STANDARDS AND INFORMATION DOCUMENTS

AES-R16-2016

AES project report - PTP parameters for AES67 and SMPTE ST 2059-2 interoperability

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Abstract

Three profiles for Precision Time Protocol (PTP) might potentially be used in the professional media environment: the Peer-to-Peer Default PTP Profile of IEEE Std 1588-2008, the Media Profile of AES67 and the SMPTE Profile of SMPTE ST 2059-2. This report compares the profiles and identifies features and parameter ranges that should enable interoperability among equipment conforming to the different profiles.

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2016-05-02 printing

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Foreword

This foreword is not part of the *AES-X226 AES Standards Report - PTP parameters for AES67 and SMPTE ST 2059-2 interoperability*.

This document was developed in project AES-X226 in the SC-02-12-M task group on AES67 development under the leadership of Kevin Gross.

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AES Standards Report - PTP parameters for AES67 and SMPTE ST 2059-2 interoperability

1 Introduction

AES and SMPTE have both specified profiles for IEEE 1588-2008 Precision Time Protocol (PTP) for use in professional media applications; the respective standards being AES67 and SMPTE ST 2059-2. The design goals were somewhat different: the AES standard was aimed at interoperability of some existing networked audio systems and the SMPTE standard at meeting requirements of the EBU/SMPTE Task Force on Timing and Synchronization. Nevertheless, it is clear that there is significant overlap in the application space and that some users will want to use equipment conforming to AES and SMPTE specifications on the same network and in the same PTP domain.

Each standard defines a profile in terms of ranges and recommended default settings for parameters. The requirements of the two standards are not mutually exclusive and this report explores suitable parameter choices for interoperation. The overlapping operating conditions identified in this document are not intended to replace any profile, but rather to identify a common set of parameters and options that satisfy multiple applications.

This document is based on a reading of the two standards and the knowledge that interoperation was a stated development goal for both AES and SMPTE. Further experience with interoperation of these profiles may lead to revisions of this document or one or both of the involved standards.

In this report, a Courier typeface may be used to identify computer code expressions to distinguish them from regular text.

2 Interoperability use-case

The interoperability use-case addressed in this document is as follows:

A user has some equipment that conforms with the IEEE 1588 default profile (as required by AES67), some equipment that conforms with the AES67 Media profile, and some equipment that conforms with the SMPTE ST 2059-2 profile. The user wants to use this equipment in a single PTP domain. What parameter choices will ensure that all the equipment operates correctly?

Equipment that conforms with a particular profile is assumed to implement all required (“shall”) provisions of the profile and to support the full range of attribute values allowed by the profile.

3 Relevant PTP profiles

AES67 specifies that devices shall support IEEE 1588-2008 Default Profiles and should use AES67 Media Profile “PTP profile for media applications” in certain circumstances. SMPTE ST 2059-2 specifies the “SMPTE profile for synchronization in a professional broadcast environment”.

There are four potentially relevant PTP Profiles:

- ***Delay Request-Response* Default** PTP profile, specified in IEEE Std 1588-2008, Annex J, clause J.3
- ***Peer-to-Peer* Default** PTP profile, specified in IEEE Std 1588-2008, Annex J, clause J.4
- **AES Media** Profile, specified in AES67-2015, Annex A
- **SMPTE** Profile, specified in SMPTE ST 2059-2:2015

As explained later, the peer delay mechanism is not required by the **AES Media** or **SMPTE** profiles so the Peer-to-Peer **Default** PTP profile is not considered for the current interoperability use-case.

4 Comparison of PTP profiles

A PTP profile is a set of required options, prohibited options, and the ranges and defaults of configurable attributes. The following sections compare the provisions in the different profiles and recommend options and attribute values that will achieve interoperability.

4.1 Transport

The **AES Media** profile permits only UDP/IPv4. **SMPTE** profile permits UDP/IPv4 and UDP/IPv6.

4.2 Communication model

The **AES Media** profile makes no requirements or restrictions on use of unicast and/or multicast communication models. The **SMPTE** profile is more specific and for **`Announce`**, **`Sync`** and **`Follow_Up`** messages, it requires only multicast although unicast is permitted. For **`Delay_Req`** (and consequently for **`Delay_Resp`**) messages it permits both unicast and multicast.

