Time synchronization services for media production over 5G networks

The 5G-MAG report "Towards a comprehensive 5G-based toolbox for live media production" [1] identified a series of high-level scenarios where time synchronization is a required feature. Time synchronization is key to aligning different media sources, whether within the same location, when carried over different network domains (fixed/wireless), or to support remote operations and control.

This report provides:

- information on the ability of 5G technologies to support time distribution and synchronization services in relevant deployment scenarios; and
- guidelines in relation to time information distribution and exposure to applications.

Contents

Time synchronization requirements and expectations

The equipment and devices deployed in live media production scenarios may require support for time synchronization, in particular to:

- support alignment of user data from different sources (audio and video streams),
- minimize buffering when processing multiple isochronous data streams,
- support live audio playback without any sample rate conversion and additional buffering, and
- reduce latency by optimizing interfacing and data flow through all network entities, i.e., alignment of the user data processing with the scheduled air interface traffic.

Time synchronization is also called synchronicity or clock synchronicity, defined as the maximum allowed time offset within a synchronization domain between the sync leader and any sync device measured in seconds [s].

Time synchronization limit values

Different limit values for synchronicity are required for the different applications. Table 1 summarizes various maximum levels, ranges, or formulas for estimating limit values.

Table 1: Time synchronization limit values

Parameter	Δt [μs]
Alignment of audio and video streams: lip synchronicity (see note 1)	from -125000 to +45000
Alignment of audio streams from different audio sources (see note 2)	
targeting a mono audio signal	50 - 100
targeting a stereo audio signal	10 – 50
targeting an immersive audio signal	1 - 10
Latency reduction (cross layer synchronization) (see note 3)	slot length / 2
Alignment of various video streams (see note 4)	$2/R_F * 10^6$ e.g., 33333
3GPP TS 22.263: Service requirements for video, imaging, and audio for professional applications [3]	1

Note 1: The audio should be less than 45 ms ahead of the video or be less than 125 ms after the video (see Recommendation ITU-R BT.1359-1 [2]).

Note 2: these are estimated values that represent the range in which best performance can be achieved.

Note 3: Slot length = 1 ms, 500 μs, or 250 μs in frequency range FR1

Note 4: R_F = Frame Rate in frames per second [fps], e.g., 60 fps.

Time synchronization in media production protocols

SMPTE 2110

SMPTE ST 2110 is based on RTP (Real time Transport Protocol) and designed for professional broadcast applications by the Society of Motion Picture and Television Engineers (SMPTE). SMPTE ST 2110 transports media by splitting the video, audio, and ancillary components into independent data streams. It is a set of standards and can be split into four main components: 2110-10 for timing and synchronization, ST 2110-20 for video, ST 2110-30 for audio, and ST 2110-40 for ancillary data (see the 5G-MAG Report on SMPTE2110).

SMPTE specifies its own **Precision Time Protocol** (PTP) based on IEEE Std 1588. It is called SMPTE profile for synchronization in a professional broadcast environment and is specified in SMPTE ST 2059-2 “SMPTE Profile for Use of IEEE-1588 Precision Time Protocol in Professional Broadcast Applications”.

Node types supported by ST 2059-2 are the following:

- ordinary clock,
- boundary clock, and
- end-to-end transparent clock.

Not supported is a peer-to-peer transparent clock. The permitted transport mechanism is UDP as specified in IEEE Std 1588.

SRT

SRT (for Secure Reliable Transport) is based on UDP (User Datagram Protocol) and designed by the SRT Alliance [4] for conveying multiple video, audio and data streams over lossy networks. Similar to TCP, it provides for connection and control, along with retransmission of lost packets, but during a limited period based on the latency (default 120 ms) configured by the application.

SRT does not specify a time synchronization protocol, but the consistent latency assures that the packet cadence received by the decoder is identical to the one entering the network. Consequently, a proper timestamping of user-data packets could maintain the time synchronization of all devices.

Wireless audio

In the field of wireless microphones and in-ear monitors, there is currently no common transport protocol specified. One reason may be that every vendor uses its specific audio codec; another may be the stringent latency requirements. Where uncompressed audio, e.g., PCM (Pulse-Code Modulation), is transmitted, an investigation of whether AES3 or AES67 is suitable would be required.

