Proposal for an ***"AVB Profile for Bridged Automotive Ethernet Networks"*** *as used by BMW*

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It is not an official draft of the Task or Working Group.

*ID: AE*_AVB_0217

Objekt Type: Information

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Objekt Type: Heading

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Objekt Type: Heading

1.4 References

ID: AE_AVB_0185

Objekt Type: Information

Documents referenced in this requirements specification are listed in the ‘References’ table [AE_AVB_TABLE_01] shown in [AE_AVB_0187]. The respective version of these documents valid for the development object is to be used if the validity has not been explicitly restricted by an indication of the release date.

ID: AE_AVB_0187

Objekt Type: Information

Table [AE_AVB_TABLE_01]: *List of references*

ID	Dokument-Nr. / Document no.	Titel, Herausgeber / Title, publisher
[1]	[IEEE 1722-2016]	Standard for Layer 2 Transport Protocol for Time Sensitive Applications in Bridged Local Area Networks; IEEE
[2]	[IEEE 802.1AS-2020]	Standard for Local and Metropolitan Area Networks - Timing and Synchronization for Time-Sensitive Applications in Bridged Local Area Networks; IEEE
[4]	[IEEE 802.1Q-2018]	IEEE Standard for Local and metropolitan area networks: Virtual Bridged Local Area Networks; IEEE
[5]	[IEEE 802.3-2018]	IEEE Standard for Ethernet; IEEE

ID: AE_AVB_0188

Objekt Type: Heading

1.5 Definitions and abbreviations

ID: AE_AVB_0189

Objekt Type: Heading

1.5.1 Definitions

ID: AE_AVB_0190

Objekt Type: Information

Table [AE_AVB_TABLE_02]: *List of definitions*

Glossary term	Glossary definition	Reference
Broadcast	Messages addressed to all nodes on MAC layer.	[IEEE 802.1Q-2018]
Class measurement interval	An interval of time within which only a limited and pre-defined number of bytes/frames of the according SR traffic class may be transmitted.	[IEEE 802.1Q-2018]
Listener	An end station that is the destination, receiver, or consumer of an AVTP stream.	[IEEE 1722-2016]
MAY	This word, or the adjective "OPTIONAL", means that an item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because the vendor feels that it enhances the product while another vendor may omit the same item. An implementation which does not include a particular option MUST be prepared to interoperate with another implementation which does include the option, though perhaps with reduced functionality. In the same vein an implementation which does include a particular option MUST be prepared to interoperate with another implementation which does not include the option (except, of course, for the feature the option provides.)	[RFC 2119]
Media clock	A clock which provides the clock rate for media sampling, i.e., the sample rate. The media clock must be recovered by the Listener to avoid buffer over- or under-run.	[IEEE 1722-2016]
Multicast	Messages addressed to a pre-defined subset of nodes on MAC layer.	[IEEE 802.1Q-2018]
MUST	This word, or the terms "REQUIRED" or "SHALL", mean that the definition is an absolute requirement of the specification.	[RFC 2119]
MUST NOT	This phrase, or the phrase „SHALL NOT“ means that the definition is an absolute prohibition of the specification.	[RFC 2119]
Presentation time	The instant when the [IEEE 1722] transport protocol stack passes (‘presents’) received media data to the destined application.	[IEEE 1722-2016]
rateRatio	The rateRatio can be identified with the frequency offset of two clocks. It is defined by the frequency ratio between one clock and another.	[IEEE 802.1AS-2020]
SHOULD	This word, or the adjective "RECOMMENDED", mean that there may exist valid reasons in particular circumstances to ignore a particular item, but the full implications must be understood and carefully weighed before choosing a different course.	[RFC 2119]

Glossary term	Glossary definition	Reference
SHOULD NOT	This phrase, or the phrase "NOT RECOMMENDED" mean that there may exist valid reasons in particular circumstances when the particular behavior is acceptable or even useful, but the full implications should be understood, and the case carefully weighed before implementing any behavior described with this label.	[RFC 2119]
SR class	A traffic class used for AVB streams.	[IEEE 802.1Q-2018]
Strict priority	A scheduling algorithm that selects frames for transmission based on the priority of their traffic class.	[IEEE 802.1Q-2018]
Talker	An end station that is the source or producer of an AVTP stream.	[IEEE 1722-2016]
Traffic Class	A term used for classification of frames in regard of their time-criticality and thus necessity to expedite their transmission.	[IEEE 802.1Q-2018]
Unicast	Messages addressed to a single node on MAC layer.	[IEEE 802.1Q-2018]

ID: AE_AVB_0191

Objekt Type: Heading

1.5.2 Abbreviations

ID: AE_AVB_0192

Objekt Type: Information

Table [AE_AVB_TABLE_03]: *List of abbreviations*

Abbreviation	Glossary term	Glossary definition	Reference
A/V	Audio & Video		
ARL	Address Resolution Lookup	List of MAC addresses which are reachable on a physical switch port.	[IEEE 802.1Q-2018]
AVB	Audio Video Bridging	A set of IEEE standards to govern A/V stream transport on layer 2.	
AVTP	Audio Video Transport Protocol	A Transport Protocol designed for transport of A/V streaming data in AVB networks.	[IEEE 1722-2016]
AVTPDU	Audio Video Transport Protocol Data Unit		[IEEE 1722-2016]
BMCA	Best Master Clock Algorithm		[IEEE 802.1AS-2020]
DUT	Device Under Test		
FQTSS	Forwarding and Queuing Enhancements for Time-Sensitive Streams.		[IEEE 802.1Q-2018]
gPTP	Generalized Precision Time Protocol		[IEEE 802.1AS-2020]
HW	Hardware		
IEEE	Institute of Electrical and Electronics Engineers	A professional association for electronic and electrical engineering	
IETF	Internet Engineering Task Force	A standards organization, which develops and promotes Internet standards.	
IP	Internet Protocol		[RFC 791]
ISO/OSI	ISO Open Systems Interconnection	Layer model of communication systems	
LAN	Local Area Network	In the context of this document typically a network that is interconnected on OSI Layer 2.	
MAC	Media Access Control		[IEEE 802]
MIRP	Multiple I-SID Registration Protocol		[IEEE 802.1Q-2018]
MMRP	Multiple MAC Registration Protocol		[IEEE 802.1Q-2018]
MRP	Multiple Registration Protocol		[IEEE 802.1Q-2018]

Abbreviation	Glossary term	Glossary definition	Reference
MSRP	Multiple Stream Registration Protocol		[IEEE 802.1Q-2018]
MVRP	Multiple VLAN Registration Protocol		[IEEE 802.1Q-2018]
MTU	Maximum Transmission Unit	The size of the largest packet the Ethernet protocol can transmit.	
OPEN	OPEN Alliance (One-Pair Ether-Net) Special Interest Group (SIG)	http://www.open-sig.org/about/about-open/	
PCP	Priority Code Point	A field within the VLAN tag containing the priority and potentially the drop_eligible parameters.	[IEEE 802.1Q-2018]
Pdelay	Path delay	A term used to describe the path delay of between two PTP clocks as well as the measurement method utilized by [IEEE 802.1AS-2020].	[IEEE 802.1AS-2020]
PTP	Precision Time Protocol		[IEEE 1588-2008]
QoS	Quality of Service	Measurement of the overall performance of a service and the measure to achieve it.	
RFC	IETF Requests For Comments	A memorandum on Internet standards	
SOME/IP	Scalable Service-Oriented Middleware over IP	A communication protocol serving as a middleware.	
SP	Strict Priority	A scheduling scheme	[IEEE 802.1Q-2018]
SR	Stream Reservation		[IEEE 802.1Q-2018]
SRP	Stream Reservation Protocol		[IEEE 802.1Q-2018]
SW	Software		
TCP	Transmission Control Protocol		[RFC 793]
TCP/IP		A family of communication protocols	[RFC 1011]
TPID	Tag Protocol Identifier	Tag Protocol Identifier	[IEEE 802.1Q-2018]
VID	VLAN Identifier	VLAN Identifier	[IEEE 802.1Q-2018]
VLAN	Virtual LAN	An IEEE 802.1Q term.	[IEEE 802.1Q-2018]

Object Identifier: AE_AVB_0193

Objekttyp: Heading

1.5.3 Extended glossary

Object Identifier: AE_AVB_0194

Objekttyp: Heading

1.5.3.1 Electronic control unit (ECU)

Object Identifier: AE_AVB_0195

Objekttyp: Information

An ECU might entail a host, a node, a bridge, a microcontroller and/or others.

Object Identifier: AE_AVB_0196

Objekttyp: Information

Where the term ECU is used, there might be a need to adapt the given requirement to one of the internal components mentioned before.

Object Identifier: AE_AVB_0197

Objekttyp: Heading

1.5.3.2 Ethernet terminology

Object Identifier: AE_AVB_0198

Objekttyp: Heading

1.5.3.2.1 Microcontroller

Object Identifier: AE_AVB_0199

Objekttyp: Information

A microcontroller is an entity capable of executing management and/or other tasks.

Object Identifier: AE_AVB_0200

Objekttyp: Information

A microcontroller typically participates in the communication either as node or host.

Object Identifier: AE_AVB_0201

Objekttyp: Heading

1.5.3.2.2 Node

Object Identifier: AE_AVB_0202

Objekttyp: Information

A node or end node is a communication partner on an Ethernet based network that can send and/or receive MAC-layer (layer 2) frames.

Object Identifier: AE_AVB_0203

Objekttyp: Information

A node is assigned a local (globally unique) MAC address (see [10216504]).

Object Identifier: AE_AVB_0204

Objekttyp: Heading

1.5.3.2.5 (Layer 2) switch

Object Identifier: AE_AVB_0205

Objekttyp: Information

For the purpose of this document, a layer 2 switch is always implemented in hardware.

Object Identifier: AE_AVB_0206

Objekttyp: Information

While a switch will usually require a microcontroller that manages the configuration, the switch will handle Ethernet frames in hardware only, without support of the management entity.

Object Identifier: AE_AVB_0207

Objekttyp: Heading

1.5.3.2.6 Bridge

Object Identifier: AE_AVB_0208

Objekttyp: Information

For the purpose of this document, a bridge will always consist of a layer 2 switch combined with at least one microcontroller running some management software and/or protocols.

Object Identifier: AE_AVB_0207

Objekttyp: Heading

1.5.3.2.7 AVB bridge

Object Identifier: AE_AVB_0180

Object Type: Information

An AVB bridge is defined in [IEEE 1722-2016] as an Ethernet bridge that implements AVB standards.

Object Identifier: AE_AVB_0250

Object Type: Requirement

An AVB bridge shall be capable of forwarding AVB streams and time synchronization data within 1 second after startup.

ID: AE_AVB_0209

Objekttyp: Heading

2 Scope of development

ID: AE_AVB_0210

Objekttyp: Heading

2.1 Function of the development object

ID: AE_AVB_0211

Objekttyp: Information

This document imposes requirements which are dedicated to defining the basics of handling the transport of Audio and Video Streams (AVB) over in-vehicle Ethernet networks.

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*Object Identifier: AE_*AVB_0212

Objekttyp: Heading

2.2 Delimitation of the Object of Development

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*Object Identifier: AE_*AVB_0213

Objekttyp: Information

This document describes those parameters of the Ethernet system that require configuration either at design time or dynamically during operation.

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*Object Identifier: AE_*AVB_0214

Objekttyp: Information

This document applies exclusively to the vehicle-internal network.

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*Object Identifier: AE_*AVB_0215

Objekttyp: Requirement

The term 'Ethernet' shall include all layers and methods described in [IEEE 802.3-2018] and later revisions or amendments of that document.

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*Object Identifier: AE_*AVB_0300

Objekttyp: Information

For convenience, section 5.1 of this document summarizes the time synchronization concept

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*Object Identifier: AE_*AVB_0301

Objekttyp: Requirement

AVB-specific requirements regarding Quality of Service (QoS) are defined by the requirements in sections 5.2, 5.2.1, 5.2.2 and 5.2.3.

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*Object Identifier: AE_*AVB_0302

Objekttyp: Requirement

AVB-specific requirements regarding Stream Reservation (SR) are given by the requirements in section 5.2.4 of this document.

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*Object Identifier: AE*_AVB_0309

Objekttyp: Requirement

Requirements regarding the Audio Video Transport Protocol (AVTP) are given by the requirements in section 6 of this document.

Object Identifier: AE_AVB_0001

Object Type: Heading

4 Requirements regarding framework of integration

ID: AE_AVB_0277

Objekt Type: Heading

4.1 Inter-functional requirements

Object Identifier: AE_AVB_0223

Object Type: Information

AVB systems are subsets of the in-vehicle Ethernet network, carrying media streams over the network.

Object Identifier: AE_AVB_0224

Object Type: Information

AVB allows for robust transmission of time-sensitive data with highly precise timing. By showing almost deterministic network behavior, it offers a lightweight A/V streaming solution with a small memory footprint.

