Pro Audio/Video AVB/TSN Functional and Interoperability Specification

Revision 1.1

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Avnu Alliance

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Revision History

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1 Introduction

This document is Avnu's interoperability and functional specification for Professional Audio/Video Ethernet AVB devices. This version satisfies the requirements listed in Avnu's Professional Audio Market Requirements Document [MRD] for Pro Audio V1.0 and V1.1. This document's primary goal is to provide a baseline specification of Ethernet AVB/TSN functionality on Professional Audio/Video AVB devices. Further refinement is anticipated in future versions to address specific Pro Video MRD requirements.

This specification has several uses, three of which are key. First, vendors can use this specification to guide their Professional Audio/Video AVB product development. Second, Avnu can use it to develop an effective certification process. Third, and most importantly, end-users can depend on the specification to provide a foundation for AVB/TSN functionality in their networks. End-Users can be assured that a device certified to be compliant with this specification would provide baseline AVB/TSN functionality, would not require extensive testing on their part, and would thereby allow them the time to focus on other functionality that helps differentiate their solution.

This specification focuses on establishing interoperability between devices at those levels of the communication stack where the devices share functionality compatibility. For instance, it is obvious that two devices that do no share a common media format will not interoperate; however, both devices do have AVB/TSN functionality. Therefore, it is also true that they can interact on more fundamental levels, such as sharing a common reference clock via gPTP and adhering to the traffic shaping rules of the Credit Based Shaper (CBS), all while not causing any disruption to other AVB/TSN devices on the same network. This is what is meant by Professional Audio/Video baseline functionality: The functionality required for interoperability at baseline levels for Professional Audio/Video device's communications stacks.

Critical features for the baseline Professional Audio/Video device's use cases are:

- A common clock for all devices based on the 802.1AS standard, commonly known as generalized Precision Time Protocol (gPTP)
- Guaranteed bandwidth for time-critical streams
- Low-latency and synchronized transmission of audio and video
- Distribution of a common media clock
- Common Discovery, Enumeration, Connection management and Control
- Operation on links with speeds at or above 100Mbps
- Co-existence with other AVB/TSN devices in a non-disruptive manner in a dynamic networking environment

To deliver these features, this specification draws upon the various AVB/TSN standards to specify a concise set of requirements for delivering the features necessary for the Professional Audio/Video use cases.

Regarding the lifecycle of this document, this version is the next of many anticipated updated releases for the Professional Audio/Video specification. It has been driven by two factors. The first is the goal of providing a useful baseline level of functionality for product developers. The second is to shape the certification requirements for such products.

There will be future versions of this specification that cover a variety of topics not yet addressed. Those interested in shaping additional specifications are encouraged to participate in the Avnu Alliance.

1.1 Avnu's Relationship to AVB and TSN

Avnu is an industry alliance to foster, support and develop an ecosystem of vendors providing inter-operable AVB and TSN devices for wide availability to consumers, system integrators and other system-specific applications. Avnu provides interoperability guidelines and compliance testing for device manufacturers, as well as technical guidance such as this document for implementing AVB and TSN systems. For more information, visit our website at www.avnu.org.

1.2 AVB and TSN Terminology

For the purposes of this document, the terms AVB and TSN are treated synonymously, and may appear as AVB/TSN or simply AVB. This is principally due to the evolution of the term "Audio/Video Bridging" (AVB) migrating to the more generally scoped "Time Sensitive Networking" (TSN). Both terms refer to a family of standards, principally from the IEEE 802.1 Working Group, and neither refer to any one specific standard.

192 # 2 Glossary

Term	***Meaning***
1BA	Reference to IEEE 802.1BA-2011.
AAF	AVTP Audio Format. [AVTP-2016]
ACMP	ATDECC Connection Management Protocol. IEEE Std. 1722.1™-2013 defined protocol to manage the stream identification and reservations between talker and listener nodes.
AECP	ATDECC Enumeration and Control Protocol. IEEE Std. 1722.1™-2013 defined protocol to enumerate and control AV devices.
AIF	AVTP IEC 61883-6 audio Format
AIF-AM	AVTP IEC 61883-6 AM824/MBLA audio Format
ATDECC	AVB/TSN Discovery, Enumeration, Connection management and Control. Previously known as AVDECC.
AVB	Audio Video Bridging. The original term to describe the suite of standards enabling precisely synchronized networking devices to communicate with guaranteed bandwidth and known worst-case latencies. TSN replaces this term.
AVDECC	Audio Video Discovery, Enumeration, Connection and Control protocol for AVTP devices. This is now known as ATDECC.
AVTP	Audio Video Transport Protocol for Time-Sensitive Streams. [AVTP-2011][AVTP-2016] Protocol for encapsulation of AVB streamed content and control streams.
AVTPDU	Audio Video Transport Protocol Data Unit
BMCA	Best Master Clock Algorithm
E-AVB	Ethernet AVB
CBS	Credit Based Shaper. Traffic shaping algorithm defined by Std. 802.1Qav™-2011, in Clause 34, titled Forwarding and Queuing for Time Sensitive Streams (FQTSS). Referring to the credit based shaper as the acronym CBS is preferred vs the more general FQTSS acronym.
gPTP	Generalized Precision Time Protocol. Defined by IEEE 802.1AS-2011, IEEE802.1AS-2011/Cor1, IEEE802.1AS-2011/Cor2, and under revision in IEEE P802.1AS-Rev. Defines a “Profile” of IEEE 1588, with limited extensions and additions under review in IEEE-P1588Rev,

Term	*Meaning*
FQTSS	Forwarding and Queuing for Time-Sensitive Streams. This is the title of Clause 34 in the IEEE Std. 802.1Qav™-2011. This clause defines shapers used for TSN/AVB, including the Credit-Based Shaper (CBS) traffic shaping algorithm. The CBS was the first shaper defined in IEEE Std. 802.1Qav™-2011, Clause 34. [802.1Qav] Referring to the credit based shaper as the acronym CBS is preferred vs the more general FQTSS acronym, as updates to IEEE Std. 802.1Q Clause 34 after 2011 define additional shapers within the FQTSS clause.
MAAP	MAC Address Acquisition Protocol. IEEE Std. 1722™-2011, Clause B defined protocol to dynamically allocate multicast MAC addresses for use with AVB streams. [AVTP-2011]
MRD	Avnu Alliance Marketing Requirements Document
MRP	Multiple Reservation Protocol
MRPDU	Multiple Reservation Protocol Data Unit
MSRP	Multiple Stream Reservation protocol
MVRP	Multiple VLAN Reservation protocol
MTT	Maximum Transit Time
PCP	Priority Code Point. Used in a VLAN tag on a frame to indicate which of 8 queues to which the frame should be assigned by an IEEE 802.1Q conformant bridge.
Pro	Professional
PTP	Precision Time Protocol. A protocol for establishing time synchronization defined in IEEE Std. 1588™-2008. Allows definition of "Profiles", such as gPTP.
SR	Stream Reservation
SRP	Stream Reservation Protocol. IEEE Std. 802.1Q™-2011, Clause 35 defined method to define an AVB overlay on a network. A thorough understanding of Clause 10 is also required.
TSN	Time Sensitive Networking. The modern term inclusive of AVB and use-cases beyond AV. Generally inclusive of newer standards and emerging standards from IEEE, IETF, and other related standardization efforts.
VLAN	Virtual Local Area Network.

