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| 3GPP TR 23.700-20 V1.0.1 (2020-10) | |
| Technical Report | |
| 3rd Generation Partnership Project;  Technical Specification Group Services and System Aspects;  Study on enhanced support of Industrial Internet of Things (IIoT) in the 5G System (5GS)  (Release 17) | |
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| ***3GPP***  Postal address  3GPP support office address  650 Route des Lucioles - Sophia Antipolis  Valbonne - FRANCE  Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16  Internet  http://www.3gpp.org |
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Contents

Foreword 6

1 Scope 8

2 References 8

3 Definitions of terms and abbreviations 9

3.1 Terms 9

3.2 Abbreviations 9

4 Architectural Assumptions and Requirements 9

4.1 Architectural Requirements 9

5 Key Issues 9

5.1 Key Issue #1: Uplink Time Synchronization 9

5.1.1 Description 9

5.2 Key Issue #2: UE-UE TSC communication 10

5.2.1 Description 10

5.3 Key Issue #3: Exposure of TSC services 10

5.3.1 Description 10

5.3.2 Key Issue #3A: Exposure of deterministic QoS 10

5.3.3 Key Issue #3B: Exposure of Time Synchronization 11

5.4 Key Issue #4: supporting the fully distributed configuration model for TSN 11

5.4.1 Description 11

5.5 Key issue #5: Use of Survival Time for Deterministic Applications in 5GS 12

5.5.1 Description 12

6 Solutions 13

6.0 Mapping of Solutions to Key Issues 13

6.1 Solution #1: Uplink Time Synchronization for TSN 13

6.1.1 Introduction 13

6.1.2 Functional Description 14

6.1.3 Procedures 15

6.1.3.3 BMCA procedure 18

6.1.4 Impacts on services, entities and interfaces 20

6.2 Solution #2: Handling of UE to UE communication 20

6.2.1 Introduction 20

6.2.2 Functional Description 21

6.2.3 Procedures 22

6.2.3.1 procedure for DS-TT information report 22

6.2.3.2 procedure for TSCAI and QoS 23

6.2.4 Impacts on services, entities and interfaces 24

6.3 Solution #3 UE-UE TSC communication with VN group 24

6.3.1 Introduction 24

6.3.2 Functional Description 24

6.3.3 Procedures 25

6.3.4 Impacts on services, entities and interfaces 27

6.4 Solution #4: Deterministic QoS for UE-UE TSC communication 27

6.4.1 Introduction 27

6.4.2 Functional Description 28

6.4.3 Procedures 30

6.4.3.1 Procedure for AF providing UE-UE TSC QoS information 30

6.4.3.2 Procedure for UE triggered UE-UE TSC configuration 31

6.4.4 Impacts on services, entities and interfaces 33

6.5 Solution #5: Deterministic QoS for Native 5GS 34

6.5.1 Introduction 34

6.5.2 Functional Description 34

6.5.3 Procedures 35

6.5.4 Impacts on services, entities and interfaces 38

6.6 Solution #6 TSC communication without TSN network 39

6.7 Solution #7: Exposure of Time Synchronization 39

6.7.1 Introduction 39

6.7.2 Functional Description 40

6.7.3 Procedures 41

6.7.4 Impacts on services, entities and interfaces 43

6.8 Solution #8: AF Requested TSN Synchronization Activation and Deactivation 44

6.8.1 Introduction 44

6.8.2 Functional Description 44

6.8.2.1 General 44

6.8.2.2 Functional Description for AF Requested TSN Synchronization Activation 45

6.8.2.3 Functional Description for AF Requested TSN Synchronization Deactivation 45

6.8.3 Procedure 45

6.8.3.1 procedure for AF Requested TSN Synchronization Activation 45

6.8.3.2 procedure for AF Requested TSN Synchronization Deactivation 46

6.8.4 Impacts on services, entities and interfaces 47

6.9 Solution #9: (g)PTP GM support by DS-TT 48

6.9.1 Introduction 48

6.9.2 Functional Description 48

6.9.3 Procedures 48

6.9.4 Impacts on services, entities and interfaces 49

6.10 Solution #10 UE-UE communication based on generalized Ethernet model 49

6.10.1 Introduction 49

6.10.2 Functional Description 50

6.10.3 Procedures 51

6.10.4 Impacts on services, entities and interfaces 51

6.11 Solution #11: UPF triggered UE-UE TSC communication 51

6.11.1 Introduction 51

6.11.2 High Level Description 51

6.11.3 Procedures 52

6.11.3.1 UPF triggered UE-UE TSC Communication 52

6.11.4 Impacts on services, entities and interfaces 53

6.11.5 Evaluation 54

6.12 Solution #12: The bridge U-Plane model for UE-UE communication 54

6.12.1 Introduction 54

6.12.2 Functional Description 54

6.12.3 Procedures 54

6.12.4 Impacts on services, entities and interfaces 56

6.13 Solution #13: Mechanism for AF requesting 5G network jitter 56

6.13.1 Description 56

6.13.2 Procedures 56

6.13.3 Impacts on services, entities and interfaces 58

6.14 Solution #14: Supporting Deterministic Communication 58

6.14.1 Introduction 58

6.14.2 Functional Description 58

6.14.3 Procedures 59

6.14.3.2 Impacts on services, entities and interfaces 59

6.15 Solution #15: Survival Time is pre-configured in the 5GS 60

6.15.1 Introduction 60

6.15.2 Functional Description 60

6.15.3 Procedures 60

6.15.4 Impacts on services, entities and interfaces 60

6.16 Solution #16: Survival Time for Deterministic Applications 60

6.16.1 Introduction 60

6.16.2 Functional Description 61

6.16.3 Procedures 61

6.16.4 Impacts on services, entities and interfaces 62

6.17 Solution #17: U-plane BMCA solution for the key issue#1 62

6.17.1 Introduction 62

6.17.2 Functional Description 62

6.17.3 Procedures 63

6.17.4 Impacts on services, entities and interfaces 65

6.18 Solution 18: Supporting BMCA by processing Announce message 65

6.18.1 Introduction 65

6.18.2 Functional Description 66

6.18.3 Procedures 66

6.18.3.2 Impacts on Existing Nodes and Functionality 67

6.19 Solution #19: Delay model for UE-UE communication 67

6.19.1 Introduction 67

6.19.2 Functional Description 69

6.19.3 Procedures 70

6.19.4 Impacts on existing services and interfaces 70

6.20 Solution #20: CNC controlled VLAN configuration 71

6.20.1 Introduction 71

6.20.2 Functional Description 72

6.20.3 Procedures 72

6.20.4 Impacts on existing services and interfaces 73

6.21 Solution #21: TSN stream information provisioning from CNC to 5GS 73

6.21.1 Introduction 73

6.21.2 Functional Description 73

6.21.3 Procedures 73

6.21.4 Impacts on existing services and interfaces 74

6.22 Solution #22: Detect the Burst spread at UPF 74

6.22.1 Introduction 74

6.22.2 Functional Description 75

6.22.3 Procedures 75

6.22.4 Impacts on services, entities and interfaces 75

6.23 Solution #23: Transmission Delay Measurement on N6 76

6.23.1 Description 76

6.23.2 Procedures 76

6.23.3 Impacts on Existing Nodes and Functionality 77

7 Evaluation 78

7.1 Key Issue #1: Uplink Time Synchronization 78

7.2 Key Issue #3B: Exposure of Time Synchronization 78

7.3 Key Issue#5: Use of Suvival Time for Deterministic Applications in 5GS 78

8 Conclusions 78

8.1 Key Issue #1: Uplink Time Synchronization 78

8.2 Key Issue #2: UE-UE TSC communication 79

8.3 Key Issue #3B: Exposure of Time Synchronization 79

8.4 Key Issue #5: Use of Survival Time for Deterministic Applications in 5GS 80

Annex A: Change history 81

# 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:

Version x.y.z

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

Study enhancements to the 5G System that would enable enhanced support of IEEE TSN Time Sensitive Communication to support deterministic applications.

# 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 22.104: "Service requirements for cyber-physical control applications in vertical domains".

[5] 3GPP TS 22.263: "Service requirements for Video, Imaging and Audio for Professional Applications (VIAPA)".

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

[7] IEEE 802.1Qcc: "Stream Reservation (SRP) - Enhancements and Performance Improvements".

[8] IEEE 802.1Qbv: "Forwarding and Queuing - Enhancements for Scheduled Traffic".

[9] SMPTE ST 2059-2:2015: "SMPTE Standard - SMPTE Profile for Use of IEEE-1588 Precision Time Protocol in Professional Broadcast Applications".

[10] IEC/IEEE 61850-9-3:2016: "Communication networks and systems for power utility automation - Part 9-3: Precision time protocol profile for power utility automation".

[11] 3GPP TS 38.331: "NR; Radio Resource Control (RRC); Protocol specification".

[12] 3GPP TS 23.503: "Policy and charging control framework for the 5G System (5GS); Stage 2".

[13] IEEE 1588-2008: "IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems".

[14] 3GPP TS 23.288: "Architecture enhancements for 5G System (5GS) to support network data analytics services".

# 3 Definitions of terms 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].

## 3.2 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].

# 4 Architectural Assumptions and Requirements

## 4.1 Architectural Requirements

The following architectural requirements apply:

- Solutions shall build on the 5G System architectural principles as in TS 23.501 [2], including flexibility and modularity for newly introduced functionalities.

- The 3GPP system shall support co-existence of TSN GM clock residing in the network attached to DS-TT for some TSN domains and TSN GM clock residing in network side for some other TSN domains.

# 5 Key Issues

## 5.1 Key Issue #1: Uplink Time Synchronization

### 5.1.1 Description

The objective of this Key Issue is to introduce support for Time Synchronization with TSN GM in the TSN network attached to the device. The TSN GM is assumed to be located in the network attached to the device.

For this Key Issue the following areas should be studied:

1. Support for Time Synchronization with one or more TSN GM(s) in the TSN network attached to the device:

a) Synchronizing TSN end stations behind 5G System (NW-TT) with the TSN GM in the network attached to the device.

b) Synchronizing TSN end stations behind other UE(s) with the TSN GM in the network attached to the device side via 5G System.

## 5.2 Key Issue #2: UE-UE TSC communication

### 5.2.1 Description

This Key issue aims to address UE-UE TSC communication if the network determines that the two UE(s) (including two DS-TT(s) within the same UE) are served by the same UPF.



Figure 5.1.1: UE-UE TSC communication

NOTE: In the above figure, the two UEs can be served by a single NG-AN node or two different NG-AN nodes.

For this Key Issue the following areas should be studied:

1. How the 5GS know the UE/DS-TT pairs which can perform UE-UE communication?

2. 5G System bridge delay determination considering UE-UE communication via same UPF.

a. How does the 5GS know whether to report the Bridge delay information for the port pair of two DS-TTs.

b. How does the 5GS calculate and report the Bridge delay information for the port pair of two DS-TTs.

3. Configuration of Deterministic QoS for the QoS Flows of the two UEs served by the same UPF.

a. The impact on the derivation and provision of QoS parameters and TSCAI in this scenario, if any.

## 5.3 Key Issue #3: Exposure of TSC services

### 5.3.1 Description

The objective of this Key Issue is to allow wider and more flexible use of 5GS TSC and URLLC through the 5GS Network Exposure Function framework.

The exposure framework can be used to expose network capabilities (i.e. enabling operator to offer certain capabilities as services) and also allow application to influence services offered by the network. This key issue is about enhancing the NEF (exposure) framework towards AF so that NEF can expose network capabilities to support Time Sensitive Communication.

### 5.3.2 Key Issue #3A: Exposure of deterministic QoS

Any AF that has knowledge of deterministic application requirements should be able to request TSC services from the 5GS and as authorized, be notified of pertinent network events. This key issue is intended to support in the 5GS, requirements from TS 22.104 [4] where a TSN bridged network may not be needed and requirements from TS 22.263 [5] for Video, Imaging and Audio for Professional Applications (VIAPA). Applications provide those requirements to 5GS for any type of PDU Session.

This KI focuses on enhancing NEF framework.

For this Key Issue, the following areas should be studied:

a) Ability for AF to request absolute delay and jitter requirements, and mechanisms to enable the PCF to determine the 5GS QoS parameters based on the requirements received from AF.

b) Ability for AF to indicate periodicity, burst size, burst arrival time (as defined in Rel-16 for TSC Assistance information) and Survival Time, optionally burst spread (variation of burst arrival time for DL traffic resulting from jitter on N6, if applicable) along with Time Domain (reference for these parameters) associated with these parameters to the NEF

c) How to enable an application and 5GS to agree on a TSC configuration that addresses the applications needs and can be supported by 5GS.

### 5.3.3 Key Issue #3B: Exposure of Time Synchronization

Any AF that has knowledge of time synchronization requirements should be able to learn 5GS capabilities to support time synchronization, the AF may request time synchronization with specified requirements, and supply information that can be used to optimize and configure time synchronization procedure for connected devices.

This key issue is intended to support in the 5GS, requirements from TS 22.104 [4] where a TSN bridged network may not be needed and requirements from TS 22.263 [5] for Video, Imaging and Audio for Professional Applications (VIAPA). Applications provide those requirements to 5GS for IP or Ethernet types of PDU Sessions.

Four different time sources and methods for synchronization are foreseen:

1) assuming use of a gPTP client (IEEE 802.1 [6] Time Aware System) or PTP client (IEEE 1588-2008 [13] and gPTP protocol which conveys the timing information, e.g. located in the DN, and mapping to 5GS time in 5GC (time sync methods as defined in Rel-16).

2) assuming use of the 5GS time source by 5GS and AF (e.g. it could also be GPS time source used by both 5GS and AF); where UPF/NW-TT creates the time sync methods conveyed in gPTP messages as defined in Rel-16 or in PTP messages over UDP/IP as defined in IEEE 1588-2008 [13] for conveying the timing information.

3) assuming use of the 5GS time source by 5GS and AF (e.g. it could also be GPS time source used by both 5GS and AF); where the 5G-AN provides a 5GS reference time to the UE via 3GPP radio layer and UE may provide it to the applications or devices behind the UE by implementation specific means out of scope of 3GPP.

4) assuming use of the 5GS time source by 5GS and AF (e.g. it could also be GPS time source used by both 5GS and AF); where DS-TT creates the time sync methods conveyed in gPTP messages or in PTP messages over UDP/IP as defined in IEEE 1588-2008 [13] for conveying the timing information.

For these four emethods, this key issue aims to support exposure for Time Synchronization service offered by 5GS:

A) Exposure of the 5GS capability to activate Time Synchronization from the AF for a TSN Domain GM or 5G GM (i.e. for VIAPA applications).

i. Ability for network to expose the support for synchronization and the supported time synchronization method (i.e. method 1, 2, 3 or 4 as above) from NEF towards AF.

ii. Ability for AF to request activation/deactivation of Time Synchronization service targeting a UE or a group of UEs and indicate the clock domain (i.e. IEEE TSN Domain GM or 5G GM) and clock accuracy (with an accuracy of e.g. 1 microsecond).

iii. Ability to support the time synchronization service for IP and Ethernet types of PDU Sessions.

## 5.4 Key Issue #4: supporting the fully distributed configuration model for TSN

### 5.4.1 Description

Fully distributed TSN model is defined in IEEE 802.1Qcc [7]. Unlike the fully centralized model supported in Rel-16, there is neither a Centralized Network Configuration (CNC) entity nor an entity that has the knowledge of the entire TSN network in fully distributed TSN model. The configuration information for stream resource registration is propagated along the paths from the Talker to Listeners. The 5G CP (i.e. PCF) cannot get the TSN stream requirements and configuration information from a TSN entity in control plane.

In order to support integration of 5GS with the TSN network deployed in fully distributed model, the 5GS should be able to read the configuration information carried in the TSN stream resource registration messages (e.g. MSRP messages) and modify the messages as a TSN bridge based on the 5GS capability. The 5G CN CP should also be able to retrieve the TSN stream requirements from the messages transmitted in user plane. Therefore, the enhancements needs to be studied for 5GS to support fully distributed TSN model:

- Which IEEE protocols need to be supported?

- How the 5GS retrieves the TSN stream requirements?

- How to enforce the TSN stream requirements using 3GPP QoS parameters?

- Which entity, (e.g. the UE/DS-TT, UPF/NW-TT, SMF or PCF), is responsible for read/modify the TSN stream resource registration messages, and how the 5GS modifies the TSN stream resource registration message based on 5GS Bridge capability and the configuration information carried in the message?

NOTE: This key issue is not addressed within Rel-17 timeframe.

## 5.5 Key issue #5: Use of Survival Time for Deterministic Applications in 5GS

### 5.5.1 Description

The objective of this Key Issue is to introduce Use of Survival Time for Deterministic Applications in 5GS.

Periodic deterministic communication service performance requirements are described in clause 5.2 of Rel-17 TS 22.104 [4]. Survival time is included in the requirements.

This key issue aims at studying solutions on how to transfer the survival time to RAN. In more detail:

- how to deliver survival time to 5G system;

- How 5GS acquires the additional assistance information reflecting survival time, e.g. interworking with CNC and/or use of AF or NEF without interworking with CNC or with CUC or other method..

NOTE: IEEE TSN does not provide survival time via CNC.

How and when to apply Survival Time assistance information is up to RAN WGs.

# 6 Solutions

## 6.0 Mapping of Solutions to Key Issues

Table 6.0-1: Mapping of Solutions to Key Issues

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Solutions |  |  | Key Issues |  |  |  |
|  | #1 Uplink Time Synchronization | #2 UE-UE TSC communication | #3A Exposure of TSC services:  Exposure of deterministic QoS | #3B Exposure of TSC services  Exposure of Time Synchronization | #4 supporting the fully distributed configuration model for TSN | #5  Use of Survival Time for Deterministic Applications in 5GS |
| #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 |
| #17 | X |  |  |  |  |  |
| #18 | X |  |  | X |  |  |
| #19 |  | X |  |  |  |  |
| #20 |  | X |  |  |  |  |
| #21 |  |  | X |  |  |  |
| #22 |  |  | X |  |  |  |
| #23 |  |  | X |  |  |  |
| #24 |  | X |  |  |  |  |

## 6.1 Solution #1: Uplink Time Synchronization for TSN

### 6.1.1 Introduction

The solution is proposed to solve Key Issue #1: the UL Time Synchronization. In this key issue, one or more TSN GM(s) are attached to the device side and are used to synchronize the TSN end stations behind the 5GS (i.e. NW-TTs) and behind the other UEs (i.e. DS-TTs). Based on clause 5.27.1 of TS 23.501 [2], the following principles are also applied to or UL TSN Time Synchronization:

- 5GS as a TSN bridge plays as a time-aware system.

- Only TSN TTs at the edge of 5GS need to support the desired operations in the IEEE 802.1AS [6].

- Two separate distribution time mechanisms are used for 5GS internal clock and TSN system clocks as defined in clause 5.27.1.2 of TS 23.501 [2].

- All gPTP messages generated from TSN GM(s) are transmitted using user-plane resources in 5GS.

- All the gNBs, DS-TT/UEs, and UPF/NW-TTs in the 5GS are time synchronized to the same 5GS GM.

.

Therefore, this solution proposes that similar operations defined for DL TSN Time Synchronization can be re-used for the UL TSN Time Synchronization i.e. for the TSN GM(s) attached to the device side.

Since UL TSN Time Synchronization will be distributed to the TSN end stations attached to 5GS (i.e. NW-TTs) and attached to the other UEs (i.e. DS-TTs), TSN GM(s) attached to the device will generate the UL gPTP messages and then DS-TT can perform exactly the same operations for the received DL gPTP messages as NW-TT performs for the DL gPTP messages defined in clause 5.27.1.2.2 of TS 23.501 [2]. Then, the modified UL gPTP messages will be further forwarded via the user-plane established between the devices (i.e. UE) which has TSN GM(s) attached to and the target UPFs.

After the NW-TT receives the modified gPTP messages for the case where delivery to end stations behind the 5G system (NW-TT) is required, the NW-TT can perform exactly the same operations as DS-TT performs for the received DL gPTP messages defined in clause 5.27.1.2.2 of TS 23.501 [2]. Finally, NW-TT can forward to the UL gPTP messages to the TSN end stations.

The main difference between the UL and DL Time Synchronization is that the UL gPTP messages are also required by the TSN end stations behind the other UEs (i.e. DS-TTs). For delivery of gPTP messages to TSN end stations behind other UEs, the UPF will forward the UL gPTP messages transparently to other UEs but not send it back to the source UEs. The DS-TT in the other UE can perform exactly the same operations as defined in clause 5.27.1.2.2 of TS 23.501 [2]. Finally, DS-TT can forward to the gPTP messages to the TSN end stations as described in the figure 6.1.2-1.

NOTE: The UPF forwards the gPTP message to the Ethernet connected to the N6 interface. This enables other devices on N6 and also other DS-TT/UE connected to a different UPF to receive the gPTP message.

NOTE: The gPTP messages are multicast data packet. The UPF/NW-TT prevents the occurrence of gPTP message loops.

### 6.1.2 Functional Description

Distributing the UL gPTP messages from TSN GM attached to the device to all TSN end stations behind the UPFs (NW-TTs) and behind the other UEs (DS-TTs) can be achieved by using the following steps (referred to Figure 6.1.2‑1)

- DS-TT which is attached by one or more TSN GMs will perform exactly same operations for UL gPTP messages as NW-TT perform the operations for the DL gPTP messages as specified in clause 5.27.1.2.2 of TS 23.501 [2].

- In case of synchronizing TSN end stations behind 5G System (NW-TT), NW-TT will perform exactly the same operations for UL gPTP messages as what DS-TT performs for the DL gPTP messages as specified in clause 5.27.1.2.2 of TS 23.501 [2]. After NW-TT on the UPF side receives the UL gPTP messages, the NW-TT forward the information to the TSN end stations, while adding 5GS residence time to the correction field and removing TSi timestamp from the suffix field.

- In case of synchronizing TSN end stations behind other UE(s), the UPF will forward the received UL gPTP message transparently to the other UEs to distribute the gPTP messages further to the TSN end stations behind other UEs (other DS-TTs) by applying the same forwarding principles as described in clause 5.27.1.2.2 of TS 23.501 [2] except that the PDU session of the source device connected to the corresponding DS-TT port is not included in the forwarding.

NOTE: Normal Ethernet behaviour is that the frame is not sent back to the source. So, sending back a frame on the incoming interface would be against Ethernet principles and results in risking creation of forwarding loops.

In case of synchronizing TSN end stations behind 5G System (NW-TT), all gPTP messages are transmitted using the user-plane resources in 5GS and follows the principle that one PDU session is established per DS-TT port for a UPF. To support the multiple TSN working domains attached to the device, the mechanism defined in clause 5.27.1.3 of TS 23.501 [2] can be re-used.

In case of synchronizing TSN end stations behind other UE(s), all gPTP messages are transmitted using the user-plane resources in 5GS and follow the principle that two PDU sessions are used.

To support the multiple TSN working domains attached to the device, the mechanism defined in clause 5.27.1.3 of TS 23.501 [2] can be re-used.



Figure 6.1.2-1: The distribution of UL Time Synchronization Information with the same UPF

### 6.1.3 Procedures

#### 6.1.3.1 Synchronizing end stations behind NW-TT

The procedure for synchronizing TSN end stations behind 5G System (NW-TT) with the TSN GM in the network attached to the device is described in Figure 6.1.3-1. It includes BMCA-related steps (step 1~3) because after those steps, the sync message forwarding tree is confirmed. In this case, TSN Node 0 should send sync messages to 5GS TSN Bridge, and the 5GS TSN Bridge should send sync messages to TSN Node 2. The remaining steps (step 4~8) follow principles in clause 5.27.1 of TS 23.501 [2], with the Ingress TT of DS-TT1 and the Egress TT of NW-TT.



Figure 6.1.3.1-1: Procedure for synchronizing TSN end stations behind 5G System (NW-TT) with the TSN GM in the network attached to the device side via 5G System

1. PDU Session Establishment includes UE MAC / Port Info for updates to TSN AF. After this step, TSN Node 0, 5GS logical bridge (DS-TT1/UE1, NW-TT/UPF) and TSN Node 2 can exchange Ethernet frames.

2. At BMCA step, TSN nodes exchange Announce messages and build the Sync forwarding tree for TSN Sync messages. The Sync forwarding tree is per TSN working clock domain. BMCA procedure (6.1.3.3 for gPTP) is performed when a NW-TT port or a DS-TT port receives an Announce message.