Object Identifier: AE_AVB_0318

Object Type: Information

In a regular switched Ethernet network, transmission in general is non-deterministic and subject to significant amounts of network jitter.

Object Identifier: AE_AVB_0319

Object Type: Information

When a time-sensitive media stream is transmitted over a non-deterministic medium with high jitter, neither the PLL in a listener of that stream can tune and stabilize the received media clock as fast and as accurately as required for typical use cases, nor replay can be coordinated and kept in sync among different listeners.

Object Identifier: AE_AVB_0320

Object Type: Information

An insufficient media clock recovery accuracy as described in [AE_AVB_0319] can lead to perceivable artefacts, especially – but not exclusively – in audio use cases. Lack of coordination may, in addition, lead to loss of lip sync, or loose media coupling.

Object Identifier: AE_AVB_0225

Object Type: Information

To achieve media transmission without perceivable issues that would be caused by network jitter, precision and robustness in AVB networks are ensured basically through the combination of the standards [IEEE 802.1AS], [IEEE 802.1Q] and [IEEE 1722].

Object Identifier: AE_AVB_0226

Object Type: Information

[IEEE 802.1AS] establishes a very precise, common time base within the AVB network, in this document often referred to as wall clock or global time.

Object Identifier: AE_AVB_0227

Object Type: Information

[IEEE 802.1Q] defines forwarding and scheduling schemes that ensure a calculable maximum transit time for time-sensitive streams over switched Ethernet networks while delaying effects for simultaneously transported non-time-sensitive traffic is kept at a minimum level.

Object Identifier: AE_AVB_0228

Object Type: Information

The transport protocol described in [IEEE 1722] utilizes the time base provided through [IEEE 802.1AS] and the calculable maximum transit time ensured thorugh [IEEE 802.1Q] to transport time-sensitive streams within a pre-defined, deterministic time frame from the sending application to the receiving application and orchestrate their replay.

The media replay dates thereby just sufficiently far in the future, such that all AVB Listener are able to receive the stream and stockpile a few media samples to provide continuous service and keep the memory requirements at a bare minimum.

Object Identifier: AE_AVB_0229

Object Type: Information

Typical use cases for AVB media systems are audio and/or video streams with synchronized media clocks, but other time-sensitive media types like telecommand and telemetry data streams or object lists may also be transported via AVB streams.

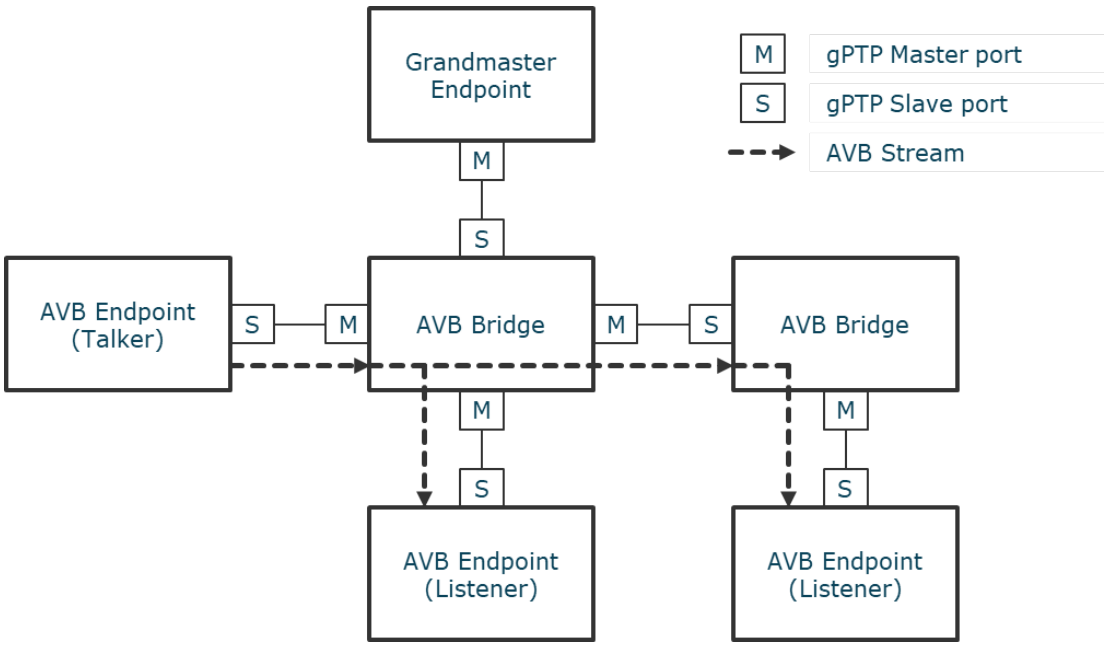
Object Identifier: AE_AVB_0003

Object Type: Requirement

ECUs that are implementing functional parts of AVB systems shall follow the requirements in this document, unless there are no other requirements in the ECU specific requirement specification.

Object Identifier: AE_AVB_0314

Object Type: Figure



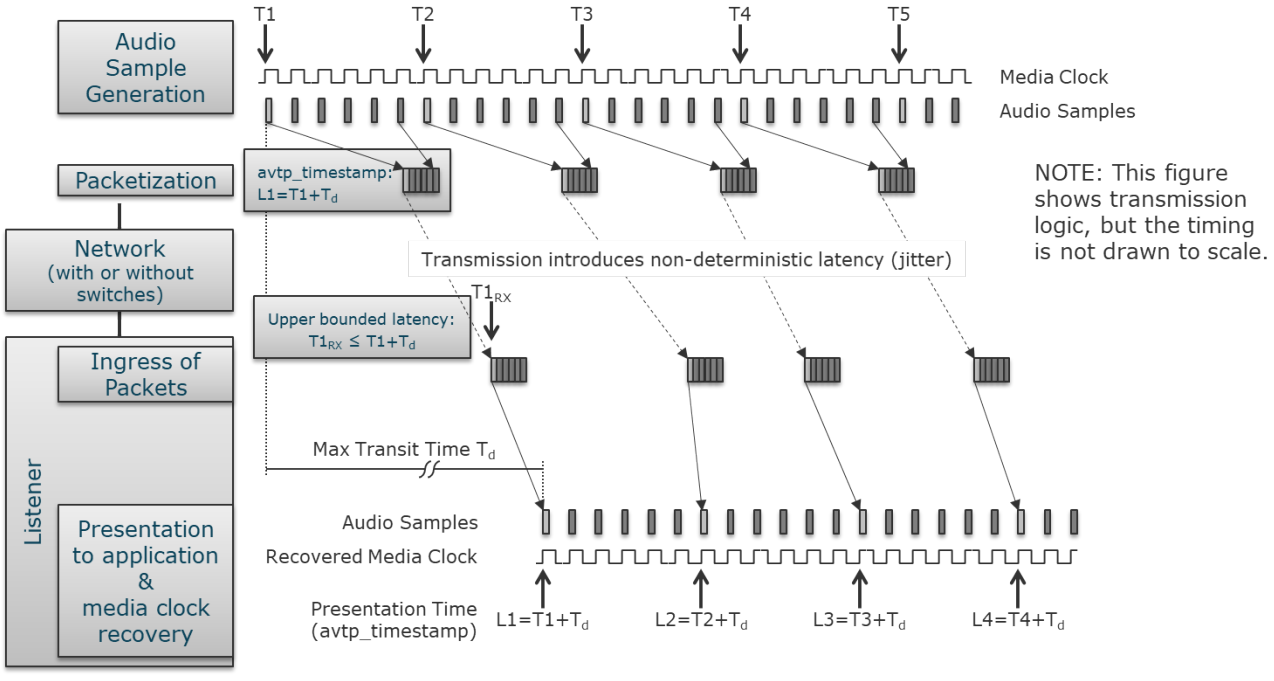
Object Identifier: AE_AVB_0315

Object Type: Caption

Figure [AE_AVB_0314]: *Generic AVB Network*

Object Identifier: AE_AVB_0312

Object Type: Figure



Object Identifier: AE_AVB_0313

Object Type: Caption

Figure [AE_AVB_0312]: *AVTP audio packetization and media clock recovery example*

ID: AE_AVB_0278

Objekt Type: Heading

4.2 AUTOSAR Disclaimer

Object Identifier: AE_AVB_0279

Object Type: Information

When this document is created, AUTOSAR does not support time synchronization in an entirely IEEE 802.1AS-compliant way. A/V streaming may therefore not be supported via AUTOSAR Time Gateways.

Object Identifier: AE_AVB_0280

Object Type: Information

As a main aspect of the deviations mentioned in [AE_AVB_0279], AUTOSAR does not (yet) support rate correction as specified in [IEEE 802.1AS].

Object Identifier: AE_AVB_0308

Object Type: Requirement

If an ECU uses the AUTOSAR implementation for time synchronization, the deviations mentioned in [AE_AVB_0279] and [AE_AVB_0280] are tolerated, unless explicitly specified otherwise.

Object Identifier: AE_AVB_0281

Object Type: Information

When this document is created, the AVB streaming protocol specified in [IEEE 1722] is neither considered nor implemented in AUTOSAR.

Object Identifier: AE_AVB_0282

Object Type: Information

When this document is created, the Stream Reservation Protocol as specified in [IEEE 802.1Q, section 35] is neither considered nor implemented in AUTOSAR.

ID: AE_AVB_0397

Objekt Type: Heading

4.3 Interfaces

Object Identifier: AE_AVB_0398

Object Type: Information

Table [AE_AVB_TABLE_04]: *List of SOME/IP signals used for stream reservation*

ID	Function	Interface	RPC
Group_01	Stream Reservation Lite	GroupMacControl	allowGroupMAC
Group_02	Stream Reservation Lite	GroupMacControl	stopALLGroupMACs
Group_03	Stream Reservation Lite	GroupMacControl	stopGroupMAC
Group_04	Stream Reservation Lite	GroupMacControl	ackAllowGroupMAC
Group_05	Stream Reservation Lite	GroupMacControl	ackStopGroupMAC

Object Identifier: AE_AVB_0002

Object Type: Heading

5 Requirements regarding functionality

ID: AE_AVB_0285

Objekt Type: Heading

5.1 Requirements placed on the time synchronization functionality

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Object Identifier: AE_AVB_0179

Object Type: Information

In AVB systems, media streams utilize precise timing information for synchronizing and of media clocks of talkers and listeners.

Object Identifier: AE_AVB_0303

Object Type: Information

The concept of media clock synchronization relies on a common understanding of time between talkers and listeners of an AVB stream which is achieved by distributing a wall clock. The time synchronization accuracy must thereby be high enough to allow for audio replay by aligning individual audio samples sampled at 48kHz, e.g., on a time grid established by IEEE 802.1AS.

Object Identifier: AE_AVB_0304

Object Type: Requirement

A maximum difference in synchronized time between two end points of 1µs is required.

Object Identifier: AE_AVB_0305

Object Type: Requirement

A maximum timestamping jitter of 100ns is required.

Object Identifier: AE_AVB_0306

Object Type: Requirement

A maximum jump of synchronized time of 800ns is required.

Object Identifier: AE_AVB_0307

Object Type: Information

[AE_AVB_0304] through [AE_AVB_0306] allow for a fast and accurate synchronization and syntonization of the media clocks of AVB talkers and listeners with the transport protocoll described in [IEEE 1722-2016] that utilizes the synchronized time and relies on its accuracy.

Object Identifier: AE_AVB_0005

Object Type: Information

In general, the techniques claimed in [AE_AVB_0004] are based on the time synchronization functionality desribed in [IEEE 802.1AS-2020], alongside with Automotive- and OEM-specific modifications, basically (but not exclusively) consisting of those described in [AE_AVB_0006], [AE_AVB_0007], [AE_AVB_0286] through [AE_AVB_0292] and [AE_AVB_0246] through [AE_AVB_0248].

Object Identifier: AE_AVB_0006

Object Type: Information

Best Master Clock Algorithm (BMCA), whose functionality desribed in [IEEE 802.1AS-2020], shall not be used for time synchronization role assignment. Instead, static roles are used.

Object Identifier: AE_AVB_0007

Object Type: Information

A Pdelay measurement according to [IEEE 802.1AS-2020] that exceeds the meanLinkDelayThresh value (cf. [IEEE 802.1AS-2020, 11.2.13.7]) may not cause setting asCapable to false or stop synchronization.

Object Identifier: AE_AVB_0286

Object Type: Information

For Automotive systems the Pdelay measurement is typically performed unidirectional and initialized by the time synchronization slave.

Object Identifier: AE_AVB_0287

Object Type: Information

Furthermore, not receiving a Pdelay_Req message may not cause a time synchronization slave to set its asCapable state to false and to stop synchronization.

Object Identifier: AE_AVB_0288

Object Type: Information

Likewise, missing Pdelay_Resp and Pdelay_Resp_Follow_Up messages may typically not cause a time synchronization slave to set its asCapable state to false and to stop synchronization.