The transmission of compressed audio data remains open and is not addressed in any body or interest group.

Time Synchronization in 5G systems

The 5G System specified by 3GPP has integrated support for **Time Sensitive Communication** (TSC) services to address requirements for precise time delivery and synchronization.

With this, systems that historically relied on Global Navigation Satellite Systems (GNSS) or the provision of an external source for timing information may be able to rely entirely on the 5G System to obtain time information.

3GPP Release 16 introduced PTP-based time synchronization based on IEEE Std 802.1AS [5], which is the **generalized Precision Time Protocol** (gPTP). With this, the 5G System plays the role of a "**time-aware system**".

3GPP Release 17 introduced compliance to IEEE Std 1588 [6]. With this, the 5G System supports operation in one or multiple PTP instances, each with one of the following modes, according to clause 5.27 of 3GPP TS 23.501 [7]:

- as described in IEEE Std 802.1AS for operation as a time-aware system,
- as **Boundary Clock** described in IEEE Std 1588, including the SMPTE Profile for use of IEEE Std 1588 Precision Time Protocol in Professional Broadcast Applications ST 2059-2,
- as **peer-to-peer Transparent Clock** as described in IEEE Std 1588, or
- as **end-to-end Transparent Clock** as described in IEEE Std 1588.

The internal 5G clock used to synchronize the RAN and distributed over the radio interface to synchronize the UE (Eser Equipment), as specified in 3GPP TS 38.331 [8], may also be leveraged for time synchronization. With this method, the 5G timing information can be further distributed to UEs and forwarded to connected equipment and devices.

In Release 17, 3GPP introduced the possibility to offer time synchronization as a service, with an API that provides to third parties the ability to access and manage time synchronization. An application server from a third party can communicate with the 5GS (5G System) via an AF (Application Function) using the time synchronization APIs introduced in Release 17, and request the service it needs for a UE or a group of UEs.

Time Distribution over 5G Access Stratum

Figure 1 illustrates the distribution of the 5G internal system clock to various network components and its exposure to external equipment via a suitable DS-TT (Device-Side TSN Translator).

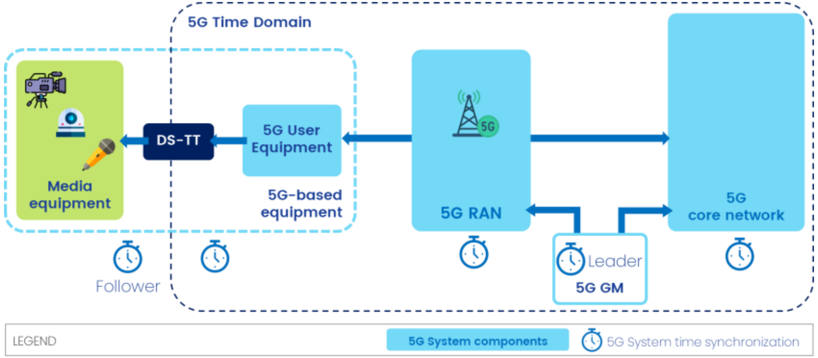

Figure 1: Downstream 5GS clock distribution

The **5G Grand Master** (5G GM in Figure 1), the internal 5G clock which is typically provided to the gNodeB, enables the synchronization of UEs via a periodic distribution of reference time information (RTI) over the air. The UE can be synchronized to the internal 5G clock using *referenceTimeInfo* together with the estimation of downlink frame boundaries. The *referenceTimeInfo* can be included within the (optional) System Information Block **SIB9** and broadcast to UEs in a cell either periodically (every 80 ms to 5.12 s) or on demand. It can also be included in dedicated Radio Resource Control (RRC) messages, in particular as part of *DLInformationTransfer*, which can be delivered to individual UEs via unicast.

Timing information via SIB9 or RRC messages

SIB9 contains information related to GPS time and Coordinated Universal Time (UTC). The UE may use the parameters provided in this system information block to obtain the UTC, the GPS and the local time.