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3 References

Name	*Reference*
802.1Q	IEEE 802.1Q-2014, “Media Access Control (MAC) Bridges and Virtual Bridge Local Area Networks,”.
AVDECC	IEEE 1722.1-2013, “IEEE Standard for Device Discovery, Connection Management, and Control Protocol for IEEE 1722 Based Devices,” 23 August 2013.
AVTP-2011	IEEE 1722-2011, “IEEE Standard for Layer 2 Transport Protocol for Time-Sensitive Applications in Bridged Local Area Networks,” May 2011.
AVTP-2016	IEEE 1722-2016, “IEEE Standard for Layer 2 Transport Protocol for Time-Sensitive Applications in Bridged Local Area Networks”
gPTP	IEEE Std. 802.1AS-2011 “IEEE Standard for Local and Metropolitan Area Networks – Timing and Synchronization for Time-Sensitive Applications in Bridged Local Area Networks”
gPTP-Cor1	IEEE Std. 802.1AS-2011/Cor 1-2013 “IEEE Standard for Local and metropolitan area networks—Timing and Synchronization for Time-Sensitive Applications in Bridged Local Area Networks—Corrigendum 1: Technical and Editorial Corrections”
gPTP-Cor2	IEEE Std. 802.1AS-2011/Cor 2-201X “IEEE Standard for Local and metropolitan area networks— Timing and Synchronization for Time-Sensitive Applications in Bridged Local Area Networks— Corrigendum 2: Technical and Editorial Corrections”
gPTP-Rev	IEEE Draft P802.1AS-Rev/D4.2 Draft IEEE Standard for Local and Metropolitan Area Networks – Timing and Synchronization for Time-Sensitive Applications”
MRD 1.0	Avnu Alliance, “Avnu Requirements Matrix (ProA),” Version 19, June 4, 2014.
MRD 1.1	Avnu Alliance, “Pro Audio Market Requirements Definition Level 1.1 – Final”, May 26th 2015
802.1BA	IEEE Std 802.1BA-2011, “Audio Video Bridging (AVB) Systems,” 30 Sept 2011.
MCLK	Avnu Alliance, “Avnu PA1 Pro Audio Media Clocking Specification Revision 1.1 “, June 7, 2016
SFS	Avnu Alliance, “Stream Format Specification “. A living document within the Avnu Alliance to document stream formats and uniquely identify them.

4 Scope

The scope of this document is to provide a baseline specification of Audio/Video Ethernet AVB functionality on professional AVB audio/video devices as a foundation for an effective certification process. The focus of the document is Professional Audio network interoperability. Professional Video devices or devices meant to co-exist on a shared network with Professional Audio devices are not in the scope of this version of the document, but are anticipated in future updates. Nonetheless, where appropriate, a device is referred to as an "Avnu Pro AV device", to include requirements that are currently deemed appropriate for a Professional Video device.

The scope of this specification is at the AVDECC service layer and below. This includes the Ethernet PHY, MAC and Bridge, gPTP, SRP, FQTSS, AVTP formats, media clock, and AVB configuration and behavior via AVDECC. This specification does not cover the behavior of applications built on top of these service layers.

An Avnu Pro device shall implement all applicable requirements that are otherwise not discussed in this specification, as defined by the set of AVB standards: [802.1Q], [802.1BA], [AVDECC], [AVTP-2011], [AVTP-2016], [gPTP], [gPTP-Cor1], and [gPTP-Cor2]. This set of AVB standards shall be considered the source of any additional requirements when such statements are made throughout this specification.

Since this specification provides a baseline set of requirements for certification testing it is necessarily limited to key requirements for the targeted use cases. This limitation should not be interpreted as a restriction on the overall functionality of any device. Vendors and OEMs can and are encouraged to implement functionality beyond that specified here.

This specification defines three device types: Endstation, Bridge and Hybrid. An Endstation is a device that connects at the edge of the Ethernet network and initiates and/or terminates AVB streams. A Bridge is within the Ethernet network and connects Endstations and other Bridges together to create the network. A Hybrid device is a device that contains both an Endstation and a Bridge within the same "enclosure."

The challenge with the Hybrid device is separating the behavior of the Endstation from the Bridge for the purposes of testing. The Ethernet link between these on a Hybrid device is often a PHY-less and connector-less PCB trace that cannot easily be monitored during testing. In such cases, this specification recommends that the Hybrid device be tested in two different modes, with a different test focus for each mode:

1) Endstation Mode: For Endstation testing, the vendor designates a single external-facing switch port as the Endstation connection. All Ethernet packets to/from the Endstation must pass through this port. When testing the device, there will be some observable differences relative to testing a pure Endstation, including:

    a) Some link-level operation on the connection, such as Auto negotiation and gPTP Pdelay will not be directly visible. Instead their effects will at best be indirectly visible in the packets sent by the Bridge (e.g. in gPTP Sync packet corrections)

    b) External visibility of Endstation packets is dependent upon the Bridge. If the Endstation sends packets before the Bridge is ready then they won't be seen.

    c) The Bridge will add some delay to packets sent and received by the Endstation. This will be barely perceptible for data packets, but could be visible for certain gPTP protocol packets such as Sync, which are consumed, processed and then re-originated by the Bridge. For instance, if the Endstation is the GM then Sync packets coming out will experience a delay according to the Bridge's local state machines.

d) If the Endstation is the GM, then the Bridge will have already corrected the observed Sync packets.

e) gPTP protocol packets will have the source address of the Bridge, not the Endstation.

f) A Hybrid device may be the composition of multiple Endstation devices (eg: Talker, Listener, Controller) behind a Bridge. Each Hybrid device will be testable in Endstation mode to the certification requirements; however, each component of the Hybrid device may be treated as distinct entities within the composite (eg: with differing source MAC address, Entity ID, etc)

2) Bridge Mode: To test the Avnu Pro Bridge, testing shall use only the Bridge's externally facing ports. At least two externally facing ports are required. Devices lacking more than 2 externally facing ports will not be tested for tests identified as requiring 3 or more external ports.

For the purposes of management, it is left to implementation choice whether the Hybrid device reports itself as one or more devices. However, the information content obtainable from the Hybrid device shall be the superset of both the Endstation and Bridge requirements described in this specification.

5 Background on AVB/TSN

The Audio/Video Bridging (AVB) standards are integrated into the IEEE 802 standards – such as IEEE Std. 802.1BA™-2011, IEEE Std. 802.1Q™-2014, IEEE Std. 802.3™-2012, IEEE Std. 802.11™-2012 and IEEE Std. 802.1AS™-2011. The AVB extensions were developed to enable networking products to transport time-sensitive networking (TSN) media streams.

A simple example of a time-sensitive networking media stream is the transmission of live audio data over a network for immediate playback over speakers. To implement such a system requires several key features and modifications to the legacy behavior of IEEE 802 networks.

While a few dropped packets are usually tolerated on Ethernet networks, lost AVB packet data results in audible artifacts – such as pops – when digitized audio data is converted back into the analog domain. AVB provides a bandwidth reservation method to establish bandwidth guarantees throughout a multi-hop Ethernet network from the source of data to all possible recipients. This bandwidth guarantee eliminates packet drop due to network congestion. This also distributes information about stream availability and network configuration parameters required for Endstations to send or receive streams.