Object Identifier: AE_AVB_0289

Object Type: Information

A time-aware system typically stores the last measured pDelay and use it upon re-start for an accelerated synchronization process.

Object Identifier: AE_AVB_0290

Object Type: Information

A time-aware system may also store the last measured rateRatio and neighborRateRatio value and use it upon re-start for an accelerated synchronization process.

Object Identifier: AE_AVB_0291

Object Type: Information

When not receiving Sync/Follow_Up messages anymore, a time-aware bridge will continue sending Sync and Follow_Up messages based on the last received Sync/Follow_Up pair and its local clock for MAX_BACKUP_TIME, if and only if it has received at least one Sync/Follow_Up message pair already.

Object Identifier: AE_AVB_0386

Object Type: Requirement

If the grandmaster or neighboring bridge is not sending Sync/Follow_Up messages, the transmission of Sync/Follow_Up shall not be started by any time-aware bridge.

Object Identifier: AE_AVB_0292

Object Type: Requirement

When not receiving Sync/Follow_Up messages anymore, a time-aware slave endpoint shall stay synchronized based on the last received Sync/Follow_Up pair and its local clock for SYNC_LOSS_TIMEOUT, if and only if it has received at least one Sync/Follow_Up message pair in the current session.

Object Identifier: AE_AVB_0247

Object Type: Information

Chapter 7 defines a testing and validation concept to demonstrate compliance with the defined time synchronization requirements which need to be implemented in order to validate integrity, accuracy, interoperability and seamless operation of time synchronization.

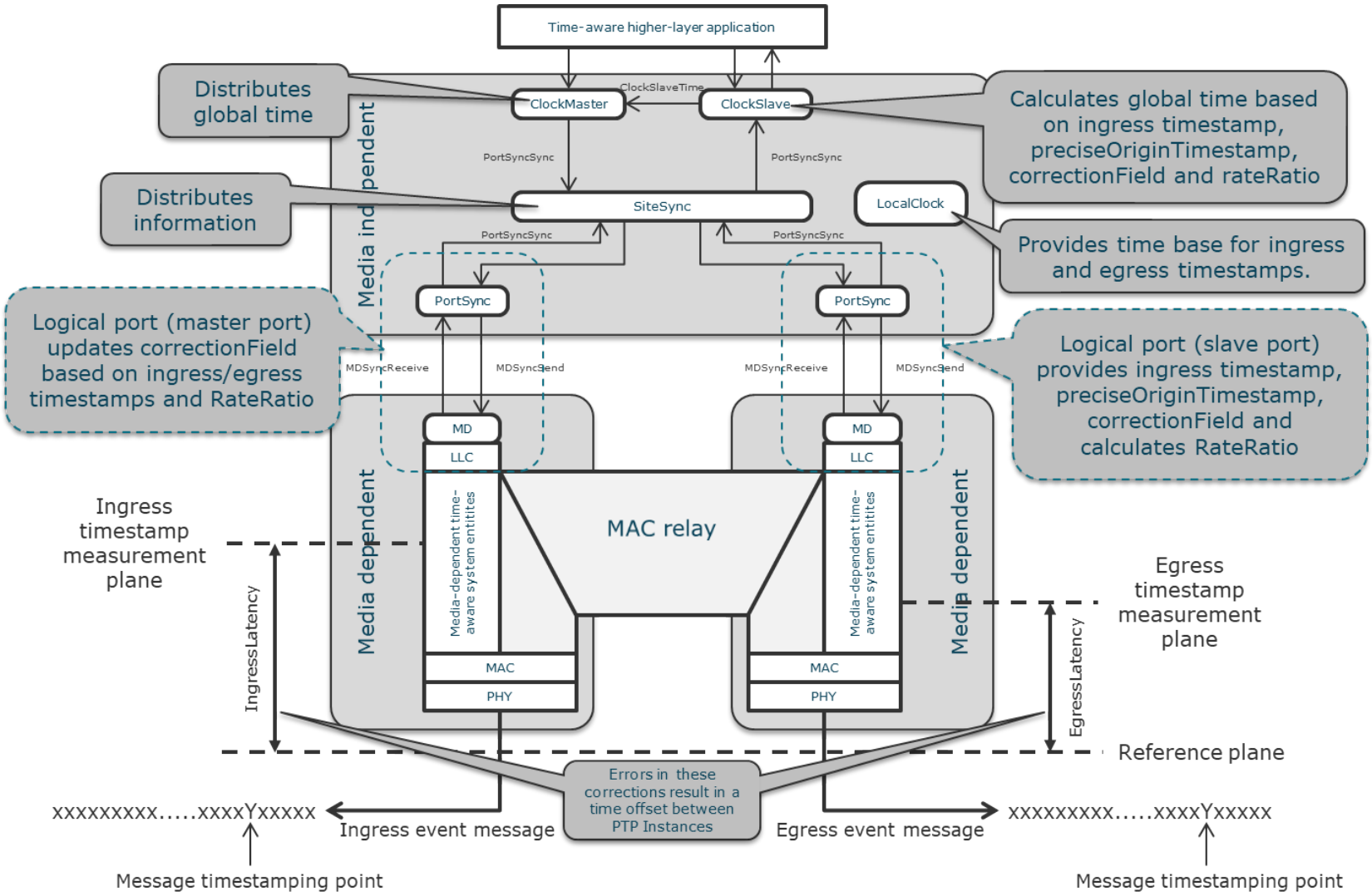
Object Identifier: AE_AVB_0248

Object Type: Information

The concept mentioned in [AE_AVB_0247] particularly includes methods for timestamp accuracy assessment that are based on the assumption of continuous progression of involved clocks within specified tolerances.

Object Identifier: AE_AVB_0310

Object Type: Figure



Object Identifier: AE_AVB_0311

Object Type: Caption

Figure [AE_AVB_0310]: *PTP Instance model with timestamping reference annotations*

Object Identifier: AE_AVB_0009

Object Type: Heading

5.2 Quality of Service (QoS) and Stream Reservation (SR)

Object Identifier: AE_AVB_0022

Object Type: Information

According to [IEEE 802.1Q-2018], the term ‘traffic class’ describes a classification that is used to expedite transmission of frames. Each traffic class is assigned a number from 0 through 7 and is associated with a corresponding outbound queue of the transmitting port.

Object Identifier: AE_AVB_0023

Object Type: Information

According to [IEEE 802.1Q-2018], the term ‘stream reservation class’ or ‘SR class’ describes a traffic class as described in [AE_AVB_0022] whose bandwidth can be reserved for AVB streaming data. Each SR class is assigned a letter alphabetically, starting with A.

Object Identifier: AE_AVB_0024

Object Type: Requirement

In AVB bridges as well as end nodes, all SR class traffic must be subject to shaping according to the credit-based shaper algorithm defined in [IEEE 802.1Q-2018].

Object Identifier: AE_AVB_0010

Object Type: Heading

5.2.1 Prioritization and traffic class assignment

Object Identifier: AE_AVB_0012

Object Type: Requirement

Unless a more sophisticated ingress prioritization imposed by IEEE 802.1Qci is agreed on, the “VLAN priorities” encoded in the PCP (Priority Code Point) field according to [IEEE 802.1Q-2018] shall be mapped to traffic classes and vice versa according to table [AE_AVB_TABLE_05] in requirement [AE_AVB_0013].

Object Identifier: AE_AVB_0013

Object Type: Requirement

Table [AE_AVB_TABLE_05]: *Mapping between VLAN priority and traffic class*

VLAN priority (PCP)	Traffic class	Examples
3	7 (highest) - SR class A	Highly time critical (typically physically limited) AVB traffic like noise cancelation
2	6 - SR class B	AVB audio streams, AVB video streams incl. Surround View or gesture control
7	5	SOME/IP, PTP
6	4	
5	3	VoIP
4	2	
0	1	Internet, Customer Devices
1	0 (lowest)	Debugging, DLT

Object Identifier: AE_AVB_0014

Object Type: Information

Table [AE_AVB_TABLE_05] represents the mapping for AVB systems with two SR classes as recommended in [IEEE 802.1Q-2018]. Note that the highest the “priority” in this table is on the top, i.e., VLAN priority 3 experiences the most prior treatment.

Object Identifier: AE_AVB_0218

Object Type: Information

The ‘example’ column in table [AE_AVB_TABLE_05] is by no means exhaustive or even mandatory.

Object Identifier: AE_AVB_0015

Object Type: Requirement

Table [AE_AVB_TABLE_05] assumes that up to two SR classes are used. If more SR classes or more sophisticated ingress prioritization measures are required in the future, the mapping described in the respective communication data base shall be binding.

Object Identifier: AE_AVB_0016

Object Type: Requirement

Unless specified otherwise, untagged frames shall be associated with the default VLAN priority 1 and, hence, with traffic class 0 at ingress of an AVB bridge.

Object Identifier: AE_AVB_0072

Object Type: Information

PTP messages according to [IEEE 802.1AS-2020] are untagged.

Object Identifier: AE_AVB_0017

Object Type: Requirement

According to [IEEE 802.1AS-2020] PTP messages shall be transmitted in expedited manner compared to other best effort traffic.

Object Identifier: AE_AVB_0018

Object Type: Information

However, PTP messages in the same traffic class, where AVB lives, or above, would compromise the delay of AVB streaming frames, unless its influence was factored in upon reservation.

Object Identifier: AE_AVB_0019

Object Type: Requirement

As a consequence of [AE_AVB_0017] and [AE_AVB_0018] PTP messages constitute an exception for [AE_AVB_0016] and require special treatment upon processing that must be coordinated with the HW supplier.

Typically, PTP messages are packed into the highest unshaped TC.

Object Identifier: AE_AVB_0021

Object Type: Requirement

[AE_AVB_0072] implies that PTP messages shall always be transmitted without VLAN tag.

Object Identifier: AE_AVB_0028

Object Type: Heading

5.2.2 Transmission selection

Object Identifier: AE_AVB_0026

Object Type: Requirement

The strict priority algorithm shall be used as IEEE 802.1Q-2018 transmission selection algorithm.

Object Identifier: AE_AVB_0027

Object Type: Requirement

In case that frames in two or more queues are available for transmission at the same time at the egress of any ECUs port, the strict priority algorithm shall select the frame to be transmitted first based on the queues' traffic classes, where higher traffic classes are preferred over lower traffic classes.

Object Identifier: AE_AVB_0029

Object Type: Heading

5.2.3 Bandwidth reservation

Object Identifier: AE_AVB_0031

Object Type: Information

Bandwidth reservation for SR classes in an AVB bridge is achieved indirectly by applying the credit-based shaper to SR class traffic and assigning it to the highest traffic classes.

Object Identifier: AE_AVB_0032

Object Type: Information

The reserved bandwidth for an SR class is defined by the variable 'idleSlope' as defined in [IEEE 802.1Q-2018] which basically describes the credit regeneration rate of the credit-based shaper for that very SR or traffic class.

Object Identifier: AE_AVB_0034

Object Type: Information

In general, the idleSlope of every SR class needs to be chosen such that it is high enough to guarantee the required bandwidth of all streams using this SR class generously.

Object Identifier: AE_AVB_0181

Object Type: Information

The clock or frequency drift between two clocks describes the phenomenon that the frequencies of two clocks are not exactly identical.

Object Identifier: AE_AVB_0182

Object Type: Information

The drift desribed in [AE_AVB_0181] can be measured with the rate ratio which is defined as the ratio of the clock rates of the two clocks.

Object Identifier: AE_AVB_0068

Object Type: Requirement

To determine a suitable idleSlope according to [AE_AVB_0034], the worst-case drift between two clocks on which the credit-based shaper mechanisms of two transmission ports are based on must be considered.

Object Identifier: AE_AVB_0033

Object Type: Information

The Forwarding and Queuing Enhancements for time-sensitive streams (FQTSS) method in [IEEE 802.1Q-2018] recommends a maximum bandwidth reservation of 75% of a port's line-rate for AVB traffic.

Object Identifier: AE_AVB_0035

Object Type: Requirement

For AVB Bridges (Switches), the sum of idleSlope values for all SR classes shall be 75% of the port's line-rate, unless otherwise specified by the configuration database.

Object Identifier: AE_AVB_0036

Object Type: Requirement

Any AVB node and in particular AVB Talkers are required to support and use the credit-based shaper in HW according to [IEEE 802.1Q-2018]. The idleSlope of Talkers shall compensate for clock drifts and be fine-tuned according to the respective current streaming needs.

Object Identifier: AE_AVB_0389

Object Type: Information

If a talker endpoint would not stick to the shaping rules according to the credit-based shaper and transmits an oversubscribed burst of two or more packets, an AVB switch that shapes correctly might possibly cause packet loss or increase delay variations. This shows the necessity of [AE_AVB_0036].

Object Identifier: AE_AVB_0390

Object Type: Information

In contrast to [AE_AV_0389], if a talker endpoint sticks to the shaping rules according to the credit-based shaper, an AVB switch that shapes with an oversubscribed idleSlope will not introduce an additional shaping delay which justifies the oversubscription of switches defined in [AE_AV_0035].