SIB9 information element

```
-- ASN1START
-- TAG-SIB9-START
SIB9 ::=                            SEQUENCE {
    timeInfo                            SEQUENCE {
        timeInfoUTC                         INTEGER (0..549755813887),
        dayLightSavingTime                  BIT STRING (SIZE (2)),
        leapSeconds                         INTEGER (-127..128),
        localTimeOffset                     INTEGER (-63..64),
    }
    lateNonCriticalExtension            OCTET STRING,
    ...,
     [[
    referenceTimeInfo-r16           ReferenceTimeInfo-r16
    ]]
}
-- TAG-SIB9-STOP
-- ASN1STOP
```

Note that ***timeInfoUTC*** indicates the Coordinated Universal Time corresponding to the SFN boundary at or immediately after the ending boundary of the SI-window in which SIB9 is transmitted. The field counts the number of UTC seconds in 10 ms units since 00:00:00 on Gregorian calendar date 1 January, 1900 (midnight between Sunday, December 31, 1899 and Monday, January 1, 1900).

The UE may use this field together with the ***leapSeconds*** field to obtain GPS time as follows: GPS Time (in seconds) = timeInfoUTC (in seconds) - 2,524,953,600 (seconds) + leapSeconds, where 2,524,953,600 is the number of seconds between 00:00:00 on

Gregorian calendar date 1 January, 1900 (start of UTC time) and 00:00:00 on Gregorian calendar date 6 January, 1980 (start of GPS time).

The **DLInformationTransfer** message is used for the downlink transfer of NAS, non-3GPP dedicated information or time reference information.

DLInformationTransfer message

```
-- ASN1START
-- TAG-DLINFORMATIONTRANSFER-START
DLInformationTransfer ::=           SEQUENCE {
    rrc-TransactionIdentifier           RRC-TransactionIdentifier,
    criticalExtensions                  CHOICE {
        dlInformationTransfer           DLInformationTransfer-IEs,
        criticalExtensionsFuture            SEQUENCE {}
    }
}
DLInformationTransfer-IEs ::=       SEQUENCE {
    dedicatedNAS-Message                DedicatedNAS-Message,
    lateNonCriticalExtension            OCTET STRING,
    nonCriticalExtension                DLInformationTransfer-v1610-IEs
}
DLInformationTransfer-v1610-IEs ::= SEQUENCE {
    referenceTimeInfo-r16               ReferenceTimeInfo-r16,
    nonCriticalExtension                DLInformationTransfer-v1700-IEs
}
DLInformationTransfer-v1700-IEs ::= SEQUENCE {
    dedicatedInfoF1c-r17                DedicatedInfoF1c-r17,
    rxTxTimeDiff-gNB-r17                RxTxTimeDiff-r17,
    ta-PDC-r17                          ENUMERATED
{activate,deactivate},
    sib9Fallback-r17                    ENUMERATED {true},
    nonCriticalExtension                SEQUENCE {}
}
-- TAG-DLINFORMATIONTRANSFER-STOP
-- ASN1STOP
```

The ***ReferenceTimeInfo*** element contains timing information for the 5G internal system clock used for, e.g., time stamping, see [7], clause 5.27.1.2.

ReferenceTimeInfo information element

```
-- ASN1START
-- TAG-REFERENCETIMEINFO-START
ReferenceTimeInfo-r16 ::= SEQUENCE {
    time-r16                            ReferenceTime-r16,
    uncertainty-r16                     INTEGER (0..32767),
    timeInfoType-r16                    ENUMERATED {localClock},
    referenceSFN-r16                    INTEGER (0..1023)
}
ReferenceTime-r16 ::=               SEQUENCE {
    refDays-r16                         INTEGER (0..72999),
    refSeconds-r16                      INTEGER (0..86399),
    refMilliSeconds-r16                 INTEGER (0..999),
    refTenNanoSeconds-r16               INTEGER (0..99999)
}
-- TAG-REFERENCETIMEINFO-STOP
-- ASN1STOP
```

Note that ***referenceSFN*** indicates the reference SFN corresponding to the reference time information. ***Time*** indicates time reference with 10ns granularity. The indicated time in 10ns units from the origin is refDays*86400*1000*100000 + refSeconds*1000*100000 + refMilliSeconds*100000 + refTenNanoSeconds. The refDays field specifies the sequential number of days (with day count starting at 0) from the origin of the time field. ***Uncertainty*** indicates the uncertainty of the reference time information provided by the time field. The uncertainty is 25ns multiplied by this field. If this field is absent, the uncertainty is unspecified.