The internal details of how packets are queued within Ethernet Bridges can result in highly variable packet propagation latencies through a network. AVB gives priority to the time-sensitive network data by placing requirements on the forwarding and queuing behavior for those streams. This guarantees delivery of data from any source (a Talker) to any receiver (a Listener) with a bounded maximum latency. These requirements apply to both the intermediate Bridges as well as the Talkers in the AVB network.

Finally, AVB supplies a high-precision time synchronization protocol. This protocol enables network nodes to achieve synchronized clocks which differ by less than 1 microsecond[1]. This in turn enables high-precision recovery of media sample clocks over Ethernet networks, and synchronized rendering by multiple separate Listener devices. By precisely matching the sample rate and phase-alignment between multiple devices, AVB can meet the exacting requirements of the professional audio industry for high-quality audio distribution.

Combining these mechanisms enables a system designer to build a distributed network of devices to play back media content with high fidelity and excellent user experience. In addition, other network applications – such as timed industrial controls or an automotive ECU data bus– can use the same timing- and latency-sensitive networks.

5.1 Common Hardware Requirements

Although much of the AVB functionality of an Endstation can be implemented in software, the specifications demand some behaviors from the Endstations that require special hardware assistance and others that may impose a heavy computational overhead without hardware assistance. Many combinations of hardware and software may be used to correctly implement AVB, so it is important to know the constraints and capabilities of different approaches when designing a system.

Talkers must limit the transmission of traffic belonging to an AVB traffic class to less than or equal to the bandwidth allocated for that traffic class on a specific port. Implementation of the class-based Forwarding and

[1] IEEE Std. 802.1AS™-2011, Annex B.3.

Queuing Enhancements for Time-Sensitive Streams (FQTSS) Credit Based Shaper's (CBS's) traffic shaping algorithm may, depending on other platform capabilities, require specialized hardware; e.g. a packet queue providing an implementation of the credit-based shaper described in the standard, or a MAC that supports time-triggered transmission of data frames to construct logically identical behavior to that generated by a hardware CBS.

Listeners do not have traffic shaping requirements, but some media transport protocols such as AVTP place an upper bound on the time available from the moment a sample arrives at the network PHY and when it must be presented to the media application. AVB uses a priority code point (PCP) and VLAN identifier to segregate the time-sensitive traffic from other, lower priority traffic. The LAN interface must be capable of handling packets with the additional tag present, and specialized filtering of traffic based on the tag values or other AVB-specific fields can relieve a significant burden from software.

While not required, LAN interfaces with 4 or more independent transmit and receive queues simplify AVB design requirements by providing the ability to steer AVB-related protocol frames (SRP and gPTP, described later) based on MAC address or packet priority to higher-priority transmit and receive queues. Two FQTSS queues are commonly expected to shape time-sensitive streams of AVB data, separated into two classes of time sensitive streams, known as Stream Reservation (SR) Class A, and SR Class B. While both are shaped time-sensitive streams, SR Class A is treated as a higher priority than SR class B, and thus enjoys a lower worst-case latency expectation compared to SR Class B traffic. The associated SRP and gPTP protocols also benefit from prioritized processing over best-effort traffic, but at lower priority than the FQTSS queues. For example, a common problem develops when best-effort LAN traffic stalls delivery of SRP frames. The SRP protocol is dependent on timers to age out stale or non-existent streams from the network. Long SRP processing delays are sufficient to trigger the AVB network to tear down existing stream reservations because the AVB network believes the stream has disappeared. This stream teardown results in interruptions of streaming data across the network until the talker re-establishes reservations through the network. Hence an implementation is encouraged to have at least two queues for non-time-sensitive traffic, internally prioritizing the SRP and gPTP protocol traffic over other best-effort traffic.

The time synchronization protocols require the system to timestamp the clock synchronization packets with typically 10's of nanosecond precision and accuracy. These requirements cannot typically be met by software running on a general-purpose CPU, so most AVB systems require hardware timestamp support in the Ethernet MAC hardware. Some systems have a simple trigger mechanism in the MAC hardware that interfaces with a centralized timestamp capture system, while others implement a sophisticated timing engine in the Ethernet block.

Recovery of other clocks, such as media clocks encoded within transport streams, often requires additional hardware to meet product requirements. This feature requires precise timestamp capture of media clock edges on both Talker and Listener. The system must translate those timestamps to the exact gPTP time at which the capture events occurred. It also typically involves a software-adjustable PLL on the Listener, which provides fine tuning within a small frequency range (<1PPM) for the clock that is being recovered.

6 Avnu Pro AV Stream Formats

Avnu Pro AV devices may support a variety of stream formats. Identified below is a set of formats that are encouraged to be supported by a certified Avnu Professional device. The list is not exhaustive, and no specific format is required. For certification purposes, the Avnu Alliance maintains an Avnu Stream Formats Specification (SFS) which can be tested for conformance and/or interoperability and certified.

6.1 Avnu Pro Audio Stream Formats

Professional audio applications require the Ethernet AVB network to carry a variety of audio stream formats.

6.1.1 AVTP IEC 61883-6 AM824/MBLA Format (AIF-AM)

If a Pro Audio AVB Device supports the AIF-AM format, then it shall support:

- IEC 61883 data encapsulation as defined in IEEE 1722-2011, clause 6.
- AM824 audio data as defined in IEC 61883-6, clause 8.2.
- MBLA label of 0x40 as defined in IEC 61883-6, clause 8.2.3.
- 24bit twos complement audio samples as defined in IEC 61883-6, clause 8.2.3.
- Non-blocking mode as defined in in IEC 61883-6, clause 7.4.
- Asynchronous mode as defined in IEEE 1722-2016, annex I.2.2.3.3
- SR class A as defined in IEEE 802.1Q-2014, clause 34.
- AVTPDU's per 125us SR class A cycle, per stream shall be 1.
- A default SR class A presentation time of 2ms, as defined in IEEE 1722-2011, clause 5.5.2.

6.1.1.1 Mono48kHz

A Pro Audio AVB Device may support 1 channel AIF-AM with a 48 kHz sample rate. If this format is supported then:

- The AVDECC stream format, as defined in IEEE 1722-2016 Annex I.2.1.1.2.2.3, shall be 0x00A0020140000100.
  - FDF as defined in IEC 61883-6, clause 10 shall be 0x02.
  - DBS as defined in IEC 61883-6, clause 6.2 shall be 0x01.
  - The number of MBLA quadlets per data block shall be 1.
- The number of samples per channel per AVTPDU shall be 6 ± 1. Talkers should send 6 samples per AVTPDU but may send 5, 6 or 7.

6.1.1.2 Octo48kHz

A Pro Audio AVB Device may support 8 channel AIF-AM with a 48 kHz sample rate. If this format is supported then:

- The AVDECC stream format, as defined in IEEE 1722-2016 Annex I.2.1.1.2.2.3, shall be 0x00A0020840000800.
  - FDF as defined in IEC 61883-6, clause 10 shall be 0x02.

- DBS as defined in IEC 61883-6, clause 6.2 shall be 0x08.
- The number of MBLA quadlets per data block shall be 8.