Object Identifier: AE_AVB_0037

Object Type: Requirement

If a native credit-based shaper algorithm implementation is not available in an AVB talker node, the traffic shall be sent in a manner that is comparable with the operation of the credit-based shaper algorithm in terms of the behavior described in [IEEE 802.1Q-2018, 34.6.1].

Object Identifier: AE_AVB_0175

Object Type: Information

In cases where an AVB talker generates frames in constant intervals natively, e.g., in case of a single audio stream, [AE_AVB_0037] may be fulfilled without the need of a specific mechanism.

Object Identifier: AE_AVB_0219

Object Type: Requirement

In practice, stream reservation (especially at the talker) is performed based on the so-called measurement interval, the AVB transmission interval and the frame size. A reservation is defined by the maximum number of AVTP frames with a well-defined size transmitted in a measurement interval. (Note that this definition corresponds to a bandwidth.) The credit-based shaper algorithm of a talker shall be (re-)configured based on all reservations of its SR class(es).

Note: AAF, for instance, requires, that the same number of audio sample frames are present in every AVTPDU. To ensure that the number of audio samples is the same in every AVTP frame the transmission interval of a stream depends on the sampling rate rather than the measurement interval.

Object Identifier: AE_AVB_0172

Object Type: Information

In general, it cannot be guaranteed that the time base in which the measurement interval is determined is aligned with the actual media clock that samples the AVB media data and generates the AVTP frame.

Object Identifier: AE_AVB_0173

Object Type: Information

In case that the measurement interval is not determined in the time base of the media clock, but of a different clock, it is possible, due to clock drift, that the number of generated frames occasionally exceeds the allowed number of frames per measurement interval resulting in delay accumulation and eventually to buffer overflows.

Object Identifier: AE_AVB_0174

Object Type: Requirement

To avoid the discrepancy described in [AE_AVB_0173], the clocks that determines the measurement interval shall allow a maximum clock drift of 200.1ppm (cf. [AE_AVB_0183]) that is compensated for.

Object Identifier: AE_AVB_0069

Object Type: Requirement

An AVB stream carrying audio data with 6 samples per packet and a sample rate of 48 kHz shall use a nominal measurement interval of 125 µs (SR Class A).

Object Identifier: AE_AVB_0220

Object Type: Requirement

An AVB stream carrying audio data with 6 samples per packet and a sample rate of 44,1 kHz shall use a nominal measurement interval of 125 µs (and SR Class as defined in [AE_AVB_0013]) resulting in a slight over-reservation of the required bandwidth, as the transmit interval is roughly 136µs.

Object Identifier: AE_AVB_0401

Object Type: Requirement

An AVB stream carrying audio data with 6 samples per packet and a sample rate of 24 kHz shall use a nominal measurement interval of 125 µs (SR Class A) resulting in an two-folded over-reservation of the required bandwidth, as the transmit interval is 250 µs.

Object Identifier: AE_AVB_0045

Object Type: Requirement

An AVB stream carrying audio data with 64 samples per packet and a sample rate of 48 kHz shall use a nominal measurement interval of 1333 µs (SR Class B).

Object Identifier: AE_AVB_0046

Object Type: Requirement

An AVB stream carrying audio data with 64 samples per packet and a sample rate of 44.1 kHz shall use a nominal measurement interval of 1333 µs (SR Class B) resulting in a slight over-reservation of the required bandwidth, as the transmit interval is only roughly 1451µs.

Object Identifier: AE_AVB_0049

Object Type: Requirement

For an AVB stream carrying video or other non-audio data or audio data with a format different than described in [AE_AVB_0069], [AE_AVB_0220], [AE_AVB_0045] or [AE_AVB_0046.

Object Identifier: AE_AVB_0221

Object Type: Requirement

The class measurement interval shall be configurable without code changes.

Object Identifier: AE_AVB_0071

Object Type: Information

As a theoretical example for [AE_AVB_0070], an audio talker that streams a 96 kHz stream with 64 samples per packet would require two frames carrying 64 samples in a measurement interval of 1333 µs. For comparison, the same number would be necessary for an audio talker that streams two individual 48k Hz streams with 64 samples per packet.

Object Identifier: AE_AVB_0165

Objekttyp: Requirement

If an AVB talker uses more than 10% of the available bandwidth on any link for all of its SR classes, the supplier shall obtain agreement with the system department.

Object Identifier: AE_AVB_0047

Object Type: Heading

5.2.4 Stream Reservation Protocol (SRP)

Object Identifier: AE_AVB_0048

Objekttyp: Information

SRP as defined in [IEEE 802.1Q-2018] serves multiple purposes in an AVB network:

1. Agree on the VLAN ID for AVB transport and make sure the correct ports are members.

2. Communicate the required bandwidth for the AVB traffic and make sure it is added to the correct port-queue/traffic class.

3. Communicate the traffic class of the AVB traffic.

4. Discovery of available sources.

5. Communicate the multicast MAC address for the AVB traffic to allow the sink to open its RX filter.

6. Communicate the multicast MAC address for the AVB traffic and make sure it is forwarded to the correct ports (set up the multicast MAC address' forwarding path).

Object Identifier: AE_AVB_0055

Objekttyp: Requirement

The functionalities 1, 2 and 3 of [AE_AVB_0048] shall be handled via the central communication database, as they are pre-defined.

Object Identifier: AE_AVB_0056

Objekttyp: Requirement

The functionalities 4 and 5 of [AE_AVB_0048] shall be handled and communicated by the audio/video management entity.

Object Identifier: AE_AVB_0057

Objekttyp: Information

The functionality 6 of [AE_AVB_0048] can be implemented more easily using the GroupMacControl SOME/IP service interface (0xB02C) listed in AE_AVB_0398 in some scenarios.

Object Identifier: AE_AVB_0321

Objekttyp: Requirement

The allowGroupMAC method of the GroupMacControl service interface shall allow for re-configuration of a single switch to forward frames with the according groupMAC, VLAN ID and SR class to the requesting ECU.

Object Identifier: AE_AVB_0322

Objekttyp: Requirement

The stopGroupMAC method of the GroupMacControl service interface shall allow for re-configuration of a single switch (that may or may not be in control of the AVB talker) to stop forwarding AVB traffic with the according groupMAC, VLAN ID and SR class to the requesting ECU.

Object Identifier: AE_AVB_0323

Objekttyp: Requirement

The stopALLGroupMACs method of the GroupMacControl service interface shall allow for re-configuration of a single switch to stop forwarding any AVB traffic with groupMAC to the requesting ECU.

Object Identifier: AE_AVB_0324

Objekttyp: Requirement

The ackAllowGroupMAC and ackStopGroupMAC events of the GroupMacControl service interface shall be used to acknowledge the allowGroupMAC or stopGroupMAC methods, respectively.

Object Identifier: AE_AVB_0387

Objekttyp: Requirement

The exact service definition and data types as well as the interaction with the audio/video management entity shall be taken from the central communication database.

Object Identifier: AE_AVB_0059

Objekttyp: Information

Due to the protocol sub-structure of the protocols MRP, MMRP, MVRP, MSRP, MIRP and the involved state machines, SRP is considered as hard to implement and test.

Object Identifier: AE_AVB_0060

Objekttyp: Requirement

An SRP implementation shall nonetheless be available for new developments as an optional functionality, as a full-fledged SRP implementation might be required in some scenarios.

Object Identifier: AE_AVB_0061

Objekttyp: Requirement

While **only one AVB bridge** in the internal network needs to be dynamically configured for multicast forwarding, SRP as defined in [IEEE 802.1Q-2018] shall not be used, but the SOME/IP solution described in [AE_AVB_0321] through [AE_AVB_0324].

Object Identifier: AE_AVB_0377

Objekttyp: Requirement

If any AVB stream is associated with a single “point-to-point” network path from talker to listener, dynamic registration and resource allocation is unnecessary and, hence, SRP shall not be used but the SOME/IP service described above to control streaming.

Object Identifier: AE_AVB_0379

Objekttyp: Information

[AE_AVB_0377] allow for simplified AVB streaming with a largely static configuration.

Object Identifier: AE_AVB_0062

Objekttyp: Requirement

The SRP message processing shall be active before the forwarding of AVTPDU in an AVB bridge is activated.

Object Identifier: AE_AVB_0316

Objekttyp: Requirement

In order to prevent unexpected dynamic changes of the VLAN configuration, MVRP and MIRP shall not be used in SRP implementations.

Object Identifier: AE_AVB_0317

Objekttyp: Information

[AE_AVB_0316] applies for SRP implementations in endpoints and bridges, i.e., an SRP implementation shall not send MVRP or MIRP frames and shall ignore MVRP or MIRP frames upon reception.

Object Identifier: AE_AVB_0380

Objekttyp: Requirement

MMRP shall not be used for registration of unicast MAC addresses.

Object Identifier: AE_AVB_0068

Objekttyp: Requirement

In accordance with [IEEE 802.1Q-2018], different multicast streams must use unique multicast addresses.

Object Identifier: AE_AVB_0063

Objekttyp: Information

In typical non-automotive Ethernet AVB networks, the multicast MAC addresses of AVB streams are assigned via the MAC Address Acquisition Protocol (MAAP) as specified in [IEEE 1722-2016, Annex B].

Object Identifier: AE_AVB_0064

Objekttyp: Information

According to [IEEE 1722-2016], MAAP may choose multicast MAC addresses from the range 91-E0-F0-00-FE-00 through 91-E0-F0-00-FE-FF for AVB traffic.

Object Identifier: AE_AVB_0065

Objekttyp: Information

Due to the protocol sub-structure of MAAP and the involved state machines, MAAP is considered hard to implement and test.

Object Identifier: AE_AVB_0066

Objekttyp: Requirement

MAAP as defined in [IEEE 1722-2016] shall not be used.

Object Identifier: AE_AVB_0067

Objekttyp: Requirement

If ARL conflicts cannot be resolved by other means, the talkers' management entities shall check for ARL conflicts before communicating the Group Address of a certain AVB stream by requesting/probing a multicast MAC Address from the range defined in [AE_AVB_0064] from the central Switch that does not lead to unresolvable ARL conflict with existing entries in the ARL table.

Object Identifier: AE_AVB_0073

Objekttyp: Requirement

For (dynamic) streams handled by the audio/video management entity, the management entity shall assign and propagate the selected multicast MAC addresses of a stream via the respective stream reservation method, if not already implicitly clear for the listener by its request.

Note: A change of the requested groupMAC upon re-selection after an ARL conflict resolution (see [AE_AVB_0067]) would require such information in the method response.

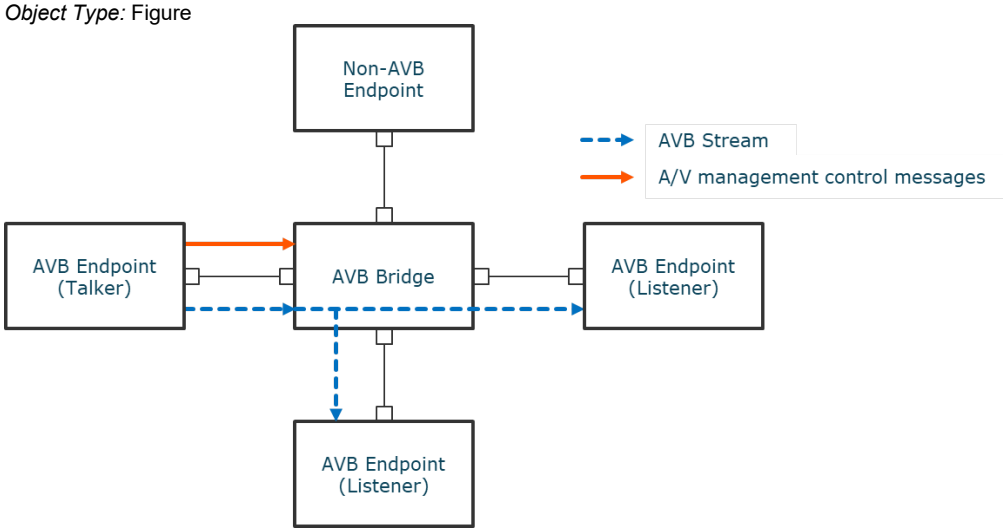
Object Identifier: AE_AVB_0166

Objekttyp: Requirement

An AVB listener of multiple AVB streams shall be able to receive streams with different destination MAC addresses.