Note that acquiring SIB9 can be performed by any device, even if not subscribed given that SIB9 is broadcast over a cell. Acquiring RRC messages requires subscription.

(g)PTP Time Distribution over the 5G System

(g)PTP-based Time Distribution provides timing among entities in a (g)PTP domain with the profiles defined in [5] and in [6]. With this approach, the 5G System can be used to distribute (g)PTP domain synchronization of an external time-synchronized network.

According to [5], the differences between gPTP (IEEE Std 802.1AS-2020) and PTP (IEEE Std 1588-2019) are, among others:

- gPTP assumes all communication between PTP instances is done only using IEEE 802 MAC PDUs and addressing, while PTP supports various layer 2 and layer 3/4 communication methods.
- gPTP specifies a medium-independent sublayer that simplifies the integration within a single timing domain of multiple different networking technologies with different medium access protocols. gPTP specifies a medium-dependent sublayer for each medium. The information exchanged between PTP Instances has been generalized to support different packet formats and management schemes appropriate to the networking technology. PTP introduces an optional new architecture based on medium-independent and medium-dependent sublayers. PTP is retained for IPv4, IPv6, Ethernet LANs, and various industrial automation control protocols.
- In gPTP there are only two types of PTP instance: **PTP End Instances** and **PTP Relay Instances**, while PTP has Ordinary Clocks, Boundary Clocks, end-to-end Transparent Clocks, and peer-to-peer Transparent Clocks.
- PTP Instances communicate gPTP information only directly with other PTP Instances. That is, a gPTP domain consists only of PTP Instances. Non-PTP Relay Instances cannot be used to relay gPTP information. In PTP according to IEEE Std 1588-2019 it is possible to use non-IEEE-1588-aware relays in an IEEE Std 1588 domain, although this slows timing convergence and introduces extra jitter and wander that must be filtered by any IEEE Std 1588 clock.

5G System as TSN bridge

gPTP supports time synchronization for Time-aware end stations and Time-aware Bridges at Layer 2. 3GPP TS 23.501 Release 16 specifies the 5G System to play the role of a "Time-aware system", as defined in IEEE 802.1AS, and designated as a logical or virtual TSN bridge. The bridge is also called "Transparent clock" its existence is not known by the PTP Leader and PTP Follower. Figure 2 illustrates the PTP GM clock distribution model via the 5G System operating as a TSN bridge.

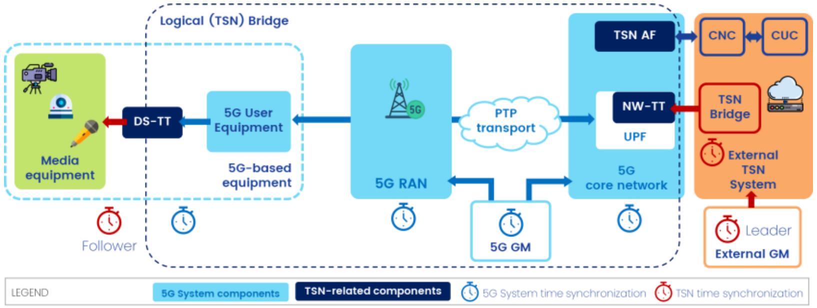

Figure 2: 5G system as a 802.1AS “time-aware system”

gPTP is supported at the edges of the 5G System via two translation entities: **Device-Side TSN Translator** (DS-TT) on the UE side and the **Network-Side TSN Translator** (NW-TT) on the 5G network side: The **TSN Application Function** (TSN AF) is used as a control plane translator for interaction with, for example, the external CNC (Centralized Network Configuration) of the TSN system which interacts with the CUC (Centralized User Configuration).

5G System as PTP node

3GPP Release 17 adds a second mode of operation to integrate the 5GS in a PTP network acting as an additional PTP node that distributes either the 5GS clock or an external GM. It now extends from Layer 2 to UDP/IP applications (Layer 3/4). In addition to its original support for Ethernet through IEEE 802.1AS Time-Aware System, it has been updated to include the four types of PTP instance described in IEEE 1588.