- The number of samples per channel per AVTPDU shall be 6 ± 1 (There are 48 total samples per AVTPDU). Talkers should send 48 samples per AVTPDU but may send 40, 48 or 56.

6.1.1.3 Mono96kHz

A Pro Audio AVB Device may support 1 channel AIF-AM with a 96 kHz sample rate. If this format is supported then:

- The AVDECC stream format, as defined in IEEE 1722-2016 Annex I.2.1.1.2.2.3, shall be 0x00A0040140000100.
  - FDF as defined in IEC 61883-6, clause 10 shall be 0x04.
  - DBS as defined in IEC 61883-6, clause 6.2 shall be 0x01.
  - The number of MBLA quadlets per data block shall be 1.
- The number of samples per channel per AVTPDU shall be 12 ± 1. Talkers should send 12 samples per channel per AVTPDU but may send 11, 12 or 13.

6.1.1.4 Octo96kHz

A Pro Audio AVB Device may support 8 channel AIF-AM with a 96 kHz sample rate. If this format is supported then:

- The AVDECC stream format, as defined in IEEE 1722-2016Annex I.2.1.1.2.2.3, shall be 0x00A0040840000800.
  - FDF as defined in IEC 61883-6, clause 10 shall be 0x04.
  - DBS as defined in IEC 61883-6, clause 6.2 shall be 0x08.
  - The number of MBLA quadlets per data block shall be 8.
- The number of samples per channel per AVTPDU shall be 12 ± 1. (There are 96 total samples per AVTPDU). Talkers should send 96 samples per AVTPDU but may send 88, 96 or 104.

6.1.2 AVTP Audio Format (AAF)

If a Pro Audio AVB Device supports the AAF format, then it may still be certified despite this specification version does not explicitly address AAF (or other audio formats).

Certification testing requires compatible talkers and listeners to be available for interoperability and co-existence testing.

6.2 Avnu Pro Video Stream Formats

Professional video applications require the Ethernet AVB network to carry a variety of video stream formats. While none are explicitly identified in this document, a device supporting a particular Pro Video stream format may still be certified.

Certification testing requires compatible talkers and listeners to be available for interoperability and co-existence testing.

7 Generalized Precision Time Protocol (gPTP)

The Generalized Precision Time Protocol (gPTP) provides an accurate time base to all elements in an Ethernet network. The use for gPTP in a Pro AV system is to provide a timing reference for recovery of media clocks in listener devices and providing synchronous media delivery across multiple listener devices. All Pro Audio Talker devices are required to also act as Listener devices such that multiple Talkers can be synchronized based on listening to a common media clock stream referenced to the gPTP timebase.

7.1 Scope

This section covers the differences between a standard gPTP implementation and an Avnu Pro AV Endstation implementation and Avnu Pro Bridge implementation as well as clarifications or emphasis on key standard-defined requirements. An Avnu Pro device shall implement all requirements of gPTP that are not discussed in this section in accordance with the relevant standards. [gPTP][gPTP-Cor1][gPTP-Cor2]

This section proposes concepts that may require changes to standard implementation of the gPTP state machines and other operations. Details of these changes are not specified here and left to the implementer.

All references of the form [gPTP 11.2.2] refer to the specified clause in the identified reference, in this example, IEEE Std. 802.1AS-2011 clause 11.2.2.

7.2 gPTP Configuration

An Avnu Pro AV system is expected to operate in a dynamic environment where gPTP capable devices are added or removed without significant impact to the overall system. The system is also expected to automatically configure itself with little or no user intervention. To support these desires, devices in the system are expected to support the best master clock algorithm (BMCA) defined in gPTP 10.3. Note that the BMCA establishes a timing spanning tree for propagating Announce, Sync and Follow Up messages. This Timing Spanning Tree is independent of any RSTP or MSTP established by those protocols.

7.2.1 priority1 [gPTP 8.6.2.1]

The ability to configure the device's priority1 value is recommended. By default, an Avnu Pro AV system's priority1 value shall be 246, 248 or 250. These values correspond to Network Infrastructure for a Time-Aware System (246), "Other Time-Aware System"(248), and "Portable Time-Aware System" (250).

A device that is intended to be the gPTP grandmaster is recommended to utilize a default value of 246. A device that is intended to connect and disconnect to the gPTP network frequently is recommended to utilize a default value of 250.

Note, as a direct result of the standard's recommendation to have infrastructure devices utilize a default value of 246, it is strongly recommended that a Bridge that is not recommended by the manufacturer to be a suitable grandmaster for an Avnu Pro AV network, should instead identify itself as an "Other" device and thus utilize a default priority value of 248. Avnu Certification does not presuppose the purpose of a device to be Infrastructure, Other or Portable, and instead leaves this determination to the device manufacturer.

7.2.2 neighborPropDelayThresh [gPTP-Cor1 11.2.2]

Per [gPTP-Cor1], any Avnu Pro AV device utilizing a copper interface (specifically 100Base-TX or 1000Base-T) must implement a neighborPropDelayThresh threshold with a default value of 800 ns. This path delay threshold helps ensures that the path to the next link partner is free of sources of packet jitter, such as may be caused by a full-duplex repeater. A common limit for copper media is 100 meters, which represents approximately 538ns of path delay. A device that determines the path delay of a link exceeds the threshold should ensure that the port cannot become asCapable.

For devices that support copper interfaces, at their default settings, a certified device is required to properly become asCapable and emit Announce messages on the maximum length cable supported by the relevant standard (nominally 100 meters). [Avnu PTP-3]

With the threshold left at default values, a certified device is required to not become asCapable and thus not send Announce messages when on a link with 1000ns or more of delay. [Avnu PTP-1c]

For certification testing purposes, an Avnu certified device shall support a method to either: [Avnu PTP-6]

a) Enable and disable the neighborPropDelayThresh threshold; or,

b) Configure the neighborPropDelayThresh value to a value larger than 30 ms.

This configuration capability need not be exposed to an end-user. This capability allows common in-line monitoring tools to be utilized to analyze and troubleshoot device issues.

On a fiber port, the device must disable the neighborPropDelayThresh. [Avnu PTP-4]

7.3 gPTP Operation

7.3.1 neighborPropDelay Accuracy [gPTP 10.2.4.7]

All Avnu certified devices must be able to determine the path delay on a gPTP capable link. During certification testing, when connected to a calibrated link partner via a cable of known delay, the device must measure the cable delay via the peer delay measurement process and shall be accurate to within +/- 100 ns of the known cable delay.

The connected calibrated link partner shall report the cable delay to within +/- 100ns. [per Avnu MDFDPP-6-9]

Note, a maximum quantization error of 40ns per timestamp is allowed, principally due to the clock rate of 100Mbps link. This allowed error results in a worst case quantization error in the peer delay calculation to be +/- 80ns, with the remaining allowed error in the computation of neighborPropDelay due to inaccuracies in ingress and egress latency corrections.

While ingress and egress latency corrections may be imperfect, the device is expected to correct its time-stamping plane to the Media Dependent Interface (MDI), eg: an RJ-45 jack. This behavior is also required on pluggable module ports supporting copper interfaces as well (eg: SFP+ based 1000Base-T ports). A device manufacturer may limit the models of pluggable modules supported, or may leverage standards based interfaces such as those defined by IEEE 802.3bf-2011.