Unicast transmission may be negotiated (using optional Unicast Negotiation feature) or not. Masters are required to respond to **`Delay_Req`** messages in the same mode in which they are sent; that is, multicast **`Delay_Req`** is responded to with multicast **`Delay_Resp`**, or unicast **`Delay_Req`** with unicast **`Delay_Resp`** (see IEEE 1588-2008 section 9.5.12). This allows unicast **`Delay_Req`** and **`Delay_Resp`** messages to be initiated without using Unicast Negotiation but simply by the slave sending unicast **`Delay_Req`** messages. A "mixed mode" where **`Announce`**, **`Sync`**, **`Follow_Up`** are multicast and **`Delay_Req`**, **`Delay_Resp`** are unicast without negotiation is therefore possible although it has the disadvantage that the Master does not communicate its maximum supported delay request rate to the Slave (further explanation in section 4.8.5).

4.3 Path delay measurement mechanism

The **AES Media** and **SMPTE** profiles specify that the default path-delay measurement mechanism shall be the delay request-response mechanism. The **AES Media** profile says the peer delay mechanism should be supported and the **SMPTE** profile says it may be supported. In other words, neither AES nor SMPTE require support for the peer delay mechanism. Equipment designers should be aware that the peer delay mechanism may be advantageous for some applications, so they should give due consideration to supporting this optional mechanism.

4.4 Optional features

The **AES Media** profile makes no requirements or restrictions on optional features. The **SMPTE** profile makes no requirements although it does prohibit Grandmaster clusters and Unicast discovery.

4.5 TLV specifications

The **AES Media** and **Default** profiles do not specify any additional type-length-value elements (TLVs). The **SMPTE** profile specifies that ports in Master state shall send management messages with a Synchronization Metadata TLV appended. It also specifies that ports should not issue an ACKNOWLEDGE message in response to Synchronization Metadata management messages.

IEEE 1588-2008 says that nodes which cannot parse a management message are required to ignore it. Therefore the presence of these messages will not cause a problem for non-SMPTE profile equipment.

SMPTE profile slave devices might rely on these management messages for certain functionality (for example, time code generation) and their behaviour in the absence of these messages is undefined. Therefore, for interoperability, master devices need to send these messages.

4.6 Quality of service

IEEE Std 1588-2008 says that in the IPv4 mapping: "*For PTP event messages, the value of the differentiated service (DS) field in the Type of Service (ToS) field should be set to the highest traffic class selector code point available*." It is not entirely clear what the appropriate value is but both Expedited Forwarding (EF) with a Differentiated Services Code Point (DSCP) value of 46 decimal and Class Selector 7 (CS7) with a DSCP value of 56 decimal are possibilities.

AES67 requires that a traffic class "Clock" (consisting of PTP **`Announce`**, **`Sync`**, **`Follow_Up`**, **`Delay_Req`**, **`Delay_Resp`**, **`Pdelay_Req`**, **`Pdelay_Resp`** and **`Pdelay_Resp_Follow_Up`** messages) be supported and that outgoing traffic be tagged with an appropriate DSCP value. For this particular traffic class (for example, PTP traffic), AES67 recommends EF. Note that the AES requirement goes beyond IEEE 1588-2008 because it applies to non-event messages such as Announce, **`Follow_Up`**, **`Delay_Resp`** and **`Pdelay_Resp_Follow_Up`**. The requirement for DSCP tagging applies regardless of whether the **Default** profile or the **AES Media** profile is used.

SMPTE ST 2059-2 makes no additional requirements concerning quality of service.

For interoperability, it is preferable that all PTP event messages are handled with the same priority in the network. Consideration also needs to be given to the priority of other traffic on the network such as media streams. This other traffic should preferably be handled with lower priority than the PTP event messages.

Enterprise networks often base DiffServ behaviour on traffic attributes such as destination address and UDP port number. On these networks, the DSCP markings supplied by end stations are ignored and replaced by network-generated markings. Network applied DSCP markings are considered more secure than end station markings.

Less sophisticated networks classify traffic based on DSCP markings generated by devices. PTP messages from different devices with potentially different DSCP markings, may be assigned the same priority by mapping multiple DSCP values to the same network queue or traffic class. Alternatively, where supported, devices can be configured to use common DSCP values.

When support for PTP exists in network equipment, QoS is not a paramount consideration as the network equipment compensates for any delivery delays by accurately timestamping and compensating for actual arrival and departure times of all time-critical packets.

4.7 Clock physical requirements

4.7.1 Frequency accuracy

The **SMPTE** profile states that for application as the master reference for a plant synchronization system, the PTP grandmaster clock shall maintain a frequency accuracy within ± 5 parts per million (ppm) with respect to rated frequency in terms of the reciprocal SI second. The corresponding accuracy requirement for the **AES Media** profile is that of Grade 2 DARS, that is ± 10 ppm, and that for the **Default** profile is ± 100 ppm.