When distributing its internal clock, the 5GS acts as a **PTP Boundary Clock** which provides the GM for the endpoint PTP devices attached to it. When distributing an external GM, the 5GS instead operates as a **PTP Transparent Clock**. It relays all PTP relevant messages from an external leader GM to follower devices (and vice versa) and additionally measures the time the PTP messages need to travel through it. This latency is called **residence time** and is used to correct the PTP messages accordingly. Two different modes are supported:

- **end-to-end mode:** the latency of the entire link is measured directly between the leader and follower node.
- **peer-to-peer mode:** only Sync, Follow_Up, and Announce messages are forwarded and used to measure the latency of each link segment.

Both PTP modes are based on two concurrent synchronization processes: 5GS synchronization and external PTP synchronization. PTP synchronization provides the synchronization service to devices in the PTP enabled network, whereas the 5GS provides an internal system clock for 5GS internal synchronization to synchronize the gNodeB, the NW-TT at the UPF (User Plane Function) side and the DS-TT at UE side, to the 5G internal system clock.

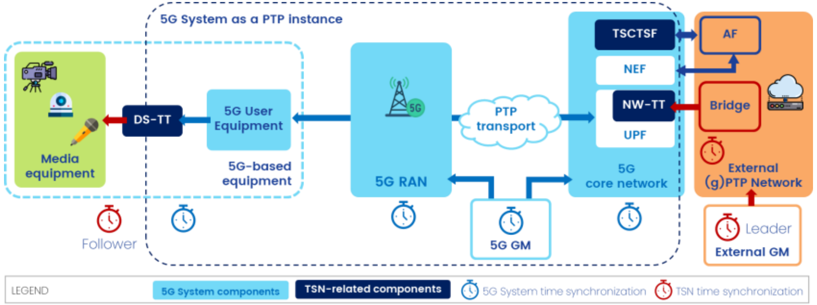

Figure 3: Extension of the 5G System architecture to support (g)PTP synchronization

Time-Sensitive Networking Functions and interaction with the 5G System

Network & Device Translators: NW-TT and DS-TT

These TSN translators (TTs) are responsible for PTP transport operations (e.g., timestamping, PTP message correction, PTP path or link delay measurements, etc.).

The ingress TT (NW-TT or DS-TT) is responsible for capturing the Ingress Timestamp of the relevant PTP message (e.g. sync message) generated by the PTP Leader in the external network once it reaches the 5G network. It also measures the delay between ingress TT and the PTP Leader. The Ingress Timestamp is embedded within the sync message and transmitted to the UE via the user plane or a PDU session.

When the UE receives the sync message, it forwards it to the egress TT (DS-TT or NW-TT). The **egress TT** calculates the resident time by subtracting the Ingress Timestamp received in the sync message from the Egress Timestamp, which represents the time at which the sync message reaches the receiver. The corrected time can be determined by adding the resident time to the delay time indicated in the sync message.

Through the assistance of the TSN translators, the PTP Follower receives the message and obtains information about time deviation and other relevant data for further adjustment. More information on these procedures is available in [7].

The generic mechanisms for gPTP message delivery are set out in IEEE Std 802.1AS and IEEE Std 1588-2019. However, there are specific requirements for the DS-TT and the NW-TT in terms of the signalling of ingress time. According to 3GPP TS 24.535 [9], support for these operations is optional for PTP but mandatory for gPTP where the ingress TT is NW-TT and the egress TT is DS-TT. Organization specific TLV extensions are included the Suffix field of a gPTP message as specified in clause 14.3 of IEEE Std 1588-2019. The Suffix field contains an Organization ID field, the value of which for 3GPP needs to be assigned by the IEEE.

Scenarios when the GM is behind the UE (uplink), behind the network (downlink) and for multiple (g)PTP domains are supported. When 5GS operates as Boundary Clock, NW-TT and DS-TT should support generating ***Sync***, ***Follow_Up*** and ***Announce*** messages.

The TTs can support the following PTP transport modes described in IEEE 1588: over UDP/IPv4; over UDP/IPv6; over IEEE 802.3 (Ethernet).

