristics information to the TSCTSF. The TSCTSF constructs a TSC Assistance Container (including flow direction, periodicity and Burst Arrival Time) for an application and provides it to PCF. Optionally, the AF provides Alternative Burst Arrival Time (BAT)s or time windows showing the accepted sending time of the traffic (by the AF). The TSCTSF provides alternative BATs or time windows in the TSC Assistance Container to the PCF based on the AF request if so.

NOTE 12: This solution assumes that 5GS and AF are time synchronized.

The SMF determines the TSCAI for the QoS Flow based on the TSC Assistance Container of the PCC rule bound to the QoS Flow as described in clause 5.27.2.4 of TS 23.501 [2]. Alternative BATs or time windows should be mapped from an external clock to the 5G clock based on the same principle.

When NG-RAN receives the TSCAI, NG-RAN determines a Semi-Persistent Scheduling scheme according to the TSCAI and the PDB. To maximize the time for transmission/re-transmission over the air interface and to minimize the scheduling time (within the PDB available for the QoS Flow), the NG-RAN may calculate the offset time between the Burst Arrival Time and the determined scheduling time.

NOTE 2: It is assumed the connection between RAN and UPF is deterministic, e.g. via optical fiber directly or the transport network is deterministic. Thus, the BAT in TSCAI can be the exact time.

For example, the adjusted packet for DL traffic based on the offset should arrive at a time slot before and closest to the determined scheduling time slot so that it could be transferred immediately. The RAN may provide the expected BAT directly, e.g. when there are Alternative BATs or time windows in the TSCAI, the NG-RAN may select the BAT within the Alternative BATs or time windows, the NG-RAN may select the Alternative BAT or time windows which is before and closest to the determined scheduling time.

NG-RAN forwards the offset time or expected BAT to the SMF. SMF will send it back to the AF via PCF/TSCTSF/NEF. If NG-RAN provides expected BAT to the SMF, the SMF should map it from the 5G clock to the external clock based on the time offset and cumulative rateRatio (when available) between external time and 5GS time as measured and reported by the UPF.

AF receives the offset time or expected BAT and notifies the application to adapt the DL transmission schedule to it.

The AF updates the TSCTSF with the new BAT. The TSCTSF updates the TSCAC based on the AF update.

NOTE 3: this solution could also be used for UL as BAT could be used for both UL and DL.

### 6.12.3 Procedures

 Figure 6.12.3-1 describe the procedure for this solution:



Figure 6.12.3-1: Procedure for Cross layer scheduling optimization based on RAN feedback

1. AF/TSCTSF provides TSCAC to the SMF as described in clause 5.27.2 of TS 23.501 [2]. Optionally, the TSCTSF provides alternative BATs or time windows in the TSC Assistance Container to the PCF based on the AF request.
2. The determines the TSCAI for the QoS Flow based on the TSC Assistance Container of the PCC rule (including alternative BATs or time windows) bound to the QoS Flow as described in clause 5.27.2.4 of TS 23.501 [2].
3. The SMF transfer the TSCAI generated in step 2 to the RAN.
4. NG-RAN provides the feedback as described in clause 6.x.2.
5. 6-7. The SMF maps the feedback from the 5G clock to the external clock based on the time offset and cumulative rateRatio (when available).
6. The AF receives the offset time or expected BAT and notifies the application to adapt the DL transmission schedule to it. The AF updates the TSCTSF with the new BAT. The TSCTSF updates the TSCAC based on the AF update and may initiate step 1 with the new BAT.

### 6.12.4 Impacts on services, entities and interfaces

NG-RAN:

* supports of time offset/expected BAT calculating and reporting

AF:

* receiving time offset/expected BAT
* providing Alternative BAT
* notifying the applications to adapt the DL transmission schedule to it

SMF:

* mapping the expected BAT/Alternative BAT between external clock and the 5G clock
* support of signaling time offset/expected BAT/Alternative BAT

PCF/TSCTSF/NEF

* support of signaling time offset/expected BAT/Alternative BAT

## 6.13 Solution #13: Pro-active RAN burst timing preference provision

### 6.13.1 Introduction

This solution enables AF to configure burst transmission scheduling (transmission time and/or periodicity) optimally considering the radio configuration. This is achieved by signaling RAN burst timing preferences pro-actively to AF at the time of QoS configuration phase.