4.7.2 Frequency adjustment range

The **Default** profile requires that any clock in the slave state be able to correct its frequency to match any master clock meeting the frequency accuracy requirement of the profile (± 100 ppm) and recommends an adjustment range of ± 250 ppm. The **SMPTE** profile has a similar requirement to be able to match a master clock meeting the accuracy requirement of the profile (± 5 ppm). The **AES Media** profile refers to Grade 2 DARS, that is a recommendation of ± 50 ppm adjustment range.

4.8 Attribute values

4.8.1 Domain number

There will be no interoperation unless devices use the same domain number.

	domainNumber		
	Min	**Max**	**Default**
1588 Default Profile	0	127	0
AES Media Profile	0	255	0
SMPTE Profile	0	127	127
Default-AES-SMPTE interoperability	0	127	See 5.3.1 for proposal

4.8.2 Announce interval

This is an important attribute as far as interoperability is concerned. For proper functioning of Best Master Clock Algorithm (BMCA), the **Announce** interval needs to be uniform throughout a domain (IEEE 1588-2008 Section 7.7.2.2). Even slave-only devices use **Announce** interval because the state machine uses **AnnounceReceiptTimeout** and the rate of State Decision Events is linked to **Announce** rate.

	logAnnounceInterval		
	Min	**Max**	**Default**
1588 Default Profile	0	4	1
AES Media Profile	0	4	1
SMPTE Profile	-3	1	-2
Default-AES-SMPTE interoperability	0	1	See 5.3.1 for proposal

4.8.3 Announce receipt timeout

This is also used in BMCA and state machine and, in conjunction with **Announce** interval, needs to be uniform throughout a domain. IEEE 1588-2008 section 7.7.3.1 states that the minimum value should be 3.

	announceReceiptTimeout		
	Min	**Max**	**Default**
1588 Default Profile	2	10	3
AES Media Profile	2	10	3
SMPTE Profile	2	10	3
Default-AES-SMPTE interoperability	2	10	See 5.3.1 for proposal

4.8.4 Sync interval

Sync messages are sent by the active Master. It is not necessary for the value of **Sync** interval to be uniform across all ports in a domain.

	logSyncInterval		
	Min	Max	Default
1588 Default Profile	-1	1	0
AES Media Profile	-4	1	-3
SMPTE Profile	-7	-1	-3
Default-AES-SMPTE interoperability	-1	-1	See 5.3.1 for proposal
AES-SMPTE interoperability	-4	-1	See 5.3.2 for proposal

4.8.5 Delay request interval

logMinDelayReqInterval is a dynamic attribute whose value is determined and advertised by a master clock based on the ability of the master clock to process the **Delay_Req** message traffic. The minimum value is **portDS.logSyncInterval**; that is, the same interval as **Sync** messages, and the maximum value is **logSyncInterval**+5; that is, one **Delay_Req** message every 32 **Sync** messages.

A multicast **Delay_Resp** message carries the value of **logMinDelayReqInterval** in the **logMessageInterval** field of the message. Unicast **Delay_Resp** messages do not carry the value of **logMinDelayReqInterval** (see IEEE 1588-2008, Table 24). If unicast negotiation is used to request unicast **Delay_Resp** messages, then the grant of such messages will include a **logInterMessagePeriod** and this corresponds to the maximum allowed **Delay_Req** message rate. However, if unicast negotiation is not used, the maximum allowed **Delay_Req** message rate is not sent by the master.

Although **logMinDelayReqInterval** represents a minimum mean interval, the provisions of IEEE 1588-2008 section 9.5.11.2 have the effect that for the multicast communication model, the mean interval will be equal to this value. For the unicast communication model, an alternative is to send at the same rate as **Sync** messages are received. In the case where **Delay_Resp** messages are sent unicast without negotiation, the latter is the only option because the minimum **Delay_Req** interval is not sent by the Master.

	logMinDelayReqInterval		
	Min	**Max**	**Default**
IEEE 1588 Default	Greater of 0 and **logSyncInterval**	Lesser of 5 and **logSyncInterval**+5	0 [for default **logSyncInterval**]
AES67	Greater of -3 and **logSyncInterval**	Lesser of 5 and **logSyncInterval** +5	0 [for default **logSyncInterval**]
SMPTE	**logSyncInterval**	**logSyncInterval** +5	**logSyncInterval**
Default-AES-SMPTE	Greater of 0 and **logSyncInterval**	Lesser of 5 and **logSyncInterval** +5	
Default-AES-SMPTE simplified (explanation below)	0	4	See 5.3.1 for proposal
AES-SMPTE	Greater of -3 and **logSyncInterval**	Lesser of 5 and **logSyncInterval**+5	See 5.3.2 for proposal