TSN Application Function and control modes

Control of PTP operation is performed through two types of container, which exchange messages about the capabilities of the network (e.g., message intervals, GM capabilities, port status, etc). They are: Port Management Information Container (PMIC) and User Plane Node Management Information Container (UMIC). The PMIC controls the operation of a port at the DS-TT or the NW-TT. The UMIC controls the operation of the 5GS as a PTP instance at the NW-TT.

The TSN Application Function (**TSN AF**) is responsible for managing the integration of the 5GS with the TSN network. It provides interaction with the Central Network Controller (CNC), which is responsible for controlling the TSN bridges in the network as defined in IEEE 802.1Qcc-2018. TSN AF is operated by the administrator of the TSN network and exchanges PMIC/UMIC messages to configure PTP operation.

The CNC receives information from the Centralized User Configuration (CUC) and performs scheduling and planning tasks. It calculates the optimal transmission schedule for the TSN traffic based on factors such as bandwidth requirements, latency constraints, and network conditions. Once the transmission schedule is computed and confirmed, CNC proceeds to deploy the necessary network resource configuration on the TSN switches. This ensures that the TSN network operates efficiently and effectively in delivering the required QoS (Quality of Service) for the application services.

Procedures for Ethernet port management and Bridge management are specified are specified in 3GPP TS 24.539 [10]. It includes the messages described in Table 2.

Table 2: Message definition and contents

Message	Content	Direction
Manage Ethernet port command	Ethernet port mgnt. service message type Ethernet port mgnt. list	TSN AF to DS-TT TSN AF to NW-TT
Manage Ethernet port complete	Ethernet port mgnt. service message type Ethernet port mgnt. capability Ethernet port status Ethernet port update result	DS-TT to TSN AF NW-TT to TSN AF
Ethernet port management notify	Ethernet port mgnt. service message type Ethernet port status	DS-TT to TSN AF NW-TT to TSN AF
Ethernet port mgnt. notify ack	Ethernet port mgnt. service message type	TSN AF to DS-TT TSN AF to NW-TT
Ethernet port mgnt. notify complete	Ethernet port mgnt. service message type	DS-TT to TSN AF
Ethernet port mgnt. capability	Ethernet port mgnt. service message type Ethernet port mgnt. capability	DS-TT to TSN AF
Manage Bridge command	Bridge mgnt. service message type Bridge mgnt. list	TSN AF to NW-TT
Manage Bridge complete	Bridge mgnt. service message type Bridge mgnt. capability Bridge status Bridge update result	NW-TT to TSN AF
Bridge management notify	Bridge mgnt. service message type Bridge status	NW-TT to TSN AF
Bridge management notify ack	Bridge mgnt. service message type	TSN AF to NW-TT

TSCTSF and AF

The **Time-Sensitive Communication and Time Synchronization Function** (TSCTSF) is introduced in 3GPP Release 17 to support TSC features for any application.

For time synchronization, the TSCTSF is responsible for controlling DS-TT and NW-TT operation (via exchange of PMIC and UMIC) to configure gPTP or PTP operation (supported PTP instance types; supported transport types; supported PTP delay mechanisms; GM capability; supported PTP profiles; number of supported PTP instances, etc.).

TSCTSF is introduced between PCF and NEF to support AF requests related to TSC. In case that the 5GS and AF are in the same trust domain, the AF provides input directly via the TSCTSF, otherwise via NEF. The AF uses the procedure for configuring the (g)PTP instance in 5GS as described in clause 4.15.9.3 of TS 23.502 [11] or uses the procedure for providing the 5G access stratum time distribution as described in clause 4.15.9.4 of [11] for the UEs.

The TSCTSF may support the AF to, for example, activate and deactivate time synchronization services; control the time synchronization service for a target UE or group of UEs; configure the TTs to operate on an AF-selected method, managing the DS-TT and NW-TT via exchange of PMIC and UMIC; provide a specific QoS traffic pattern; create the TSC Assistance Container based on individual traffic pattern parameters from the NEF/AF and provide it to the PCF. For instance, the AF can provide traffic pattern parameters to the NEF, which the NEF will forward to the TSCTSF. An AF trusted by the operator can directly provide such traffic pattern parameters to the TSCTSF.

Additional details on protocols between these functions can be found in [10] and [11].