Ingress and egress delays are likely to vary per PHY, including various link speeds on a fixed port. Care should be taken to ensure the measured cable delay remains within the requirement above at all link speeds supported by gPTP on the device.

Future specification versions may tighten the above requirement to decrease allowed sources of error.

7.3.2 gPTP Message Intervals

Allowed timer values are as follows (over a minimum of 100 observations) [per Avnu PTP-8]

PTP Interval	*Tolerance*	*Default*	*Minimum*	*Maximum*
Pdelay transmission	+50%/-10%	1s	900ms	1500ms
Announce transmission	+50%/-10%	1s	900ms	1500ms
Sync transmission	+50%/-10%	125ms	112.5ms	187.5ms

Table 1 – PTP Interval Tolerances

These values are derived from adjusting the nominal interval time -10% and +50% to allow for variance in the observed intervals. The requirement is similar to the IEEE 1588 interval requirements of -30% and +30%, but is shifted to encourage systems to favor providing a slower interval, rather than a faster interval, to ease the processing burden on resource constrained systems.

For Certification testing, the Sync transmission interval is evaluated by excluding the smallest 5% of observed intervals, and computing the mean and standard deviation of the remainder. The observed mean +/- the observed standard deviation must be within 25ms of the nominal value (125ms). This methodology is driven by a known deficiency in gPTP being corrected in the IEEE P802.1AS-Rev effort. This deficiency can result in some Sync transmission intervals at 0.5*syncInterval, resulting in a skewed interval analysis.

Announce interval and Pdelay intervals are analyzed such that the mean and standard deviation of all observed intervals are computed. The observed mean +/- the observed standard deviation must be within the minimum and maximum values in the table above. This methodology is followed to minimize the impact of solitary outliers that may occur given the software generated nature of these messages.

7.3.3 gPTP Timeout Value Tolerances

The gPTP timeouts shall be within the ranges listed below: [per Avnu PTP-8]

a) For announceReceiptTimeout, 2.7sec to 4.5seconds (3 times allowed Announce transmission interval)
b) For syncReceiptTimeout, 337.5ms to 562.5ms (3 times allowed Sync transmission interval)
c) For followUpReceiptTimeout, 112.5ms to 187.5ms (same as Sync transmission interval)

These values are derived from the -10% and +50% tolerances allowed on the corresponding intervals.

7.3.4 asCapable [gPTP 10.2.4.1]

An Avnu Pro AV device shall detect asCapable is TRUE after no less than 2 and no more than 10 successfully received Pdelay Responses and Pdelay Response Follow Ups to the Pdelay Request messages sent by the device. This requirement ensures that all certified Avnu Pro AV device's become asCapable within a bounded time. [per Avnu PTP-11]

To become asCapable, a device must set neighborRateRatioValid to True, which can occur after no fewer than 2 Pdelay exchanges. It is expected that an implementation will continue to track and refine the computed neighborRateRatio.

Once asCapable is TRUE, an Avnu Pro AV device is expected to send Announce messages, even if the device is configured to be slave-only.

7.3.5 Receipt of multiple Pdelay Responses for one Pdelay Request

An Avnu Pro AV device that detects more than one response to a Pdelay Request that it transmits is a sign of a network fault. An Avnu certified device that detects more than one Pdelay Response message has been received from multiple clock identities for each of three successive Pdelay Request messages shall cease Pdelay Request transmission for 5 minutes. After 5 minutes, or a link state toggle, or portEnabled is toggled, or pttPortEnabled is toggled, the Pdelay Request transmission shall resume. [per Avnu PTP-5]

7.3.6 Residency Time

Per gPTP B.2.2, Residence Time is required to be a value less than or equal to 10ms. This requirement shall not be enforced for Avnu certification testing. This is due to contradictory requirements in the gPTP standard defined state machines that can prevent this Residence Time from being met. [per Avnu PTP-9]

Future standard updates will correct the standard defined state machines to allow lower Residence Times, at that point, the maximum Residence Time requirement may be added as a requirement for Avnu certification. Implementers are encouraged to refer to [gPTP-rev]. No certification test will penalize an implementation that provides a consistently low residency time.

7.3.7 Pdelay Turnaround Time

Per B.2.3, Pdelay turnaround time requires a value less than or equal to 10ms. This requirement shall be relaxed by 50% for Avnu purposes and require only the mean to meet the time requirement. Hence the mean Pdelay turnaround time shall be less than or equal to 15ms. Responses later than this time may or may not be processed by a gPTP device, but should not result in asCapable being set to FALSE if 3 or more consecutive responses are received later than 10ms but before pdelayReqInterval(typically 1 second). [Avnu PTP-10]

7.3.8 transportSpecific

As required in [gPTP-Cor1], PTP messages with transportSpecific values other than 0x1 shall be ignored. [Avnu PTP-12]

7.3.9 Pdelay Storm Avoidance

As required in Figure 11-8, the MDPDelayReq state machine per [gPTP], a received Pdelay_Response or Pdelay_Response_Follow_Up that is in error may result in a transition to the RESET state. A common scenario where this may occur is if a device responds late to a Pdelay_Req, and thus has a mis-matched sequence ID. If this occurs, per [gPTP], a new Pdelay_Req will be immediately transmitted, and a pattern is likely to be established where the Pdelay_Response from the link partner continues to be late and treated as an error, resulting in a storm of Pdelay_Req message transmissions from the device.

It is strongly recommended that Avnu certified devices implement the requirements of [gPTP-Cor2], enabling a Pdelay Request transmission interval delay (pdelayIntervalTimer), nominally 1 second, rather than the unconditional (UTC) transition from the RESET to the SEND_PDELAY_REQ state as specified in [gPTP]. By forcing a delay before exiting the RESET state, a storm of Pdelay_Req trasnmissions can be avoided.

8 Forwarding and Queuing for Time Sensitive Streams

The IEEE 802.1Qav standard for Forwarding and Queuing for Time Sensitive Streams (FQTSS) initially defined the operation of the Credit Based Shaper (CBS). IEEE 802.1Qav was later incorporated in IEEE 802.1Q-2014. The use of a CBS in a Pro AV system is to provide proper pacing of stream data through the switched network in the presence of interfering legacy traffic.

8.1 Scope

This section covers only the differences between the standard CBS requirements and an Avnu Pro implementation. An Avnu Pro AV Endstation and Avnu Pro Bridge shall implement all CBS requirements that are not discussed in this section.

8.2 Avnu Pro Bridge CBS Operation

8.2.1 Filtering of stream frames

A Bridge will not flood traffic on an AVB priority on a Port in the AVB Domain. This applies to an incoming stream to a Destination Address that is unknown by the Bridge; or, any limitation on a device's ability to lookup entries in its Forwarding table. [Avnu_Qav-3]

A devastating error to the AVB network is the flooding of an AVB stream when a Bridge does not know the Destination Address of the stream. These flooding streams can overflow AVB queues on AVB enabled ports resulting in the loss of stream frames, which must not occur. A Bridge should filter AVB priority tagged streams to any Destination Address unknown to that Bridge. Alternatively, the Bridge may forward such AVB priority tagged stream frames to an AVB capable port, however they must be modified to a priority not used by any SR class, such as zero.