3. [Optional] If the operator decides to follow the recommendation to limit the bridge residence time to 10 ms, as defined in IEEE 802.1AS [6], clause B2.2 (stated as recommendation), then Based on the Sync frame forwarding information the TSN AF may trigger QoS setup for the Sync frame delivery. PDB1 which is the UL PDB for the QoS flow of PDU session for UE1, plus UE1-DS-TT residence time, should be less than 10ms, as the residence time in a node should be less than 10ms. This step can be skipped if step 1 satisfies the QoS requirements.

NOTE 1: The PDB value for the case of dedicated synchronization communication (i.e. a QoS flow dedicated for transmitting gPTP messages) can be pre-configured by the operator at the PCF. In this case, the PCF sets up QoS parameter (i.e. PDB) to fulfil DS-TT to UPF delay to be less than 5 ms, such that the total limit is achieved, without the need for the PCF to learn if this concerns a DS-TT/UE to NW-TT/UPF communication or a DS-TT/UE to DS-TT/UE communication.

NOTE 2: As a result of steps 2 and 3, BMCA Announce messages are delivered in a default QoS flow but only time synchronization messages are delivered in the new QoS flow.

4. Sync message is delivered from the previous TSN node to DS-TT/UE1. It has time stamp of TSN GM clock. It also includes correction and rateRatio fields. The rateRatio is (GM clock frequency) / (local clock frequency).

5. DS-TT/UE1 updates the Sync message. It adds the link delay between the DS-TT/UE1 and the previous TSN node to the correction field. It also updates the rateRatio field with the previous rateRatio multiplied by neighborRateRatio. The neighborRateRatio = (local clock frequency of the previous TSN Node) / (local clock frequency). It also attaches Ingress Timestamp based on 5G GM clock to the Sync message.

6. Sync message is delivered from DS-TT/UE1 towards NW-TT/UPF. It has time stamp of TSN GM clock. It also includes correction, rateRatio and Ingress Timestamp fields.

7. NW-TT regenerates the Sync message. It calculates the residence time as Egress 5G GM Time - Ingress 5G GM TS) \* rateRatio in the sync message. It updates the correction field as the previous correction field value + the residence time. Then, it removes the Ingress timestamp.

8. Sync message is delivered from the NW-TT to TSN Node 2. It has time stamp of TSN GM clock. It also includes correction and rateRatio fields.

#### 6.1.3.2 Synchronizing end stations behind DS-TT

The procedure for synchronizing TSN end stations behind other UE(s) with the TSN GM in the network attached to the device is described in Figure 6.1.3.2-2. It also includes BMCA-related steps (step 1~3). After those steps, the sync message forwarding tree is confirmed. In this case, TSN Node 0 should send sync messages to 5GS TSN Bridge, and the 5GS TSN Bridge should send sync messages to TSN Node 3. The remaining steps (step 4~8/8a) follow principles in clause 5.27.1 of TS 23.501 [2], with the Ingress TT of DS-TT1 and the Egress TT of DS-TT2.



Figure 6.1.3.2-1: Procedure for synchronizing TSN end stations behind other UE(s) with the TSN GM in the network attached to the device side via 5G System

1. PDU Session Establishment includes UE MAC / Port Info for updates to TSN AF. After this step, TSN Node 0 and 5GS logical bridge (DS-TT1/UE1, NW-TT/UPF) can exchange Ethernet frames.

1a. For UE-to-UE case, PDU Session Establishment includes UE MAC / Port Info for updates to TSN AF. After this step, TSN Node 3 and 5GS logical bridge (DS-TT2/UE2, NW-TT/UPF) can exchange Ethernet frames. Local switching at the UPF is also enabled.

2. At BMCA step, TSN nodes exchange Announce messages and build the Sync forwarding tree for TSN Sync messages. The Sync forwarding tree is per TSN working clock domain. BMCA procedure (6.1.3.3 for gPTP) is performed when a NW-TT port or a DS-TT port receives an Announce message.

3. [Optional] If the operator decides to follow the recommendation to limit the bridge residence time to 10 ms, as defined in IEEE 802.1AS [6], clause B2.2 (stated as recommendation), then Based on the Sync message forwarding information the TSN AF may trigger QoS setup for the Sync message delivery. PDB1, which is the UL PDB for the QoS flow of PDU session for UE1, should be less than 10ms, as the residence time in a node should be less than 10ms.

3a. [Optional] If the operator decides to follow the recommendation to limit the bridge residence time to 10 ms, as defined in IEEE 802.1AS [6], clause B2.2 (stated as recommendation), then, Based on the Sync message forwarding information, the TSN AF may trigger QoS setup. As the TSN AF can know DS-TT1/UE1 forwards Sync messages to DS-TT2/UE2 via local switching at the UPF, it sets the QoS should meet the sum of PDB1, UE1/DS-TT1 residence time, local switching delay, UE2/DS-TT2 residence time and PDB2 should be less than 10ms. PDB2 is the DL PDB for the QoS flow of PDU session for UE2. For this, the TSN AF may trigger the QoS change for PDU session for UE1.

NOTE 3: Calculation of the UE-UE delay can be consistent with the UE-UE TSC communication solution chosen.

NOTE 4: The PDB value for the case of dedicated synchronization communication (i.e. a QoS flow dedicated for transmitting gPTP messages) can be pre-configured by the operator at the PCF. In that case, the PCF sets up QoS parameter (i.e. PDB) in all cases fulfilling DS-TT to UPF delay to be less than 5 ms, such that the total limit is achieved.

NOTE 5: Based on BMCA results, the TSN AF informs the SMF of the associated PDU sessions. That is, the TSN AF informs the SMF of the PDU Session for the DS-TT port with Slave role and the PDU Session for the DS-TT port with Master role.

NOTE 6: As a result of steps 2 and 3, BMCA Announce messages are delivered in a default QoS flow but only time synchronization messages are delivered in the new QoS flow.

Editor's note: Calculation of the UE-UE delay, consistent with the UE-UE TSC communication solution chosen, needs to be updated for this step.

Editor's note: If SMF needs to know then how the SMF knows the UEs that need to communicate and which PDU sessions to associate is FFS.

4. Sync message is delivered from the previous TSN node to DS-TT/UE1. It has time stamp of TSN GM clock. It also includes correction and rateRatio fields. The rateRatio is (GM clock frequency) / (local clock frequency).

5. DS-TT/UE1 regenerates the Sync message. It adds the link delay between the DS-TT/UE1 and the previous TSN node to the correction field. It also updates the rateRatio field with the previous rateRatio multiplied by neighborRateRatio. The neighborRateRatio = (local clock frequency of the previous TSN Node) / (local clock frequency). It also attaches Ingress Timestamp based on 5G GM clock to the Sync message.

6. Sync message is delivered from DS-TT/UE1 towards NW-TT/UPF. It has time stamp of TSN GM clock. It also includes correction, rateRatio and Ingress Timestamp fields.

6a. For UE-to-UE case, the NW-TT/UPF performs local switching and forwarding for the Sync message. Before local switching, the NW-TT/UPF can perform multiplication if needed.

6b. For UE-to-UE case, Sync message is delivered from the NW-TT/UPF to DS-TT/UE2. It has time stamp of TSN GM clock. It also includes correction, rateRatio and Ingress Timestamp fields.

7a. For UE-to-UE case, DS-TT/UE2 updates the Sync message. It calculates the residence time as Egress 5G GM Time - Ingress 5G GM TS) \* rateRatio in the sync message. It updates the correction field as (the previous correction field value) + (the residence time). Then, it removes the Ingress timestamp.

8a. For UE-to-UE case, Sync message is delivered from the DS-TT/UE2 to TSN Node 3. It has time stamp of TSN GM clock. It also includes correction and rateRatio fields.

#### 6.1.3.3 BMCA procedure

One of the following alternative methods for the BMCA procedure may be implemented. The BMCA state machines required in IEEE 802.1AS [6] clause 5.4.1, may run in different parts of the 5G system.

**Method 1:**

When a NW-TT port or a DS-TT port receives an Announce message, if the Announce information is better than the current best master information it knows about (per clock domain), the port reports the Announce information to TSN AF using PMIC signalling. NW-TT and DS-TT also inform TSN AF if a previously reported best clock is not available anymore (determined based on lack of Announce or Time Sync messages from that clock). Based on the received Announce information and local information of 5GS, the TSN AF runs the PortStateSelection state machine and decides the BMCA port roles for the ports in the 5GS bridge as described in IEEE 802.1AS-Rev [6] and configures each port role (per clock domain) accordingly using PMIC signalling. The port that is configured to Slave role, receives Sync and Announce messages from a node outside 5GS and sends the Sync and Announce messages to other port(s) inside 5GS. The port that is configured to Master role, receives Announce messages from the port with Slave role inside the 5GS bridge, increases the stepsRemoved field of the Announce messages with one, replaces the value of sourcePortIdentity field of Sync/Announce messages with its portIdentity, and runs the PortAnnounceTransmit state machine to send Announce messages to a node outside the 5GS. When DS-TT port configured to Passive role receives a Sync message from outside of 5GS, it discards the message. Optinally, NW-TT and DS-TT with port(s) with Master role(s) can generate Announce messages based on information from TSN AF (e.g. DS-TT or NW-TT acts as a (g)PTP grandmaster). In this case, Announce messages are not exchanged inside 5GS. (Details of BMCA procedure implemented by TSN AF are described in Solution #18 in clause 6.18..)

NOTE 1: Depending on the solution to expose the time syncronization service, the BMCA port roles can be assigned either by TSN AF or NEF.

**Method 2:**

In this alternative, NW-TT receives Announce messages from any NW-TT and DS-TT ingress port (DS-TT forwards all Announce messages to NW-TT) and NW-TT runs the PortStateSelection state machine and decides the BMCA port state.

Upon completion of BMCA, if the TSN AF (or NEF) has subscribed for the BMCA result reports, and if the NW-TT determines that the result of the BMCA has change (which may cause the (g)PTP grandmaster must be activated or deactivated in DS-TT(s)), NW-TT reports the BMCA result to TSN AF using BMIC signaling. Based on this, TSN AF configures the port states in DS-TT(s) using PMIC signaling. If TSN AF is not deployed then NEF terminates PMIC and BMIC signaling, i.e. NEF receives the BMCA result from NW-TT and configures configures the port states in DS-TT using PMIC signaling.

NOTE 2: NEF terminating BMIC/PMIC signaling does not have any impact on PCF/SMF as existing Rel-16 functionality is reused for this.

Port states of NW-TT ports are configured locally by NW-TT based on the BCMA result. When a DS-TT configured to Master role receives Announce messages from the NW-TT via 5GS user plane, it increases the stepsRemoved field of the Announce messages with one, replaces the value of sourcePortIdentity field of Sync/Announce messages with its portIdentity, and runs the PortAnnounceTransmit state machine to send Announce messages to a node outside the 5GS. When DS-TT port configured to Passive role receives a Sync message from outside of 5GS, it discards the message. If the NW-TT time outs to receive Announce message from the Slave port in DS-TT or NW-TT and has available Passive port(s) in DS-TT or NW-TT, the NW-TT selects a Passive as new Slave port and update port state(s).

**Method 2b:**

Optionally, Method 2 can be optimized to filter the Announce messages in the ingress port.

For BMCA, each TSN node sends Announce messages to its neighbours. When a TSN node receives an Announce message, from its neighbour TSN node, it can locally calculate the status of the receiving port based on the priority vector. A TSN node with multiple ports, the status of each port and priority vector need to be aggregated to make a centralized decision on the TSN node level. If the aggregation is done via User Plane, for each port to send the received Announce message to a central unit inside the TSN node may be a solution. On the other hand, for each port to send the changed Announce message to the central unit inside the TSN node will do the same effects in terms of the central unit, because repeating the same Announce messages from a port to the central unit does not make any differences. If a port detects a receipt timeout event for an Announce message from its neighbour, it means the port updates its local decision and the port priority vector. In that case, the change needs to be delivered to the central unit of the TSN node. The port may also send an Announce message that was expected to arrive with an additional field to inform receipt timeout event.

**Method 3:**

Support BMCA via the interworking between the DS-TT and NW-TT:

- When DS-TT received any announce messages from the port(s) of the DS-TT, if the message Priority Vector of the announce message is better than the Port Priority Vector of the received port, the DS-TT sends the received announce messages to NW-TT via UE.

Editor's note: It is FFS how a Passive port would learn the Port Priority Vector.

- The NW-TT/UPF learns the received port for the announce message based on the port number associated with the PDU session sending the announce message. The NW-TT determines the best grand master based on the received announce messages, the port number of the received port on the DS-TT(S) and NW-TT, and the System Priority Vector. If the determined grand master is updated, the NW-TT decides the port state and announce message for next hop accordingly.

- If the port state of a NW-TT port is master port, the NW-TT forwards the determined announce message to the NW-TT port directly. For each DS-TT port which is a Master port, the NW-TT/UPF runs the PortAnnounceTransmit state machine to send Announce messages towards the PDU session associated with the DS-TT port. Upon receiving the announce message the DS-TT forwards it to the port associated the PDU session receiving the announce message and update the Port Priority Vector accordingly.

- When DS-TT port configured to Passive role receives an Announce message or a Sync message from outside of 5GS, it forwards it to to NW-TT who discards the message.

**Method 4:**

Support BMCA process in NW-TT (Details are described in Solution #17).

- There is a BMCA function in the NW-TT. It runs the BMCA state machine and keeps the state of all the ports.

- When the DS-TT port or NW-TT port receives the Announce message, it forwards the message to BMCA function in NW-TT via U-plane.

- The BMCA function run the BMCA state machine to qualify the message, determines the best grand master and determines the DS-TT port and NW-TT port states.

- If the Announce message is received from the slave port, the BMCA function updates the Announce message and generates an Announce message separately for each DS-TT and NW-TT port which state is Master.

- If the Announce message is reveived from a non-slave port, the BMCA function discards this message.

- Upon completion of BMCA, if the TSN AF (or NEF) has subscribed for the BMCA result reports, and if the NW-TT determines that the result of the BMCA has changed which may cause the (g)PTP grandmaster in 5GS (e.g. DS-TT) must be activated or deactivated, the NW-TT reports the BMCA result to TSN AF (or NEF) using BMIC signalling. Based on this, TSN AF enables or disables the GM in DS-TT using PMIC signalling. Solution #9 describes the details how to activate/deactivate the grandmaster in DS-TT.

### 6.1.4 Impacts on services, entities and interfaces

For synchronizing TSN end stations behind 5G System (NW-TT) with the TSN GM in the network attached to the device, the impacts on UE, SMF, PCF, TSN-AF and UPF are like the following.

- The Ingress TT is DS-TT.

- The Egress TT is NW-TT.

For synchronizing TSN end stations behind other UE(s) with the TSN GM in the network attached to the device side via 5G System, the impacts on UE, SMF, PCF, TSN-AF and UPF are like the following.

- The Ingress TT is DS-TT of a UE.

- The Egress TT is DS-TT of the other UE.

-

- [Optional] The TSN AF needs to trigger QoS setup procedures in case the operator decides to follow the recommendation to limit the bridge residence time to 10 ms

- The UPF needs to perform local switching for Sync messages without NW-TT interaction.

Method 1 of BMCA procedure:

NW-TT port/DS-TT port:

- Reports Announce information to TSN AF

TSN AF:

- Receives the Announce information reported by DS-TT/NW-TT port;

- Executes BMCA to determine the port role and configure port role to associated DS-TT/NW-TT port.

## 6.2 Solution #2: Handling of UE to UE communication

### 6.2.1 Introduction

This solution addresses Key Issue #2: UE-UE TSC communication.



Figure 6.2.1-1: Two DS-TT connecting to different UE



Figure 6.2.1-2: Two DS-TT connecting to the same UE

NOTE: In Figure 6.2.1-1 and Figure 6.2.1-2, SMF1 and SMF2 can be same or not; PCF1 and PCF2 can be same or not.

After that the PDU session for a DS-TT port is established to the UPF used for the 5GS Bridge, the DS-TT port becomes one of the ports of the 5GS Bridge. As shown in Figure 6.X.1-1 and Figure 6.X.1-2, 5GS Bridge include three ports: Port\_1 at DS-TT\_1, Port\_2 at DS-TT\_2 and Port\_3 at NW-TT. The possible port pair could be [Port\_1, Port\_2], [Port\_2, Port\_3], and [Port\_1, Port\_3].

For centralized architecture, in case End Station\_1 generates a TSN service request with the destination as End Station\_2, it will negotiate with CUC and CUC will negotiate with CNC. Based on the collected LLDP information from each port and bridge capabilities (e.g. bridge delay for each port pair), CNC is aware of End Station\_1, End Station\_2 can communicate with each other via [Port\_1, Port\_2] of 5GS Bridge. The CNC will provide the following TSN information to 5GS Bridge:

- TSN QoS and for egress port (i.e. Port\_2).

- PFSP information for ingress Port (i.e. Port\_1).

The traffic forwarding in the UPF can be established in a number of different ways:

* Based on the general Ethernet forwarding principles using flooding and MAC learning, as specified in 23.501[2] section 5.8.2.5.3.
* Based on 5G VN, as specified in 23.501[2] section 5.8.2.13. This may involve operator pre-configuration.
* Based on CNC provided static filtering entries. In release 16 this is specified for the uplink direction only; release 17 enhancements are needed to extend CNC provided static filtering entry support for all directions.

Traffic forwarding setup takes place before the establishment of the TSN stream. The traffic forwarding mechanisms are general and apply to both TSC and non-TSC traffic.

5GS Bridge configures the QoS mapping and TSCAI for PDU Session\_1 and PDU Session \_2 respectively, based on the received information.

### 6.2.2 Functional Description

Bride Delay and QoS mapping for two DS-TT ports are different from the port pair of a DS-TT port and a NW-TT port.

- For bridge delay, since two PDU Sessions' SMF and PCF may be different, it requires AF to derive the Bridge delay of port pair which is comprised of Port\_1 of DS-TT\_1 and Port\_2 of DS-TT\_2:

- In order to support AF to derive the Bridge delay of port pair [Port\_1, Port\_2], the UE provide the DS-TT information of the DS-TT port together with the port management information in the Port Management Container.

- The Bridge Delay for the port pair [Port\_1, Port\_2] includes the delay in the uplink and in the downlink direction.

Editor's note: The detailed calculation for the bridge delay is FFS, e.g. Option1: as the sum of UE-DS-TT Residence Time for Port\_1, PDB for PDU Sesion\_1, UE-DS-TT Residence Time for Port\_2 and PDB for PDU Session\_2; Option2: as the sum of the delay for PDU Session 1, the delay for PDU Session 2 and the sum of the residence times for UE-DS-TT1, UE-DS-TT2 and UPF residence time.

- For QoS mapping, so far, the AF has the TSN information associated with the egress port and PFSP information associated with ingress port. Thanks for these information, the AF can associate PDU session1 and PDU session2. The AF derives the TSC QoS parameters for PDU session1 and PDU session2 and transmit them to PCF\_1 and PCF-2 respectively. The QoS flow in PDU Session\_1 is uplink and the QoS flow in PDU Session\_2 is downlink.

- In order to minimize impacts on 5GS, it is also proposed SMF(s) to calculate the TSCAI according to TSC Assistance Container from TSN AF which is same with R16 mechanism.

### 6.2.3 Procedures

#### 6.2.3.1 procedure for DS-TT information report



Figure 6.2.3.1-1: DS-TT information report procedure

The procedure is based on the UE requested PDU Session Establishment or Modification procedure and SMF initiated SM Policy Association Modification procedure in TS 23.502 [3].

1. DS-TT indicates the port's DS-TT information in the Port Management Container and UE forwards the received Port Management Container in the PDU Session Modification Request. The Port Management Container is sent to AF via AMF, SMF and PCF.

2. AF based on the collected the detected port's DS-TT information, UE-DS-TT residence time, PDB, AF calculate bridge delay for all port pairs as follows:

- Deduce the 1st kind of port pair, comprised of a DS-TT port and a NW-TT port.

- Deduce the 2nd kind of port pair, comprised of a DS-TT port (Port\_1) and another DS-TT port (Port\_2).

- When applicable, the bridge delay for the 3rd kind of port pair, comprised of two NW-TT ports, can also be calculated.

#### 6.2.3.2 procedure for TSCAI and QoS



Figure 6.2.3.2-1: as defined in Figure 4.16.5.2-1: PCF initiated SM Policy Association Modification in TS 23.502 [3]

The procedure is based on PCF initiated SM Policy Association Modification procedure in TS 23.502 [3], with following difference in the step 1a (AF sends Application/Service Infor to the PCF):

1. AF can determine the egress port and the ingress port based on the combination of information provided by the CNC and local information such as local configuration.

2. AF can derive the TSN QoS requirement for egress port and ingress port, based on the received TSN information (i.e. IEEE 802.1Qbv [8] and PFSP):

- IEEE 802.1Qbv [8] for egress port (Port\_2): e.g. Traffic class, priorities of the traffic class.

- PFSP for ingress port (Port\_1): e.g. Stream Priority.

3. AF can derive the TSC Assistance Container for UL and DL TSN flow based on PFSP for ingress port (Port\_1).

4. AF provide PCF the TSN QoS information as follows:

- AF provide to PCF\_1 which is associated with PDU Session\_1 the following information:

(a) TSN QoS parameters for Port\_1.

(b) TSN parameters used for UL TSCAI for the TSN flow.

- AF provide to PCF\_2 which is associated with PDU Session\_2 the following information:

(a) TSN QoS parameters for Port\_2.

(b) TSN parameters used for DL TSCAI for the TSN flow.

### 6.2.4 Impacts on services, entities and interfaces

AF:

- Based on the DS-TT information of the DS-TT port, deduce all the possible port pairs. For port pair of the two DS-TT, comprised of Port\_1 of DS-TT\_1 and Port\_2 of DS-TT\_2, and calculate the bridge delay.

- Based on information from the CNC and local information, derive the ingress and the egress ports.

(a) Derive TSN QoS parameters for PDU session1 related to Port\_1 and TSN QoS parameters for PDU session2 related to Port\_2 respectively.

(b) Derive TSC Assistance Container used for downlink TSCAI and uplink TSCAI respectively.

## 6.3 Solution #3 UE-UE TSC communication with VN group

### 6.3.1 Introduction

This solution address Key Issue #2 "UE-UE TSC communication", i.e., UE-UE TSC communication between two UE(s) that are served by the same UPF.

VN group mechanism as defined in Rel-16 TS 23.501 [2] clause 5.29 or clause 5.8.2.13 is reused to achieve the UE-UE TSC communication.

The UE-UE TSC communication with VN group is applied for that both PDU Sessions of UEs that served by the same UPF. In the case that the SMF could determine the UE-UE DS-TT port pair that allows to communicate with each other based on the 5G VN group data, then the same SMF is required as specified in TS 23.501 [2] clause 5.29.3. In the case that the AF could determine the UE-UE DS-TT port pair that allows to communicate with each other e.g., based on 5G VN group configuration or local operator policy, and there is no N19 tunnel in the 5G VN, then different SMFs can be used. The AF can divide the UE-UE stream to each PDU sessions serving by the same or different SMFs, and instruct the SMF/PCF to apply the local switch for UE-UE TSC communication as specified in TS 23.501 [2] clause 5.8.2.13.

### 6.3.2 Functional Description

This solution is based on the following principles:

- The 5GS knows the UE/DS-TT pairs which can perform the UE-UE TSC communication under condition that UEs/DS-TT pairs belonging to the same 5G VN.

- The SMF and optionally AF can know the VN group information as defined in TS 23.501 [2].

- When the SMF knows the two UEs/DS-TTs are belonging to the same VN group and served by the same (anchor) UPF, SMF will pair them and report the port pair numbers to the TSN AF. Bridge delay of this UE-UE port pair is the sum of the two PDU Sessions associated to this port pair and is calculated by the TSN AF.

- When the AF discovers a new UE/DS-TT port of a 5GS bridge, if the AF is configured to determine the UE-UE DS-TT port pair that allows to communicate with each other based on 5G VN group configuration, the AF can receive the UE ID, i.e., GPSI from the SMF or PCF, then the AF could check the other UEs that belong to the same VN group with the new UE using the 5G VN group configuration, as well as connect to the same 5GS bridge with the new UE, and then compose the UE-UE DS-TT port pair that allows to communicate with each other.

- When the AF discovers a new UE/DS-TT port of a 5GS bridge, if the AF is configured to determine the UE-UE DS-TT port pair that allows to communicate with each other based on local operator policy, the AF could check the other UEs that connect to the same 5GS bridge with the new UE, and then compose the UE-UE DS-TT port pair that allows to communicate with each other using local operator policy.