Conclusions and Recommendations

Applicability to live media production scenarios

Taking as reference the deployment models introduced in "Deploying standalone non-public 5G networks for media production" and "5G NPNs for media production in collaboration with third party networks", additional detail around these scenarios is provided as follows.

Along with media production use case, several other verticals require precise clock information at the application layer, including: industrial IoT, power grid, commercial banking and stock trading platforms. Not only is the availability of the clock signal important but also its quality in terms of accuracy, authenticity, integrity, and resilience. Depending on the application, different levels of clock signal quality are required.

For media production the requirements on clock quality are described in Section 2. In contrast to industrial automation where the 5G System acts as a logical TSN bridge to support IEEE Time Sensitive Networking (TSN), in content production the 5GS should provide internal clock information of the 5G System clock or should distribute a leader clock signal (see Section 2).

As media production setups may be quite different from one event to another, it is important to understand what is the most preferable time synchronization architecture to be deployed. In addition, it is important to consider what legacy devices can support.

When S-NPNs or PNI-NPNs are deployed without a local wired network (e.g. ST 2110):

- For a single S-NPN, the Access Stratum-based time distribution method may be a straightforward option.
- For multiple S-NPNs able to share a common clock, the common 5GS clock can act as GM and the Access Stratum-based time distribution method may be used. If sharing is not possible, a GM may be set, and the PTP-based time distribution method used.
- For a single PNI-NPN, the Access Stratum-based time distribution method may be used, subject to the network operator offering this service in the SLA.
- For multiple PNI-NPNs and when a common clock cannot be shared, the PTP-based distribution method may be used, subject to the network operator offering this service in the SLA.

When infrastructure equipped with a local wired network (e.g. ST 2110) is co-located with a 5G network, the following may be considered:

- If one or multiple S-NPNs share a 5GS clock, this may act as a GM for the wired network and the Access Stratum-based time distribution method may be used. When sharing is not possible, the GM of the wired network could be distributed using a PTP-based time distribution method.
- If the wired network is co-located with one or multiple PNI-NPN(s), the GM of the wired network could be distributed using a PTP-based time distribution method, subject to the network operator offering this distribution method, subject to the network operator offering this service in the SLA.

Implementation and potential gaps

Starting with 3GPP Release 16, PTP-based synchronization is in general supported by the 5G System in the following ways:

- as a distribution of the 5G internal system clock
- as a distribution of PTP time information.

Both methods are already specified including a minimum set of functionalities that are mandatory if the 5G System supports TSN. On the UE side this means that the DS-TT interface is available if the UE supports TSN.

Support of Access Stratum-based Time Distribution

Support at the UE
Support of DS-TT depends on: – Support of API in the operating system of a COTS device (e.g. Android/iOS, ...) Exposure of SIB9 and RRC messages in a vendor-specific chipset/module implementation. Note that in this case the implementation of a DS-TT is required, which is not specified by 3GPP. This solution may be available in commercial modules exposing a PPS signal, which could be combined with SIB9/RRC messages.
Support in the network
SIB9 or RRC messages may be propagated over the air in: – a public mobile network if the MNO offers time synchronization “as a service” – a SNPN, where support is up to the network operator. The periodicity for SIB9 broadcast is specified to be between 80 ms and 5.12 s. There is an open question as to who can configure this rate and how.

Support of PTP Time Distribution

Support at the UE
According to clause 5.2 in 3GPP TS 24.535 [9]: If the DS-TT acts as an ingress TT (uplink), support of DS-TT operations such as delay measurements or signalling of ingress time is optional for both gPTP and PTP messages. If a Rel-16 DS-TT acts as an egress TT (downlink), support of DS-TT operations is mandatory for gPTP but optional for PTP messages. From Rel-17 onwards, gPTP support is optional also for the DS-TT.
Support in the network
According to clause 5.2 in 3GPP TS 24.535 [9]: If the NW-TT acts as an ingress TT (downlink), support of NW-TT operations such as delay measurements or signalling of ingress time is mandatory for gPTP and optional for PTP. If the NW-TT acts as an egress TT (uplink), support of NW-TT operations is optional for both gPTP and PTP messages.
Exposure of functionalities and configuration
Supported for any application by providing the connection from AF – to NEF/TSCTSF or for TSN systems by providing the connection with TSN AF.