The scenario discussed in this section pertains to a malfunctioning AVB device that continues to send AVB priority tagged frames with no valid stream reservation in place, thus no Destination Address exists in the Filtering Database for the stream frames. While the default behavior of a Bridge might be to flood, the requirements of this specification clarify that such behavior in this circumstance is disallowed.

Note that this situation is distinct from the more common scenario where an AVB capable Bridge receives a flow of traffic tagged on an AVB priority but received on a port outside of the AVB Domain. In this scenario, the typical behavior expected, as per the standard, is to remap the received frames from the AVB priority to a priority not used by any SR class, typically zero.

A Bridge must forward traffic based on entries in its Filtering Database, and thus must never flood if access to this database is restricted for any reason. If a Bridge has a large number of stream reservations mixed with legacy traffic consuming the remaining of its capacity, then it is possible that some non-certifiable Bridge implementations will be overwhelmed, exceeding the implementation's capacity to access its Filtering database, and could as a result flood the traffic out all ports. This specification requires that a certified Bridge have adequate capacity to lookup AVB stream related Filtering Database entries without loss of AVB stream traffic nor the flooding of AVB stream traffic while in a stressed condition. The behavior of non-AVB stream traffic is not specified.

8.2.2 Default deltaBandwidth

An AVB device's default deltaBandwidth is set to 75% of the forwarding rate of the Bridge. If the Bridge does not forward traffic at line-rate without packet loss, then the value of deltaBandwidth must be 75% of the forwarding rate at which packet loss does not occur.

When streams are reserved on a link, the default deltaBandwidth ensures that a percentage of traffic is reserved for non-stream frames, including gPTP and MRP traffic. Refer to IEEE Std 802.1Q-2011 sub-clause 34.3.1. The parameter deltaBandwidth is defined in terms as a percentage of the portTransmitRate (the link speed). However, an 802.1Q Bridge might not forward traffic at the maximum rate of arrival of a single link. If such a Bridge failed to forward line-rate traffic, yet allowed the reservation of streams up to 75% of line-rate (regardless of the Bridge's actual forwarding rate) then the reliability of the AVB domain would be compromised.

To allow for Bridges that forward at less than line-rate in the market, this specification requires that the default deltaBandwidth be set to 75% of the Bridge's forwarding rate. [Avnu_Qav-4] AVB-capable Bridges are recommended to be able to forward traffic at the line rate supported by the Bridge. Bridges that cannot forward at line rate may be low-port count, low-cost products, or high port modular Bridges supporting high speed Etherent link speeds. The requirement made in this subclause ensures that if a Bridge's forwarding rate is constrained, its behavior will not disrupt the AVB network. Network planners may elect to use such Bridges, taking care to place such constrained Bridges appropriately in the network topology to not limit required stream bandwidth.

For certification testing, the forwarding rate of the Bridge will be validated only under simplistic conditions, specifically one ingress port and one egress port will be exercised. Architectural limitations are not exhaustively explored during certification. System designers should consider any architectural limits before setting the default supported value for deltaBandwidth.

8.2.3 Reservations with MaxIntervalFrames of Zero

A Dynamic Reservation Entry shall not be created if a Talker Advertise is received with a MaxIntervalFrames of zero. Such a Talker Advertise will be propagated as a Talker Failed. [Avnu-Qav-5]

If a Tspec is received with a MaxIntervalFrames value of 0, in the absence of this requirement, a Bridge device might add a dynamic reservation entry but would not result in any change to the operIdleSlope. This is undesirable, thus the receipt of any Talker Advertise with a MaxIntervalFrames value of 0 must result in a Talker Failed being propagated and the Bridge should not create a Dynamic Reservation Entry. This requirement clarifies the behavior when the value is zero, which is erroneously shown as permissible in Table 12-11 of IEEE 802.1Q-2011

8.2.4 Bandwidth Calculations

A Bridge must use 68-bytes as the minimum Ethernet Frame size when performing Bandwidth Calculations. [Avnu_SRP-11]

IEEE Std 802.1Q-2011 sub-clause 6.7.1(j) allows for the possibility of a device transmitting tagged frames with a minimum frame length of 68 bytes, instead of the typical minimum frame length of 64 bytes. As a result, when a Bridge is computing remaining Bandwidth during SRP, the transport overhead must include this minimum 68-byte frame size (rather than 64-byte) in its bandwidth calculations, thereby assuring that the Stream Reservation is never oversubscribed by any Endstation or Bridge that may pad to 68-bytes per 6.7.1(j).

8.2.5 Credit Based Shaper Accuracy

When the shaper is forwarding SR traffic, the accuracy of the shaper in bytes per second is expected to be within +/- 1 of the maximum occupied frame size of the active streams over the period of an observation window of at least one second. The observation window must start and end free of the interfering frames, such that the credit based shaper is at zero credit before sending a stream frame.

A Bridge's CBS must never be slower than the actual data rate of the reserved streams, otherwise it creates a bottleneck and it will run out of buffers. A CBS compensates for the PPM effects between Bridge's crystals by adding 1 byte per frame to its rate calculations.

This requirement ensures that the hardware's rate was correctly programmed by the software and to ensure the hardware works as required in the absence of any interference.

The frame jitter of the credit based shaper is currently not constrained by certification testing. Specifically, this refers to jitter on the order of the SR Class observation interval, as only the overall traffic rate over a long observation period (eg: 1 second) is examined for certification purposes.

8.3 Avnu Pro AV Endstation FQTSS Operation

8.3.1 Per-stream shaping

Per the standard, an Avnu Pro AV Endstation is expected to shape each individual stream, as well as the overall SR class.

9 Multiple Reservation Protocol (MRP) and Applications (MSRP & MVRP)

IEEE 802.1Q standard defines the Multiple Reservation Protocol (MRP) which is used to share information between devices in a LAN. MRP is defined by clause 10 of IEEE 802.1Q, Clause 11 defines the Multiple VLAN Registration Protocol (MVRP), clause 35 defines the Multiple Stream Registration Protocol (MSRP). MVRP utilizes MRP to share VLAN configuration information between Bridges and Endstations in a LAN. Similarly, MSRP utilizes MRP to share Stream Reservation (SR) information between Bridges and Endstations in a LAN.

The use of a MRP, MSRP, and MVRP in a Pro AV system is to provide dynamic and automatic configuration of the network based on device needs and available stream bandwidth from the network.

9.1 Scope

This section covers only the differences between standard MRP, MSRP and MVRP requirements and an Avnu Pro AV implementation. An Avnu Pro AV device shall implement all applicable MRP, MSRP and MVRP requirements that are not discussed in this section.

9.2 MRP General Operation Notes

9.2.1 MRP Timer Tolerances and Default Values.

MRP makes use of various timers and defines them as specific values. Given the software nature of common implementation, these timer values must have allowed ranges for certification test purposes.