Object Identifier: AE_AVB_0391

Object Type: Figure



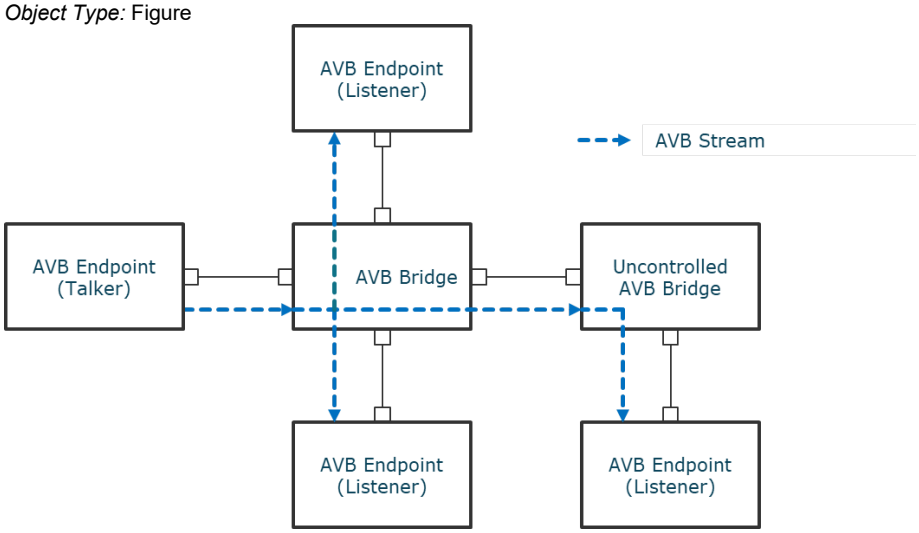
Object Identifier: AE_AVB_0392

Object Type: Caption

Figure [AE_AVB_0391]: *AVB stream scenario with single AVB bridge controlled by the talker implementing the GroupMacControl service interface*

Object Identifier: AE_AVB_0393

Object Type: Figure



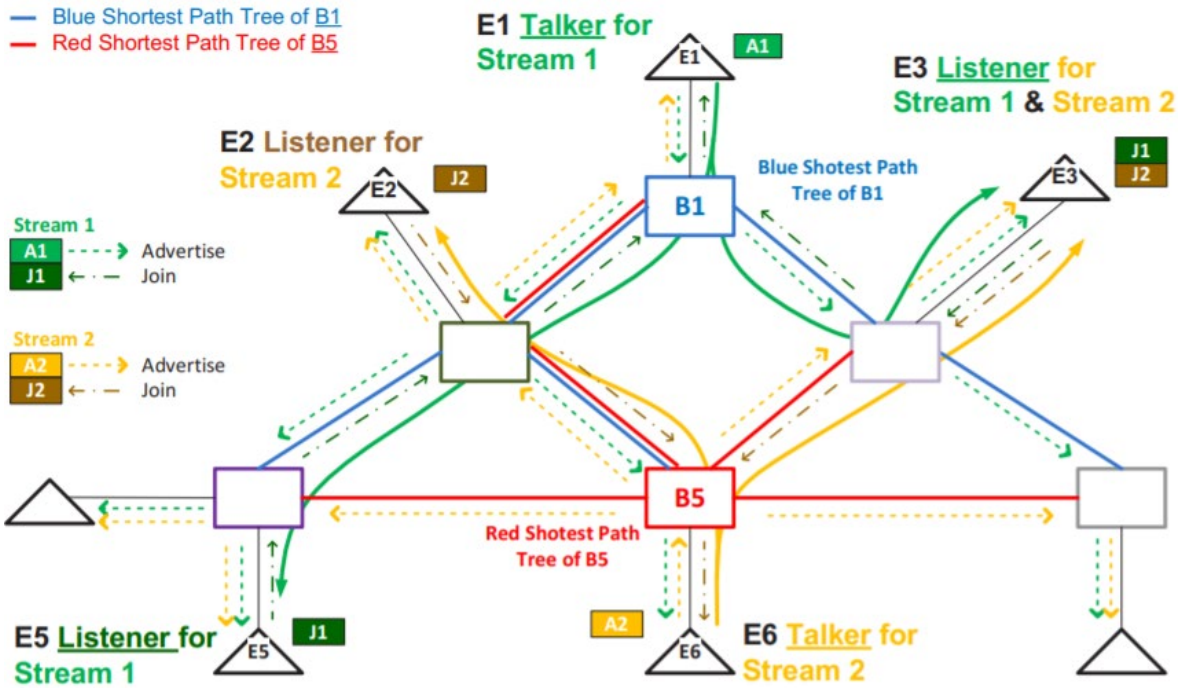
Object Identifier: AE_AVB_0394

Object Type: Caption

Figure [AE_AVB_0393]: *AVB stream scenario with a controlled AVB bridge and single network path connecting only one listener through a bridge that needs no centralized management*

Object Identifier: AE_AVB_0395

Object Type: Figure



Object Identifier: AE_AVB_0396

Object Type: Caption

Figure [AE_AVB_0395]: *General AVB stream scenario with multiple switches and multiple listeners (taken from https://link.springer.com/content/pdf/10.1007/978-3-662-59895-5_1.pdf)*

Object Identifier: AE_AVB_0074

Object Type: Heading

6 IEEE 1722 Audio Video Transport Protocol (AVTP)

Object Identifier: AE_AVB_0089

Object Type: Heading

6.1 General AVTP requirements

Object Identifier: AE_AVB_0075

Objekttyp: Requirement

AVB data shall be transported via Audio Video Transport Protocol (AVTP) as specified in [IEEE 1722-2016].

Object Identifier: AE_AVB_0106

Objekttyp: Requirement

A talker and/or listener of an AVB stream shall be configurable to act as a CRF talker and listener as defined in [AE_AVB_0096].

Object Identifier: AE_AVB_0107

Objekttyp: Requirement

The CRF role as talker or listener shall be configurable without code change.

Object Identifier: AE_AVB_0129

Objekttyp: Requirement

An ECU in an AVB network shall be capable of performing both talker and/or listener roles that may be assigned to it according to [AE_AVB_0128] and stream the respective media.

Object Identifier: AE_AVB_0078

Objekttyp: Requirement

An AVB audio talker shall support an audio sample rate of 24 kHz, 44.1 kHz and 48 kHz in its AVB audio stream.

Object Identifier: AE_AVB_0122

Objekttyp: Requirement

Regardless the supported sampling rates an audio talker with an implemented audio source shall be able to perform sample rate conversion for the audio source.

Object Identifier: AE_AVB_0085

Objekttyp: Requirement

A talker shall populate the stream_id field of AVTP frames in accordance with [IEEE 1722-2016, 4.4.4.8].

Object Identifier: AE_AVB_0086

Objekttyp: Information

The 64-bit stream_id field according to [AE_AVB_0085] consists of the 48-bit MAC address that is associated with the stream, followed by a 16-bit Unique ID.

Object Identifier: AE_AVB_0087

Objekttyp: Requirement

The MAC address segment of the stream_id according to [AE_AVB_0086] shall be set to the multicast MAC address assigned to the particular AVB stream.

Object Identifier: AE_AVB_0088

Objekttyp: Requirement

The Unique ID in [AE_AVB_0086] shall be set to the stream ID that is provided by the management entity.

Object Identifier: AE_AVB_0099

Objekttyp: Requirement

The AVTPDU alternative header described in chapter “4.4.6 AVTPDU alternative header” of [IEEE 1722-2016] shall not be used.

Object Identifier: AE_AVB_0149

Object Type: Heading

6.2 Media clock recovery

Object Identifier: AE_AVB_0138

Objekttyp: Information

Time synchronization through [IEEE 802.1AS-2020] allows distribution of a global time over an entire AVB network, but media applications typically record samples based on local media clocks that are independent and not directly synchronized with the remaining network and thus with the recipients of the media streams and their media clocks.

Object Identifier: AE_AVB_0150

Objekttyp: Information

The main problem of different media clocks in media talkers and listeners lies in the clock drift and frequency offset, i.e., differences of the clock rates that will lead to buffer underruns or overflows at the listener after some time if the clocks are not properly syntonized.

Object Identifier: AE_AVB_0151

Objekttyp: Information

Additionally, in situations where one talker transmits a stream to multiple listeners or multiple talkers transmit corresponding streams to one listener, unsynchronized media clocks might lead to perceivable offsets besides buffer-over/underruns etc.

Object Identifier: AE_AVB_0152

Objekttyp: Requirement

To mitigate the problems described in [AE_AVB_0150] and [AE_AVB_0151], AVB media streams utilize the avtp_timestamp (frequently referred to as presentation timestamp) field in AVTPDUs as described in [IEEE 1722-2016] that basically describes a point in time when the samples that are contained in the AVTPDU shall be presented to the application layer, measured in global PTP time.

Object Identifier: AE_AVB_0159

Objekttyp: Information

The presentation time is not to be confused with the playback time, i.e., with the time when a media sample is actually perceivable by a customer. It is rather affiliated with the instance in time when media samples have to be delivered to the media application.

Object Identifier: AE_AVB_0160

Objekttyp: Information

Different listeners of an AVB media stream may have different signal processing latencies in their higher layer media applications after the AVTP stack has presented the media samples.

Object Identifier: AE_AVB_0161

Objekttyp: Information

In order to achieve absolute synchronicity among multiple AVB listeners of the same stream, different signal processing latencies in the particular listeners might require additional adjustable delay compensation and buffering in some AVB listeners. This has to be considered in system design, implementation and integration processes of higher layer applications that are outside of the scope of this document.

Object Identifier: AE_AVB_0162

Objekttyp: Information

[AE_AVB_0161] also applies for use cases where multiple different streams need to be synchronized at a compound listener, e.g., in case of lip sync multimedia applications where the processing of separated audio and of video signals will have significantly different latencies.

Object Identifier: AE_AVB_0153

Objekttyp: Information

To guarantee that an AVTPDU has arrived at the listener in time such that the avtp_timestamp has not yet passed, the timestamp needs to lie sufficiently far in the future.

Object Identifier: AE_AVB_0154

Objekttyp: Information

According to [IEEE 1722-2016], the avtp_timestamp is equal to the point in time measured in global PTP time of when a designated sample contained in the AVTPDU was recorded plus the Max Transit Time TT_{max} (frequently referred to as presentation time offset).

Object Identifier: AE_AVB_0155

Objekttyp: Information

The Max Transit Time TT_{max} is basically a time interval that is considered to be the worst-case duration between the sampling time and the guaranteed time when the sample can be available to be presented to the application layer, including an individually chosen margin.

Object Identifier: AE_AVB_0137

Objekttyp: Requirement

The Max Transit Time TT_{max} shall be configurable per stream.

Object Identifier: AE_AVB_0293

Objekttyp: Requirement

Unless otherwise specified, the Max Transit Time TT_{max} shall be set to the default value of 2200 ms for topologies with only 2 hops and 4200 ms for those with 2-3 hops.

Object Identifier: AE_AVB_0156

Objekttyp: Requirement

A listener of an AVB media stream shall perform media clock recovery and lock its media clock based on the timestamps contained in the avtp_timestamp field and the media format of the particular media stream.

Object Identifier: AE_AVB_0157

Objekttyp: Information

Rate syntonization of the media clock as implied in [AE_AVB_0156], needs at least two AVTPDUs with valid timestamps, i.e., with the timestamp valid (tv) field set to 1 and the timestamp uncertain (tu) field set to 0.

Object Identifier: AE_AVB_0158

Objekttyp: Requirement

[AE_AVB_0156] implies that media sampling shall proceed based on the most recently locked media clock.

Object Identifier: AE_AVB_0112

Objekttyp: Requirement

Whenever an AVB talker is synchronized to the IEEE 802.1AS wall clock, the avtp_timestamp shall always contain a valid PTP presentation timestamp.

Object Identifier: AE_AVB_0167

Objekttyp: Requirement

[AE_AVB_0112] implies that the timestamp valid (tv) field shall be set to 1 in these AVTPDUs.

Object Identifier: AE_AVB_0113

Objekttyp: Requirement

In absence of an IEEE 802.1AS wall clock, an AVB talker may populate the avtp_timestamp with a value derived from its local clock if and only if there is only one sink for the according AVB stream.

Object Identifier: AE_AVB_0388

Objekttyp: Requirement

If the feature described in [AE_AVB_0113] is used, the functional owners for both the talker and the listener must agree on it.

Object Identifier: AE_AVB_0168

Objekttyp: Requirement

In absence of an IEEE 802.1AS wall clock, an AVB listener shall be allowed to decode the avtp_timestamp based on estimations from its local clock.

Object Identifier: AE_AVB_0114

Objekttyp: Requirement

A temporary discontinuity of less than T_DISCONT in the IEEE 802.1AS clock of an audio AVB talker or listener shall not lead to perceivable glitches or cracklings in the audio playback.

Object Identifier: AE_AVB_0115

Objekttyp: Requirement

To help accomplishing [AE_AVB_0114], an audio AVB talker shall make use of the timestamp uncertain (tu) field in affected AVB frames when a discontinuity in the wall clock has been detected.

Object Identifier: AE_AVB_0169

Objekttyp: Requirement

When an audio AVB listener receives audio frames with the timestamp uncertain (tu) field set to 1, it shall ignore the media clock recovery data in the avtp_timestamp field and stop adjusting the media clock and allow the media clock to free-wheel with the most recent media clock recovery adjustments.