- When the TSN AF receives the PSFP configuration and if applicable, traffic forwarding information (static filtering entries) from the CNC, it determines whether frames described via destination MAC address and/or VLAN index (VID) from PSFP, received on a specified ingress port and are to be forwarded through a given 5GS Bridge egress port. The ingress port and/or egress port are derived based on the local configuration or traffic forwarding information that matches with frame described via the destination MAC address and/or VLAN index from PSFP. Using the association between the MAC address used by the PDU Session, 5GS Bridge ID and port number on DS-TT (maintained at TSN AF), TSN AF further determines the flow for the UE-UE communication and divides the flow into two PDU Sessions, one for UL and one for DL. UL and DL streams are respectively triggered by the TSN AF to be established, and a UE-UE communication indication, including involved PDU sessions and flow directions, is provided by the TSN AF for the SMF to apply the local switch as specified in TS 23.501 [2] clause 5.8.2.13. Additional, if the AF knows the source MAC address of the stream, the source MAC address could be part of the Ethernet packet filter.

NOTE 1: The destination MAC address can be a unicast address or a multicast address.

NOTE 2: The AF determines ingress port of a stream based on PSFP and local information (e.g. local configuration) as 5.28.2 and Annex I.1 defined in 23.501, and it determines egress port based on traffic forwarding information or local configuration associated to destination MAC address of this stream. This solution sets the forwarding only for TSN streams that are indicated by PSFP to the TSN AF. Besides the usage of the traffic forwarding information described in this solution, further usage of the traffic forwarding information is possible.

- When the SMF receives PCC rules with a UE-UE communication indication for the UL or DL stream for a TSC PDU Session that supports 5GLAN, it determines that the flow is for UE-UE communication according to the indication and create the N4 rules (PDR, FAR, QER, URR) on the UPF to apply local switch as defined in clause 5.8.2.13 in TS 23.501 [2]. If UE-UE communication indication is not provided, the SMF determines N4 rule s (PDR, FAR) to handle packets using R16 mechanism, i.e., forwarding UL stream to NW-TT or detecting DL stream from NW-TT.

NOTE 3: The SMF determines and derives N4 rules as defined in clause 5.8 and 5.29.4 of TS 23.501 [2].

- SMF should also be able to insert I-UPF as a result of mobility (and in cases where there is no connectivity between NG-RAN and PSA UPF) within the same 5GS Bridge.

- TSCAI for UL and DL streams are respectively calculated by the SMF during UL and DL streams establishment as defined in TS 23.501 [2].

### 6.3.3 Procedures

For the scenario generating TSC stream from UE1 to UE2, procedures for bridge delay reporting and traffic detection and forwarding rule establishment is as figure 6.3.3-1 illustrates.



Figure 6.3.3-1: Procedure for bridge delay reporting and traffic detection&forwarding rule establishment

1. PDU Session Establishment for UE1 as specified in clause 4.3.2.2.1 of TS 23.502 [3].

2. Bridge Delay reporting for UE1 as specified in clause 4.16.5.1 of TS 23.502 [3].

3. PDU Session Establishment for UE2 as specified in clause 4.3.2.2.1 of TS 23.502 [3]. Optionally the SMF indicates the port number of UE1 PDU Session as part of port pair to the AF if the SMF determines the PDU Sessions of UE1 and UE2 are in the same 5G VN Group.

4. Bridge Delay reporting for UE2 as specified in clause 4.16.5.1 of TS 23.502 [3].

5. The AF determines the port numbers associated to PDU Sessions of UE1 and UE2 are port pairs based on 5G VN Group information, local operator policy or optionally according to the port pair indication in step 3. Then the AF calculates and reports the bridge delay between UE1 and UE2 to the TSN CP.

6. The TSN CNC provides the AF the PSFP configuration and Traffic Forwarding information (filtering database (FDB)), according to the TSN streams scheduled by TSN system as specified in clause 5.28.2 of TS 23.501 [2].

7-8. The AF determines ingress port and egress port of the stream based on PSFP configuration, local information, and Traffic Forwarding information. Then the AF determines that it is UE-UE TSC by combining ingress port number, egress port number with the information on association between the MAC address used by the PDU Session, 5GS Bridge ID and port number on DS-TT, as maintained at TSN AF. Then the AF triggers the 5GC to generate a UL stream for PDU Session of UE1 and a DL stream for PDU Session of UE2 according to the PDU Session Modification Procedure as specified in clause 4.3.3.2 of TS 23.502 [3]. AF calculates the TSN QoS BAT of DL stream for PDU Session of UE2 as the sum of the TSN QoS BAT of UE-UE TSC and the bridge delay for PDU Session of UE1.

During step 8 of PDU Session Modification procedure, the SMF configures the UPF to handle the UL and DL stream via local switch as defined in clause 5.8.2.13 in TS 23.501 [2] since the PDU session supports 5GLAN and TSN AF indicates that this is for UE-UE TSC communication.

If Port Management Container with scheduling information is provided to the SMF in step 7 or step 8, the SMF will respectively calculate the TSCAI for the UL and DL stream. The SMF needs to perform TSCAI calculation considering two associated PDU sessions like the following.

- TSCAI Burst arrival time for PDU session for UE1 for UL stream is calculated the same as described in clause 5.27.2 of TS 23.501 [2].

- TSCAI Burst arrival time for PDU session 2 for DL stream is calculated the same as described in clause 5.27.2 of TS 23.501 [2]

NOTE: The 5GS Bridge delay calculation could be updated e.g. if UPF residence time estimation is adopted.

### 6.3.4 Impacts on services, entities and interfaces

SMF:

- If the AF does not maintain the 5G VN Group information, the SMF determines the UE port pair base on 5G VN Group information.

AF:

- If the AF maintains the 5G VN Group information, the AF determines the UE port pair base on 5G VN Group information.

- Need to perform TSCAI calculation considering two associated PDU sessions and indicates the UE-UE TSC to 5GS.

Npcf\_SMPolicyControl\_Update request:

- If the AF does not maintain the 5G VN Group information, the SMF indicates PCF the (DS-TT, DS-TT) port pair.

Npcf\_PolicyAuthorization\_Notify:

- If the AF does not maintain the VN Group information, the PCF indicates AF the (DS-TT, DS-TT) port pair.

## 6.4 Solution #4: Deterministic QoS for UE-UE TSC communication

### 6.4.1 Introduction

The solution is proposed to solve Key Issue #2: UE-UE TSC communication. In this Key Issue, more than one UE attached to the 5GS are communicating with each other without involving the DN. The solution does not rely on 5G VN, but it may co-exist with 5G VN when supported. Figure 6.4.1-1 illustrates the target scenario a UE-UE pair that is assumed by this solution. In the figure, user plane packets sent by the source UE are delivered to the destination UE(s) through the UPF. It could be one or more SMFs controlling the UPF. In the assumed scenario, the UEs can be served by a single NG-(R)AN node or different NG-(R)AN nodes. Additionally, the serving SMFs may insert in the data path of a PDU Session an I-UPF (Intermediate UPF) between the common PSA UPF and the NG-RAN(s) to extend the service area of the common PSA UPF (e.g. due to UE mobility). Based on TS 23.501 [2], a PDU session is the association between the UE and a Data Network (DN) that provides a PDU connectivity service

This solution works with TSC UEs that are part of a 5GS bridge integrating into a TSN network, or with a standalone 5GS with IP or ETH PDU Session type.

When configuring the deterministic QoS for UE-UE TSC, the PCF and SMF need to perform session management for two associated PDU Sessions considering the information obtained from the AF (or TSN AF). The coordination of QoS parameters for UE-UE communications operates the same for IP or ETH PDU Session types.



Figure 6.4.1-1: UE-UE TSC communication scenario before UE2 mobility event



Figure 6.4.1-2: UE-UE TSC communication scenario after UE2 mobility event

### 6.4.2 Functional Description

This solution is based on the following principles:

- The deterministic QoS requirements for the TSC communication are obtained from the network administrator or AF, incl. TSN AF. The AF sends request separately for the talker (uplink traffic) and each listeners (downlink traffic).

- The PCF determines QoS policies considering AF request(s) for the individual PDU Sessions are established for the talker and the listeners.

To monitor UE peers in a PDU Session, the PCF can request the SMF to notify when new UE destinations are detected in a PDU Session via Policy Control Request Triggers (PCRT) within the Session Management. Then, the SMF can configure via N4 rules (i.e. Packet Detection Rules and Usage Reporting Rule) at the UPF to classify the traffic and report Session ID of the target UE (alternatively, target UE’s MAC@ or target UE’s IP@) if the UPF determines optimized UE-UE routing can be applied (i.e. local switching).

NOTE: the solution applies to unicast addresses only, for cases where the traffic is switched at a single UPF (i.e., no N19).

- Upon notification from UPF, the PCF and/or SMF can determine the associated PDU Sessions. The PCF may trigger reconfiguration of deterministic QoS for the PDU Sessions with UE-UE TSC communication under the same UPF.

- The two PDU Sessions are established independently for UE-UE communications. The PCF configures UE1's policies when the PDU Session for UE1 is established. Later when the request for UE2 is received and the PDU Session is being established for UE2, UE2's policies are determined and if needed UE1's policies may be reconfigured.

- To coordinate UE-UE TSC communication configuration, more than one SMF may be involved (i.e. different SMF(s) being selected for the different PDU Sessions). The PCF(s) are responsible of providing the policies to individual SMF(s).

- The SMF may insert an I-UPF on one leg of the UE-UE data path to extend the service area of the common PSA UPF if UEs mobility triggers the change to a NG-(R)AN node without connectivity to the common PSA UPF.

NOTE: The proposal of insertion of an I-UPF is not specific to UE to UE communication.

- Once the SMF determines UE-UE TSC traffic using the Session ID for the target UE (alternatively, target UE’s MAC@ or target UE’s IP@) reported by the UPF, it pairs the two DS-TT ports and reports back to the TSN AF after completing PDU Session procedures via PCF.

- TSN AF can compute the initial value for the 5GS Bridge delay for UE-UE TSC communication with the UE-DS-TT residence time value(s), PDB for the two QoS Flow(s). The 5GS Bridge Delay should be set as sum of UE-DS-TT-1 residence time, PDB of QoS Flow-1, PDB of QoS Flow-2, and UE-DS-TT-2 residence time. The bridge delay may be updated later based on QoS reconfiguration.

### 6.4.3 Procedures

#### 6.4.3.1 Procedure for AF providing UE-UE TSC QoS information

The procedure for the AF providing the configuration of deterministic QoS for UE-UE TSC communication is described in Figure 6.4.3.1-1. The steps are similar to the procedure defined in clause 4.3.6.2 of TS 23.502 [3].



Figure 6.4.3.1-1: Procedure for deterministic QoS coordination for UE-UE TSC communication

1. The AF sends TSC QoS request to the NEF (e.g. using solution #5) independently for talkers and listeners.

2. The NEF checks whether the AF is authorized to send the TSC QoS request and forwards the request to the UDR.

3. The UDR updates the impacted UE(s) SM subscription data.

4. The UDR responds to the NEF.

5. The NEF acknowledges the AF. To configure UE-UE TSC communicaitons, steps 1-5 may be performed multiple times to configure the talker and the listeners.

6. The PCF(s) that have subscribed to modifications of AF requests receive(s) a Nudr\_DM\_Notify notification of data change from the UDR.

7. If needed, the PCF updates the SMF with corresponding new PCC rule(s).

8. When a PCC rule is received from the PCF, the SMF may take appropriate actions to reconfigure the user plane.

##### 6.4.3.2 Procedure for UE triggered UE-UE TSC configuration

The procedure for configuring UE-UE TSC routing from UE requests and for TSN deployments the reporting of DS-TT port pairs is described in Figure 6.4.3.2-1 when two UEs are assumed.



Figure 6.4.3.2-1: Procedure for UE-UE TSC routing reconfiguration and DS-TT port pair reporting

1. UE1 initiates PDU Session Establishment procedure.

2. UE2 initiates PDU Session Establishment procedure.

3. For TSN scenarios, the TSN AF can determine the DS-TT port pair based on the collected DS-TT information for all UEs connected to the same TSN network.

4. Based on previous AF's or UE's requests, the PCF determines the need to monitor user plane traffic to identify UE-UE peers and dynamically adjust QoS configuration for TSC traffic. The PCF requests SMF for notification (e.g. via a PCRT).

5. The SMF configures UPF's N4 Session to report target UE’s session ID or target UE’s MAC@ or target UE’s IP@ (to enable determination of UE-UE local switching).

6. Inspecting the user plane traffic, the UPF identifies the PDU sessions for which optimized routing was employed based on MAC address learning (in case of Ethernet PDU Sessions) or IP address learning (in case of IP PDU Sessions).

7. The UPF reports the UE-UE peers to the SMF via N4 Session signaling. The UPF may report target UE’s session ID, MAC@ or IP@.

8. SMF stores UE-UE peers' information and reports to the PCF via SMPolicyControl service.

9. PCF performs policy decision. For every UE, the PCF may determine a different QoS configuration (e.g. 5QI) considering AF TSC QoS requests, the E2E TSC requirement and UEs' connectivity status.

10. PCF may update PCC rules and trigger the SMF to reconfigure the QoS requirements for the user considering the UEs policies and the requested PDU Sessions and/or QoS Flows belonging to the UE-UE TSC communication.

NOTE: If multiple PCFs are applicable for the two UE(s), as described in TS 23.501 [2] clause 6.3.7.2, the PCFs can subscribe to receive the requests (via UDR). Each PCF may be subscribed to the known UE peers (not being served by itself) to receive notifications from the UDR when the QoS are configured for another PCF. Therefore, every PCF configures the QoS considering only the UE(s) it is serving and via UDR notifies the remain PCFs to check if the E2E requirement can be satisfied (i.e. one PCF cannot determine UE's policies including UEs it is not serving).

11. SMF may determine the appropiate actions to reconfigure UE1's and/or UE2's user plane (e.g. access specific QoS parameters).

12. For TSN scenarios, the SMF can determine DS-TT port pair UPF provided DS-TT port number during N4 Session establishment and UPF reported session ID for the target DS-TT when UPF performs local switching. The SMF may report the port pair to the TSN AF via PCF.

### 6.4.4 Impacts on services, entities and interfaces

PCF:

- Recognition of UE-UE TSC communication based on the information received from AF request(s), traffic description, targeted PDU Sessions attributes, or UEs PDU Session procedure requests.

- Conversion of the received TSC QoS requirements (end-to-end requirements) to 5GS QoS parameters and applying it also in case of UE-UE TSC communication.

- Consideration of the policies of more than UE when deriving the PCC rules per UE.

- Determination of UE-UE traffic monitoring.

SMF:

- Recognition of UE-UE TSC QoS need based on the information received from the PCF and UEs requests (e.g. traffic description and targeted PDU Sessions attributes).

- Reconfiguration of the user plane (e.g. N4 session) from more than one UE considering the UEs policies and the requested PDU Sessions and/or QoS Flows belonging to the UE-UE TSC communication.

- Storage of UE-UE peers' information and forwarding to PCF.

UPF:

- Reporting of source UE- target UE peers (involved in local switching) to the SMF based on UPF configured reporting rules (URR).

UDR:

- Harmonizes the contexts for optimization between different PCF instances.

## 6.5 Solution #5: Deterministic QoS for Native 5GS

### 6.5.1 Introduction

For Key Issue #3A: Exposure of deterministic QoS, a solution is needed that allows "any AF that has knowledge of deterministic application requirements" to "be able to request TSC services from the 5GS and as authorized, be notified of pertinent network events." This solution provides a mechanism to do that whereby the AF may learn 5GS capabilities to support TSC, request QoS with specified requirements and supply information that can be used to derive TSCAI for 5GS QoS flows. The solution is applicable for all PDU Session Types (IP, Ethernet and unstructured), and is independent of DN TSN protocols (IEEE 802.1Qbv [8], IEEE 802.1Qci, IEEE 802.1Qcc [7]).

To enable the above capabilities, this solution proposes to enhance External Exposure of Network Capability (see TS 23.501 [2], clause 5.20), specifically for Provisioning and Monitoring capabilities, to notify for the support of the capability to provide deterministic QoS. To reuse the "Setting up an AF session with required QoS" procedure in TS 23.502 [3], clause 4.15.6.6 is proposed for setting QoS for TSC.

To cover a wide range of possible QoS parameters for TSC applications, the QoS Reference currently used in AF QoS requests is supplemented with requirements for specific parameters. When a requirement for a specific parameter is provided in the AF request, the PCF may, for the referenced QoS profile, dynamically replace default values with values that meet the specific requirement provided by the AF.

### 6.5.2 Functional Description

The following capabilities are proposed using QoS request from AF:

- The AF requests TSC QoS and provides traffic pattern as assistance parameters via procedure "Setting up an AF session with required QoS procedure", supplying the NEF. with requirements for one or more of a 5GS delay, jitter, Guaranteed Flow Bit Rate, Flow Direction, Burst Arrival Time at UE (uplink) or UPF (downlink), Burst Size, Burst Periodicity, Survival Time, and a Time Domain. The AF also provides a Traffic Description, Target UE PDU session Identification, AF Identification, and a QoS Reference. AF may also request subscription to events defined in Table 6.1.3.18-1, TS 23.503 [12]. Example of relevant events are Resource allocation outcome, QoS targets can no longer (or can again) be fulfilled, QoS Monitoring parameters. Service Data Flow deactivation (when the QoS flow is removed); and then the PCF may decide to subscribe to PCRTs in the SMF example PCRTs that may be used as defined in, Table 6.1.3.5-1, TS 23.503 [12] such as GFBR of the QoS Flow can no longer (or can again) be guaranteed. Additional events and PCRTs may be considered in the normative phase. Note GPSI may be applied to identify the individual UE in a manner similar to that used for AF influence on Traffic Routing (see TS 23.501 [2], clause 5.6.7). The NEF authorizes the AF request and forwards the request to the PCF. Then:

- The PCF may, according to PCC rule authorization, choose a 5QI based on the QoS Reference and dynamically set the PDB and/or MDBV according to the received 5GS Delay and Burst Size requirements. As authorized, AF specified parameter values are used to over-ride default values, for the 5QI. If an AF request for a parameter value exceeds an authorization, the PCF may assign the highest authorized value. The GFBR for QoS Flow is set according to the Guaranteed Flow Bit Rate.

- The 5GS may set the TSCAI Burst Arrival Time (BAT), Periodicity and Survival Time according to the requested Periodicity, Burst Arrival Time and Survival Time received from the AF.

- If Time Domain information was supplied by the AF and the 5GS uses the same Time Domain, then no adjustment is needed for deriving TSCAI information. If the Time Domain provided by AF is different from 5GS Time Domain and the SMF has clock drift information for that Time Domain (i.e. clock drift between 5G timing and AF supplied Time Domain), then 5GS may adjust the TSCAI information so that it reflects the 5GS Clock. If Time Domain information is not provided or the SMF does not have synchronization information for a requested Time Domain, then the TSCAI information will be used without adjustment.

- If the AF provides burst spread, the 5GS will provide burst spread as part of TSCAI to the NG-RAN.

- When subscribed events are met the PCF reports them to the NEF, and NEF will notify the AF. The subscribed event may be reported once the SMF reports a PCRT to the PCF.

- Following the procedure in clause 4.16.5.1, TS 23.502 [3] PCF reports the events to the NEF, and NEF notifies the AF.

- NOTE: the minimum and maximum 5GS delays are independent from packet-length transmission time.

- The 5GS provides the response to a request from an AF for TSC QoS.

Editor's note: Whether and how to apply Hold and forward buffers for Ethernet PDU sessions if CNC is not present is FFS.

The following capabilities are proposed for TSC connectivity monitoring:

- The AF sends request to NEF to monitor the status of TSC connectivity via a set of events for a UE or group of UEs.

- If the request is authorized, the NEF subscribes the required monitoring events to suitable NFs (e.g. AMF, SMF).

- When the NF detects the subscribed events occurs, the NF sends the event notification to NEF. The NEF forwards to the AF the received reporting event.

To support notification, the additional events may be added to the list of monitoring capabilities specified for the NEF in TS 23.502 [3] (see clause 4.15.3.1). Existing events in that list that are relevant for TSC and can be subscribed toare : PDU Session Status (detected by SMF), Communication failure(detected by AMF), and Loss of Connectivity (detected by AMF). The jitter measurements as described in Solution 13 can also be reported via the Nnef\_AFsessionWithQoS service or Nnef\_EventExposure services to support subscription and notification of QoS Monitoring for URLLC (see TS 23.502 clause 4.2.6.9 and TS 23.503 clause 6.1.3.18).

For supporting TSC communication, which may be beyond IEEE 802.1 TSN applications, DS-TT and NW-TT in Rel-17 have similar functionalities as in Rel-16 such as: handling of PTP messages similarly as gPTP messages are handled in Rel-16, BMIC signalling for NW-TT and PMIC signalling for both DS-TT and NW-TT.

#### 6.5.2.1 Hold and Forward support

One option is envisioned to support Hold and Forward Buffers in Rel-17:

1. **H&F buffers are configured according to R16 IEEE Qbv parameters**, only for Ethernet PDU Sessions. Since there is no CNC, it is the responsibility of the AF/NEF to construct the 802.1Qbv managed objects which are transferred in the PMIC as in Rel. 16. The Gate Control managed objects are defined in TS23.501, Table 5.28.3.1-1, are reproduced below.

Table 6.5.2.1-1: Gate Control Parameters in PMIC

![A picture containing clock

Description automatically generated]()

There are two sub-options when using 802.1Qbv Managed Objects (MOs):

**2** – 802.1Qbv MOs are used to configure H&F buffers only for Ethernet PDU Sessions

A comparison of these options is given in the table below:

Table 6.5.2.1-2: Comparison of Options for Configuring H&F Buffers

|  |  |
| --- | --- |
|  | **802.1Qbv for Ethernet PDU Sessions** |
| Impacts UE/DS-TT and UPF/NW-TT | No Impact |
| AF/NEF needs to create Qbv parameters | Yes |
| 802.Qbv parameters are used in the 5GS but not in the DN (no TSN DN or CNC). | Yes |

### 6.5.3 Procedures

An overall procedure for Native 5GS deterministic QoS is illustrated in Figure 6.6.3-1:



Figure 6.5.3-1: Procedure for Exposure the deterministic QoS

1. PDU Session Establishment for UE1 as specified in clause 4.3.2.2.1 of TS 23.502 [3]. If the AF is located inside the operator's domain, the PCF exposes the UE-DS-TT residence time to the AF as defined in TS 23.502 [3] and the AF is configured with the UE to UPF/NW-TT delay per Type of Service.

2. If the AF is located outside the operator's domain, the NEF exposes Deterministic QoS Capability to AF, as shown in Figure 6.5.3-2. If the NEF learns the UE-DS-TT residence time from PCF and NEF is configured with the UE to UPF/NW-TT delay per Type of Service.

3. Setting up an AF session with required QoS procedure specified in the TS 23.502 [3] clause 4.15.6.6. is executed with the following modifications:

- The parameters described in clause 6.5.2 "Function Description" may be specified in the AF request to the NEF

- The NEF may forward to the PCF the additional parameters received at the NEF, and the PCF derives the 5QI and sets the PCC Rule accordingly. The PCF includes the Time Domain to the PCC Rule.

- The response from PCF to NEF, and NEF to AF contains additional information on the TSC resources allocated for the request.

4. The PCF creates the PCC rule and provides to SMF. And PCF also includes the TSC traffic pattern information from NEF/AF.

5. The SMF may calculate the TSCAI similar to TS 23.501 [2] clause 5.27.2, with the following modifications:

The SMF assigns the TSCAI with the Time Domain as received from the PCF to a QoS Flow. If the SMF receives clock drift information from UPF for that Time Domain (i.e. clock drift between 5G timing and AF supplied Time Domain), then SMF may adjust the TSCAI information of the QoS Flow so that it reflects the 5GS Clock.

6. The SMF configures the U-plane and sends the N2 message with TSCAI to NG-RAN. The SMF distributes the parameters for Hold and Forward Buffering to the UE and UPF.

**AF requested TSC QoS:**

The following procedure is used to expose 5GS information to aid the AF in formulating a request for TSC QoS (step 3 of Figure 6.5.3-1).

The information provided in the Capability Response can aid the AF in formulating a request for TSC QoS by allowing the AF to:

1. Requesting delay and jitter based on 5GS reported minimum and maximum delay (between two UE(s) or UE and DN) for PDU Sessions.