MRP Timer	*Tolerance*	*Default*	*Minimum*	*Maximum*
periodictimer	+50%/-10%	1000ms	900ms	1500ms
joinTime	+20%/-10%	200ms	180ms	240ms
LeaveTime	+50%/-10%	600-1000ms	540ms	1500ms
leavealltimer	±0.5s	10-15s	9.5s	15.5s

Table 2 - MRP Timer Tolerances

For certification test, a device is expected to be at all standard defined default values, as identified in the table above. For leavealltimer, the timer is expected to be a value in the range listed. Formally, this timer has a default value of 10 seconds, with an additional 0-5seconds randomly added per interval, this is to ensure that LeaveAll events between devices do not occur simultaneously. For the LeaveTime, an implementation may choose a default value in the range listed. [Avnu-MRP-11]

While a device may choose any default value for LeaveTime in the listed range, all certification testing presumes that a device implements a 600ms timer. Without careful control of an intended environment, network planners should presume that at least one device in the LAN implements LeaveTime at the minimum value (600ms).

9.2.2 Scheduling of Transmit Opportunities

An MRP application on a device operating on a point-to-point medium shall schedule transmit opportunities immediately upon request, subject to rate limiting. A device is recommended to send MRPDUs as soon as possible to minimize delay. [Avnu-MRP1]

The rate limit is set to no more than 3 MRPDUs in 1.5 times the JoinTime timer value, whose default value is 200ms. In default conditions, this is 3 MRPDUs in 300ms per MRP Participant.

Note, an MRP Participant in this sense is per application, per MAP Context, per 10.3.1 (IEEE 802.1Q-2014), "For a given Port of an MRP-aware Bridge and MRP application supported by that Bridge, an instance of an MRP Participant can exist for each MRP Attribute Propagation Context (MAP Context) understood by the Bridge. A MAP Context identifies the set of Bridge Ports that form the applicable active topology." The *active topology* is either the *Base Spanning Tree Context* when RSTP is in use, or the *VLAN Context* when MSTP is in use.

For Certification testing, an MRP device at default values must never send MRPDUs slower than the worst case allowed JoinTime, which is 200ms + 20%, or 240ms.

9.2.3 MRP Bridge port behavior with Spanning Tree Port in non-Forwarding state

A Bridge implementing MRP and utilizing any form of Spanning Tree (RSTP or MSTP) may have one or more of its Ports not in the Forwarding state for the associated spanning tree instance. While not in the forwarding state, any received MAD_Join.requests for an attribute shall not be propagated to or from the Port. [Avnu-MRP2] A Port that is not in the Forwarding state that receives a MAD_Join.request will still register the attribute on the Port, and is required to resume propagation should the Port enter the Forwarding state.

A Bridge Port that is not in the Forwarding state for the spanning tree instance may or may not propagate MAD_Leave.requests to the Port. Due to ambiguities between IEEE 802.1Q-2011 Clause 10.3 and IEEE 802.1Q-2011 Clause 10.7.6.1, both behaviors are allowed. As rapid bandwidth reclamation is desired following a topology change, the ability to propagate a Leave message is desirable, however given the standard's ambiguity, an Avnu Bridge may or may not allow such transmission of Leave messages while not in the Forwarding state. In the absence of the MAD_Leave.request being sent, eventually LeaveAll messages will clear old reservations.

9.2.4 Handling of badly formed MRPDUs

A device that receives a badly formed MRPDU is expected by the standard to discard the entire PDU. This requirement is relaxed by this specification to allow for implementations that choose to process the portion of the MRPDU prior to the improper field. [Avnu-MRP4]

The standard specifically allows for examples of partial MRPDU corruption handling, per IEEE 802.1Q-2014 subclause 10.8.3.4, case (a), which indicates that an MRPDU that is truncated, but with a complete VectorAttribute, should be processed normally.

Certification examines badly formed MRPDUs using unknown (thus invalid) field values with Protocol Version matching the current version (zero).

Certification testing allows the device under test to accept of all Messages received in a single MRPDU before a Message with an invalid field. A device may also choose to discard the entire MRPDU per the standard. Certification testing also allows the Message containing the invalid field to be partially processed up to the invalid field value. A device may choose to discard the entire Message with the invalid field, but process all valid Messages received before the offending Message.

In all cases, an MRP implementation must discard the information following an invalid field within the same Vector Attribute list, and any subsequence Messages received in the same MRPDU.

Note: Refer to Figure 10-5 of IEEE 802.1Q-2014 to review MRPDU structure including Message and Vector Attribute List structure.

9.2.5 EndMarks for MRPDUs

When an MRPDU is to be transmitted, if sending the EndMark as "End of PDU" would result in PAD following the "End-Mark", then the EndMark must be sent as 0x0000. This is a clarification of the requirements in 10.8.1.2 that define the EndMark to be either “End of PDU” or 0x0000.

An Ethernet frame that is smaller than the minimum frame size is required to be transmitted with a PAD field. The contents of this field is undefined, but is typically filled with bytes of 0x00. The requirement above ensures an EndMark is identifiable from the PAD field.

9.3 MSRP Operation

9.3.1 Talker Pruning is not used

Avnu Pro AV devices do not perform Talker pruning. [Avnu_SRP-1]

9.3.2 Domain Declarations

Avnu Pro AV devices shall send MSRPDUs declaring an SRP Domain regardless of whether one is received. [Avnu_SRP-6] The default SR_PVID used in this declaration shall be 2. [Avnu_SRP-4] The default SR Class Priority shall be 3 for Class A and 2 for Class B.

Transmission of SRP Domain Messages shall not be dependent on the state of gPTP or the Forwarding state of RSTP or MSTP on the port.

9.3.3 MSRP does not use Periodic transmissions

Avnu Pro AV devices do not send MSRP declarations periodically per the periodic! event. This requirement is per IEEE 802.1Q-2014 subclause 5.4.4(f) and the associated Note, and repeated here only for clarity.

9.3.4 Talker Stream prioritization

Avnu Pro AV Talker devices are required to behave such that if an active stream can still be offered after all streams of higher importance are assigned (or denied) bandwidth, then that stream should not be dropped. [Avnu_SRP-9]

A stream should not be cancelled unnecessarily. When a stream of higher importance needs bandwidth (such as anew stream with the Rank bit reset) then the Bridge must cancel the reservation of the youngest streams until there is sufficient bandwidth for the new stream; however, if a stream that would have been cancelled need not be, then it should not be. Take for example the following situation, on a link with all SR class bandwidth assigned, the youngest stream consumes only 5% of the bandwidth, and the next youngest stream consumes 20% of the bandwidth. If a new stream needing 10% bandwidth comes in with the Rank bit reset, then only the next youngest stream should ultimately be cancelled.

If a stream associated with a registered Talker Advertise can be provided on a given link without dropping any active streams of higher importance, then the stream should be propagated as a Talker Advertise. Otherwise MAP will declare a Talker Failed on the outbound port and add appropriate FailureInformation. [Avnu_SRP-10]

This requirement clarifies IEEE 802.1Q-2014 subclause 35.2.4.3 "MAP will analyze available bandwidth and other factors to determine if the outbound port has enough resources available to support the Stream". Take for example the following situation, on a link with all SR class bandwidth assigned to non-Emergency traffic (the Rank bit is set), and an Emergency stream (with the Rank bit reset) advertisement is received, then the Emergency Stream advertisement must propagate as a Talker Advertise. If it would be possible to satisfy a reservation if a Listener Ready message was received, then the Bridge should propagate as a Talker Advertise - provided streams of higher importance need not be dropped, even if some streams of lower importance would need to be dropped.