Object Identifier: AE_AVB_0170

Objekttyp: Requirement

As soon as the tu bit is reset to 0 after the situation described in [AE_AVB_0169], media clock recovery shall resume and adjust for any clock wander that has occurred since adjustments were suspended with a smooth transition such that the perceivable disruption to the stream is minimized.

Object Identifier: AE_AVB_0296

Objekttyp: Requirement

When a change in the source of the media clock of an AVB stream has occurred, an AVB talker shall make use of the mr (media clock restart) field as described in [IEEE 1722-2016, 4.4.4.3] to indicate this change.

Object Identifier: AE_AVB_0297

Objekttyp: Requirement

When an AVB listener of a media stream receives an AVTPDU with the mr field indicating a change in the source of the media clock as described in [IEEE 1722-2016, 4.4.4.3], it shall adjust its media clock quickly in order to minimize the perceivable disruption to the stream.

Object Identifier: AE_AVB_0298

Objekttyp: Requirement

[AE_AVB_0296] and [AE_AVB_0297] apply for talkers and listeners of media streams and of CRF streams.

Object Identifier: AE_AVB_0139

Objekttyp: Information

In addition to the synchronization of the media clock from an AVB talker to any number of listeners, there may be use cases that also require synchronizing in the opposite direction, i.e., from an AVB listener (or even from an uninvolved ECU) to any number of talkers. In other words, the points in time when AVB talkers are expected to record a designated sample need to be conveyed, typically in use cases where a listener has to combine/mix multiple corresponding samples that originate from different sources.

Object Identifier: AE_AVB_0140

Objekttyp: Information

To accomplish this, clock reference format (CRF) streams are used for distribution of corresponding timestamps in the crf_data field that define the instants of time in the future when a CRF listener is expected to record a sample.

Object Identifier: AE_AVB_0147

Objekttyp: Requirement

The timestamps contained in the crf_data field shall lie in the future by a period of time that is configurable per CRF stream in a comparable way as the Max Transit Time TT_{max} (cf. AE_AVB_0137).

Object Identifier: AE_AVB_0141

Objekttyp: Requirement

A talker of an AVB media stream receiving a CRF stream whose type, pull and base_frequency fields correspond to the AVB media stream shall lock its media clock in accordance to the timestamps contained in the crf_data field and the timestamp_interval field as specified in [IEEE 1722-2016, 10.4].

Object Identifier: AE_AVB_0148

Objekttyp: Requirement

[AE_AVB_0141] implies that media sampling shall always proceed based on the most recently locked media clock rate even in case that the CRF stream ceases.

Object Identifier: AE_AVB_0171

Objekttyp: Requirement

When an AVB talker and/or listener's media clock is free running, i.e., not synchronized or syntonized, it's actual base frequency shall not exceed the range of ± 100 ppm relative to its nominal base frequency measured in International Atomic Time (TAI).

Object Identifier: AE_AVB_0183

Objekttyp: Information

As a consequence of [AE_AVB_0171], the clock drift between two clocks will never exceed the range of ± 200.1 ppm towards each other (measured w.r.t TAI).

Object Identifier: AE_AVB_0090

Object Type: Heading

6.3 Media format specific requirements

Object Identifier: AE_AVB_0100

Objekttyp: Requirement

Unless explicitly specified otherwise, a talker of an AVB audio stream shall use the AAF media format as defined in [AE_AVB_0093].

Object Identifier: AE_AVB_0101

Objekttyp: Requirement

Unless explicitly specified otherwise, a listener of an AVB audio stream shall be capable of decoding the AAF media format as defined in [AE_AVB_0093].

Object Identifier: AE_AVB_0108

Objekttyp: Requirement

Support of the IEC 61883/IIDC format as defined in [AE_AVB_0091] or of the MMA format as defined in [AE_AVB_0092] are only mandatory for an AVB audio talker and/or listener if explicitly required.

Object Identifier: AE_AVB_0102

Objekttyp: Requirement

Unless explicitly specified otherwise, a talker of an AVB video stream shall use the CVF media format as defined in [AE_AVB_0094].

Object Identifier: AE_AVB_0103

Objekttyp: Requirement

Unless explicitly specified otherwise, a listener of an AVB video stream shall be capable of decoding the CVF media format as defined in [AE_AVB_0094].

Object Identifier: AE_AVB_0104

Objekttyp: Requirement

Unless explicitly specified otherwise, a talker of a non-audio, non-video AVB stream shall use the ACF media format as defined in [AE_AVB_0095].

Object Identifier: AE_AVB_0105

Objekttyp: Requirement

Unless explicitly specified otherwise, a listener of a non-audio, non-video AVB stream shall be capable of decoding the ACF media format as defined in [AE_AVB_0095].

Object Identifier: AE_AVB_0091

Objekttyp: Heading

6.3.1 IEC 61883/IIDC format specific requirements

Object Identifier: AE_AVB_0104

Objekttyp: Information

The IEC 61883/IIDC format is currently not considered a typical use case.

Object Identifier: AE_AVB_0109

Objekttyp: Requirement

If the IEC 61883/IIDC format is explicitly required, the gv (gateway_info valid) field shall be set to zero as streams are not to be terminated outside of the domain.

Object Identifier: AE_AVB_0092

Objekttyp: Heading

6.3.2 MMA format specific AVTP requirements

Object Identifier: AE_AVB_0105

Objekttyp: Information

The MMA format is currently not considered a typical use case.

Object Identifier: AE_AVB_0093

Objekttyp: Heading

6.3.3 AAF specific AVTP requirements

Object Identifier: AE_AVB_0123

Objekttyp: Requirement

AAF frames shall be assigned to SR class A or SR class B according to AE_AVB_523.

Object Identifier: AE_AVB_0084

Objekttyp: Informational

In sparse timestamping mode of AAF streams according to [IEEE 1722-2016, 7.2.4], the AVTP presentation time is only valid in every eighth AVTP frame of a stream.

Object Identifier: AE_AVB_0081

Objekttyp: Requirement

AVB talkers shall not use sparse timestamping mode according to [IEEE 1722-2016, 7.2.4] in AAF streams.

Object Identifier: AE_AVB_0082

Objekttyp: Requirement

[AE_AVB_0081] implies that the sparse timestamp (sp) field shall never be set to true in an AAF frame.

Object Identifier: AE_AVB_0083

Objekttyp: Requirement

A listener of an AAF stream shall support both normal and sparse timestamping.

Object Identifier: AE_AVB_0117

Objekttyp: Information

The sample format is conveyed in the format field in the AAF header as specified in [IEEE 1722-2016, 7.2.].

Object Identifier: AE_AVB_0118

Objekttyp: Information

The sample format-specific parameters are conveyed in the format-specific data fields in the AAF header as specified in [IEEE 1722-2016, 7.2].

Object Identifier: AE_AVB_0119

Objekttyp: Requirement

An AAF talker shall not use the event (evt) field in AAF streams, unless explicitly required.

Object Identifier: AE_AVB_0094

Objekttyp: Heading

6.3.4 CVF specific AVTP requirements

Object Identifier: AE_AVB_0126

Objekttyp: Requirement

CVF frames shall be assigned to SR traffic class B.

Object Identifier: AE_AVB_0163

Objekttyp: Requirement

A CVF talker shall not use the event (evt) field in CVF streams, unless explicitly required.

Object Identifier: AE_AVB_0095

Objekttyp: Heading

6.3.5 ACF specific AVTP requirements

Object Identifier: AE_AVB_0130

Objekttyp: Information

The purposes of ACF streams can be very versatile and use cases may be highly time-critical or not time-critical at all.

Object Identifier: AE_AVB_0121

Objekttyp: Information

If the ACF format is required for particular use cases, association of ACF frames with traffic classes cannot be defined universally.

Object Identifier: AE_AVB_0120

Objekttyp: Information

[IEEE 1722-2016] allows transmission of ACF traffic as best-effort traffic instead of SR traffic.

Object Identifier: AE_AVB_0131

Objekttyp: Requirement

A talker of a time-critical ACF stream shall use the Time-Synchronous Control Format according to [IEEE 1722-2016, 9.3] in the particular ACF streams.

Object Identifier: AE_AVB_0135

Objekttyp: Requirement

A listener of a time-critical ACF stream shall be capable of decoding the Time-Synchronous Control Format according to [IEEE 1722-2016, 9.3] in the particular ACF streams.

Object Identifier: AE_AVB_0132

Objekttyp: Information

The applicability of [AE_AVB_0131] is independent of any underlying timing requirements for the particular ACF stream.

Object Identifier: AE_AVB_0133

Objekttyp: Requirement

Unless specified further, a talker of a time-uncritical ACF stream shall use the Time-Synchronous Control Format according to [IEEE 1722-2016, 9.3] or the Non-Time-Synchronous Control Format according to [IEEE 1722-2016, 9.2] in the particular ACF streams.

Object Identifier: AE_AVB_0134

Objekttyp: Requirement

Unless specified further, a listener of a time-uncritical ACF stream shall be capable of decoding both the Time-Synchronous Control Format and the Non-Time-Synchronous Control Format.

Object Identifier: AE_AVB_0295

Objekttyp: Requirement

Data shall be serialized and encapsulated in the ACF payload as defined in the communication database.

Object Identifier: AE_AVB_0096

Objekttyp: Heading

6.3.6 CRF specific AVTP requirements

Object Identifier: AE_AVB_0136

Objekttyp: Requirement

CRF frames shall be assigned to SR class B.

Object Identifier: AE_AVB_0142

Objekttyp: Information

[IEEE 1722-2016, 10.5] states recommendations for the CRF transmission rates for different audio and video stream formats.

Object Identifier: AE_AVB_0143

Objekttyp: Requirement

For each CRF stream, a CRF talker shall transmit at least as many timestamps per second as recommended in [IEEE 1722-2016, 10.5].

Object Identifier: AE_AVB_0144

Objekttyp: Requirement

For each CRF stream, a CRF talker shall transmit at least as many CRF AVTPDUs per second as recommended in [IEEE 1722-2016, 10.5].

Object Identifier: AE_AVB_0146

Objekttyp: Requirement
The number of timestamps per CRF AVTPDU shall stay constant for every CRF stream.

Object Identifier: AE_AVB_0329

Object Type: Heading

7 Testing and verifying function and reliability of the development object

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Object Identifier: AE_AVB_0330

Object Type: Heading

7.1 General testing requirements

Object Identifier: AE_AVB_0332

Object Type: Requirement

Testing of any AVB functionality of an ECU shall be performed in the authority of its manufacturer.

Object Identifier: AE_AVB_0334

Object Type: Requirement

Test equipment that is used for timestamping measurements shall provide timestamping accuracy that is compliant with the requirements that are placed on ECUs in an AVB system.

Object Identifier: AE_AVB_0335

Object Type: Information

Testing of timestamping accuracy has to consider measurement inaccuracy induced by the test equipment.

Object Identifier: AE_AVB_0336

Object Type: Requirement

Calculations regarding testing of timestamping accuracy shall be based on timestamps captured at a test station that are all referencing to the same common time base and time plane on all ports.

Object Identifier: AE_AVB_0381

Object Type: Requirement

If a test station’s timestamping mechanisms does not provide timestamps for all links in the same time base, timestamps must be synthetically converted into one common time base to fulfill [AE_AVB_0336].

Object Identifier: AE_AVB_0382

Object Type: Information

A typical situation where timestamp conversion as described in [AE_AVB_0381] is necessary due to a time base mismatch is a test setup that includes two or more capture components with individual, independent timestamping clocks that are not synchronized. In such setups, the timestamping of frames captured with different timestamping clocks do not reference to a common time base.

Object Identifier: AE_AVB_0383

Object Type: Information

A typical situation where some kind of timestamp correction is necessary due to a time plane mismatch is the use of in-line spy devices that only support ingress timestamping, but not egress timestamping. The timestamps of incoming and outgoing frames from the test stations reference therefore to a common time base, but not a common time plane.

Object Identifier: AE_AVB_0384

Object Type: Information

There are various test scenarios and setups that require timestamp conversion as described in [AE_AVB_0381], including variations and combinations of the situations described in [AE_AVB_0382] and [AE_AVB_0383]. Therefore, a universally valid description of the timestamp conversion procedure is hardly feasible. Sometimes, one can utilize appropriate time tuples that are derived from a common reference event to convert from one time base to another.

Object Identifier: AE_AVB_0385

Object Type: Requirement

As a consequence of [AE_AVB_0384], the test personnel shall ensure the alignment of capture timestamps at a test station to a common time base and a common time plane for every particular test scenario and test setup individually.

Object Identifier: AE_AVB_0331

Object Type: Heading

7.2 IEEE 802.1AS testing

Object Identifier: AE_AVB_0091

Objekttyp: Heading

7.2.1 Time synchronization timestamp testing

Object Identifier: AE_AVB_0325

Object Type: Requirement

Testing of [IEEE 802.1AS] functionality shall include analyzation of timestamping accuracy for time synchronization with Sync/Follow_Up messages for all time synchronization master ports, i.e., for all grandmaster ECU master ports and for all master ports of an AVB bridge.