2. Specify in the request for QoS, the relevant MAC address, GPSI or IP address.

NOTE: For Ethernet PDU sessions, "UE MAC address" is a required input parameter for the Nnef\_AFsessionWithQoS\_Create service operation - se



Figure 6.5.3-2: TSC Capability exposure towards external AF

The NEF obtains 5GS capability to support Determinists QoS for a PDU session using the PCF provided information and the local configuration in NEF. The AF receives 5GS bridge minimum and maximum delay information. Since the "Minimum 5GS Delay supported" and "Maximum 5GS Delay supported" are dependent on UE residence time, this information is reported as part of the capability exposure procedure:

Procedure for 5GS TSC Capability exposure towards AF:

1. The AF requests the 5GS Capabilities to support Determinists QoS. The AF includes one or more MAC addresses of devices, GPSIs or IP addresses in the Nnef\_TSC\_Capability\_Request, one or more MAC addresses of devices, GPSIs or IP addresses. It also includes an Application Identifier. Note some of these MAC addresses may belong to devices connected via a UE, and some to devices connected via the DN as the AF may be unaware of network topology.

2. The NEF finds the PCF (e.g: by using the BSF) that serves the PDU session and then NEF sends a request to the PCF.

3. If the UE-DS-TT has reported a residence time and the PCF indicates TSC QoS is supported for the Application Identifier, then the PCF provides the UE-DS-TT Residence time and TSC QoS information for the AF Identifier to the NEF..

4. For devices where UPF MAC learning has detected the AF requested MAC address as a Source Address in an uplink frame (and hence the device is connected via the associated PDU session), or where the IP address and GPSI is associated with a UE (and hence the BSF found a PCF for the UE address/GPSI, the NEF provides in the Nnef\_TSC\_Capability\_Response:

a. The "minimum 5GS delay supported" and "maximum 5GS delay supported" for the Application Identifier, taking into account UE Residence time and the delay associated with a TSC 5QI.

For other devices (those whose MAC address has not been detected by the UPF as a Source Address in an uplink frame), or where the IP address or GPSI is not recognized, the NEF indicates in the Nnef\_TSC\_Capability\_Response that the device is not connected via a PDU Session..

NOTE 2: NEF aggregates UE-DS-TT residence time and per QoS configured UE to UPF/NW-TT delay to determine the delay to be provided to the AF.

**TSC connectivity monitoring:**



Figure 6.5.3-3: Procedure for TSC connectivity monitoring

1. The AF sends Nnef\_EventExposure\_Subscribe Request to NEF to monitor the status of TSC connectivity via a set of events for a UE or group of UEs. The events are those listed in clause 4.15.3.1 of TS 23.502 [3].

Event Reporting Information defines the type of reporting requested (e.g. one-time reporting, periodic reporting or event-based reporting, for Monitoring Events).

2. If the reporting event subscription is authorized by the NEF, the NEF sends the Subscribe Requests to the related NFs that detect the events, as described in TS 23.502 [3] procedures for subscription to these events.

3. The NEF sends Nnef\_EventExposure\_Subscribe Response to AF as described in TS 23.502 [3] procedures for subscription to these events.

4. The NFs detects the monitored event occurs and sends the event report to the NEF as described in TS 23.502 [3] procedures for subscription to these events.

5. The NEF sends to the AF the notification of TSC communication monitoring event changed as described in TS 23.502 [3] procedures for subscription to these events.

### 6.5.4 Impacts on services, entities and interfaces

Impacts on existing entities and interfaces

The solution has the following impacts:

1. An additional Nnef service is used to expose 5GS TSC capabilities to support Deterministic QoS.

2. Additional parameters are included in existing messages in the "AF session with required QoS procedure" specified in the TS 23.502 [3] clause 4.15.6.6.

3. The PCF uses the additional AF supplied parameters to calculate a PCC rule.

4. "Burst Spread" is sent from the PCF to the SMF, which uses it to determine a Burst Spread TSCAI parameter.

5. Time Domain is provided from PCF to the SMF, which is used by the SMF to associate the QoS Flow to a Time Domain.The solution assumes that the 5GS can be made aware of the timing in the AF supplied Time Domain, this can be provided via Time Synchronization service as described in Solution #7.

NOTE: UE and UPF impacts are noted in the Addendum on Hold and Forward Buffers

AF:

- Deliver TSC connectivity monitoring request message to NEF.

- Deliver TSC QoS request with TSC QoS reference, TSC traffic pattern, and subscription to events to the PCF.

### 6.5.5 Addendum: Hold and Forward Buffers for Deterministic QoS

#### 6.5.5.2 H&F Buffer Options

1. **H&F buffers are configured according to R16 IEEE Qbv parameters**, possibly only for Ethernet PDU Sessions. Since there is no CNC, it is the responsibility of the AF/NEF to fabricate the 802.1Qbv managed objects which are transferred in the PMIC as in Rel. 16. The Gate Control managed objects are defined in TS23.501, Table 5.28.3.1-1, and are reproduced below.

![A picture containing clock

Description automatically generated]()

Table 6.x.2-1: Gate Control Parameters in PMIC

**2** – 802.1Qbv MOs are used to configure H&F buffers only for Ethernet PDU Sessions

## 6.6 Solution #6 TSC communication without TSN network

This solution has been merged with Solution #5

## 6.7 Solution #7: Exposure of Time Synchronization

### 6.7.1 Introduction

For Key Issue #3B: Exposure of time synchronization, a solution is needed that allows "any AF that has knowledge of deterministic application requirements" to "be able to request TSC services from the 5GS and as authorized, be notified of pertinent network events." This solution provides a mechanism to do that whereby the AF may learn 5GS capabilities to support time synchronization, request time synchronization with specified requirements, and supply information that can be used to optimize and configure time synchronization procedure for connected devices.

The solution is applicable for IP and Ethernet types of PDU Sessions. The solution is applicable for non-TSN deployments, i.e. when the 5GS is not part of an IEEE TSN network.

The solution is applicable for the following synchronization methods:

1) assuming use of a gPTP client (IEEE 802.1AS [6] Time Aware System) or PTP client (IEEE 1588-2008 [13]), e.g. including leveraging the DS-TT and NW-TT capabilities defined in Rel-16 with IEE802.1AS protocol support.

2) assuming use of a gPTP client (IEEE 802.1AS [6] Time Aware System) or PTP client (IEEE 1588-2008 [13]) in UPF/NW-TT, where the time source is provided by 5GS, and UPF/NW-TT is configured to create the (g)PTP message for acting as grand master clock and conveying the timing information .

3) assuming use of the 5GS time source by 5GS; where the 5G-AN provides a 5GS reference time to the UE via 3GPP radio layer and UE may provide it to the applications or devices behind the UE by implementation specific means out of scope of 3GPP.

4) assuming use of the 5GS time source by 5GS; where the 5G-AN provides a 5GS reference time to the UE via 3GPP radio layer and DS-TT provides (g)PTP messages for acting as grand master clock and conveying the timing information to devices behind the UE.

This solution can be used together with e.g. Solution #1 for the time source to locate in a TSN node behind the DS-TT/UE.

To enable the above capabilities, this solution proposes to enhance External Exposure of Network Capability (see TS 23.501 [2], clause 5.20), specifically for Provisioning and Monitoring capabilities.

To cover a wide range of possible time synchronization requirements for TSC applications, the AF requests is supplemented with requirements for synchronization. When a requirement for a specific synchronization parameter is provided in the AF request, the PCF may dynamically replace default values with values that meet the specific requirement provided by the AF.

### 6.7.2 Functional Description

The following capabilities are proposed:

- The AF requests Time Synchronization service via External Parameter Provisioning, supplying the NEF with requirements for one or more time synchronization methods, and parameters such as supported (g)PTP versions, Time Domain, grandmaster priorities, required PTP device type supported by the 5GS in case of PTP for time synchronization method 1, and required synchronization accuracy (both in terms of required (g)PTP message rate for each port in the DN side, and number of connected (g)PTP slaves in case 5GS provides the Time Domain). The AF also provides Target UE(s) Identification or Spatial Validity Condition (i.e. to target a geographical area), AF Identification. Note GPSI may be applied to identify the individual UE in a manner like that used for AF influence on Traffic Routing (see TS 23.501 [2], clause 5.6.7). Then:

- Time synchronization method 1 (the time source is located in the DN or device side):

Time Domain is provided from the DN or Device Side and gPTP or PTP method is applied,The PCF may, according to PCC rule authorization, choose a 5QI based on the QoS Reference and dynamically set the PDB and/or MDBV according to requirements for (g)PTP protocol (e.g. required number of synchronization clients and gPTP message rate). For Ethernet type PDU sessions, both PTP over UDP/IP and gPTP over Ethernet are applicable. For IP type PDU sessions, PTP over UDP/IP is applicable. In this case, neither the NW-TT port or DS-TT port is a (g)PTP grandmaster.

NOTE 1: It is assumed that 5G internal system clock is made available to all user plane nodes in the 5G system (e.g. to UEs via SIB/RRC messages).

- Time synchronization method 2 (the time source is provided by the UPF/NW-TT in 5GS via gPTP or PTP):

Time Domain is to be provided from the 5GS (or the AF and the 5GS shares the same Time Domain). The 5GS acts as a (g)PTP grandmaster and the (g)PTP grandmaster resides in NW-TT.) The PCF may, according to PCC rule authorization, choose a 5QI based on the QoS Reference and dynamically set the PDB and/or MDBV according to requirements for (g)PTP protocol. Further, the PCF may, according to PCC rule authorization, choose a (g)PTP message generation rate for the UPF/NW-TT adaptively. If the AF does not provide a required (g)PTP message rate, the 5GS may determine a (g)PTP message rate based on 5GS constraints. If the AF does not provide the BMCA information, the NW-TT determine the Announce message based on 5GS configuration. For Ethernet type PDU sessions, both PTP over UDP/IP and (g)PTP over Ethernet are applicable. For IP type PDU sessions, PTP over UDP/IP is applicable.

- Time synchronization method 3 (the time source is provided by the 5GS and 5G-AN provides a 5GS reference time to the UE via 3GPP radio layer; UE provides time information to attached devices using implementation specific means):

Time Domain is not applicable. A PCC rule for time synchronization is not required. The method is applicable for both IP type and Ethernet type PDU sessions.

- Time synchronization method 4 (the time source is provided by the DS-TT in 5GS via gPTP or PTP):

Time Domain is to be provided from the 5GS (or the AF and the 5GS shares the same Time Domain). The 5GS acts as a (g)PTP grandmaster. For Ethernet type PDU sessions, both PTP over UDP/IP and gPTP over Ethernet are applicable. For IP type PDU sessions, PTP over UDP/IP is applicable. The (g)PTP grandmaster resides in DS-TT. Solution #9: "(g)PTP GM support by DS-TT" describes the details for the (g)PTP grandmaster in DS-TT. In case the DS-TT cannot act as a GM, then the GM is activated in NW-TT which is the method 2. NEF can be the coordinator to activate/deactivate the PTP functionalities in DS-TT and NW-TT.

Editor's note: whether there is a need to send requested synchronization accuracy to UE/DS-TT (e.g. when it supports proprietary sync protocol) is FFS.

- If the AF does not provide a required synchronization accuracy over the air interface, the 5GS may determine a synchronization accuracy based on 5GS constraints.

- The AF controls the time window the time synchronization service is valid in 5GS via activation/deactivation requests sent to the NEF.

- For all time synchronization methods, the PMIC or BMIC can be used to manage the (g)PTP operation for the DS-TT or NW-TT, respectively, influenced by the AF requested synchronization configuration. Following are some parameters that need to be included as part of PMIC and BMIC for Time Sync:

- Requested synchronization accuracy.

- If DS-TT has indicated that it is capable of acting as (g)PTP GM, then the network may request the DS-TT to generate (g)PTP messages to devices attached to the UE by providing (g)PTP parameters (incl. (g)PTP version, domain number(s), sending rate, etc.) and an instruction to start sending (g)PTP messages. For supporting BMCA, the network provides the Announce message to DS-TT. This is also described in solution 9.

- The network may request the NW-TT to generate (g)PTP messages by providing (g)PTP parameters (incl. (g)PTP version, domain number(s), sending rate, etc.)

- DS-TT capabilities for acting as (g)PTP GM, which version(s) the DS-TT supports, (g)PTP default Data Set (e.g. clock identity, clock class, clock accuracy, etc),

- (g)PTP port Data Set (e.g. port number, port role, port enabled, announce interval, etc).

- DS-TT and NW-TT used for IP type PDU Sessions need to support only the parameters in PMIC and BMIC required for Time synchronization service. DS-TT and NW-TT used for TSC service support the parameters in PMIC and BMIC as described in TS 23.501.

- The AF is in control to activate and deactivate the service. If an AF request for TimeSync service activation or modification is received for UE/DS-TT for which PDU Session does not exists, then the NEF may store the information in the UDR until the target UE establishes the PDU Session, or a new AF request to deactivate TimeSync service is received. Also, the NEF may store DS-TT/NW-TT capabilities for UE(s) with active PDU Sessions. If the TimeSync service deactivation is received for an ongoing PDU Session(s), the NEF indicates the deactivation to the DS-TT(s) and NW-TT via PCF/SMF. If the TimeSync service deactivation is received for which the service activation was previously stored in the UDR, the NEF revokes the TimeSync service information from the UDR.

- The AF may provide a temporal validity condition to the NEF when the AF activates the TimeSync service. Temporal validity condition contains the start-time and stop-time attributes that describe the time period when the TimeSync service is active. If the start-time and/or the stop-time is in the future, the NEF includes the temporal validity condition to the Npcf\_PolicyAuthorization\_Create service operation it sends to the PCF. If the start-time is in the past, the NEF treats the AF request as if the TimeSync service was activated immediately. If the AF request for TimeSync service activation is targeted for multiple UEs or for future PDU session(s), the NEF stores the temporal validity condition to the UDR as part of the service information, and PCF(s) receive(s) the temporal validity condition from the UDR. The PCF maintains the start-time and stop-time for the TimeSync service for the PDU Session. When the PCF notices that the start-time or stop-time is reached, the PCF notifies the NEF via Npcf\_PolicyAuthorization\_Notify service operation for the event. Upon reception of the start-time or stop-time event, the NEF sends PMIC/BMIC signaling to configure the (g)PTP functionality in DS-TT and NW-TT accordingly.

Editor’s Note: It is FFS whether the temporal validity condition could contain multiple start-stop time periods.

NOTE 2: This is intended for a wide range of applications, ex. motion control use-cases, VIAPA, smart grid applications where requirements for synchronization accuracy and deployment scenario may be very diverse.

- The 5GS exposes the following to aid the AF in formulating a request for Time Synchronization that will be acceptable to the 5GS:

- 5GS Support for Time Synchronization to 5GS.

- supported time synchronization methods (i.e. method(s) 1, 2, 3, 4).

- For method 2 and 4, additional information is exposed, including grandmaster clock accuracy and clock identity that are provided by UPF/NW-TT or DS-TT, respectively.

- supported (g)PTP versions:

- IEEE 802.1AS [6] (i.e. gPTP), and/or

- PTP over UDP/IPv4 according to IEEE 1588-2008 [13] Annex D, and/or

- PTP over UDP over IPv6 according to IEEE 1588-2008 [13] Annex E.

- Minimum Time Synchronization accuracy supported.

- Minimum gPTP or PTP message generation rate supported, and maximum number of clients that can be supported at the minimum gPTP or PTP message generation rate.

- Considering the AF requested time synchronization service, NEF determines the time distribution method to use to provide the service, the allowed time synchronization requirements (e.g. clock synchronization requirement, time domain, message rate), etc. Depending on the time synchronization service to configure, time synchronization policies may be associated to a PDU Session (for example for methods 1 and 2), or the policies may be independent of the user plane configuration the UE has (for example for methods 3 and 4).

- To cover all cases, the policy and charging framework enables time synchronization service control to be applied on a PDU Session (i.e. time synchronization parameters will determine the QoS requirements for the PDU Session or QoS Flow) using PCC rules and independent of any PDU Session (i.e. time synchronization parameters only impact control plane management in 5G AN) without requiring PCC rules.

- The NEF stores the time synchronization service parameters in the UDR.

- The following subscription information is defined for time synchronization services:

* whether the UE is authorized to use time synchronization services and the methods allowed.
* the list of time synchronization parameters as defined in solution #7 and solution #9.
* Policy control and charging information.

To support notification, the additional events may be added to the list of monitoring capabilities specified for the NEF in TS 23.502 [3] (see clause 4.15.3.1).

If DS-TT is acting as a GM, solution #1 can be used with this solution to manage BMCA procedure for the time domain.

### 6.7.3 Procedures

For IEEE TSN integration, i.e. if TSN AF is deployed, TSN AF controls the gPTP functionality in DS-TT or NW-TT using existing PMIC or BMIC signalling, respectively. Otherwise (i.e. for IP or Ethernet PDU Sessions not part of an IEEE TSN network), the NEF terminates the PMIC signaling instead of TSN AF.

The following procedure is used to expose 5GS information to aid the AF in formulating a request for Time Synchronization in 5GS.



Figure 6.7.3-1: Time Synchronization capability exposure towards AF

The following procedure is used by the AF to request activation/deactivation/modification of the Time Synchronization service in 5GS.



Figure 6.7.3-2: Activate/Deactivate/Modify UE's Time Synchronization Service

0. PDU session may be established between UE/DS-TT and UPF/NW-TT. . It could also be established using device trigger procedure as defined in TS 23.501 [2], TS 23.502 [3].

1. An AF sends a Time Sync Service Request indicating e.g.the target UE, group of UEs, or DNN and S-NSSAI, and the clock domain to the PCF via NEF to activate/deactivate/modify UE's time synchronization service. The activation or modification request may contain a temporal validity condition.

If the request is target for multiple UEs or for future PDU session(s), the NEF determines the time synchronization service policy based on the Time Sync Service Request and stores the time synchronization service policy to UDR. The PCF(s) receive(s) a Nudr\_DM\_Notify notification of data change from the UDR (as illustrated in Figure 6.7.3-3). The time synchronization service policy may include time synchronization method and allowed synchronization requirements (e.g. time synchronization protocol), and the NEF address (a subscription for the PCF to send notifications to this NEF address). The PCF subscribes the synchronization service policy stored as DataSet "Application Data" and Data Subset "Service specific information" with the specific S-NSSAI and DNN in the UDR.

2. The NEF ensures the necessary authorization control and sends PMIC/BMIC signaling to configure the (g)PTP functionality in DS-TT and NW-TT, respectively. PCF derives QoS policies and forwards the PMIC/BMIC information to SMF.

3. The PCF notifies the SMF via Npcf\_SMPolicyControl\_UpdateNotify message.

4. The SMF triggers the SM Policy Association establishment/modification procedure to create a QoS flow (or release the QoS flow) for transmitting the clock domain's (g)PTP message.

5a. The SMF forwards BMIC to the UPF/NW-TT through the N4 session level modification message, if needed.

5b. The SMFforwards PMIC to the UE/DS-TT.

6a. Upon reception of the notification in step 5, UPF/NW-TT performs consequent behaviours to support time synchronization of corresponding GM, for example if the time source for the Time Sync service requested to be activated is in the UPF/NW-TT, then the UPF will start to create and distribute the (g)PTP messages of the 5G GM to the UE.

6b. Upon reception of the notification in step 5, UE/DS-TT starts or stops to handle the (g)PTP messages as indicated in the notification.

7. If PCF receive Time Sync service request from NEF, the PCF responses the NEF and the NEF responses the AF with the Time Sync service request result.

If the request in Step 1 is targeted for multiple UEs or for future PDU Sessions and a PDU session is established, the PCF receives time synchronization service policy from the UDR and notifies the NEF for the event when a new PDU session is established. The NEF may then obtain the capabilities from the DS-TT via PMIC, and send PMIC signaling to the DS-TT (via PCF) to configure the (g)PTP functionality in the DS-TT.

### 6.7.4 Impacts on services, entities and interfaces

AF:

- Provides the parameters to the NEF to configure the Time Synchronization service.

- Provides parameters required for the operation of the BMCA.

NOTE: The configuration of the BMCA parameters can be used to ensure that the time source provided by 5GS (viaDS-TT an/or NW-TT) is selected for the devices outside 5GS (the 5GS is selected as the grandmaster).

NEF:

- Exposes the 5GS capabilities to support Time Synchronization service. Authorizes the Time Synchronization service request from the AF. Controls the (g)PTP functionality in DS-TT and NW-TT via SMF.

- Determines the time synchronization service policy and stores it to the UDR.

- Upon reception of the start-time or stop-time event notification from the PCF, sends PMIC or BMIC to control the (g)PTP functionality for TimeSync service in the DS-TT or NW-TT accordingly.

UE:

- Distributes the 5G reference time to DS-TT and optionally to applications or devices behind the UE (by mechanism out of scope of 3GPP), for IP and Ethernet types of PDU Sessions.

DS-TT:

- Indicates a support for PTP/UDP/IP residence time calculation in Port Management Information container to the network.

- When activated by NEF, calculates and adds the measured residence time between the NW-TT and DS-TT into the Correction Field (CF) of the PTP time synchronization messages conveyed over UDP/IP, applies to IP and Ethernet types of PDU Sessions.

- When activated by NEF, (if the time source is located behind the DS-TT as in Solution #1): Inserts a timestamp to the PTP time synchronization messages conveyed over UDP/IP, applies to IP and Ethernet types of PDU Sessions.

- When activated by NEF, (if the time source is located in the DS-TT): generates (g)PTP time sync messages (with the indicated PTP version, domain number(s), sending rate, etc), applies to IP and Ethernet types of PDU Sessions. Solution #9: "(g)PTP GM support by DS-TT" describes the details for the (g)PTP grandmaster in DS-TT.

UPF/NW-TT:

- When activated by NEF, (if the time source is located in the DN): Inserts a timestamp to the PTP time synchronization messages conveyed over UDP/IP, applies to IP and Ethernet types of PDU Sessions.

- When activated by NEF, (if the time source is located in the NW-TT): generates PTP time sync messages (with the indicated PTP version, domain number(s), sending rate, etc), applies to IP and Ethernet types of PDU Sessions.

- Forwards the PTP time synchronization messages conveyed over UDP/IP in DL direction to the PDU Sessions, applies to IP and Ethernet types of PDU Sessions.

UDR:

- Stores new data format (time synchronization service policy).

PCF:

- Subscribes and receives the time synchronization service policy from the UDR.

- Policy and charging framework for time synchronization service independent of any PDU Session.

- Maintains the temporal validity condition (start-time, stop-time) for the TimeSync service for the PDU Session. Notifies the NEF when start-time or stop-time is reached.

## 6.8 Solution #8: AF Requested TSN Synchronization Activation and Deactivation

### 6.8.1 Introduction

This solution addresses Key Issue #3B: AF requested TSN synchronization Activation and Deactivation.

It is assumed that as below:

- A TSN GM for TSN Domain 1 is attached to the DS-TT of a UE and a PDU Session is established for this UE to deliver the UL gPTP/PTPoIP(PTP over UDP/IP) message to the UPF/NW-TT.

- A TSN GM for TSN Doman 2 in the NW-TT side can send DL gPTP/PTPoIP message to all the UPFs attached to the same DN Ethernet network.

- All the UPF/NW-TT in the 5GS can create gPTP/PTPoIP message for the 5GS time domain and send the gPTP/PTPoIP message to the UE connected to this UPF/NW-TT.

- All the PDU Sessions for the TSN delivery for all the UEs with the same DN TSN domain (except the 5GS domain) are controlled by the same SMF and the same UPF.

### 6.8.2 Functional Description

#### 6.8.2.1 General

The AF request the UDM via the NEF to configure UEs SM Subscription with a dedicated S-NSSAI and DNN for the TSN activation method by providing the following information:

- S-NSSAI and DNN for the TSN PDU Session.

- TSN domain.

- UL/DL TSN synchronization method.

- Activation/Deactivation.

The similar function as defined in clause 4.25.3 NIDD Configuration of TS 23.502 [3] is reused.

#### 6.8.2.2 Functional Description for AF Requested TSN Synchronization Activation

During the UE requested PDU Session Establishment for the TSN synchronization, the UE provide the following information in the PDU Session Establishment Request message:

- S-NSSAI/DNN for the TSN PDU Session.

The same SMF and the same UPF of the UE/DS-TT attached with the TSN GM is selected.

#### 6.8.2.3 Functional Description for AF Requested TSN Synchronization Deactivation

After AF request the UDM via the NEF to cancel the configuration of the TSN activation method by providing information as described in clause 6.x.2.1, the UDM will update the UEs SM subscription with the dedicated S-NSSAI and DNN for the TSN and sends the deactivation indication to all the registered SMFs of the UEs. And the SMF will initiate the PDU Session Release procedure.

### 6.8.3 Procedure

#### 6.8.3.1 procedure for AF Requested TSN Synchronization Activation



Figure 6.8.3.1-1: AF Requested TSN Synchronization Activation

0a. There is TSN GM attached to a DS-TT/UE to provide the UL gPTP/PTPoIP message for the TSN Domain 1. This TSN GM DS-TT/UE PDU Session for the S-NSSAI/DNN uses the SMF and UPF/NW-TT.