### 6.13.2 Functional Description

This solution is based on the following principles:

* The AF indicates its burst timing adaptation capabilities in QoS request together with the TSC stream characteristics to TSCTSF. The TSCTSF sends burst timing adaption capabilities in TSCAC to the PCF.

- The application may be capable of adapting burst sending time and/or burst periodicity proactively based on the feedback

* The SMF receives the TSCAC including burst timing adaptation capability from the PCF and sends it to the RAN in TSCAI.
* For a given UE, the RAN node derives the preferred time window for burst arrival taking at least radio configuration and radio resource status into account and communicates the derived burst timing preferences to 5GC. RAN burst timing preferences include burst arrival window (BAW) in absolute time and burst periodicity separately for UL and DL. Burst arrival window (BAW) refers to the time period that is provided by RAN, including the earliest possible absolute time and the latest possible absolute time (taking radio configuration and radio resources status into account).

Editor’s note: whether BAW and periodicity are provided together always or they can also be provided independently is FFS.

* The SMF translates the (absolute time) burst arrival window from 5G clock to external clock (depending on AF time domain) and from RAN reference point to 5G ingress reference point considering the clock drift between the 5G clock and external clock, UE/DS-TT residence time and CN PDB. The SMF forwards the preferred 5G Ingress BAW and preferred periodicity for UL and DL along with UE/DS-TT residence time to the PCF.
* The TSCTSF receives burst timing preferences (BAW and periodicity) from the PCF. The TSCTSF may derive exact 5G ingress burst arrival times from the burst arrival window from the RAN node.

Editor’s note: need to coordinate BATs across different streams using the same RAN node is FFS.

* The TSCTSF forwards burst timing preferences to the AF.

NOTE: Achieving determinism for the transport network (i.e. to avoid inaccuracies with CN PDB) is out of scope for this solution.

### 6.13.3 Procedures

As shown in figure below, the solution utilizes existing procedures. Mainly following enhancements are proposed:

1. The AF session with requested QoS procedure (clause 4.15.6.6 in TS 23.502) is used for burst timing adaptation capability signalling from AF to PCF.
	* The TSCTSF includes the burst timing adaptation capabilities in TSCAC.
2. The burst timing adaptation capability is forwarded to RAN by reusing PDU session modification procedure. The PDU session modification procedure is also used for RAN timing preference signalling to the PCF.
	* The SMF derives the TSCAI and includes the burst timing adaptation capabilities in TSCAI.
	* The RAN derives RAN burst timing preferences (preferred RAN BAW and periodicity) based on the radio configuration and radio resource status, and performs admission control. RAN communicates the derived timing preferences to SMF (through AMF).
	* The SMF translates RAN BAW to 5GS ingress BAW and signals RAN preferences to PCF.
3. The notification procedures are utilized for burst timing preference signalling from PCF to TSCTSF and from TSCTSF to AF.
	* The TSCTSF derives exact BAT from the BAW and includes BAT into to the NEF.



Figure 6.13.3.1-1 Procedure for AF requested QoS with burst timing adaptation.

### 6.13.4 Impacts on existing services and interfaces

AF:

* Indication of burst timing adaptation capabilities.
* Burst sending schedule adaptation according to the received timing preferences.

TSCTSF:

* Reception and forwarding of burst timing adaptation capabilities.
* Receptions of RAN timing preferences from the PCF.
* Derivation of the exact BAT from the wider BAW from the RAN and timing coordination between burst of different TSC streams.

RAN:

* Reception of Adjustment Capability flag that triggers derivation of RAN Burst arrival window.
* Derivation of RAN burst timing preferences from the radio configurations and radio resource status.