Object Identifier: AE_AVB_0333

Object Type: Requirement

Testing of timestamping accuracy of Sync/Follow_Up messages at an AVB bridge shall verify if the correctionField value in a Follow_Up message received from one of the bridge's master ports corresponds with the measured time between sending the corresponding Sync message to the bridge's slave port and receiving the Sync message from the same master port.

Object Identifier: AE_AVB_0337

Object Type: Requirement

Testing of timestamping accuracy of Sync/Follow_Up messages at a time synchronization grandmaster shall verify the linear progression of time and the synchronism between all master ports.

Object Identifier: AE_AVB_0338

Object Type: Information

The linear progression of time of a grandmaster's Sync/Follow_Up messages on one particular port can be verified by comparing the difference of the preciseOriginTimestamp values of two Follow_Up frames with the measured time between the two corresponding Sync messages at the test station. These two time deltas need rate conversion to the same time base by multiplication with the rate ratio between the PTP clock and the test station's capture timestamping clock.

Object Identifier: AE_AVB_0343

Object Type: Information

The rateRatio between the PTP clock and the test station's timestamping clock can be estimated with the following equation:

$$\text{rateRatio}[i+1] = \alpha \cdot \frac{\text{correctionField}[i+1] - \text{correctionField}[i]}{\text{captureTimestamp}[i+1] - \text{captureTimestamp}[i]} + (1 - \alpha) \cdot \text{rateRatio}[i] \ ,$$

where correctionField[i] is the correctionField value in the i-th Follow_Up messages of the measurement, respectively,

captureTimestamp[i] is the capture timestamps of the corresponding Sync messages measured at the test station, and

α is the weight of the exponentially weighted moving average which shall be set to 0.2.

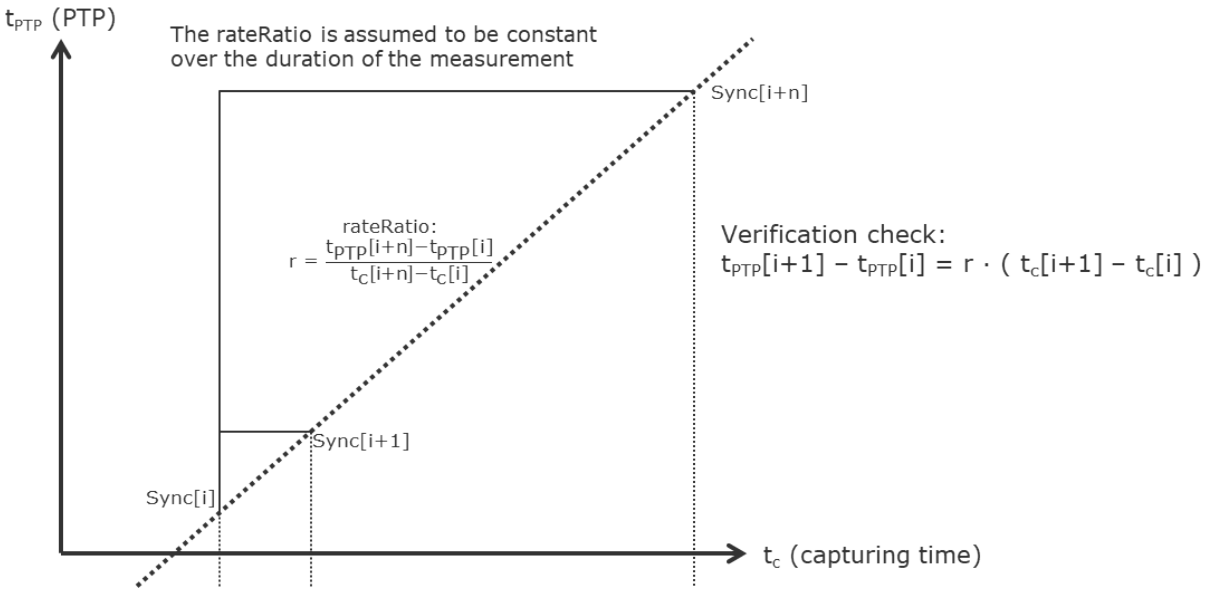
Object Identifier: AE_AVB_0342

Object Type: Information

The verification method described in [AE_AVB_0338] and [AE_AVB_0343] is illustrated in figure [AE_AVB_0339].

Object Identifier: AE_AVB_0339

Object Type: Figure



Object Identifier: AE_AVB_0340

Object Type: Caption

Figure [AE_AVB_0339]: *Verification of the linear progression of time at one grandmaster port*

Object Identifier: AE_AVB_0341

Object Type: Information

The synchronism between any two grandmaster ports can be verified by comparing the difference of the preciseOriginTimestamp values of two Follow_Up frames from two different ports with the measured time between the two corresponding Sync messages at the test station. These two deltas need rate conversion to the same time base by multiplication with the rateRatio between the PTP clock and the test station's capture timestamping clock.

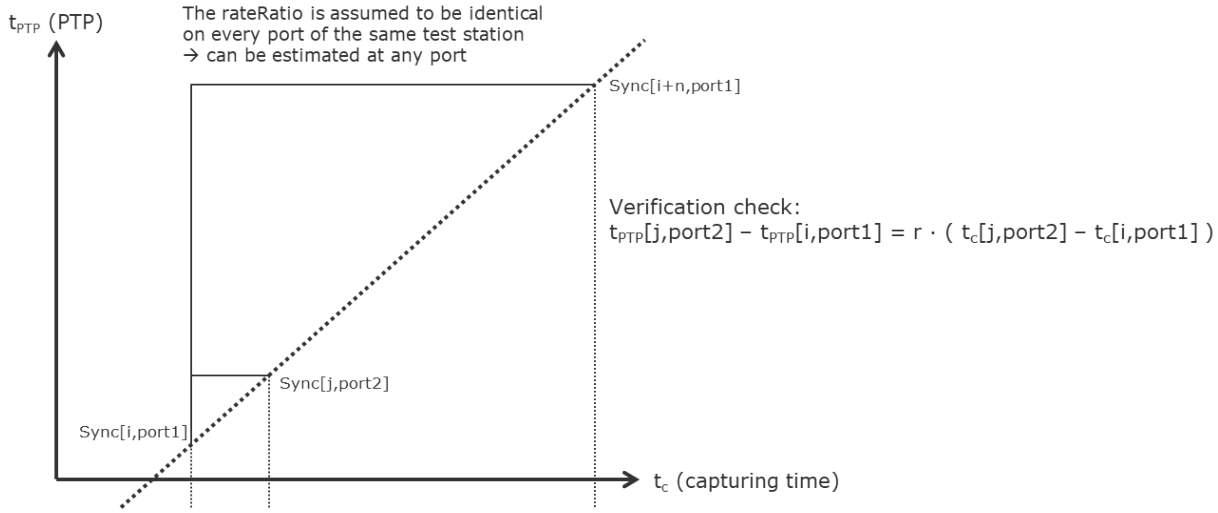
Object Identifier: AE_AVB_0344

Object Type: Information

The verification method described in [AE_AVB_0341] is illustrated in figure [AE_AVB_0345].

Object Identifier: AE_AVB_0345

Object Type: Figure



Object Identifier: AE_AVB_0346

Object Type: Caption

Figure [AE_AVB_0345]: *Verification of synchronism between two grandmaster ports*

Object Identifier: AE_AVB_0347

Objekttyp: Heading

7.2.2 Pdelay timestamp testing

Object Identifier: AE_AVB_0326

Object Type: Requirement

Testing of [IEEE 802.1AS] functionality shall include analyzation of timestamping accuracy for Pdelay measurement for all time-aware ports.

Object Identifier: AE_AVB_0327

Object Type: Requirement

[AE_AVB_0326] explicitly applies also for time synchronization slave ports although they are not expected to receive Pdelay_Req messages during normal operation.

Object Identifier: AE_AVB_0328

Object Type: Requirement

[AE_AVB_0327] implies that slave ports are required to correctly respond to Pdelay_Req messages.

Object Identifier: AE_AVB_0348

Object Type: Information

The timestamping accuracy of Pdelay_Resp and Pdelay_Resp_Follow_Up messages can be verified by comparing the difference of the RequestReceiptTimestamp of a Pdelay_Resp message and the ResponseOriginTimestamp of the corresponding Pdelay_Resp_Follow_Up message with the measured time at the test station between transmission of the Pdelay_Req message and reception of the Pdelay_Resp message at the test station. These two deltas need rate conversion to the same time base by multiplication with the rateRatio between the Pdelay timestamping clock and the test station's capture timestamping clock.

The difference between the two time deltas is expected to correspond with twice the latency of the cable and, if necessary, of intermediate measurement equipment.

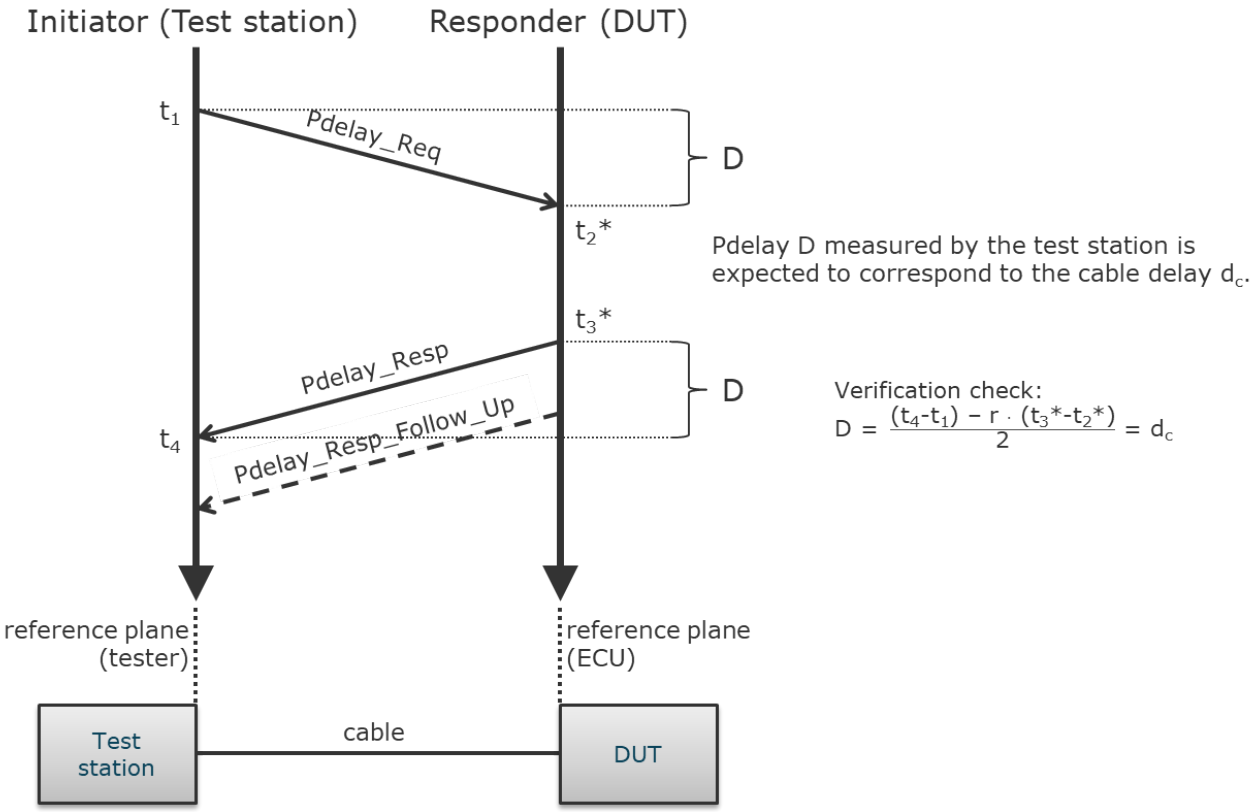
Object Identifier: AE_AVB_0349

Object Type: Information

The verification method described in [AE_AVB_0348] is illustrated in figure [AE_AVB_0350].

Object Identifier: AE_AVB_0350

Object Type: Figure



Object Identifier: AE_AVB_0351

Object Type: Caption

Figure [AE_AVB_0350]: *Verification of Pdelay timestamping accuracy*

Object Identifier: AE_AVB_0352

Object Type: Information

The rateRatio between the Pdelay timestamping clock and the test station's timestamping clock can be estimated with the following equation:

$$\text{rateRatio} = \frac{\text{requestReceiptTimestamp[i+n]-requestReceiptTimestamp[i]}}{\text{captureTimestamp[i+n]-captureTimestamp[i]}},$$

where requestReceiptTimestamp[i] and requestReceiptTimestamp [i+n] are the requestReceiptTimestamp values in the first and last Pdelay_Resp messages of the measurement, respectively, and

captureTimestamp[i] and captureTimestamp[i+n] are the transmission timestamps of the corresponding Pdelay_Req messages measured at the test station.