The allowed values for **logMinDelayReqInterval** depend on **logSyncInterval** (see IEEE 1588-2008 section 7.7.2.4); the minimum value is **logSyncInterval** and the maximum is **logSyncInterval**+5. The **Default** profile simply specifies a range of 0 to 5. The table below shows the effect of **logSyncInterval** value on the allowed range for **logMinDelayReqInterval** in the **Default** profile.

logSyncInterval	**logMinDelayReqInterval in Default Profile**		
	Min	**Max**	
-1	0	4	
0	0	5	
1	1	5	

For **Default-AES-SMPTE** interoperability, the only permissible value for **logSyncInterval** is −1. Therefore the permissible range for **logMinDelayReqInterval** is 0 to 4.

4.9 Additional attribute values

4.9.1 clockClass

The **AES Media** profile adds further allowed values of the **clockClass** attribute. The **SMPTE** Profile adds a subset of these with the same meanings. The Best Master Clock Algorithm (BMCA) uses **clockClass** but it only compares numerical values; therefore additional values do not cause an interoperability issue.

4.9.2 timeSource

The **SMPTE** profile adds further allowed values of the **timeSource** attribute. This attribute is information-only and not used in the BMCA; therefore additional values do not cause an interoperability issue.

5 Conclusions for interoperability

5.1 Features

The following provisions should ensure interoperability of devices conforming to the **Default**, **AES Media** and **SMPTE** Profiles.

- Transport should be UDP/IPv4
- Master should send **Announce**, **Sync** and **Follow_Up** as multicast. Slaves may send **Delay_Req** as multicast or as unicast without negotiation. (**Delay_Resp** will be in same mode as the corresponding **Delay_Req** message.)
- Path delay measurement mechanism should be Delay request-response.
- Optional features (of IEEE 1588-2008 sections 16 and 17) should not be used.
- Masters should send Synchronisation Metadata TLV management messages as per the **SMPTE** profile.
- PTP nodes and network devices should be configured so that all PTP event messages are handled with equal priority. Other traffic, such as media streams, should be handled with lower priority.
- Additional values for **clockClass** and **timeSource** may be used.

5.2 Clock physical requirements

To meet the requirements of all involved profiles in an interoperability scenario, the grandmaster clock should meet or exceed the most stringent requirement for frequency accuracy among the profiles involved, for example the ± 5 ppm limit of the **SMPTE** profile.

For clocks in slave state to lock successfully to a master, the frequency adjustment range of the slave should be sufficient to accommodate the frequency inaccuracy both of its own oscillator and of the grandmaster.

In theory, a slave designed for use with the **SMPTE** profile might not have sufficient adjustment range to lock to a master operating at the limits of the accuracy range allowed by the **AES Media** profile. In practice, however, grandmasters for all the profiles can be expected to have oscillators with an accuracy better than ± 2.5 ppm and are, in any case, likely to be locked to a reference time source such as GPS.

5.3 Proposed attribute values

5.3.1 Interoperability between Default, AES and SMPTE Profiles

The following proposed values should ensure interoperability of devices conforming to the **Default**, **AES Media** and **SMPTE** profiles.

	Min	Max	Proposed	Further info
`domainNumber`	0	127	0	Must be same for all ports.
`logAnnounceInterval`	0	1	1	Must be same for all ports.
`announceReceiptTimeout`	2	10	3	Must be same for all ports.
`logSyncInterval`	-1	-1	-1	
`logMinDelayReqInterval`	0	4	0	For **`logSyncInterval`** = -1

The above settings are the same as the Delay Request-Response **Default** PTP Profile with the exception that **`Sync`** rate is increased from 1 per second to 2 per second.

5.3.2 Interoperability between AES and SMPTE Profiles

The following proposed values should ensure interoperability of devices conforming to the **AES Media** and **SMPTE** profiles.

	Min	Max	Prop.	Further info
`domainNumber`	0	127	0	Must be same for all ports.
`logAnnounceInterval`	0	1	0	Must be same for all ports.
`announceReceiptTimeout`	2	10	3	Must be same for all ports.
`logSyncInterval`	-4	-1	-3	
`logMinDelayReqInterval`	Greater of -3 and **`logSyncInterval`**	**`logSyncInterval`** +5	-3	Recommended value is for **`logSyncInterval`** = -3

The above settings are the same as the Delay Request-Response **Default** PTP Profile with the exception that **`Announce`** rate is increased to 1 per second, and **`Sync`** and **`Delay_Req`** rates are increased from 1 per second to 8 per second.