SMF:

* Translation of RAN burst arrival window to 5GS ingress burst arrival window.

NEF, PCF:

* Support of signalling burst timing adaptation capabilities and RAN timing preferences.

6.14 Solution #14: Assisted and Complement Timing Support

6.14.1 General

This solution is addressing the requirement for timing resiliency towards a client network (external network that requires a resilient timing service by the 5GS), as backup when the local primary time source fails, or as a complement to calibrate an inaccurate local primary timing source in the client network.

In these cases, delivering a stable and accurate phase or frequency is sufficient (no need to deliver time information over the 5G network).

This solution proposes to support Assisted Timing to provide backup timing service which if applied to 5GS implies a low impact since the only timing information to be provided is a stable phase or frequency. As an alternative, the stable phase/frequency timing information could be offered in order to complement (by calibrating) the external inaccurate primary local source, i.e., Complement Timing.

If the client network supports receiving some form of assisted/complement timing and requires Timing Resiliency from 5GS via the already supported Time Synchronization service activation, the 5GS will be able to provide assisted/complement timing, where the timing information may be phase or frequency. The AF request therefore may indicate during the Time Synchronization service activation, that Timing Resiliency is required, whether assisted or complement timing is required, the type to timing information (phase or frequency). Additional parameters could be provided such as service availability (including holdover time), and frequency/phase stability and accuracy. The timing service can be provided over different types of external interfaces, e.g., (g)PTP as defined in TS 23.501 [x] or by an implementation specific interface.

If Timing Resiliency is required, the client network should receive feedback (status report) whenever the service requirements (e.g., error budget, UTC traceability, etc.) are out of the agreed range. Moreover, status reports content just indicate that requirements were not achieved, instead of including the actual values of the parameters. How to provide the status report is out of the scope in this solution.

6.14.2 Functional Description

This solution is based on the following principles:

- AF may include in its request for time synchronization service the following:

- Timing Resiliency requirement, including the following parameters:

- assisted/complement timing requirement,

- type of timing information required (phase or frequency),

Editor's Note: Whether to include the phase/frequency level of stability and accuracy, and the service availability (including holdover time) from the AF request is FFS.

Editor’s Note: Use of the two types timing method (assisted and complement) details by NG-RAN are FFS.

- Status report is sent to UE application and to AF when one or more agreed requirements are out of range, indicating that service requirements are not achieved.

6.14.3 Procedures

Existing time synchronization activation procedures (see TS 23.502 [x], clause 4.15.9) are reused, where the AF request content is modified to include, e.g., Timing Resiliency additional requirement, whether assisted/complement timing is required, the type of timing information (phase or frequency).

6.14.4 Impacts on services, entities and interfaces

- AF: Formulation of the AF request that may include parameters indicating requirements for Timing Resiliency, assisted timing/complement timing and type of timing information. These parameters are delivered to RAN.

Editor's Note: If is FFS how these parameters should influence to the content of (g)PTP messages or (g)PTP-related IEEE data sets in PMIC/UMIC.

- NG-RAN: gNB may receive requirement parameters such as Timing Resiliency requirement, assisted/complement timing, the timing information type to be delivered. This information enables NG-RAN to determine if and how to provide 5G reference timing information to the UE efficiently (i.e., RRC/SIB). How NG-RAN is using this information is up to RAN implementation.

## 6.15 Solution #15: Burst arrival time adaptation

### 6.15.1 Introduction

This solution enables the network to adjust the burst arrival time by signaling positive or negative offset values (e.g. +3 ms) for UL scheduling and DL scheduling to the AF so that the AF can adjust the burst sending time accordingly.