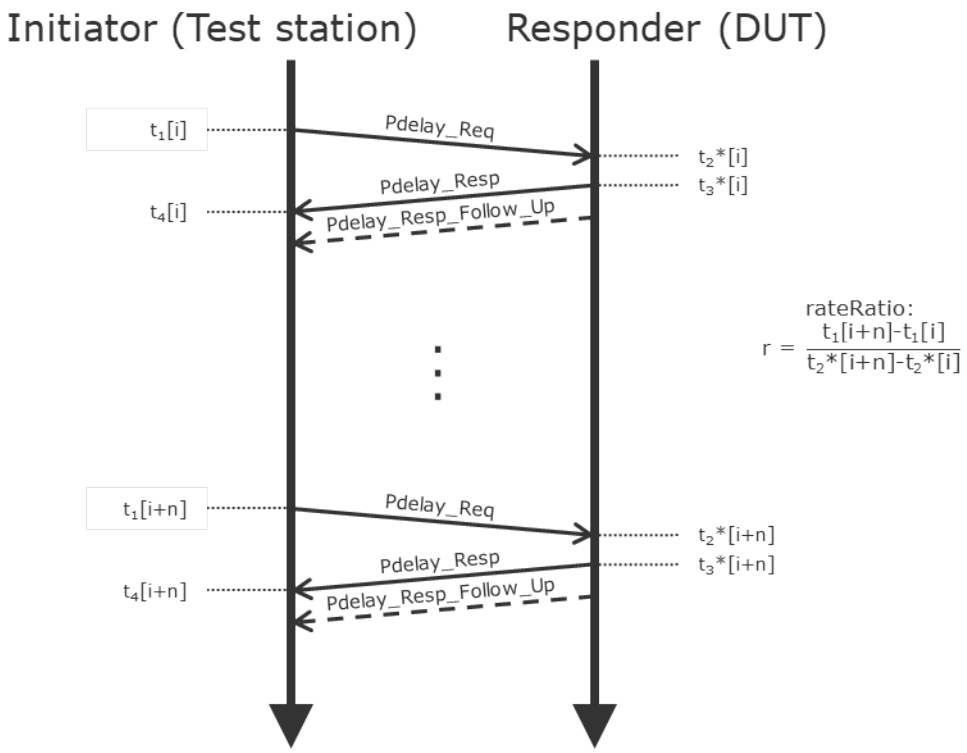
Object Identifier: AE_AVB_0353

Object Type: Information

The method for estimating the rateRatio between the Pdelay timestamping clock and the test station's timestamping clock described in [AE_AVB_0352] is illustrated in figure [AE_AVB_0354].

Object Identifier: AE_AVB_0354

Object Type: Figure



Object Identifier: AE_AVB_0355

Object Type: Caption

Figure [AE_AVB_0354]: *Estimation of the rateRatio between the Pdelay timestamping clock and the test station's timestamping clock for Pdelay Responders*

Object Identifier: AE_AVB_0402

Object Type: Information

The method described in [AE_AVB_0352] through [AE_AVB_0354] for estimating the rateRatio between the clocks of a device under test and of a tester assumes the calculation in the tester's time base; therefore, it differs from the rateRatio calculation method described in 11.2.19.3.3 of [IEEE 802.1AS-2020].

Object Identifier: AE_AVB_0356

Object Type: Heading

7.3 IEEE 1722 avtp_timestamping testing

Object Identifier: AE_AVB_0357

Object Type: Requirement

Testing of [IEEE 1722] functionality shall include analysis of timestamping plausibility for non-zero avtp_timestamps of AVB streams.

Object Identifier: AE_AVB_0358

Object Type: Information

Based on the AVTPDU's ingress timestamp in PTP time at the test station, the plausibility of avtp_timestamps can be verified by reversely analyzing if the avtp_timestamp is within the range of the earliest possible sampling time plus Max Transit Time (MTT) and the latest possible sampling time plus MTT.

Object Identifier: AE_AVB_0399

Object Type: Information

For a precise plausibilization of an avtp_timestamp value according to [AE_AVB_0358], multiple delay values along the entire path of the stream would be required, e.g., internal delays in switches, cable delays, maximum and minimum transit times. During development and integration phases, these delays are usually hard to obtain, and they contribute only a small amount to the precision and relevance of the plausibility evaluation.

Object Identifier: AE_AVB_0400

Object Type: Information

The expectable effort and the neglectable impact of detailed delay values as described in [AE_AVB_0399] justifies a simplified method for the avtp_timestamp plausibility evaluation.

Object Identifier: AE_AVB_0359

Object Type: Information

As an approximation for the minimum possible delay of an AVB packet, a value of 0 is assumed.

Object Identifier: AE_AVB_0360

Object Type: Information

As an approximation for the maximum delay of an AVB packet, the value of the MTT is assumed.

Object Identifier: AE_AVB_0361

Object Type: Information

When receiving an IEEE 1722 PDU at a point of time $T_{ingress}$, the avtp_timestamp is expected to be bigger than or equal to $t_{PTP}(T_{ingress})$, where $t_{PTP}(T_{ingress})$ is the time $T_{ingress}$ converted into the PTP time.

Object Identifier: AE_AVB_0362

Object Type: Information

When receiving an IEEE 1722 PDU at a point of time t, the avtp_timestamp is expected to be smaller than or equal to $t_{PTP}(T_{ingress})$, where $t_{PTP}(T_{ingress})$ + MTT, where $t_{PTP}(T_{ingress})$ is the time $T_{ingress}$ converted into PTP time.

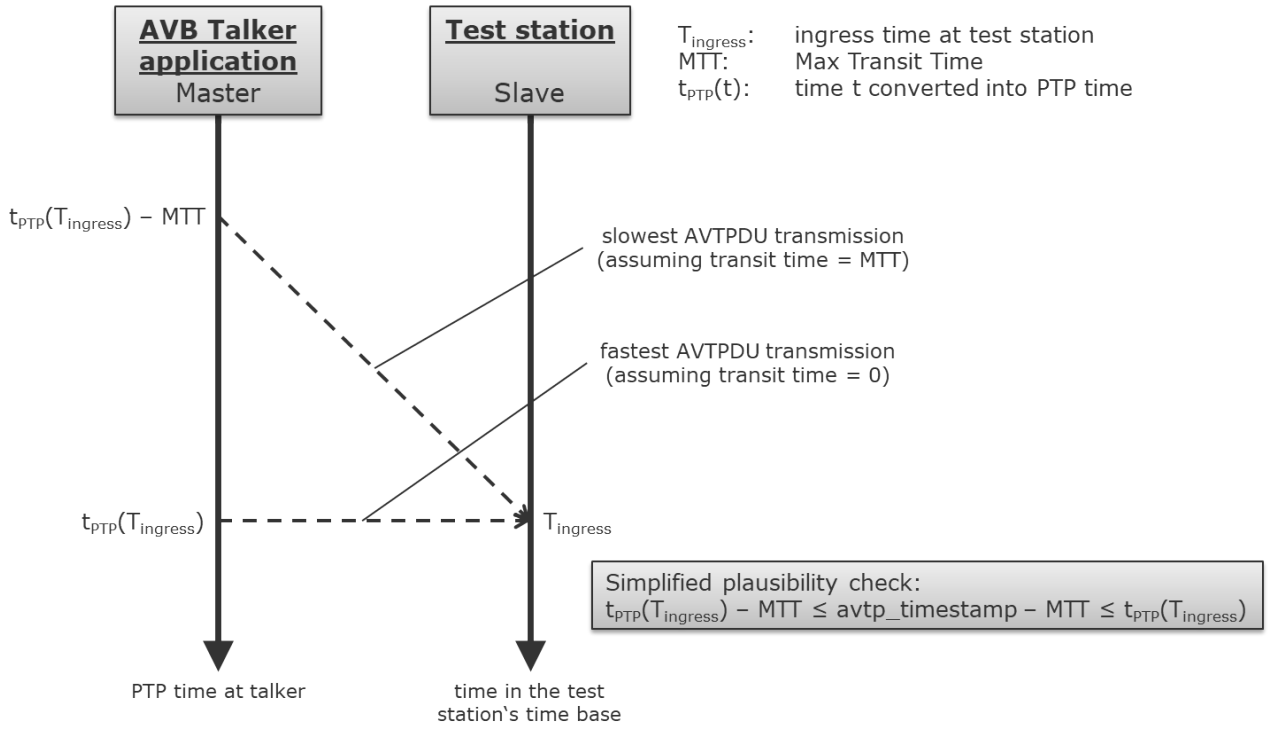
Object Identifier: AE_AVB_0369

Object Type: Information

The method for assessing the avtp_timestamp plausibility described in [AE_AVB_0359] through [AE_AVB_0362] is illustrated in figure [AE_AVB_0370].

Object Identifier: AE_AVB_0370

Object Type: Figure



Object Identifier: AE_AVB_0371

Object Type: Caption

Figure [AE_AVB_0370]: *Assessment of avtp_timestamp plausibility*

Object Identifier: AE_AVB_0372

Object Type: Information

The converted PTP time $t_{PTP}(t^*)$ of a point in time t* that has been timestamped in a capturing clock's time base $t_c(t^*)$ can be derived from two preceding Sync/Follow_Up message pairs with the following equation:

$t_{PTP}(t^*) = t_{PTP}(t_{Sync2}) + r \cdot (t_c(t^*) – t_c(t_{Sync2}))$, where

$t_{PTP}(t_{Sync2})$ is the PTP time corresponding to the last Sync message before t*,

$t_c(t_{Sync2})$ is the timestamp in the capturing clock's time base and

r is the rateRatio between the PTP clock and the test station's capturing clock.

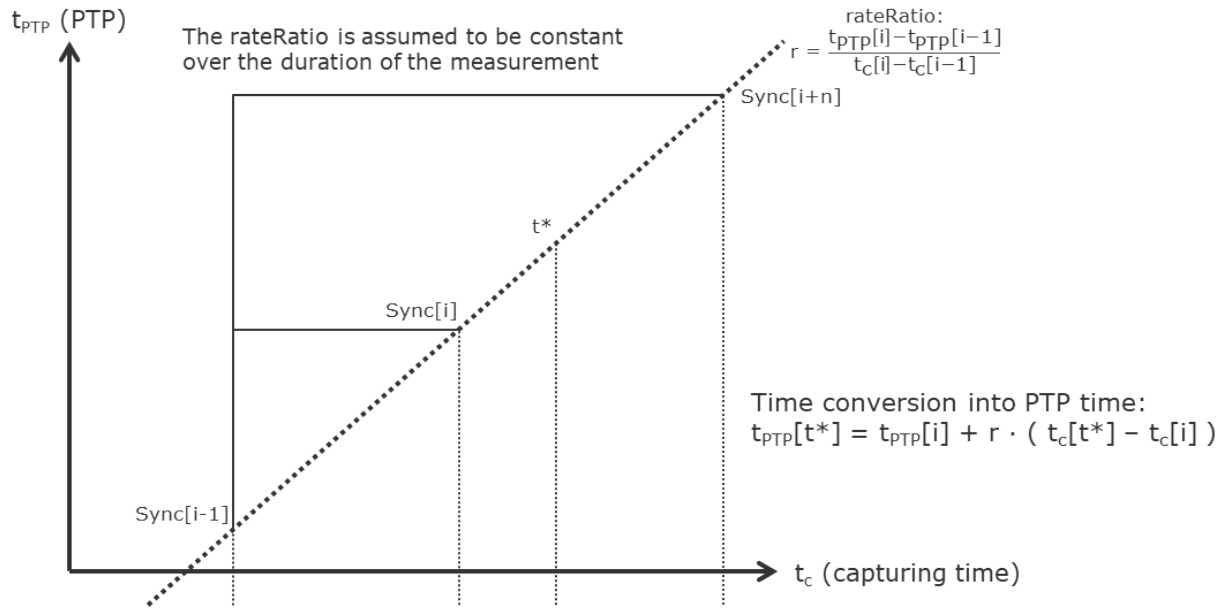
Object Identifier: AE_AVB_0373

Object Type: Information

The method for converting a timestamp from a capturing clock's time base into PTP time as described in [AE_AVB_0372] is illustrated in figure [AE_AVB_0374].

Object Identifier: AE_AVB_0374

Object Type: Figure



Object Identifier: AE_AVB_0375

Object Type: Caption

Figure [AE_AVB_0374]: *Time base conversion from capturing clock time base into PTP time*

Object Identifier: AE_AVB_0376

Object Type: Information

The PTP time $t_{PTP}(t_{Sync2})$ corresponding to the last Sync message before t* used in [AE_AVB_0372] is the sum of the corresponding Follow_Up message's preciseOriginTimestamp, correctionField, and, if the DUT is the time synchronization master, the cable delay between test station and DUT.