0b. There is TSN GM for TSN domain 2 located in the NW-TT side, and this TSN GM sends the DL gPTP/PTPoIP message to all the UPF/NW-TT connected the same ethernet network for S-NSSAI/DNN.

Steps 1 to 6 follow the similar function as defined in clause 4.25.3 NIDD Configuration of TS 23.502 [3] as below:

1. The AF sends the Nnef\_TSNConfiguration\_Create Request (S-NSSAI, DNN AF ID, TSN Domain ID, UL/DL TSN synchronization method, TSN Activation Indication, UE ID or External Group ID) to the NEF. The TSN Activation Indication will indicate whether it is TSN Activation or Deactivation.

2. The NEF checks whether the AF is authorized to send the request. If there is UE ID or External Group ID, the NEF needs to map it the SUPI or internal group ID.

3. The NEF sends an Nudm\_TSNAuthorisation\_Get Request (S-NSSAI, DNN, AF ID, TSN Domain ID, UL/DL TSN synchronization method, TSN Activation Indication, SUPI or internal group ID) to the UDM to authorise the TSN synchronization configuration request for the received S-NSSAI and DNN.

4. The UDM examines the Nudm\_TSNAuthorisation \_Get Request message.

If TSN Activation Indication indicates TSN Activation and the authorisation is successful and if an External Group Identifier was included in step 3, the UDM updates the UEs SM subscription data of the dedicated S-NSAAI and DNN with TSN synchronization method on the TSN Domain ID.

5. The UDM sends an Nudm\_TSNAuthorisation\_Get Response (Result) message to the NEF to acknowledge acceptance of the Nudm\_TSNAuthorisation\_Get Request.

6. The NEF sends a Nnef\_TSNConfiguration\_Create Response (Cause) message to the AF to acknowledge acceptance of the Nnef\_TSNConfiguration\_Create Request.

7. UE initiates a PDU Session Establishment Request (S-NNSAI, DNN, etc.), the UE Requested PDU Session establishment procedure and the SMF registered the PDU Session ID to the UDM are defined in clause 4.3.2.2.1 in TS 23.502 [3] and the same SMF and UPF are selected as described as in clause 6.X.2.

8a. If DL TSN synchronization for TSN domain 2 is activated, the UPF/NW\_TT will update the Correct Field and forward the updated DL gPTP/PTPoIP message to the UE/DS-TT and to the TSN end station behind the UE/DS-TT as defined in clause 5.27.1.2.2 of TS 23.501 [2]. The TSN end station time is updated and is time synchronized with TSN domain 2 based on IEEE 802.1AS [6] for gPTP or IEEE 1588-2008 [13] for PTPoIP.

8b. If DL TSN synchronization for 5GS domain is activated, the UPF/NW\_TT will generate the DL gPTP/PTPoIP message for the 5GS TSN domain and sets Correct Field and forward the DL gPTP/PTPoIP message to the UE/DS-TT and to the TSN end station behind the UE/DS-TT as defined in clause 5.27.1.2.2 of TS 23.501 [2]. The TSN end station time is updated and is time synchronized with 5GS domain based on IEEE 802.1AS [6] for gPTP or IEEE 1588-2008 [13] for PTPoIP.

8c. If DL TSN synchronization for TSN domain 1 is activated, UPF/NW-TT locally switches and forwards the UL gPTP/PTPoIP message of TSN domain 1 to the UE/DS-TT and to the TSN end station behind the UE/DS-TT as defined in Solution#1. The TSN end station time is updated and is time synchronized with TSN domain 1 based on IEEE 802.1AS [6] for gPTP or IEEE 1588-2008 [13] for PTPoIP.

#### 6.8.3.2 procedure for AF Requested TSN Synchronization Deactivation



Figure 6.8.3.2-1: AF Requested TSN Synchronization Deactivation

0a. There is TSN GM attached to a DS-TT/UE to provide the UL gPTP/PTPoIP message for the TSN Domain 1. This TSN GM DS-TT/UE PDU Session for the S-NSSAI/DNN uses the SMF and UPF/NW-TT. If UL TSN Synchronization is activated to the UE connected to the UPF/NW-TT, the UL gPTP/PTPoIP message is forwarded to the UE/DS-TT as described in clause 6.8.3.1.

0b. There is TSN GM for TSN domain 2 located in the NW-TT side, and this TSN GM sends the DL gPTP/PTPoIP message to the UPF/NW-TT connected the same ethernet network for S-NSSAI/DNN. The DL gPTP/PTPoIP message is forwarded from the UPF/NW-TT and then to the UE/DS-TT as described in clause 6.8.3.1.

0c. If DL TSN Synchronization for the 5GS domain is activated to the UE/DS-TT connected to the UPF/NW-TT, the DL gPTP/PTPoIP message is generated by the UPF/NW-TT and is forwarded to the UE/DS-TT as described in clause 6.8.3.1.

1. The AF initiates the TSN synchronization Deactivation procedure as defined in steps 1 to 6 in clause 6.8.3.1 with the "TSN Activation Indication" indicates TSN Deactivation. If TSN Activation Indication indicates TSN Deactivation and the authorisation for the request is successful, the UDM updates the UEs SM subscription data of the dedicated S-NSSAI and DNN with cancelling the TSN synchronization on the TSN Domain ID and remove the registered SMF IDs and PDU Session IDs associated with this SM subscription.

2. The UDM sends the Nudm\_UECM\_DeregistrationNotification (SUPI, PDU Session ID, Cause:TSN Synchronization Deactivation) to the registered SMF IDs.

3. The SMF initiates the network requested PDU Session Release procedure as defined in clause 4.3.4.3 of TS 23.502 [3], and the UPF/NW-TT deactivate the function to forward the gPTP/PTPoIP message to the DS-TT/UE.

### 6.8.4 Impacts on services, entities and interfaces

AF:

- Provide new configuration to UDM via the NEF to activate/deactivate the TSN synchronization.

UDM:

- Dynamical create or update the SM subscription data for TSN synchronization similar as the defined in clause 4.25.3 NIDD Configuration of TS 23.502 [3].

AMF:

- Select the same SMF for the PDU Sessions for UL TSN synchronization with the same TSN domain.

NW-TT/DS-TT:

- Support TSN time synchronization PTP messages over UDP/IP as defined in IEEE 1588-2008 [13].

## 6.9 Solution #9: (g)PTP GM support by DS-TT

### 6.9.1 Introduction



Figure 6.9.1-1: DS-TT distributes 5GS time to devices attached to DS-TT using (g)PTP

This solution addresses KI#3B. As illustrated in Figure 6.9.1-1, key idea of this solution is that DS-TT acts as a (g)PTP grand master (GM) for devices attached to DS-TT. The time information used in (g)PTP is based on the time information received from the gNB as defined in TS 38.331 [11].

External network sees a single GM, even though inside the 5GS the GM is distributed to multiple DS-TTs. This means the GMs in the DS-TTs use the same (g)PTP clock identity, etc relevant GM attributes.

### 6.9.2 Functional Description

The solution is based on the following principles

- DS-TT indicates to the network inside a Port Management Information Container (PMIC) whether DS-TT is capable of acting as (g)PTP GM and which version(s) it supports

- IEEE 802.1AS [6] (i.e. gPTP), and/or

- PTP over UDP/IPv4 as per IEEE 1588-2008 [13] Annex D, and/or

- PTP over UDP over IPv6 as per IEEE 1588-2008 [13] Annex E.

- If DS-TT has indicated that it is capable of acting as (g)PTP GM, then the network may request the DS-TT to generate (g)PTP messages to devices attached to the UE by providing (g)PTP parameters (incl. (g)PTP version, domain number(s), sending rate, initial Announce interval, etc.) and an instruction to start sending (g)PTP messages inside PMIC to the DS-TT.

NOTE: DS-TT can be configured to support different (g)PTP profiles, e.g. SMPTE ST 2059-2 [9] or IEC/IEEE 61850-9-3 [10] by providing the (g)PTP parameters defined for those profiles to DS-TT.

### 6.9.3 Procedures

For IEEE TSN integration, i.e. if TSN AF is deployed, TSN AF controls the gPTP functionality in DS-TT using existing Port Management Information Container (PMIC) signaling between DS-TT and TSN AF.

Otherwise (i.e. for IP or Ethernet PDU Sessions not part of an IEEE TSN network), the NEF terminates the PMIC signaling instead of TSN AF. To achieve this, NEF generates PMIC signaling to control the (g)PTP client in DS-TT based on time synchronization API requests from an AF and sends PMIC to DS-TT using existing Rel-16 PCF functionality. Similarly, NEF receives PMIC from PCF using Rel-16 functionality.

It is assumed that a single NEF is handling all time synchronization API requests for a given UE.

Existing Port Management Information Container (PMIC) signalling is reused between DS-TT and the network.

The following figure illustrates an overview of the procedure to activate (g)PTP grandmaster functionality in DS-TT.



Figure 6.9.3-1: Procedure for synchronizing (g)PTP clients attached to DS-TT with the 5G clock

1. The AF activates the time synchronization service as described in Solution #7. Upon PDU Session establishment, the DS-TT indicates to the NEF (or TSN AF) inside a Port Management Information Container (PMIC) whether DS-TT is capable of acting as (g)PTP GM and which version(s) it supports. NEF receives PMIC from PCF using Rel-16 functionality.  
  
The NEF generates PMIC signaling to control the (g)PTP client in DS-TT based on time synchronization API requests from an AF and sends PMIC to DS-TT using existing Rel-16 PCF functionality. The NEF includes the GM attributes (e.g. grandmaster identity, grandmaster quality) as described in IEEE 802.1AS [6] or IEEE 1588-2008 [13] to the PMIC. The NEF informs the NW-TT in BMIC that the grandmaster is active in DS-TT(s). The NEF informs the NW-TT in BMIC with the GM attributes (default dataset) that are sent by the DS-TT(s) in the time-synchronization event messages if the grandmaster in DS-TT(s) is active. The NEF informs the NW-TT in BMIC also if the grandmaster is deactivated in DS-TT(s). The NEF subscribes for the BMCA reports from the NW-TT using BMIC.

2. DS-TT/UE receives the time information from the gNB as defined in TS 38.331 [11].

3. DS-TT generates the (g)PTP events based on the time information received from the gNB, and based on the GM attributes received in the PMIC.   
  
BMCA procedure to activate or de-activate the GM in DS-TT(s):

While the GM is active in the DS-TT, the DS-TT generates the Announce messages as described in IEEE 802.1AS [6] or IEEE 1588-2008 [13]. Upon reception of Announce message from a device behind the DS-TT, the DS-TT forwards the Announce message to the NW-TT for the execution of the BMCA. If the NW-TT determines that due to the result of the BMCA the (g)PTP grandmaster must be deactivated in DS-TT(s), the NW-TT reports the BMCA result to NEF using BMIC signalling. The NEF generates PMIC signalling to control the (g)PTP client in DS-TT(s) and disables the GM in DS-TT(s). The 5GS starts to distribute the GM from the device outside 5GS as described in Solution #1.

The details of the BMCA procedure while the GM in DS-TT(s) is not active is described in Solution #1. If the NW-TT determines that due to the result of the BMCA the (g)PTP grandmaster must be re-activated in DS-TT(s), the NW-TT reports the BMCA result to NEF using BMIC signalling. The NEF generates PMIC signaling to control the (g)PTP client in DS-TT(s) and enables the GM in DS-TT(s).

### 6.9.4 Impacts on services, entities and interfaces

DS-TT:

- Optionally send (g)PTP capabilities; receive (g)PTP parameters.

- Optionally generate (g)PTP messages based on network request.

- Generates and sends the Announce message according to the information received from TSN AF/NEF.

TSN AF/NEF:

- Support Rel-16 PMIC signaling via PCF.

- Support for the BMCA result report as requested by NEF

- Provide (g)PTP parameters incl. (g)PTP version, domain number(s), sending rate, initial Announce interval, etc to DS-TT

NW-TT:

- Support for the BMCA result report subscription from the NEF

## 6.10 Solution #10 UE-UE communication based on generalized Ethernet model

### 6.10.1 Introduction

This solution addresses the traffic forwarding aspect of Key Issue #2: UE-UE TSC communication. From a 3GPP system perspective, UE-UE communication is a special case as that requires the UPF to be able to forward traffic between UEs without going through a NW-TT. From the TSN network perspective, however, the UE-UE communication is not special; as the 5GS models a TSN bridge, it just corresponds to communication between two ports. Currently, static forwarding rules can only be configured by the CNC for the uplink direction in the UPF/NW-TT to select between the NW-TT ports. However, centrally managed TSN networks require the capability of configuring static forwarding rules in any direction so that the CNC can set up the TSN streams according to the delay requirements. Note also that centrally configured static forwarding rules are applicable also to non-TSN traffic.

This solution generalizes the forwarding capability 5GS bridge model, so that is becomes capable of TSC communication between any two ports. That includes communication between a DS-TT port and a NW-TT port, as already supported, but also extended to include communication between two DS-TT ports (i.e., UE to UE communication), as well as communication between two NW-TT ports. The solution makes the 5GS model comply to IEEE bridging functionality by including the Bridging forwarding function as a single entity which can then realizes the needed forwarding functions. In this way the 5GS provides a general framework that can apply to all cases, while vendors are free to implement the bridge forwarding function however they want.

The solution is illustrated in the figure 6.x.1-1 below. The bridge forwarding inside the NW-TT realizes Ethernet bridging functionality and makes use of the static forwarding rules to any port as provided by the CNC. The PDU Sessions are bound to the bridge forwarding function as logical ports, which act in the same way as physical ports from the point of view of forwarding. In case of downlink traffic, the bridge forwarding functionality determines which PDU Session to use. N4 rules configured by the SMF are still possible to use according to the current specification, e.g. for QoS enforcement or usage reporting; i.e., the CUPS mechanism remains as specified today. But as the bridge forwarding mechanism already determines the PDU Session to use, there is no need to set up N4 rules for selecting the downlink PDU Session.

NOTE: The impact on PDU session lookup is to be evaluated.



Figure 6.10.1-1 Static forwarding rule setup

This solution focuses only on the forwarding aspect, and hence it does not address questions related to the delay model and QoS.

### 6.10.2 Functional Description

- The CNC has the possibility to configure static forwarding rules into the bridging function within the NW-TT. Static forwarding rules may be configured for forwarding between any two ports in any direction, including the possibility of static forwarding between two DS-TT ports (UE to UE) or between two NW-TT ports. The possibility of static forwarding rules makes the 5GS logical bridge act similarly as TSN Ethernet bridge where centrally controlled forwarding rules are expected to be supported. This allows the CNC to explicitly establish the traffic forwarding path using the destination MAC address and VLAN combination of the TSN stream, even that MAC address/VLAN combination is different from what is used for non-TSN traffic from the given host which is observed by MAC learning.

NOTE: Configuring/updating static forwarding rules between two NW-TT ports in a UPF using the Rel-16 BMIC mechanism, which is based on PDU-session related signaling, is only supported as long as at least one PDU session for TSN is established towards the related UPF. This solution focuses on the forwarding aspect, and the mechanism used to convey the forwarding rules to the UPF is out of scope of this solution.

- For the purposes of static forwarding in the downlink in the NW-TT, the PDU Sessions correspond to bridge ports. When static forwarding dictates that a frame is to be forwarded on a given port, the NW-TT binds the port to the given PDU Session. How this binding is realized is implementation specific. The UPF does not need to install additional filtering in the packet detection rules (PDRs) to determine which PDU Session to select for the downlink traffic once the port is already determined by the static forwarding rules. Therefore, the PDRs may contain e.g., match-all filters or filters that correspond to the appropriate QoS or other rules; the downlink traffic that is offered to the PDR in the given N4 session corresponding to the PDU Session does not include the traffic that goes to another port as determined by the bridging function in the NW-TT.

Note that the solution does not restrict how the UPF binds the PDU Sessions to bridge ports in the implementation. One possible implementation could be to assign an interface identifier to the PDU Sessions as well as to the bridge ports and tag the packets with the interface identifier to realize the binding. The N4 rules are extended within the UPF automatically to map packets marked with the interface identifier to the given PDU session. Other implementation options are also possible. The implementation of how this binding is done is not visible outside of the UPF, hence it does not impact the N4 sessions. By binding the PDU sessions to bridge ports, the PDU Sessions act as logical ports, which act the same way as physical ports from the point of view of bridge forwarding.

Editor's note: It is FFS how to manage the interface identifier in 5GS and how to maintain the binding between PDU session or N19 tunnel, interface identifier and (logical/physical) bridge port.

The solution realizes the bridge forwarding in a single logical function. It is up to the implementation to what extent that logical function makes use of PDR/FAR rules, and how the bridge forwarding implementation is integrated with the existing N4 rules.

- The solution assumes any two DS-TT ports are allowed to communicate, as determined by the CNC/CUC.

- The solution does not rely on 5G VN mechanism. The solution can co-exist with some features of the 5G VN mechanism, such as group management and the setup of N19 tunneling. An N19 tunnel may be bound to a port of the bridge forwarding function similarly as PDU sessions are bound to a port. As the centrally managed TSN network use static forwarding rules provided by the CNC, there is no need for using SMF provided PDRs for mapping downlink traffic to PDU Sessions; instead the selection of the downlink PDU Session is performed in the bridge forwarding function as described above.

### 6.10.3 Procedures

The following new or adjusted procedures are needed for the solution.

- The scope of the possible static forwarding rules is extended as these are currently specified for uplink traffic from the UEs to the NW-TT ports. This solution allows static forwarding rules to be provided between any two ports of the 5GS Bridge. As already specified, the CNC may provide static forwarding rules to the TSN AF, which includes the static forwarding rules in the Bridge Management Information Container that is forwarded to the NW-TT that implements the forwarding accordingly. When implementing the forwarding rules, the bridging function in the NW-TT binds PDU Sessions to logical ports so that no additional filtering in the PDRs are needed to determine which PDU Session to select for the downlink once the port is already determined by the static forwarding rules that are part of the bridging function in the NW-TT.

### 6.10.4 Impacts on services, entities and interfaces

NW-TT:

- The NW-TT implements static forwarding rules not only in the uplink direction from a UE to the NW-TT ports, but also between any two ports.- PDU Sessions are bound to the logical ports in the NW-TT bridging function so that when the bridge forwarding rules dictate that a frame is forwarded on a port corresponding to a PDU Session, no additional filtering is needed in the PDRs to send the frame on the given PDU Session. It is implementation specific how the bridge forwarding function is realized and how the binding between the bridge ports and the PDU Sessions are implemented within the UPF.

SMF:

- Do not provide PDR filter conditions for mapping downlink traffic to PDU sessions.

## 6.11 Solution #11: UPF triggered UE-UE TSC communication

### 6.11.1 Introduction

This solution addresses Key issue #2: UE-UE TSC communication.

### 6.11.2 High Level Description

- During PDU establishment, UPF assigns port number for DS-TT of UE and the corresponding NW-TT for the PDU sessions.

- During a sequential approach, when UE1 initiates a PDU session it provides source and destination address.

Editor's note: Whether it can be assumed that a UE1 knows the destination address of other UEs (or devices attached to the UE) before-hand is FFS, especially considering that UE1 may also provide Ethernet connectivity for other devices attached to UE1.

- If the UPF determines that the destination address happens to be a UE which it had served in the past, the UPF could inform the SMF about the port-pair optimisation without traversing N6.

- UPF provides the port-pair recommendation to the TSN AF via UPF🡪SMF 🡪 PCF.

- TSN AF calculates the Bridge delay information for the UE-UE TSC communication.

- Bridge delay information of UE-UE TSC communication = [UE1-DT-TT residence time + PDB of PDU session (1)] + [UE2-DS-TT residence time + PDB of PDU session (2)].

Editor's note: How 5GS calculates bridge delay between two UEs if UE1 has not provided a MAC address that it will send traffic to before-hand) is FFS.

- TSN AF provides the TSCAI and QoS configuration to the PCF. PCF creates updated PCC rules and sends to the SMF.

- SMF initiates PDU Session Modification Procedure for UE1 and UE2. After PDU session modification is complete, the UPF routes the packets directly to UE2 without the involvement of the N6.

### 6.11.3 Procedures

#### 6.11.3.1 UPF triggered UE-UE TSC Communication

The procedure in Figure 6.11.3.1-1 shows a signalling flow in which the UPF determines the eligible port-pair for UE-UE TSC communication:



Figure 6.11.3.1-1: Procedure for UPF determining the eligible port-pair for UE-UE TSC communication

1a. UE1+DS-TT initiates a PDU session establishment Request to SMF. The destination address of UE2 is included in the PDU Establishment Request. In this case, the call flow continues to step 2.

1b. UE1+DS-TT initiates a PDU session establishment Request to SMF. UE1 includes the port-pair suggestion of UE2-DS-TT in the request. In this case, the call flow continues to step 5.

NOTE 1: The call flow is also applicable to a UE with multiple DS-TT ports. In this case UE1 and UE2 will be same, but DS-TT ports are different.

NOTE 2: UE1 could have knowledge of UE2-DS-TT based on previous connection or if they belong to same network. Assuming a scenario when the two UE(s) were performing a UE-UE communication and the connection was abruptly terminated at UE1 due to any abnormality or UE issue (e.g. baseband crash, power failure, etc.). In these conditions, it makes more time saving for UE1 to report the port-pair directly in PDU Session Establishment Request to SMF.

Editor's note: Definition of port-pair suggestion is FFS. How it can be determined that a previous port pair is still valid is FFS.

2. SMF performs UPF selection and sends N4 establishment request to UPF for providing the port numbers and 5GS Bridge ID.

3. UPF determines that the destination port number could also be served by the same 5GS Bridge and informs SMF about the port-pair details.

NOTE 3: UPF may determine that serving the destination address could be a port pair based on various factors: VN network, historical PDU session establishment with UE2, etc., among some examples.

NOTE 4: UPF may maintain the cache history of the MAC address until the lifetime of the PDU session or a time-limit configured by SMF in the N4 Establishment Request.

4. UPF reports the port-pair to SMF.

5. UE1 completes the PDU Establishment procedure as defined in TS 23.502 [3], clause 4.3.2.2.1, steps 10-14.

6. Based on the paging, UE2+DS-TT establishes a PDU Session to SMF as defined in TS 23.502 [3], clause 4.3.2.2.1.

Editor's note: Relation to paging is FFS.

7. After the establishment of PDU Sessions of UE1 and UE2 DS-TTs, SMF forwards the port-pair and the 5GS Bridge Information to the PCF/NEF. PCF/NEF forwards the new 5GS bridge information to the TSN AF.

8. AF calculates the Bridge delay information as follows:

- Bridge delay information = UE1-DS-TT residence time + PDB of PDU session (1) + UE2-DS-TT residence time + PDB of PDU session (2).

9. AF evaluates the QoS for the UL and DL links for UE-UE communication and shares to PCF along with the TSCAI. AF requests PCF to create corresponding PCC rules for SMF to use for the PDU sessions via Npcf\_Policy Authorization service.

NOTE 5: AF could request CNC of TSN to provide the QoS or could be able to provide the QoS and TSCAI based on the TSN configuration received from CNC during the establishment of the PDU sessions at step 1 and step 2.

10. PCF creates PCC rule for Uplink transmission and updates SMF of PDU session (1) via Npcf\_SMPolicyControl\_UpdateNotify procedure.

11. SMF modifies the PDU session of UE1-DS-TT with the updated QoS as defined in TS 23.502 [3], clause 4.3.3.2.

12. SMF modifies the PDU session of UE2-DS-TT with the updated QoS as defined in TS 23.502 [3], clause 4.3.3.2.

Based on UPF determination, UE-UE TSN communication is setup successfully.

NOTE 6: Alternatively, PCF could use the existing TSC Configuration provided by TSN AF during PDU Session Establishment procedure and provide the updated PCC Rules and TSCAI to the SMF (for UE-UE Communication) via Npcf\_SMPolicyControl\_UpdateNotify procedure.

### 6.11.4 Impacts on services, entities and interfaces

- 5GS Bridge information should include port-pair information.

- UPF should report the port-pair information to the SMF.

### 6.11.5 Evaluation

Editor's note: This clause provides an evaluation of the solution.

## 6.12 Solution #12: The bridge U-Plane model for UE-UE communication

### 6.12.1 Introduction

This solution is to Key Issue 2: UE-UE TSC communication. Specially, this solution proposes a unified u-plane forwarding architecture. This solution does not touch the port pair determination, 5GS bridge delay of the port pair calculation and the configuration of deterministic QoS for the UE-UE TSC. It can work with existing solution for Key issue#2, e.g. solution 2, 3 and 4.