### 6.15.2 Functional Description

This solution is based on the following principles:

* For DL scheduling: refer to solution #2.
* For UL scheduling: Upon reception of UL packets from UE, UE determines a relative burst arrival time offset value in reference to the current Burst Arrival Time experienced by UE (i.e., in reference to when UE currently receives bursts) and the scheduling UL time slot at UE (e.g. in Configured Grants, as defined in TS 38.321[x]). UE sends the time offset to RAN via RRC message when the time offset value reaches the configured threshold, and NG-RAN sends the burst arrival time offset value to SMF in the same way as for DL scheduling.

- For downlink or uplink flows AF adapts the burst sending time based on the received offset.

### 6.15.3 Procedures

In addition to clause 6.2.3 in solution #2, RRC message to signal support of burst arrival time offset value from UE to RAN

### 6.15.4 Impacts on services, entities and interfaces

Besides the impacts documented in clause 6.2.4 of solution #2:

 - UE: Support of determining and signalling burst arrival time offset to RAN via RRC message.

## 6.16 Solution #16: BAT adjustment during a QoS Flow setup or modification

### 6.16.1 Introduction

This solution enables the 5GC to adapt applications to the downstream scheduling, and to upstream scheduling if necessary, in Uu reference point to meet really low latency (e.g. 2msecs) requirement.

This solution makes the following assumptions:

- NG-RAN can indicate an adjustment to the Burst Arrival Time (BAT offset) in a response to QoS Flow establishment or modification request.

- The solution builds upon Solution 10: 5GC acting as a CUC for CNC in TN; Solution X is used to configure the underlay network in the TN for the required traffic characteristics of the QoS Flow. This ensures that jitter in the transport network in DL direction can be reduced and thus the accuracy of the Burst Arrival Time for DL packets at the ingress of NG-RAN is improved.

- The same assumptions as in Solution 10 apply.

### 6.16.2 Functional Description

The solution is based on the architecture in Figure 6.16.2-1:



Figure 6.16.2-1: Architecture to support adaptation to the upstream / downstream scheduling

- The solution supports deployments with and without external TSN network:

a) When integration with IEEE TSN applies: In addition what is described in Solution X, this solution provides Burst Arrival Time (BAT) offset for DL direction from NG-RAN via SMF and PCF to the TSN AF. TSN AF can act as a CUC towards the CUC in external TSN network and provide the BAT offset as feedback to the external TSN network. The CUC then controls the CNC in external TSN network and adjusts the TSN streams accordingly.

b) When integration with IEEE TSN does not apply: In addition to what is described in Solution X, this solution provides Burst Arrival Time (BAT) offset for DL direction from NG-RAN via SMF and PCF to the AF. The AF can then adjust the data streams accordingly by means that are out of scope of 3GPP.

- As described in Solution X, Transport Network deploys a CNC that can be controlled by a CUC residing in the 5GC via the procedures specified in IEEE 802.1Qjd [X]. In addition what is described in Solution X, this solution can provide an adjusted BAT for both UL and DL directions to the Transport Network, based on the feedback received from the NG-RAN.

### 6.16.3 Procedures

The figure 6.16.3-1 describes the overall procedure how QoS Flows are established with the solution.



Figure 6.16.3-1: Overview of the QoS Flow establishment

1. [No changes to Solution 10]: PCF receives the Policy Authorization service request from the AF/NEF/TSCTSF. The PCF composes the PCC Rules as specified in Release 17. PCF includes the TSCAC in the request when it invokes the SMF.

2. [No changes to Solution 10]: SMF receives the PCC Rules from the PCF. The SMF binds the PCC rule to a QoS Flow.

3. [No changes to Solution 10]: SMF indicates N4 rules for a QoS Flow to the UPF. The UPF assigns the CN tunnel endpoint address. The SMF determines a dynamic value for the CN PDB, based on the UPF and NG-RAN of the PDU Session.

4. As described in Solution 10, the SMF provides the QoS profile for the QoS Flow to the NG-RAN. The SMF signals the dynamic value for the CN PDB for the QoS Flow to NG-RAN. NG-RAN assigns the AN tunnel endpoint address.