Note that for PTP frames the value of Organization ID for 3GPP still needs to be assigned by the IEEE at the time of publishing this report.

Definitions (from IEEE Std 1588-2019)

Note: The present document uses "leader" and "follower" terminology instead of the original "MASTER" and "SLAVE" definition provided below.

Boundary Clock: A PTP Instance that has multiple PTP Ports in a domain and maintains the timescale used in the domain. Within a domain, it may serve as the source of time to other PTP Instances, that is, be a Master Clock, and it can in addition synchronize to another Boundary Clock or Ordinary Clock, that is, be a Slave Clock.

end-to-end port: A PTP Port that is configured to use the delay request-response mechanism.

end-to-end Transparent Clock: A Transparent Clock that supports the use of the delay request-response mechanism between a PTP Port in the MASTER state and a PTP Port in the SLAVE state in the same domain.

epoch: The origin of a timescale.

Grandmaster Clock: In the context of a single PTP domain, the Local PTP Clock of an Ordinary Clock or a Boundary Clock that is the source of time to which all other Local PTP Clocks in the domain are synchronized.

Local PTP Clock: The clock of a PTP Instance that provides the local estimate of the time of its Grandmaster Clock, that is it is synchronized to the time of the Grandmaster Clock. It is either a physical or a mathematical clock, and it provides PTP or ARB (arbitrary) time.

Master Clock: In the context of a single PTP Communication Path, the Local PTP Clock of an Ordinary Clock or Boundary Clock that is the source of time to which all other Local PTP Clocks on that PTP Communication Path synchronize.

Ordinary Clock: A PTP Instance that has a single PTP Port in its domain and maintains the timescale used in the domain. An Ordinary Clock can serve as a source of time, that is, contain a Master Clock, or alternatively, the Local PTP Clock of an Ordinary Clock can be synchronized, that is, be a Slave Clock, to the Local PTP Clock of a Boundary Clock or another Ordinary Clock in the domain.

peer-to-peer Transparent Clock: A Transparent Clock that, in addition to providing PTP event transit time information, also corrects for the propagation delay of the PTP Link connected to the PTP Port receiving the Sync message. In the presence of peer-to-peer Transparent Clocks, delay measurements between Slave Clocks and the Master Clock are performed using the peer-to-peer delay mechanism.

Precision Time Protocol (PTP): The protocol defined by IEEE Std 1588.

Network: A network consisting of a combination of PTP Nodes and possibly non-PTP devices and/or PTP Management Node(s). Non-PTP devices include, e.g., some bridges, routers, and other infrastructure devices, and possibly devices such as computers, printers, and other application devices.

PTP Node: A device that contains one or more PTP Instances and/or PTP services (e.g., Common Mean Link Delay Service).

Slave Clock: In the context of a single PTP Communication Path, the Local PTP Clock of an Ordinary Clock or Boundary Clock that synchronizes to the Local PTP Clock of the Master PTP Instance on that PTP Communication Path.

Transparent Clock: A PTP Instance that measures the time for a PTP event message to transit the PTP Instance and provides this information to PTP Instances receiving this PTP event message. Peer-to-peer Transparent Clocks also correct for PTP Link delay.

Related documentation

[1] 5G-MAG Report: “Towards a comprehensive 5G-based toolbox for live media production”.

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[4] IETF draft-sharabayko-srt-01, Internet Draft (Work in Progress), The SRT Protocol, 2021.

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[6] IEEE Std 1588-2019: “IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems”.

[7] 3GPP TS 23.501: ”System architecture for the 5G System (5GS); Stage 2” (Release 18).

[8] 3GPP TS 38.331: “NR Radio Resource Control (RRC) protocol specification” (Release 17).

[9] 3GPP TS 24.535: “Device-Side Time Sensitive Networking (TSN) Translator (DS-TT) to Network-Side TSN Translator (NW-TT) protocol aspects; Stage 3” (Release 17).

[10] 3GPP TS 24.539: “Network to TSN translator (TT) protocol aspects; Stage 3” (Release 18).

[11] 3GPP TS 23.502: ”Procedures for the 5G System (5GS); Stage 2” (Release 17).

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