### 6.12.2 Functional Description

In the figure 6.12.2-1, it introduces a FP (forwarding process) in the NW-TT. All the downlink and uplink traffic are sent to the FP first, and then the FP decides where the packet is forwarded to.



Figure 6.12.2-1: The forwarding process architecture

With this solution, the static filter entry is only sent to NW-TT in the BMIC (Bridge management information container).

### 6.12.3 Procedures

There are two phase for the u-plane handling.

**Phase-1: receiving phase:**



Figure 6.12.3-1: receiving phase

As shown in the figure 6.12.3-1, when the downlink or uplink data is received, it is forwarded to Forwarding process in the NW-TT.

- When the UPF receives the uplink traffic from PDU session for TSC, it forward to the FP/NW-TT.

- When the NW-TT receives the downlink packet from N6/DN, it forward to FP.

**Phase-2: forwarding phase:**



Figure 6.12.3-2: Forwarding phase

As shown in the figure 6.12.3-2, the FP decides how to forward the packet according to port map in the forward rule (i.e. static filter entry).

- If the packet matches the port of NW-TT, the FP forwards the packet to the Port of NW-TT;

- Otherwise, the FP forwards the packet to the UPF. The UPF uses the N4 rules, e.g., PDR/FAR/QER/URR to handle the packet to the related PDU session.

Editor's note: It is FFS how to handle packets to unknown destinations, which may need to be sent on the NW-TT ports as well.

Editor's note: It is FFS how a static filtering rule sent by the CNC is handled when the filtering rule applies for packets in the downlink direction.

Editor's note: It is FFS how packet replication is achieved (i.e., for broadcast, multicast or unknown unicast frames).

### 6.12.4 Impacts on services, entities and interfaces

Editor's note: This clause lists impacts to existing entities and interfaces

## 6.13 Solution #13: Mechanism for AF requesting 5G network jitter

### 6.13.1 Description

This solution is for key issue#3A, which addresses Exposure of deterministic QoS including aspects related to:

- Ability for AF to request absolute delay and jitter requirements, and mechanisms to enable the PCF to determine the 5GS QoS parameters based on the requirements received from AF.

- Ability for AF to indicate periodicity, burst size and burst arrival time (as defined in Rel-16 for TSC Assistance information), optionally burst spread (variation of burst arrival time for DL traffic resulting from jitter on N6, if applicable) along with Time Domain (reference for these parameters) associated with these parameters to the NEF.

This solution proposes a mechanism for the AF to request jitter and the PCF is required (via NEF if untrusted AF) to calculate an estimation of jitter based on measured delay values obtained using QoS monitoring.

The main idea is that the AF provides request for jitter, and 5G system calculate the jitter based on a group of E2E packet delay between UE and PSA UPF. After PCF getting a group of E2E delay data in measurement period, the PCF may use the IETF RFC1889 method to calculate the jitter and send the jitter value to AF. Considering R16 QoS monitoring mechanism, only average packet delay measurement in RAN has been defined and that the PSA UPF calculates the UL/DL packet delay between UE and PSA UPF based on the received RAN part of UL/DL average packet delay result and the calculated UL/DL packet delay between RAN and PSA UPF. In order to introduce the jitter calculation mechanism in R17, there is no enhancement for RAN and UPF, and the average delay from RAN can be used to calculate an estimation of the jitter.

AF sends a request for jitter calculation by using Nnef\_AFsessionWithQoS\_Create request message to NEF, the indication of jitter requirement, jitter measurement period, sample frequency, reporting threshold or reporting frequency(TS 23.503 6.1.3.21) may be included in the request, and are sent to PCF via NEF.

When PCF accepts the jitter requirement, PCF generates the QoS Monitoring policy for a service data flow, based on the request from AF. In the QoS Monitoring PCC rule, the QoS monitoring period can be the same as jitter measurement period. Then PCF provides the QoS Monitoring policy to the SMF.

When SMF gets the PCC rules for jitter calculation, the SMF sends the QoS Monitoring request to the PSA UPF via N4 and NG-RAN via N2 signalling to request the QoS monitoring between PSA UPF and NG-RAN, as described in TS 23.501 [2] clause 5.33.3.When the reporting trigger(s) is satisfied, e.g. the reporting period expires, or the PDU Session is released, the UPF reports the calculated packet delay value(s) to the SMF, and the SMF sends the reports to the PCF. PCF may use the IETF RFC1889 method to calculate an estimation of jitter based on some measured delay values, which are measured for sampled packets using QoS monitoring, and then sends the estimated jitter value to AF.

The sample packet frequency for jitter calculation may comply with Poisson sampling, because it ensures an unbiased and uniformly distributed sampling during jitter measurement period. However, alternate sampling methodologies are possible. For example, continuous sampling of a constant bit rate stream (i.e., periodic packet transmission) is a possibility. (IETF RFC 3393)

### 6.13.2 Procedures

The mechanism for AF requesting jitter requirements can be described in the Figure 6.13.2-1.



Figure 6.13.2-1: AF requesting jitter requirements

0. The PDU session has been established.

1. The AF sends a QoS monitoring request to the NEF by Nnef\_AFsessionWithQoS\_Create request message. The request message includes indication of jitter, jitter measurement period, sample frequency.

2. The NEF authorizes the AF request and sends the jitter calculation parameter in the AF request message to the PCF through the Npcf\_PolicyAuthorization\_Create request.

3. PCF generates the authorized QoS Monitoring policy based on the AF request, measurement period, sample frequency, and triggers SMF to initiate PDU Session Modification procedure by sending Npcf\_SMPolicyControl\_UpdateNotify request.

4a. SMF activates the end to end UL/DL packet delay measurement between UE and PSA UPF for the QoS Flow or GTP-tunnel during the PDU Session Modification procedure. SMF sends QoS Monitoring request to AMF by Namf\_Communication\_N1N2MessageTransfer message, and AMF sends QoS monitoring request to NG-RAN through N2 interface.

4b. The SMF sends a QoS Monitoring request to the PSA UPF via N4

5. AMF sends QoS monitoring request to NG-RAN through N2 interface.

6. The NG-RAN initiates the measurement of UL/DL average packet delay on Uu interface based on the QoS Monitoring request from SMF, and NG-RAN performs delay measurement based on the existing procedures in 5.33.3.2 in TS 23.501 for QoS monitoring for URLLC.

7. NG-RAN reports the UL/DL average packet delay result on Uu interface to the UPF in the UL packet data as defined in TS 23.501 clause 5.33.3.2.

8. UPF calculates the end to end packe delay between NG-RAN and PSA UPF, as described in TS 23.501 [2] clause 5.33.3, and reports the packe delay value(s) to SMF.

9. The SMF reports the obtained packet delay value(s) to the PCF by sending an Npcf\_SMPolicyControl\_UpdateNotify response message.

10. When PCF gets the packet delay value(s), it calculate delay jitter based on packet delay value(s), jitter measurement period, sample frequency. Then PCF replies the delay jitter value to NEF by using Npcf\_PolicyAuthorization\_Notify message. The jitter value provided to the AF is “estimated jitter”.

11. NEF sends jitter and other QoS monitoring data to AF through Nnef\_AFsessionWithQoS\_Notify.

### 6.13.3 Impacts on services, entities and interfaces

PCF:

- Receiving the AF jitter requirement indication.

- Calculating the estimated jitter value based on QoS monitoring E2E latency value(s).

There is no new functionality requirement for RAN and UPF.

## 6.14 Solution #14: Supporting Deterministic Communication

### 6.14.1 Introduction

This solution is for key issue #3A: Exposure of deterministic QoS.

The scope of this solution is to support deterministic communication to the UEs operating applications. The main source of QoS related information for applications is AF, and a UE could operate multiple applications simultaneously. To take benefits of TSC supporting features, Rel-16 allows the AF to provide a QoS reference that is mapped by the PCF into QoS parameters.

The fundamental mechanism of this solution is to utilize network analytics from NWDAF. NWDAF can collect network data, and able to provide the analytics about Observed Service Experience as defined in TS 23.288 [14]. PCF can decide if QoS parameters fulfil the QoS requirements.

This solution proposes that a PCF, that responsible for deciding a PCC rule of deterministic communication, consumes network analytics on Observed Service Experience from NWDAF.

### 6.14.2 Functional Description

An AF provides QoS requirements, TSCAI related information, and survival time to the PCF, and PCF decide QoS parameters for serving QoS flow of the application. The below is the principles of the solution.

- An AF provides QoS related parameters to PCF for the deterministic communication such as GPSI, application ID, maximum/minimum delay, maximum burst data volume, periodic indicator, periodic time, and survival time with traffic description. The all parameters are not mandatory to be provided. For untrusted AF case, NEF can be uses to deliver the parameters to PCF.

- The PCF checks the received parameters maps then to a QoS value, TSCAI, and survival time used in 5GS. If, the PCF may requests to NWDAF to monitor the Observed Service Experience.

Editor's note: It is FFS whether this is need and how for PCF to distinguish the AF request that needs PCF to derive the TSC related parameters and AF request targeting to a non TSC QoS flow. The details of the derivation of TSC Assistance Container, TSN QoS information are FFS. It is FFS whether there is a need and how to apply the TT functionalities at DS-TT or NW-TT in case the PCF derives the TSC related parameters.

### 6.14.3 Procedures

For the procedure to utilize network analytics for the PCF to check if the Service Experience is fulfilled, the procedure is depicted in figure 6.14.3-1.



Figure 6.14.3-1: procedure to utilize network analytics for the PCF

1. An AF provides QoS related information for a target UE or application. The deterministic communication can be targeted using the combination of GPSI, S-NSSAI, DNN, and traffic descriptor. The QoS related information could contain burst arrival time, burst data volume, periodicity indicator, period time, and survival time.

2. An UE request PDU session for a specific S-NSSAI and DNN.

3. An SMF select a PCF could serve the requested S-NSSAI and DNN, and make a SM policy association.

4. The PCF check that the AF provided parameters map them to QoS parameter, Burst Arrival Time, Periodicity, and survival time. the PCF request to monitor the Observed Service Experience to NWDAF.

5. The PCF derives QoS parameters, BAT, Periodicity, and survival time if needed.

6. The PCF deliver the derived information to SMF using PCC rule.

7. The SMF derives TSCAI and establish/modify N4 session according to the PCC rule.

8. The SMF provides N2 messages to the (R)AN with TSCAI and survival time. If needed, PDU session establishment accept message can be delivered to the UE.

### 6.14.3.2 Impacts on services, entities and interfaces

Editor's note: This clause is TBD.

## 6.15 Solution #15: Survival Time is pre-configured in the 5GS

### 6.15.1 Introduction

This solution is to Key Issue 5: Use of Survival Time for Deterministic Applications in 5GS.

### 6.15.2 Functional Description

In the TS 22.104 [4], the survival time is equal to transfer interval or several times the transfer interval in most of the use cases. (In some cases, the survival time is equal to zero, see TS 22.104 [4] Table A.2.3.1-1).

This paper proposes that, the survival time for IEEE TSN based application can be pre-configured in the TSN AF.

With this solution, the TSC Assistance Container defined in the R16 can be enhanced to carry the survival time from TSN AF to SMF. SMF can add the survival time with the TSCAI according to the TSC Assistance Container and send to NG-RAN.

If TSN AF does not include survival time in the TSCAI, then NG-RAN behaviour is implementation specific.

NOTE: The NG-RAN e.g. based on combination of S-NSSAI and 5QI whether and which survival time is applied.

### 6.15.3 Procedures

If the survival time is pre-configured in TSN AF, there is no change to procedure, only TSC Assistance Container and TSCAI are enhanced to carry the survival time.

### 6.15.4 Impacts on services, entities and interfaces

If the survival time is pre-configured in TSN AF:

TSN AF:

- is pre-configured with survival time;

- sends the survival time with the TSC Assistant Container to SMF via PCF.

SMF:

- receives the survival time with the TSC Assistance Container from TSN AF via PCF.

- sends the survival time to NG-RAN in the TSCAI.

NG-RAN:

- receives the survival time with the TSCAI.

If the survival time is not provided in the TSCAI, then NG-RAN behavior is implementation specific.

## 6.16 Solution #16: Survival Time for Deterministic Applications

### 6.16.1 Introduction

This contribution proposes a solution to Key Issue 5: Use of Survival Time for Deterministic Applications in 5GS whereby mechanisms used to convey TSCAI are extended to include a Survival Time parameter.

This solution is based on the following principles:

- If a TSC traffic has Survival Time available, the SMF decides whether to establish a dedicated TSC QoS Flow for the TSC traffic with an indicated Survival Time based on configuration.

- Survival Time can be provided by the AF

- Survival Time is transferred as a TSCAI parameter but the TSCAI may not always comprise of Survival time.

- Survival Time is included in the TSC Assistance Container and delivered to PCF in an AF request.

- The PCF provides the Survival Time to SMF in the TSC Assistance container.

- The SMF determines TSCAI Survival Time and sends it to the NG-RAN together with QoS profile without requiring AN or N1 specific signalling exchange with the UE.

- Survival Time is specified by the AF in units of "time" with the timescale corresponding to burst periodicity or as the maximum number of consecutive message transmission failures. It is conveyed together with TSCAI Periodicity parameter (the time between periodic TSC bursts) and burst size (e.g. MDBV).

### 6.16.2 Functional Description

It is proposed that the mechanism used to transfer TSCAI parameters from the AF to the SMF as described in TS 23.501 [2] clause 5.27.2 is applied also for Survival Time. The AF includes the Survival Time, if available, in the TSN AF QoS Container passed to the PCF as currently specified in TS 23.503 [12], clause 6.3.1. The PCF subsequently sends the Survival Time to the SMF together with other TSCAI parameters. Any AF, including a TSN-AF or an AF supporting Key Issue #3: Exposure of TSC services, may provide Survival Time to the PCF directly or via the NEF.

The method the AF uses to acquire Survival Time is up to implementation. The AF may acquire Survival Time values for an application via direct provisioning on the AF, the AF may set the Survival time to a multiple of the TSCAI Periodicity, or the AF may obtain Survival Time via other means out-of-scope for 3GPP.

Survival Time is specified by the AF in units of "time" with the timescale corresponding to burst periodicity or as the maximum number of consecutive message transmission failures where a message is a single burst comprising a single packet/frame or an aggregated set of packets/frames and a transmission failure occurs when the Packet Delay Budget requirement corresponding to the message is not satisfied. It is conveyed together with TSCAI Periodicity parameter (the time between periodic TSC bursts) and burst size (e.g. MDBV). To meet TS 22.104 [4] requirements, in case it is described in units of "time" with timescale, the minimum value should be zero, and a maximum of several seconds, with sub-millisecond granularity , in case it is described as maximum number of consecutive message transmission failures, its value should be an integer and the minimum value should be zero.

### 6.16.3 Procedures

Survival Time is an optional parameter as part of TSC Assistance container. For the scenario that the service performance requirements include the Survival Time, procedures to transfer the survival time from AF to RAN is illustrated in figure 6.16.3-1.



Figure 6.16.3-1: Transferring Survival Time to RAN

0. Survival Time is provisioned to the AF.

1. The AF includes Survival Time in the TSC Assistance Container. Then an AF session with required QoS procedure is triggered.

2. The AF sends the TSN Assistance Container to the PCF. The procedure is performed as defined in clause 4.3.6.2 of TS 23.502 [3].

3. The PCF triggers Npcf\_SMPolicyControl\_UpdateNotify message to update the PCC rule to the SMF and the TSC Assistance container is included in the PCC rule.

4. When SMF receives the message, it sets the TSCAI Survival Time as the Survival Time included in the TSN Assistance Container. If the Survival Time is described in units of "time" with the timescale, the SMF may correct the value to 5G clock.

5. The SMF triggers a PDU Session Modification to update the Survival Time included in TSCAI sent to the NG-RAN without requiring AN or N1 specific signalling exchange with the UE.

NOTE: How NG-RAN uses Survival Time for the QoS handling is up to RAN WG.

### 6.16.4 Impacts on services, entities and interfaces

AF:

- Include the Survival Time in AF request, when available.

SMF:

- Retrieves Survival Time from the TSC Assistance Container And it includes Survival Time as part of TSCAI sent to the RAN.

PCF:

- Forwards TSC Assistance container including Survival Time.

NG-RAN:

- Ability to receive survival time.

## 6.17 Solution #17: U-plane BMCA solution for the key issue#1

### 6.17.1 Introduction

The solution is proposed to solve Key Issue #1: the UL Time Synchronization. Specially, this solution resolves the BMAC part of UL Time Synchronization. It can work with Solution#1.

In the IEEE 802.1AS [6], before the time synchronization is performed, the time-synchronization spanning tree shall be established first for particular TSN time domain. The spanning tree is to 1) avoid the message loop for time synchronization and 2) determine the port state of the gPTP instance.

There are two methods to establish the time-synchronization spanning tree:

- BMCA (best master clock algorithm).

- The port states and grandmaster are configured.

To support the BMCA in the 5GS logical TSN Bridge, a centralized handling is required.

### 6.17.2 Functional Description

In the figure 6.17.2-1, it introduces a BMCA function in the NW-TT. All the BMCA related process is handled by BMCA function



Figure 6.17.2-1: 5GS TNS bridge support BMCA

When the DS-TT port or NW-TT port receives the Announce message, it forwards the message to BMCA function in U-plane.

The BMCA function runs the BMCA algorithm according to 802.1AS[6]. The BMCA function:

- determines the GrandMaster clock for a clock domain;

- determines and maintains the port state of DS-TT port and NW-TT port of the 5GS TSN bridge;

- runs a PortAnnounceTransmit state machine for each DS-TT port and NW-TT port to update and send Announce messages to nodes outside the 5GS.

### 6.17.3 Procedures

The procedure for BMCA is described in Figure 6.17.3-1. It assumes there are 3 GM clock candidates. The clock-1 resides in the network connect to the DS-TT1/UE1, the clock-2 resides in the network connect to the DS-TT2/UE2, and the clock-3 resides in the network connect to the NW-TT.



Figure 6.17.3.-1: Procedure for BMCA via 5G System

The NW-TT port is Port-N.

1. The DS-TT1/UE1 establish the PDU Session for TSC which is specified in the TS 23.502 [3]. The UPF/NW-TT allocates the Port-1 for the DS-TT1/UE1.

2. The DS-TT2/UE2 establish the PDU Session for TSC which is specified in the TS 23.502 [3]. The UPF/NW-TT allocates the Port-2 for the DS-TT2/UE2.

3. The gPTP Announce message from clock-3 arrives the Port-N (i.e. NW-TT).

4. The BMCA function in the UPF/NW-TT determine the clock 3 as GM clock for the time domain. The BMCA function locally assigns the state of port which receives the Announce message from clock 3 as SlavePort (i.e. Port-N), and Port-1 and Port-2 as MasterPort.

5. The BMCA function generates and forwards the Announce message(s), separately for each DS-TT and NW-TT port, from GM clock (i.e. clock-3) to MasterPort(s) based on the updated PortStates and AnnouceSendTimer of the port.

6. The gPTP Announce message from clock-2 arrives the Port-2 (i.e. DS-TT2/UE2). The DS-TT2/UE2 forwards the message to UPF/NW-TT.

7. The BMCA function in the UPF/NW-TT determine the clock 2 as GM clock for the time domain. The BMCA function locally assign the state of port which receives the Announce message from clock 2 as SlavePort (i.e. Port-2), and Port-1 and Port-N as MasterPort.

8. The BMCA function generates and forwards the Announce message(s), separately for each DS-TT and NW-TT port, from GM clock (i.e. clock-2) to MasterPort(s) based on the updated PortStates and AnnouceSendTimer of the port.

9. The gPTP Announce message from clock-1 arrives the Port-1 (i.e. DS-TT1/UE1).The DS-TT1/UE1 forward the message to UPF/NW-TT.

10. The BMCA function in the UPF/NW-TT determines the GM clock and Port state are not changed. The BMCA function generates and forwards the Announce message(s) from GM clock (i.e. clock-2) to MasterPort(s) based on the existing PortStates according to AnnouceSendTimer of the port.

Upon completion of BMCA, if the TSN AF (or NEF) has subscribed for the BMCA result reports, and if the NW-TT determines that due to the result of the BMCA the gPTP grandmaster in 5GS (e.g. DS-TT) must be activated or deactivated, the NW-TT reports the BMCA result to TSN AF (or NEF) using BMIC signaling. Based on this, TSN AF (or NEF) enables or disables the GM in DS-TT(s) using PMIC signaling. Solution #9 describes the details how to activate/deactivate the grandmaster in DS-TT.

### 6.17.4 Impacts on services, entities and interfaces

NW-TT/UPF:

- There is BMCA function inside the NW-TT/UPF.

- The BMCA function run the BMCA algorithm according to 802.1AS[6]. It:

- determines the GrandMaster clock for a clock domain;

- determines and maintains the port state of DS-TT port and NW-TT port of the 5GS TSN bridge;

- runs a PortAnnounceTransmit state machine for each DS-TT port and NW-TT port to update and send Announce messages to nodes outside the 5GS.

## 6.18 Solution 18: Supporting BMCA by processing Announce message

### 6.18.1 Introduction

This solution is for key issue #1: Uplink Time Synchronization and #3B: Exposure of Time Synchronization.

This solution is an option of method 1 of clause 6.1.3.3.

The objective of this solution is to enable BMCA for selecting and managing Grand Master Clock via 5G TSN bridge. The TSN supporting feature defined during rel-16, it only describes on how to process (g)PTP messages in the aspect of residence time and RateRatio. It enables to deliver the time sync frame, but it is hard to say working as a member of TSN domain because 5GS is not supporting announce messages which is essential to maintain TSN topology and master-slave hierarchy. This solution contains the method to process Announce messages for enabling BMCA and Grand Master Clock management such as building Master-Slave hierarchy among TSN nodes and their ports.

According to IEEE 802.1AS, it is required to support BMCA for exchanging master clock information to maintain best grand master clock for a specific TSN domain. The clock information exchange is done by means of Announce message which containing the system identity of system and root clock for the given TSN entity. The announce message contains the information of current grandmaster which the TSN device currently referring such as grand master priority, stepsRemoved, and etc. If a bridges and end-stations received an Announce message from the neighbour link, it confirms the liveness of neighbourhood, and compares the best grand master clock. By exchanging the announce messages, the TSN entities can determines the current grand master for a specific gPTP domain and shares the sense of time by referring the same grand master, and it also needed to build the spanning tree where the gPTP messages propagate over the TSN.

The fundamental mechanism is to configure DS-TT/NW-TT for processing and transmitting Announce messages correctly by TSN AF. To realize this solution, it is needed that 1) DS-TT/NW-TT needed to receiving/sending Announce message with neighbour TSN nodes, 2) PMIC/BMIC needed to extended to contain Port Announce information, and 3) TSN AF needed to be extended to processing BMCA and configure DS-TT/NT-TT to enable the processing of Announce messages.

### 6.18.2 Functional Description

An TSN AF process Announce messages instead of DS-TT/NW-TT, and configure DS-TT/NW-TT for how to processing Announce message. When TSN AF detecting the changes on the Grand Master Clock, it need to inform DS-TT/NW-TT for triggering the transmit of Announce messages to neighbour TSN nodes. To support Exposure of Time Synchronization, either TSN AF or NEF can configure DT-TT/NW-TT port roles for processing Announce message based on the method 1 of the clause 6.1.3.3.

- DS-TT and NW-TT has a capability to receiving and transmitting Announce messages.

- DS-TT and NW-TT could be configured to processing Announce messages. For example, when a Port of DS-TT or NW-TT receiving Announce message, they need to report the received Port Announce Information to TSN AF using PDU session or N4 session modification procedure with PMIC.

- TSN AF need to maintain the Master-Slave hierarchy per TSN domain based on received Port Announce Information from DS-TT/NW-TT ports, and deliver the Announce messages for each port to neighbourhoods. The Announce message will be delivered to NW-TT/DS-TT using PMIC according to TS 23.501 [2] TSN related procedure.

- To reduce the signalling of Announce messages from all TSN ports of NW-TT or DS-TT, a signalling optimization mechanism could be applied. For example, only reports Port Announce Information to TSN AF when detecting new Grand Master Clock or Announce message timeout. NW-TT/DS-TT need to maintain System Identity and Grand Master Identity information locally per port.

### 6.18.3 Procedures

The procedure to enable BMCA using (g)PTP Announce message support by 5G TSN bridge is depicted in the figure 6.18.3-1.



Figure 6.18.3-1. A procedure to support BMCA with (g)PTP Announce Message Processing

Step 1. A Time Aware End Stand behind DS-TT send (g)PTP Announce Message periodically or notify the change of previously notified information such as Grand Master or Port Role has changed. This step can be applicable to NW-TT ports when NW-TT received (g)PTP Announce Message from DN side Time aware node.