As described in Solution 10, upon receiving the TSCAI for a QoS Flow from the SMF, if the TSCAI includes a BAT in UL direction, the RAN determines the corresponding BAT offset in UL direction at the gNB egress. The NG-RAN provides the value to the SMF in a response. As an enhancement to Solution X, when the NG-RAN provides the offset value to SMF, the NG-RAN may adjust the offset value based on the upstream scheduling in Uu reference point.

 As an enhancement to Solution 10, if the NG-RAN determines a need to adjust the Burst Arrival Time for DL direction to adapt the applications to the downstream scheduling in Uu reference point, NG-RAN includes a BAT offset for DL direction in the response to the SMF.

 BAT offset is relative to the BAT value in corresponding direction NG-RAN has received from the SMF in TSCAI. BAT offset can take positive or negative values.

5. After the SMF has setup a QoS Flow between UPF and NG-RAN, if the NG-RAN indicated a BAT offset for UL or DL direction to the SMF, the SMF deducts the received BAT offset from the BAT in UL or DL direction, respectively, that the SMF has received in the TSCAI for the given QoS Flow, and indicates the resulted new BAT value(s) to the Transport Network using the procedure as described in Solution X.

The SMF provides the BAT offset values in UL and DL direction (if available) to NEF/AF or TSN AF via PCF. When integration with IEEE TSN applies, TSN AF can act as a CUC towards the CUC in external TSN network and provide the BAT offset as feedback to the external TSN network. The CUC then controls the CNC in external TSN network and adjusts the TSN streams accordingly.

Editor's note: Typically for TSN flows there would be already an external CUC. Whether CNC can handle two CUCs for the same flows is FFS. Whether CNC can replan TSN flows after they have started is FFS.

 When integration with IEEE TSN does not apply, the BAT offset values are provided to the AF, and the AF can then adjust the data streams accordingly by means that are out of scope of 3GPP.

### 6.16.4 Impacts on services, entities and interfaces

The same impacts as in Solution 10: 5GC acting as a CUC for CNC in TN. In addition, the following impacts are caused by this solution:

- SMF:

- If the NG-RAN indicates a BAT offset for UL or DL direction to the SMF in a response to the QoS Flow establishment or modification request, the SMF deducts the received BAT offset from the current BAT in UL or DL direction, respectively, in the TSCAI for the given QoS Flow, and indicates the resulted new BAT value(s) to the Transport Network using the procedure as described in Solution X.

- NG-RAN:

- Determines a BAT offset in UL direction, based on the BAT in UL direction the NG-RAN receives from the SMF in TSCAI and the upstream scheduling in Uu reference point.

- Determines a BAT offset in DL direction, based on the BAT in DL direction the NG-RAN receives from the SMF in TSCAI and the downstream scheduling in Uu reference point.

 - Provides the BAT offset values to the SMF in a response to the QoS Flow establishment or modification request.

# 7 Evaluation

# 8 Conclusions

Annex A:
Change history

|  |
| --- |
| **Change history** |
| **Date** | **Meeting** | **TDoc** | **CR** | **Rev** | **Cat** | **Subject/Comment** | **New version** |
| 2022-02 | SA2#149E | S2-2201055 | - | - | - | Proposed skeleton agreed at S2#149E | 0.0.0 |
| 2022-02 | SA2#149E |  |  |  |  | Implemented agreed CRs at S2#149E – S2-2201759, S2-2201760, S2-2201761, S2-2201762, S2-2201763, S2-2201764, S2-2201765, S2-2201766, S2-2201768, S2-2201769, S2-2201770. | 0.1.0 |
| 2022-04 | SA2#150E |  |  |  |  | Implemented agreed CRs at S2#150E - S2-2203462, S2-2203463, S2-2203464, S2-2203465, S2-2203466, S2-2203467, S2-2203468, S2-2203469, S2-2203470, S2-2203471, S2-2203472, S2-2203473, S2-2203474, S2-2203475, S2-2203476, S2-2203477, S2-2203478. | 0.2.0 |