Step 2. When the UE US-TT received (g)PTP Announce Message from the neighbour link, it reports the received Port Announce Information to SMF using PDU session modification procedure. If NW-TT case, UPF report the received Port Announce Information to SMF using N4 session modification. This step follows the PMIC delivery procedure defined in clause 5.28 of TS 23.501 [2].

Editor's note: It is FFS how to reduce the number of signalling for reporting (g)PTP Announce messages such as optimization mechanism.

Step 3. The SMF reports the received PMIC to TSN AF via PCF. This step follows the PMIC delivery procedure defined in clause 5.28 of TS 23.501 [2].

Step 4. The TSN AF collects the PMICs from NW-TT and DS-TT ports, and select the role of each ports of 5G TSN bridge such as Master/Slave. The port role selection algorithm may be the same defined in the IEEE 802.1 AS [6]. In this step, TSN AF can maintain own System Identify to compare the Port Priority with the received port information from the previous step.

TSN AF can configure and maintain the bridge system identity the port role(s), and the current selected Grand Master Clock Identity to each DS-TT/NW-TT per TSN domain.

If TSN AF detect new Grand Master Clock or timeout of the Announce message from the existing nodes, TSN AF can calculate new role(s) of each ports. In this case, TSN AF need to notify the change to the neighbouring TSN nodes by transmitting Announce message. TSN AF generate the (g)PTP Announce message for each ports.

Step 5. TSN AF deliver PMIC information for each NW-TT/DS-TT ports. The PMIC may contain port number, Port configuration information, and generated (g)PTP Announce message to transmit. Port configuration information may contain port role, system identity, and the current grand master clock identity.

Step 6. SMF distribute PMIC received from PCF to each NW-TT or DS-TT according to the port number. For DS-TT, PDU session modification procedure can be used for delivering PMIC. For NW-TT port, N4 session modification procedure can be used.

Step 7. Each port of DS-TT or NW-TT locally configure with port configuration information and transmit generated (g)PTP Announce message by TSN AF.

### 6.18.3.2 Impacts on Existing Nodes and Functionality

NW-TT/DS-TT:

- Need to report Port Announce Information to TSN AF using PMIC.

TSN AF:

- Need to maintain Master-Slave hierarchy based on Port Announce Information reported from NW-TT/DS-TT ports.

- Need to process BMCA including Port Configuration and Role Selection.

- Need to generate and deliver to NW-TT/DS-TT Port Announce Information to be transmitted to the neighbour TSN Nodes.

NEF:

- Support Rel-16 PMIC signaling via PCF.

## 6.19 Solution #19: Delay model for UE-UE communication

### 6.19.1 Introduction

This solution addresses Key Issue #2: UE-UE TSC communication. The solution proposes a delay model that addresses the shortcoming of the current delay model which supports only communication between the UE and the data network. That is because the current model assumes traffic to go via a NW-TT port, while UE to UE traffic does not go via the NW-TT ports. Note that the proposed delay model can be used as a standalone solution or it could be combined with other solutions for the UE to UE key issue as well.

This solution generalizes the 5GS bridge delay model, so that it will support TSC communication between any two ports pairs. That includes communication between a DS-TT port and a NW-TT port, as already supported, but also extended to include communication between two DS-TT ports (i.e., UE to UE communication). Besides, the solution enables the communication between two NW-TT ports since the model allows the TSN AF to calculate the delay between NW-TT port pairs, even though that is not the main focus. The solution tries to minimize the special 3GPP handling of these options and proposes a general framework that is equally applicable to all cases.

The solution makes use of the concept of the UPF residence time, as illustrated in the figure 6.19.1-1 below. The UPF residence time represents the time it takes for packets from an ingress UPF port to an egress UPF port within the UPF node.



Figure 6.19.1-1 UPF residence time calculation

The figure illustrates UPF ports D.1, D.2, D.3, corresponding to the device side of the UPF node, and ports N.1, N.2 corresponding to the network side of the UPF, i.e., NW-TT ports. The UPF residence time is shown for some example port pairs, such as between two device side UPF ports, between two network side UPF ports, and between a device and network side UPF port. The UPF residence time can be interpreted between any port pair of the UPF. The model takes a black box approach: the delay is represented by the time it takes from the ingress UPF port to the egress UPF port, without taking any assumption about the UPF implementation.

The UPF residence time is reported from the UPF to the TSN AF. The UPF may provide different values for the UPF residence time depending on the type of the ports in the port pair. Each UPF port has a type (such as "device side ports" and "network side UPF ports"), and the delay is provided between all possible combinations of port type pairs (for example between device and device side ports, between device and network side ports, and between network and network side ports). This allows the TSN AF to take into account the differences in the UPF residence time between e.g., network-device side port pairs and device-device side port pairs yet keep the delay reporting complexity low.

Based on the UPF residence time, the enhanced model is illustrated in the figure 6.19.1-2 below which can accommodate any traffic, including UE-network, UE-UE, network-network.

NOTE 1: The necessity to support three types of UPF residence time will be evaluated later.

NOTE 2: As is the case for the Release 16 delay model and for TSN in general, the delay does not include the queueing delays in case e.g., when a UE is receiving streams from more than one UEs or devices in the DN.



Figure 6.19.1-2: UPF residence time for UE-network, UE-UE, network-network

The model uses the following three components:

- UE-DS-TT residence time - as already specified - is reported by the UE to the TSN AF to capture the delay within the device.

- The UE-UPF delay is pre-configured in the TSN AF on a per traffic class granularity. Compared to release-17, there is a change that instead of the UE-NW-TT delay, the UE-UPF delay is pre-configured. Minimal and maximal values can also be used.

- The UPF residence time is reported by the UPF to the TSN AF to capture the delay within the UPF. The UPF residence time can be reported separately for different port type pair combinations, such as separately between a device-device side port pair, device-network side port pair and network-network side port pair. The reporting can be performed on a per traffic class granularity. The TSN AF can also be pre-configured with a default UPF residence time between any port pair, one a per traffic class granularity, in case the UPF does not report it.

Using these components, the delay can be calculated by the TSN AF for any possible port pair of the 5GS as requested by the CNC. For example:

- The delay between a DS-TT port and a NW-TT port is calculated as the sum of the UE-DS-TT residence time, the UE-UPF delay and the UPF residence time between the device-network side port pair.

- The delay between a DS-TT port and another DS-TT port is calculated as the sum of the UE-DS-TT residence time for UE1, the UE-UPF delay, UPF residence time between device-device side port pair, UE-UPF delay, UE-DS-TT residence time for UE2.

### 6.19.2 Functional Description

- The release-16 delay model of the 5GS is refined as follows. The UE-NW-TT delay is divided into two parts: the UE-UPF delay and the UPF residence time. (The UE-DS-TT residence time is not changed. Also, the definition of the Packet Delay Budget (PDB) is not affected).

- The UE-UPF delay is pre-configured into the TSN AF on a per traffic class granularity.

- The UPF residence time can be pre-configured into the UPF and provided to the TSN AF as part of the 5GS bridge configuration on a per traffic class basis. Ports are grouped into port types, and the UPF residence time is reported for all combinations of port type pairs. E.g., considering device side and network side ports as port types, the delay is reported for device-network, device-device and network-network port pair combinations.

- In case the UPF does not provide the residence time, the TSN AF can use a default value that is pre-configured on a per traffic class granularity.

- Between two DS-TT ports, the TSN AF calculates the bridge delay by adding the UE-DS-TT residence time and the UE-UPF delay for the two UEs and adding the UPF residence time for device-device. Between a DS-TT port and a NW-TT port, the TSN AF calculates the bridge delay by adding the UE-DS-TT residence time, the UE-UPF delay and the UPF residence time for device-network.

- The CNC takes into account the delay between two DS-TT ports as reported by the TSN AF when setting up TSN streams and sets the traffic classes and TSN parameters accordingly, which is provided to the TSN AF. As already specified, the TSN AF provides the TSN parameters to the PCF so that the PCF can map the TSN traffic classes/parameters into 3GPP QoS parameters. The TSN AF determines and provides the TSN parameters for the PDU Sessions separately.

- The TSN AF provides nominal QoS parameters for each PDU Session for the given traffic streams that correspond to the current definition of QoS parameters between DS-TT and NW-TT ports. The PCF can perform the QoS mapping based on the traffic classes/parameters that it receives for a given PDU Session without having to know whether the traffic is UE to UE or not. The nominal parameters for the delay and burst arrival time provided from the TSN AF to the PCF correspond to the same traffic pattern over the PDU Session, as if it was routed between the device and the NW-TT port so that the provided parameters are in line with the current definition.

- Specifically, the delay parameter corresponding to the PDB in the 3GPP (measured up to the NW-TT port) can be calculated as:

- Nominal delay for PDU Sessions = UE-UPF delay + UPF residence time (device-network).

Other ways of calculation are not excluded.

- The burst arrival time (BAT) for a PDU Session with uplink stream is unchanged. The burst arrival time (BAT) for a PDU Session with downlink stream can be calculated as follows.

- Nominal BAT for PDU Session (DL) = BAT for PDU Session (UL) + UE-DS-TT residence time for PDU Session (UL) + UE-UPF delay + UPF residence time (device-device) - UPF residence time (network-device).

Other ways of calculation are not excluded.

### 6.19.3 Procedures

The following new or adjusted procedures are needed for the solution.

- TSN AF is pre-configured with the UE-UPF delay per traffic class.

- The TSN AF determines the necessary TSN parameters for both of the PDU Sessions separately. The PCF can perform the QoS mapping based on the traffic classes/parameters that it receives for a given PDU Session without having to know whether the traffic is UE to UE or not.

- The UPF is pre-configured with the UPF residence time between its port type pairs per traffic class, and this information is provided from UPF to TSN AF within the Bridge Management Information Container.

The solution can also be applied in case of multiple TSN listeners, i.e., when more than one UE receives the downlink stream.

The solution is backwards compatible to the release 16 solution and represents an enhancement. The TSN AF may use pre-configured values for the UPF residence time in case the UPF does not provide it.

### 6.19.4 Impacts on existing services and interfaces

The solution addresses one aspect of UE to UE communication, and may be combined with other solutions for the UE to UE key issue.

TSN AF:

- Delay model is refined. The delay uses the separate UE-UPF delay (pre-configured) and the UPF residence time (provided by the UPF as part of the Bridge Management Information Container.) The TSN AF provides the TSN parameters to the PCF separately for each PDU Session.

UPF:

- UPF provides the UPF residence time as part of the Bridge Management Information Container.

## 6.20 Solution #20: CNC controlled VLAN configuration

### 6.20.1 Introduction

The solution adds general support for CNC controlled VLAN configuration. This can be also used to address UE to UE communication, Key Issue #2, in practical deployments, e.g., for logical separation of one or multiple UE to UE TSN streams, for easier management of flows or for easier setup for forwarding paths. Note that the VLAN configuration support proposed here is general for all communications, including TSN and non-TSN flows that are UE to UE as well as other flows that are between UE and network, or between multiple network ports.

It is proposed that the specification supports CNC controlled VLAN configuration only by the existing interface via TSN AF already defined for the fully centralized configuration model specified by IEEE Std 802.1Qcc [7]; therefore, MVRP is not supported or needed at DS-TT and NW-TT.

The existing release 16 specification supports Ethernet Packet Filters set by the SMF in the PDRs. However, the release 16 specification is limited to SMF controlled cases which assume that the SMF has full knowledge and control over the Ethernet network, which is not the case in many deployments that serves TSN and non TSN traffic in parallel. As another limitation, the release 16 SMF provided rules apply to the N4 sessions corresponding to the PDU Sessions and the associated DS-TT ports, while VLAN handling rules for NW-TT ports apply according to static pre-configuration at NW-TT.

This solution allows the CNC to control the VLAN configuration of IEEE 802.1Q bridges in a unified way, and thereby allows the CNC to handle the VLAN configuration for 5GS bridges in the same way as fixed bridges.

NOTE: CNC provided VLAN configuration co-exists with SMF provided PDR/FAR rules that also act on the VLAN IDs in the Ethernet headers.

The VLAN configuration affects the configuration of bridge forwarding: the forwarding rules may also include the VLAN IDs, and the VLAN configuration may refer to a specific forwarding table. In common deployments, the use and the implementation of the VLAN configuration and bridge forwarding is closely coupled.

The VLAN configuration provided by the CNC is set on a per port granularity. VLAN configuration may be set at any port, including DS-TT as well as NW-TT ports.

VLAN configuration implies a set of functionality listed below based on IEEE 802.1Q.

Table 6.20.1-1

|  |  |  |
| --- | --- | --- |
| Configuration | Reference in IEEE 802.1Q clause | Description |
| **Per Bridge VLAN Configuration** | | |
| Read Bridge VLAN Configuration | 12.10.1.1 | To obtain general VLAN information from a Bridge. |
| PVID and VID Set values | 12.10.1.2 | Set the VID value to be added to received untagged frames at a given port. |
| Acceptable Frame Types parameters | 12.10.1.3 | Used to configure whether to admit only VLAN-tagged frames, only untagged/priority tagged frames, or all frames. |
| Enable Ingress Filtering parameters | 12.10.1.4 | Whether to enable or disable ingress filtering. With ingress filtering, only ports in the member set for the given VID can admit traffic. |
| Reset Bridge | 12.10.1.5 | To reset all statically configured VLAN-related information in the Bridge to its default state. |
| VID to FID allocation | 12.10.3 | Filtering identifier for a given VID, which determines whether different VLANs use individual or shared forwarding tables. |
| FID to MSTID allocation | 12.12.2 | The FID to MSTID allocation is required to complete the VID to FID to MSTID allocation. For TSN Streams, this is used to allocate their VID to the TE-MSTID for central CNC controlled operation. (See clause 12.32.3.1 in IEEE Std 802.1Qcc-2018 for further information.) |
|  |  |  |
|  |  |  |
| **Per VLAN Configuration** | | |
| The VLAN Configuration | 12.10.2 | For setting the VLAN name and reading VLAN specific configuration. |
| **Filtering Database Configuration** | | |
| Static Filtering Entries | 8.8.1 | Defines forwarding rules based on the combination of destination MAC address and VID. Note that the use of static filtering entries is introduced and elaborated in other solutions as well, which can be used in combination with this solution. |
| Static VLAN Registration Entries | 8.8.2 | Determines whether frames are to be VLAN-tagged or untagged when transmitted; also defines member set for a VID that is used for ingress and egress filtering. |
| Dynamic Filtering Entries | 8.8.3 | Maintains the dynamically learnt addresses respecting the VID to FID allocation as configured above, i.e., whether shared or independent learning is applied among certain VLANs. |
| Default Group filtering behavior | 8.8.6 | Specifies defaults for group-addressed frames for each VID and outbound Port regarding forwarding/filtering. |

The solution reuses the mechanisms defined in Rel. 16 for the transfer of bridge and port configuration between the UPF/NW-TT, DS-TT and the TSN AF. using the already specified Management Information Container. Note that VLAN processing functionality may be set up and used even before TSN streams are established or for non-TSN traffic.

VLAN processing is a set of IEEE 802.1Q defined functionalities for Ethernet specific processing may also be realized usingN4 rules. The detailed implementation of VLAN processing is not specified; the implementation is not restricted as long as the externally observable behavior is according to the configuration.

VLAN configuration and processing is a general Ethernet functionality that is not TSN specific; however, TSN deployments often make use of this functionality. Even if there is a dependency between both, the CNC performs the VLAN configuration independent of the TSN stream configuration. For the VLAN configuration that is needed by the TSN streams, the CNC can provide the VLAN configuration before the provision of TSN stream related configuration. VLAN processing using N4 rules before TSN streams are established can be provided based on SMF configuration.

The solution could be combined with other solutions.

### 6.20.2 Functional Description

The configuration for VLAN is exchanged between the CNC and the TSN AF as part of the 5GS bridge configuration. The VLAN configuration is part of the Bridge VLAN Configuration managed object according to IEEE specifications; there is a single such managed object per Bridge, however the configuration is flexible to support different VLANs for the different ports. The TSN AF provides the information to the UPF inside the Bridge Management Information Container. Configuration can also be read from the UPF to the TSN AF and CNC in the reverse direction using the existing signaling path.

### 6.20.3 Procedures

- CNC provides VLAN configuration to the TSN AF.

- TSN AF provides the VLAN configuration inside the BMIC/PMIC using the existing signaling path to the UPF/NW-TT concerned.

- Based on the configuration, the UPF sets up the VLAN processing. The implementation of VLAN processing is not specified.

- The VLAN configuration can also be read from the UPF/NW-TT and provided to the TSN AF and CNC.

### 6.20.4 Impacts on existing services and interfaces

TSN AF:

- Forward VLAN configuration to/from the UPF NW-TT inside BMIC

UPF:

Editor’s note: support for VLAN processing for both network side and device side ports is FFS.

## 6.21 Solution #21: TSN stream information provisioning from CNC to 5GS

### 6.21.1 Introduction

For key issue #3A.

Currently, there are no mechanisms standardized in IEEE to provide TSN stream specific information from the CNC to TSN bridges, even if the information can be available at the CNC. Existing specs are based on the PSFP mechanism, but there is no guarantee that a CNC would actually use PSFP and set it for all TSN streams. Even when the CNC uses PSFP, the traffic pattern information obtained this way may not always be accurate. Additionally, ingress/egress port info might not be possible to obtain based on PSFP information.

Therefore, this solution introduces a signaling mechanism that explicitly provides the TSN stream specific information to the 5GS bridge. This gives us a clean solution without the need to reverse-engineer other mechanisms meant for different purposes. Explicitly providing the needed information from CNC to TSN AF can simplify the system architecture as well as the implementation and avoid interoperability issues. The solution does not impact the NEF and proposes direct signaling between the TSN AF and CNC.

### 6.21.2 Functional Description

The TSN AF associated with a given bridge sends a subscription message to the CNC to request that it be notified about TSN stream specific information for streams that pass through the given bridge. Each time there is a new/updated TSN stream that passes through a given bridge, the CNC sends a notification to the TSN AF which includes the following.

- Identification of the stream (for TSN as described in clause 6 of IEEE 802.1cb-2017).

- Ingress port number.

- Egress port number(s).

- Periodicity.

- Burst Arrival Time.

- Burst Size.

- Priority.

The solution may be extended with other parameters concerning TSN stream or application characteristics.

### 6.21.3 Procedures

Editor's note: Whether a mechanism to provide stream information from CNC to TSN AF (or Ethernet bridges in general) will be specified by 3GPP or IEEE is FFS. The list of stream information provided from CNC to TSN AF is FFS and the benefit of the additional stream information for 5GS is also FFS. Therefore the details listed below are merely an example of how stream information could be provided.

The solution involves the following additional steps.

1. The TSN AF of a given bridge sends a STREAM-SUBSCRIBE message to the CNC in order to request notifications about TSN stream specific information for TSN streams that pass through the given bridge.

2. The CNC sends a STREAM-NOTIFY message to the TSN AF containing information about new/updated TSN streams. The CNC also sends a STREAM-NOTIFY message to the TSN AF when a TSN stream is removed.

The TSN AF processes the information as already specified. The TSN AF does not need to consider PSFP configuration information to obtain TSN stream specific information to derive the ingress/egress port numbers and QoS information.

It could be possible to apply the solution to the non-TSN case as well where the TSN AF is replaced by the AF.

### 6.21.4 Impacts on existing services and interfaces

TSN AF:

- Support for sending a STREAM-SUBSCRIBE message indicating interest in receiving TSN stream specific information notifications.

- Support for STREAM-NOTIFY messages that provide TSN stream specific information.

- No longer needs to support obtaining the same parameters from PSFP information.

CNC (non 3GPP defined entity):

- Accept subscriptions from TSN bridges and provide notifications on TSN stream specific information.

## 6.22 Solution #22: Detect the Burst spread at UPF

### 6.22.1 Introduction

The solutions addresses Key issue 3A:

b) Ability for AF to indicate periodicity, burst size, burst arrival time (as defined in Rel-16 for TSC Assistance information) and Survival Time, optionally burst spread (variation of burst arrival time for DL traffic resulting from jitter on N6, if applicable) along with Timing Domain (reference for these parameters) associated with these parameters to the NEF.

The burst spread is the variation of burst arrival time for DL traffic resulting from jitter on N6, i.e. it was introduced by the jitter on the N6.

Before the application sends the data to the UE (causing the DL data to reach N6), AF is not aware of burst spread. After the application starts sending the data to the UE, the AF still cannot determine the burst spread by itself directly. It may get burst spread by

- A) U-plane feedback mechanism, e.g. ACK packet to the DL data. This depends on the U-plane protocol. And this mechanism cannot accurately determine the burst spread.

- B) 5GS exposure method. The 5GS (i.e. PSA-UPF) detect the burst spread of DL in N6, and notify the AF via NEF.

The option A is not accurate.

In order to send the burst spread to NG-RAN, the option B require more signalling. (i.e. UPF->SMF->PCF->NEF->AF->NEF->PCF->SMF->AMF->NG-RAN).

Depending on the option B, this solution proposes, that the UPF/NW-TT detects the burst spread of DL in N6, and reports to SMF. SMF update the TSCAI and send to NG-RAN.

Editor's note: Whether the UPF/NW-TT detects the burst spread of DL in N6 with RFC 4689 or other mechanism is FFS.

### 6.22.2 Functional Description

When the SMF establishes a QoS flow, it may request the UPF/NW-TT to detect the burst spread.

The UPF/NW-TT detects the burst spread of DL data for the particular stream and reports the burst spread to SMF.

SMF sends the updated TSCAI which include the burst spread to NG-RAN.

NOTE: The Burst Spread is provided as a separate parameter to Burst Arrival Time.

If deterministic transmission is supported on N3 interface, the UPF/NW-TT could determine an ingress time window [start time, end time] to start processing the packets of a burst in a cycle based on burst spread. The start time indicates the earliest time to process the first packet of a burst in a cycle while the end time indicates the latest time to process the first packet of a burst in a cycle. Then early arrived packets in a cycle would be buffered on the UPF until the start time. This would help to decrease the jitter introduced by transmission on N6, and to decrease the delay on N3 for transmitting TSC stream. The ingress time window could be provided to the SMF, which determines egress time window [start time, end time] for DS-TT to send out the burst. The SMF sends the egress time window to UE/DS-TT for deterministic transmission.

If deterministic transmission is not supported on N3 interface, the RAN could handle the packet starts at the time as indicated by TSCAI. The SMF could determine egress time window based on spread time and burst arrival time in TSCAI and provide the egress time window to UE/DS-TT for deterministic transmission.

It is assumed that the AF may provide the egress time window to devices behind the UE to determine its receiving time for a burst from UE, then the determined egress time window may be provided to the AF to make application aware of packet handling time.

### 6.22.3 Procedures

The procedure for synchronizing TSN end stations behind 5G System (NW-TT) with the TSN GM in the network.



Figure 6.22.3-1: Procedure for providing the Burst spread to NG-RAN

1. The AF provides the service information to PCF/NEF.

2. The PCF initiates the SM policy Association Modification service operation to provide the QoS rule to SMF.

3. SMF sends the N4 request to UPF/NW-TT, which indicate the UPF/NW-TT detect the burst spread of indicated stream.

4. AF send the DL data to UE, which arrives the UPF/NW-TT.

5. The UPF/NW-TT report the detected burst spread to SMF. If deterministic transmission is supported on N3 interface, the UPF/NW-TT could determine an ingress time window for handling the stream and provide the ingress time window to the SMF.

6. SMF sends the updated TSCAI to NG-RAN, which includes the burst spread. The SMF also determines egress time window based on spread time or ingress time window and sends the egress time window to the UE and the AF.

### 6.22.4 Impacts on services, entities and interfaces

SMF.

- Indicate the UPF to detect the burst spread for particular strea

- sends the burst spread to NG-RAN after it receives it from UPF.

- determines egress time window based on spread time or ingress time window and sends the egress time window to the UE and the AF.

UPF

- detect the burst spread and report to SMF.

- determines an ingress time window for handling the stream based on spread time and provides to the SMF.

## 6.23 Solution #23: Transmission Delay Measurement on N6

### 6.23.1 Description

This solution is for key issue#3A,which addresses exposure of deterministic QoS aspects related to:

b) Ability for AF to indicate periodicity, burst size, burst arrival time (as defined in Rel-16 for TSC Assistance information) and Survival Time, optionally burst spread (variation of burst arrival time for DL traffic resulting from jitter on N6, if applicable) along with Timing Domain (reference for these parameters) associated with these parameters to the NEF.

In Rel-16 standarization, the UL/DL transmission delay in 5G system can be measured based on QoS monitoring mechanism. The main idea is SMF activates the end to end UL/DL packet delay measurement between UE and PSA UPF through encapsulating time stamp in GTP-U header.

For unsynchronized scenario, the RTT/2 can be obtained baesd on sending QoS Monitoring Packet, which is specifically used for UL/DL packet delay measurement. But for N6 case, it is not suitable for asking application server to create specific packet for delay measurement. And for this IIoT scenario , it is supposed that the equipments in N6 support deterministic transmission, therefore the time synchronization is required.

This solution proposes a mechanism to measure the delay on N6 with the pre-condition that the application server deployed in N6 supports for time synchronization.

In this solution, the first step is to realize the time synchronization between PSA UPF and the application server before or after the PDU session establishment. Other solutions for key issue 3B can be considered to realize this.

During the PDU session establishment, the SMF sends N4 rule to PSA UPF for N6 delay measurement.The rule may include traffic direction, IP 5 tuples, the frequency of N6 delay measurement and observation period. For the UL data, the N4 rule also includes construction of extension header for carrying N6 delay measurement indication. For the DL data, the N4 rule also includes extracting the timestamp from extension header and removing the extra header.

Then PSA UPF can insert the delay measurement indication in the UL data packet when the UE sending the packet. If the packet supports IPv6 routing, the delay measurement indication is carried on IPv6 extension header. While if the packet supports IPv4, the delay measurement indication can be carried on e.g. In-band Network Telemetry header which is referred to https://p4.org/assets/INT-current-spec.pdf. The PSA UPF is responsible for constructing IPv6 extension header or INT header. There is a pre-agreement between 5GS and application server that what kind of packet header should be selected.

The UE may use specific S-NSSAI/DNN for the PDU session establishment and the SMF contacts the PCF to get PCC Rules that includes QoS monitoring parameters with indication that N6 packet delay mesurements are provided, then N4 rules related with N6 delay measurement are sent by SMF during the PDU session establishment procedure and specific UPF which can enable the N6 delay measurement may be selected by SMF. Therefore when UE sends specific paket which intents for the target application server in the PDU session, the N6 delay measurement will be triggered by UPF, and the UE gets the target application server IP address through application layer mechanism. The application server IP address provided in the PCC Rule and the one used by the UE needs to be the same one.

When the application server in N6 accepts the UL packet and identifies the delay measurement indication, the application server should record this packet's IP 5 tuples. When the application server sends the DL data which matches the recording IP 5 tuples, the application server should insert the sending timestamp in the corresponding IPv6 extension header or INT header. PSA UPF extracts the sending timestamp and calculates the N6 transmission delay.

Therefore 5GS can calculate the accurate packet burst arrivel time of RAN side by adding burst sending time provided by AF (already known by network in current specifications), N6 transmission delay and CN PDB.

### 6.23.2 Procedures

The N6 transmission delay measurement procedure is described in Figure 6.23.2-1.



Figure 6.23.2-1 Procedure for N6 transmission delay measurement

1. PSA UPF and application server supports IEEE 802.1AS, and can be synchronized before or after the PDU session establishment.

2. UE initiates PDU Session Establishment Request, SMF gets PCC Rules from the PCF including QoS monitoring, sends N4 rule to UPF through N4 session establishment request or N4 session modification request. The N4 rule may include traffic direction, IP 5 tuples, the frequency of N6 delay measurement and observation period. For the UL data, the N4 rule also includes construction of IPv6 extension header or INT header for carrying N6 delay measurement indication. For the DL data, the N4 rule also includes extracting the timestamp in IPv6 extension header or INT header.

3. UE sends a UL data packet.

NOTE: The UL data packet contains normal application data that the application anyway sends; i.e. the UE does not create any special data packets.

4. UPF detects that the destination address of the UL data packet is the application server on the N6 port, UPF constructs the extention header and inserts the N6 transmission delay measurement indication in the specified IPv6 extension header or INT header, and trigger the N6 transmission delay measurement.

5. The UL data packet is sent from PSA UPF to the application server.

6. When the server receives the UL data packet, it recognizes the N6 delay measurement indication in the extension header and decides to start the N6 delay measurement for the service flow. When the server sends DL data packets, it will add a timestamp representing the sending time in the corresponding place in the extension header.

7. When PSA UPF receives the DL data packets, it extracts the timestamp from the extension header and calculates the unidirectional downlink N6 delay according to the packet receiving time and the timestamp. PSA UPF removes the extention header.

8. The DL data packet is sent from PSA UPF to UE.

9. UPF reports the calculated N6 transmission delay to SMF through N4 Association Update Procedure.

10. SMF calclulates the Burst Arrival Time for RAN based on AF providing Burst Arrival Time, N6 transmission delay and CN-PDB.Then SMF sends the updated Burst Arrival Time to RAN.

### 6.23.3 Impacts on Existing Nodes and Functionality

Editor's note: This clause captures impacts on existing 3GPP nodes and functional elements.

PCF:

- QoS monitoring in the PCC Rule includes packet delay over N6.

SMFs:

- Configure the UPF for N6 delay, and send the corresponding N4 rules to UPF.

- Calculate the precise Burst Arrival time with considering N6 delay.

UPF:

- Support the synchronization with application server.

- Based on the N4 rules, the UPF can detect the corresponding data packets and construct the IPv6 extension header or INT header for UL packet. And the N6 delay indication can be carried on the extension header.

- Extract the timestamp in DL packet and remove IPv6 extension header or INT header

- Calculate the N6 transmission delay periodically and report to SMF.

# 7 Evaluation

## 7.1 Key Issue #1: Uplink Time Synchronization

Solution #1 is the only solution addressing KI#1 Uplink Time Synchronization.

The solution describes four alternative methods for BMCA procedure for gPTP:

Method 1:

- Most of the BMCA logic is centralized to the TSN AF (or NEF for non-TSN sessions), but also DS-TT and NW-TT participate to BMCA operation.

- DS-TT/NW-TT ingress port sends the received Announce message to BMCA function in TSN AF (or NEF) only if the received Announce is equal or better than the current Announce the bridge is sending.

- Ingress port detects the Announce and Sync reception timeouts and indicates the timeout to TSN AF (or NEF).

- DS-TT/NW-TT port is aware of the gPTP port state (Master, Slave, Passive)

- Signalling consideration: since the received Announce messages are sent from the ingress port to TNS AF (or NEF) for BMCA evaluation via PMIC/BMIC (control plane), the solution is feasible only if the ingress port pre-screens the received Announce message and sends the message only if it is better than the current Announce known to the port. In this case no Announce messages need to be sent to the TSN AF after the BMCA procedure has stabilized. Compared to other methods, this one has more signalling between TSN AF and NW-TT/DS-TT, and between NW-TT and DS-TT.

Method 4:

- BMCA logic is centralized to the NW-TT. Ingress ports forward all Announce messages to BMCA function in NW-TT.

- Ingress ports forward all Sync messages to NW-TT.

- NW-TT generates Announce messages on behalf of the egress ports.

- NW-TT detects the Announce and Sync reception timeouts for each port.

- DS-TT/NW-TT port is not aware of the gPTP port state.

- Signalling consideration: since all received Announce messages are sent from the ingress port to NW-TT for BMCA evaluation, and NW-TT generates the Announce messages on behalf of the egress ports, the solution leads to more amount of user plane traffic between ingress and egress ports, even after the BMCA procedure has stabilized but not control plane signalling.

Method 2:

- The same as Method 4, except that the Master port generates the Announce messages based on the Announce information received from the NW-TT. The Announce information is sent only if there is a change compared to the previous Announce information.

- The port must be aware whether it is Master or non-Master port. The port learns this via UP from the NW-TT.

- Signalling consideration: compared to Method 4, since the egress port generates the Announce messages based on the Announce information from NW-TT, and the Announce information is sent only if there is a change compared to the previous Announce information, this Method can reduce the user plane traffic. The trade-off is that the Master port must be aware of its port state in order to generate Announce messages.

Method 3:

- The same as Method 4, except that the ingress port sends the received Announce message to BMCA function in NW-TT if the received Announce is equal or better than the current Announce known to the port or if the ingress port expired to receive announce message from the NW-TT.

- The port stores the state of the most recent Announce it has sent for the comparison with the received Announce.

- Signalling consideration: compared to Method 4, since the ingress port sends the received Announce message to BMCA function in NW-TT if the received Announce is equal or better than the previous received Announce or if the ingress port expired to receive announce message from the NW-TT, the Method is not able to reduce any signalling after the BMCA procedure has stabilized. On the other hand complexity is increased in the ingress ports to pre-screen the received Announce messages.

To apply the Methods 2-4 with Solution #9 (i.e. GM resides in DS-TTs), the NEF (or TSN AF) needs to subscribe for the BMCA result reports from the NW-TT. If due to the BMCA result the GM needs to be activated or deactivated in the DS-TTs, the NW-TT reports the BMCA result to NEF(or TSN AF) so that NEF(or TSN AF) can activate or deactivate the GM in DS-TT.

## 7.2 Key Issue #3B: Exposure of Time Synchronization

Solution #7 supports the AF to be able to request Time Synchronization service via External Parameter Provisioning. The exposure includes service activation/deactivation/modification, it can interwork with IEEE TSN or TSC use cases, and it can target a UE or a group of UEs. The exposure proposed for time synchronization supports the 4 time synchronization methods listed in KI#3B.

Solution #8 supports AF requesting TSN Synchronization activation and deactivation providing new configuration to the UDM via NEF and triggering a PDU Session establishment. The same SMF and UPF control all PDU Sessions involved in the time synchronization service. The time synchronization service is coupled to a TSN PDU Session.

Solution #9 supports the DS-TT acting as a (g)PTP grand master (GM) for devices attached to the DS-TT. The DS-TT indicates to the network inside a PMIC whether DS-TT is capable of acting as (g)PTP GM and which version(s) it supports. The indicated capabilities can be used to support exposure for time synchronization. Additionally, the time information used in (g)PTP at the DS-TT is based on the time information received from the gNB using RRC/SIB signalling.

## 7.3 Key Issue#5: Use of Suvival Time for Deterministic Applications in 5GS

The basic principle of solution #15 and #16 for KI#5 are similar. The only difference is on how AF (a TSN-AF or an AF as stated in key issue #3B) acquires the survival time information. Solution #15 only considers the survival time for IEEE TSN based applications and proposes the survival time is pre-configured in the TSN AF. Solution #16 considers wider deterministic applications and proposes the survival time can be received by any AF from an application via direct provisioning or via other means out-of-scope for 3GPP. Other than this aspect, the two solutions are complementary with each other.

## 7.4 Key Issue #3A: Exposure of deterministic QoS

Solution#5 supports following aspects:

1. AF provides traffic related description and deterministic QoS requirement:

* a Traffic Description, Target UE PDU session Identification, AF Identification, a 5GS delay, Guaranteed Flow Bit Rate, Flow Direction, Burst Arrival Time at UE (uplink) or UPF (downlink), Burst Size, Burst Periodicity, optionally Burst Spread (variation of burst arrival time for DL traffic resulting from jitter on N6, if applicable), Survival Time and a Timing Domain and a QoS Reference.

1. The 5GS exposes the Deterministic QoS Capability information to the AF:

* Whether 5GS supports Deterministic QoS, the Minimum and maximum 5GS Delay supported by 5GS if it supports deterministic QoS.

1. The 5GS sets the TSCAI according to the information provided by the AF.
2. The AF may provide Burst Spread to 5GS. The SMF provides it as part of TSCAI to the NG-RAN.
3. The general procedure for exposure the deterministic QoS is defined and how to report 5GS delay information is also defined.
4. The NEF provides TSC connectivity monitoring service to the AF.

The detailed procedure and service operation for exposure the deterministic QoS requirement and reporting 5GS capability shall be further study in normative phase. The normative work may take the description in this solution for reference.

Solution#6 has been merged into Solution#5.

Solution#13 proposes a mechanism for AF requesting jitter measurement. The AF provides requirement for jitter measurement. The PCF gets a group of E2E delay data based on QoS monitoring mechanism, calculates the jitter and sends the jitter value to AF. In the scenarios that deterministic QoS is required, e.g., industrial manufacturing, jitter is an important parameter to show the deterministic performance of 5G network. Therefore, jitter measurement is recommended to be support in normative work.

Solution#14 proposes to utilize network analytics from NWDAF. PCF decides if QoS parameters fulfil the QoS requirements based on the Observed Service Experience analytics from NWDAF. The PCF acting as a consumer of Observed Service Experience analytics has already been supported in R16 as defined in TS 23.288. The possible impacts on 5GC have not been identified. No normative work is needed for this.

Solution#21 proposes that CNC is enhanced to provide TSN stream specific information to the TSN AF. The necessary of providing these parameters is not confirmed. The definition of CNC is out the scope of 3GPP SA2.

Solution#22 proposes that the UPF/NW-TT detects the burst spread of DL data for a stream and reports the burst spread to the SMF. The SMF updates the TSCAI which includes the burst spread to NG-RAN. UPF supports detection of Burst Spread shall be optional as the AF may also provide Burst Spread.

Solution#23 proposes that the UPF calculates the N6 transmission delay based on coordination with the AS and reports to SMF. The SMF uses the N6 delay to calculate the Burst Arrival Time in TSCAI. The N6 transmission delay measurement is dependent on AS’s capability and use of extension IPv4/IPv6 header, which are out the scope of 3GPP SA2. Therefore, N6 transmission delay is not recommended in normative work.

# 8 Conclusions

## 8.1 Key Issue #1: Uplink Time Synchronization

To enable support for Uplink Time Synchronization, following are some interim principles to be considered for the way forward:

- The following interim agreement are applied for transmission of the gPTP event messages (carried within Sync message for one-step operation or Follow\_up message for two-step operation):

- DS-TT which is attached by one or more TSN GMs will perform exactly the same operations for UL gPTP messages as what the NW-TT performs for the DL gPTP messages as specified in clause 5.27.1.2.2 of TS 23.501 [2].

- The PDU session of DS-TT port receiving the source GM's gPTP messages is used to forward the gPTP messages to the UPF/NW-TT:

- the UPF/NW-TT forwards the gPTP messages to the NW-TT and DS-TT ports in Master state.

- If the egress port is in NW-TT, the NW-TT port performs exactly the same operations for UL gPTP messages as what the DS-TT performs for the DL gPTP messages as specified in clause 5.27.1.2.2 of TS 23.501 [2].

-

- If the egress port is in other DS-TT, the other DS-TT(s) perform the operation as specified in clause 5.27.1.2.2 of TS 23.501 [2].

- As specified in TS 23.501 [2] already for Rel-16 Time Synchronization, 5GS is required to guarantee delivery of gPTP message in less than 10ms as recommended by IEEE 802.1AS[6] clause B2.2, if the operator decides to follow such recommendation.

- The following agreement is applied for BMCA procedure:

- NW-TT needs to process the received Announce messages (over user plane) for BMCA procedure, determine port states within the 5GS, maintain Master-Slave hierarchy.

- When the NW-TT acts as a gPTP grandmaster, the NW-TT (generates the Announce messages for the Master ports on the NW-TT.

Editor’s note: Whether the DS-TT or NW-TT regenerates the Announce messages for the Master ports in DS-TT(s) is FFS.

- When the DS-TT acts as a gPTP grandmaster, the DS-TT generates the Announce messages for the Master port in this DS-TT.

- If the TSN AF has subscribed for the BMCA result reports, the NW-TT reports BMCA result to the TSN AF via BMIC.

- DS-TT forwards the received Announce messages to NW-TT over User plane.

Editor's note: Whether and how the DS-TT filters the receive Announce/Sync messages are FFS.

- The TSN AF configures the grandmaster in DS-TT port (if supported) via PMIC; otherwise TSN AF configures the grandmaster in NW-TT via BMIC for PDU sessions where the DS-TT does not support acting as a gPTP GM.

## 8.2 Key Issue #2: UE-UE TSC communication

Editor's note: This clause will capture conclusions for Key Issue #2.

The following is taken as the basis for the way forward:

- UE-UE TSC (for both IEEE TSN based applications and other applications) communication (using local switching) is supported for all the UE(s) connected to the same DNN/S-NSSAI, terminating on the same UPF network instance.

- For IP PDU Sessions, UE-UE TSC communication using local switching (without routing via N6) can be supported by UPF implementation based on operator policies.

- TSN AF or any AF provides information (e.g. QoS requirements such as delay, burst size, periodicity, burst arrival time) about a UE-UE TSC stream.

- TSN AF or any AF sends the request separately for talker (uplink traffic) and listeners (downlink traffic).

## 8.3 Key Issue #3B: Exposure of Time Synchronization

To enable Exposure of Time Synchronization, it is recommended to select solutions 7 and 9 as the basis for normative work. Solutions 7 provide the description to extend the exposure framework to support AF requesting time synchronization. Solution 7 considers the exchange of information required between the 5GS and the AF to support the 4 time synchronization methods of KI#3B and the functionality required at the DS/NW-TTs for every method. Solution 9 complements the exposure of time synchronization addressing the subscription and authorization of the AF's request. Additionally, it enables the time synchronization configuration before the PDU Session is established. Solution 9 adds the support of DS-TT capabilities indication towards the 5GS.

Following are principles to be considered as the basis for normative work:

- Time Synchronization service can be provided for Ethernet PDU sessions and IP PDU sessions.

- Four time synchronization methods are supported as described in Solution #7.

- Time synchronization service may support GM residing in DS-TT(s) as described in Solution #9.

- BMCA method(s) and configuration of BMCA parameters shall follow the corresponding conclusion of KI#1, where applicable.

Editor's note: Whether Time Synchronization service policy and charging control may be applied on a PDU Session or independent of any PDU Session is FFS.

For Ethernet PDU Sessions not part of an IEEE TSN network, the transmission of the PTP messages (carried within Sync message for one-step operation or Follow\_up message for two-step operation) shall follow the corresponding conclusion of KI#1, where applicable:

- PTP as described in IEEE 1588-2008 [13] may be used instead of gPTP;

- the NEF is used instead of TSN AF.

The following interim agreement are applied for IP type PDU Sessions for the transmission of the GM time in PTP over UDP/IP messages (carried within Sync message for one-step operation or Follow\_up message for two-step operation):

- DS-TT which is attached by one or more GMs will perform exactly the same operations for UL PTP messages as what the NW-TT performs for the DL gPTP messages as specified in clause 5.27.1.2.2 of TS 23.501 [2].

- The PDU session of DS-TT receiving the source GM's PTP messages is used to forward the PTP messages to the UPF/NW-TT:

- the UPF/NW-TT forwards the PTP messages to DS-TTs and the N6 interface if it knows the DS-TT or N6 interface has active listeners for PTP multicast messages.

- If the PTP message is sent to N6 interface, the NW-TT performs exactly the same operations for UL PTP messages as what the DS-TT performs for the DL gPTP messages as specified in clause 5.27.1.2.2 of TS 23.501 [2],

- If the PTP message is sent to DS-TT/UE via a PDU Session, the DS-TT(s) perform the operation as specified in clause 5.27.1.2.2 of TS 23.501 [2].

## 8.4 Key Issue #5: Use of Survival Time for Deterministic Applications in 5GS

Principles for the way forward:

- Survival Time is transferred as part of the TSCAI parameter but the TSCAI may not always comprise of Survival time.

- Survival Time is specified by the AF in units of "time" with respect to burst periodicity or as the maximum number of consecutive message transmission failures (i.e. whose loss can be tolerated). Note that there is a single message per burst periodicity and the burst contains the application message. It is conveyed together with TSCAI Periodicity parameter (the time between periodic TSC bursts) and burst size (e.g. MDBV).

If the Survival Time is specified by the AF in units of "time" with respect to TSN working domain burst periodicity, the the Survival Time needs to be mapped to the 5GS time domain by the SMF based on latest cumulative rateRatio between the TSN time and 5G time.

When survival time information is provided for a TSN stream, then it should not be aggregated with other TSN streams into a single QoS flow, or if they are aggregated, then the survival time parameter shall not be provided as part of TSCAI.

- Survival Time is included in the TSC Assistance Container and delivered to PCF in an AF request by NEF or TSN AF.

- The PCF provides the Survival Time to SMF in the TSC Assistance container.

- The SMF determines Survival Time and sends it to the NG-RAN as part of TSCAI without requiring AN or N1 specific signalling exchange with the UE.

- It is assumed that only one format will be supported over NGAP.

Editor's note: Further work is needed to determine how Survival time is communicated towards RAN, i.e., which form is preferred over NGAP. Preferred format over NGAP depends on the feedback from RAN WG2. Whether signaling Survival Time to NG-RAN is sufficient to address the Communication service availability targets defined by SA1 in TS 22.104 Table 5.2-1 is FFS.

## 8.x Key Issue #3A: Exposure of deterministic QoS

The following is taken as the basis for the way forward:

Take solution#5 as basis for KI#3A:

- The AF provides traffic related description and QoS requirement:

- UE related Identification used to determine target UE PDU Session, AF Identification, a Traffic Description, a 5GS delay, Bandwidth, which are used to identify the target traffic and related QoS requirement.

- Flow Direction, Burst Arrival Time at UE (uplink) or UPF (downlink), Burst Size, Burst Periodicity, and a Timing Domain, which are used for efficient scheduling in RAN for Ethernet PDU sessions.

Editor's Note: Whether the Burst Spread should be included is FFS.

- For ETH PDU Sessions, in order to reuse hold and forward functionality in the DS-TT and NW-TT, Qbv parameters can be derived by NEF/PCF based on AF request (with no impact to nodes other than NEF/PCF) and provided to NW-TT/DS-TT. It is assumed that Rel-16 hold and forward functionality in DS-TT and NW-TT is re-used.

Editor's Note: Whether a requirement exists that hold and forward functionality is needed for VIAPA services needs to be confirmed by SA1.

Editor's note: Need for Jitter measurement is FFS.

Annex A:  
Change history

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Change history | | | | | | | |
| **Date** | **Meeting** | **TDoc** | **CR** | **Rev** | **Cat** | **Subject/Comment** | **New version** |
| 2019-10 | SA2#135 | S2-1910451 | - | - | - | Proposed skeleton agreed at S2#135 | 0.0.0 |
| 2019-10 | SA2#135 | - | - | - | - | Implement approved P-CRs from SA2#135 - S2-1910452, S2-1910707, S2-1910708, S2-190454, S2-190706. | 0.1.0 |
| 2019-12 | SA2#136 |  | - | - | - | Implement approved P-CRs from SA2#136 - S2-1912720, S2-1912722, S2-1912723, S2-1912724, S2-1912779. | 0.2.0 |
| 2020-01 | SA2#136-AH |  | - | - | - | Implement approved P-CRs from SA2#136AH - S2-2000784, S2-2001655, S2-2001656, S2-2001410, S2-2001657, S2-2001658  S2-2001659, S2-2001663, S2-2001661, S2-2001417, S2-2001662, S2-20001353 | 0.3.0 |
| 2020-06 | SA2#139E |  | - | - | - | Implement approved P-CRs from SA2#139E - S2-2003622, S2-2004637, S2-2004638, S2-2004639, S2-2004640, S2-2004641, S2-2004642, S2-2004643, S2-2004644, S2-2004645, S2-2003919, S2-2004646, S2-2004647, S2-2004648, S2-2003570,  S2-2004649, S2-2003987, S2-2004650, S2-2004651, S2-2003958, S2-2004652, S2-2004701 | 0.4.0 |
| 2020-09 | SA2#140E |  |  |  |  | Implemented approved P-CRs from SA2#140E - S2-2004921, S2-2005992, S2-2006035, S2-2005993, S2-2005994, S2-2005995, S2-2005996, S2-2005997, S2-2005998, S2-2005999, S2-2006000, S2-2006001, S2-2006002, S2-2005163, S2-2006003, S2-2006004, S2-2006005, S2-2006006, S2-2006007, S2-2006008, S2-2006039, S2-2005742, S2-2006036, S2-2005162, S2-2006009, S2-2005523, S2-2006010 | 0.5.0 |
| 2020-09 | SP#89-E | SP-200692 | - | - | - | MCC Editorial upate for presentation to TSG SA for information | 1.0.0 |
| 2020-10 | SA2#141E |  |  |  |  | Implemented approved P-CRs from SA2#141E - S2-2007881, S2-2007882, S2-2007883, S2-2007884, S2-2007885, S2-2007886, S2-2007887, S2-2007888, S2-2007889, S2-2007926,  S2-2007890, S2-2007891, S2-2007892, S2-2007893, S2-2007894, S2-2007895, S2-2007896, S2-2007897, S2-2007898, S2-2007899, S2-2007900, S2-2007901, S2-2007751, S2-2007902, S2-2007903, S2-2007904, S2-2007905, S2-2007775,  S2-2007504, S2-2007906, S2-2007907, S2-2007908, S2-2007910, S2-2007104, S2-2007911. | 1.0.1 |