9.3.5 Bridge Proxy for Listener

If the Talker attribute for an existing reservation is deregistered first, Avnu Pro Bridges shall act as a proxy for Listener(s) and send a Listener deregistration back to the Talker.

When a Talker attribute and Listener attribute are registered within a Bridge for a StreamID and a MAD_Leave.request is received for the Talker attribute, the Bridge shall act as a proxy for the Listener and generate a MAD_Leave.request back toward the Talker. [Avnu_SRP-5]

9.4 MVRP Operation

9.4.1 Default VLAN mode

Avnu Pro AV devices are required to support C-VLAN (Customer VLAN) tags. Bridges are required to be configured for C-VLANs by default. [Avnu_MVRP-4]

9.4.2 Statically configured VLANs

Avnu Pro AV devices are required to propagate statically set VLAN ID information via MVRP as though MVRP registered (or de-registered) the information. [Avnu_MVRP-5]

9.4.3 Bridge Ingress Filtering

Avnu Pro Bridges are allowed to have Ingress Filtering enabled by default. [Avnu_MVRP-3] Ingress Filtering is specified by IEEE 802.1Q-2014 subclause 8.6.2, which specifies that Ingress Filtering be disabled by default.

When Ingress Filtering is enabled, a Bridge will discard any packets received for a VLAN for which the ingress port is not a member.

Ingress Filtering may be enabled as a conformant Talker should utilize MVRP to join the VLAN used by its stream before sending stream frames.

9.4.4 Bridge behavior upon receipt of "new" declarations

Avnu Pro Bridges are required to behave as follows:

When any MVRP declaration marked as "new" is received on a given Port, either as a result of receiving an MVRPDU from the attached LAN (MAD_Join.indication), or as a result of receiving a request from MAP or the MVRP Application (MAD_Join.request), any Dynamic Filtering Entries in the filtering database for that Port and for the VID corresponding to the attribute value in the MAD_Join primitive are removed. [Avnu_MVRP-6]

This clarifies an ambiguity in IEEE 802.1Q-2011 11.2.5 which states that upon receipt of new "any entries in the filtering database for that Port and for the VID corresponding to the attribute value in the MAD_Join primitive are removed."

There are many entries in the filtering database:

- *Dynamic Filtering Entry* (Contains: A MAC address, FID, and Port Map for "each outbound Port")
- *Dynamic VLAN Registration Entry* (Contains: A VID, and a Port Map for "each outbound Port")
- *MAC Address Registration Entry* (Contains: A MAC address, VID, and Port Map for "each outbound Port")
- *Dynamic Reservation Entry* (Contains: A VID, a MAC address specification, and a Port Map for "each outbound Port")
- *Static Filtering Entry* (Contains: A MAC address, VID, and Port Map for "each outbound Port")
- *Static VLAN Registration Entry* (Contains: A VID, and a Port Map for "each outbound Port")

Only *Dynamic Filtering Entries* shall be removed when new is received.

10 Pro AV EndStation Requirements

Previous sections of this specification identified device requirements by protocol (gPTP, FQTSS, or MRP). In this section, additional requirements specific to an Endstation are addressed.

10.1 Scope

This section covers the differences between standard-defined Endstation requirements and requirements for an Avnu Pro AV implementation as well as clarifications or emphasis on key standard-defined requirements.

10.2 Common Avnu Pro AV Endstation Requirements

10.2.1 Scope

This section covers only the differences between a standard Endstation requirements and an Avnu Pro AV implementation.

An Avnu Pro AV device shall implement all applicable Endstation requirements that are not discussed in this section.

The class of Endstations in this scope include: IEEE 1722.1 Controllers, AVTP Talkers, and AVTP Listeners.

10.2.2 Common Avnu Pro AV Endstation Major Functionality

Major functional requirements that are common for any Avnu Pro AV Endstation are identified below.

10.2.2.1 Support for IEEE 1722.1

All Avnu Pro AV devices shall support IEEE 1722.1 for device discovery, enumeration and control. Required IEEE 1722.1 functionality is outlined in the following sections.

10.2.2.2 Entity support for Discovery via IEEE 1722.1

All Avnu Pro AV devices (including Controllers) shall be discoverable AVDECC Entities. Per IEEE 1722.1-2013 5.3.1, A discoverable AVDECC Entity is an AVDECC Entity that is capable of advertising itself on a local area network (LAN). An AVDECC Entity that is discoverable on a network shall implement: "Advertise Entity State Machine", the "Advertise Interface State Machine" and associated variables

10.3 Common Avnu Pro AV Controller Requirements

10.3.1 Scope

This section covers only the differences between a standard AVDECC Controller and an Avnu Pro AV Controller. An AVDECC Controller shall conform to requirements of 5.4 of [AVDECC], with the addition noted above that the Controller Entity be discoverable.

At this time, no additional requirements are set by Avnu, but are anticipated for future specification of certification requirements for an Avnu Pro AV Controller.

10.4 Common Avnu Pro AV Talker/Listener Requirements

10.4.1 Scope

This section covers the differences between a standard Talker or Listener requirements and an Avnu Pro AV implementation.

The class of Endstations in this scope include: AVTP Talkers and AVTP Listeners.

10.4.2 Common Avnu Pro AV Talker/Listener Major Functionality

Major functional requirements for an Avnu Pro AV Talker and/or Listener are identified below.

10.4.2.1 Support for Mandatory IEEE 1722.1 Requirements

An Avnu Pro AV Talker or Listener device shall support the mandatory requirements of sections 5.5.1 and 5.6.1 of [AVDECC], including but not limited to support for the AQUIRE_ENTITY Command; LOCK_ENTITY Command; ENTITY_AVAILABLE Command; and CONTROLLER_AVAILABLE Command. This requirement is repeated here for clarity.

In the following subsections of Section 10, some optional features of [AVDECC] are identified as Avnu requirements. Unless otherwise explicitly stated, nothing in this specification is intended to restrict or discourage implementation of additional optional features defined in [AVDECC].

10.4.2.2 Support for MVRP and C-VLANs

An Avnu Pro AV Talker or Listener device shall support MVRP and shall use C-VLAN (Customer VLAN) tags by default. [Avnu_MVRP-4].

10.4.3 Common Avnu Pro AV Talker/Listener Reporting via IEEE 1722.1

Avnu requires all Pro AV Talker/Listener devices to report information with the IEEE 1722.1 commands identified in the following subsections.

10.4.3.1 ENTITY Descriptor Information

Avnu Pro AV Talkers and Listeners shall support the IEEE 1722.1 ENTITY descriptor.

The device shall support reporting in the ENTITY descriptor:

- A manufacturer-specified, plain language name, as a read-only field, via the *entity_name* field
- A user-defined, writable, plain language name via the *group_name* field.
- A model name and number in the *model_name_string* and *entity_model_id* fields
- A serial number in the *serial_number* field
- A manufacturer/vendor name via the *vendor_name_string* field
- A product revision number via the *firmware_version* field
- A physical device ID via the *entity_id* field
- A count of supported configurations via the *configuration_count* field

10.4.3.2 CONFIGURATION Descriptor Information

Avnu Pro AV Talkers and Listeners shall support the IEEE 1722.1 CONFIGURATION descriptor.

10.4.3.3 AVB_INTERFACE Descriptor Information

Avnu Pro AV Talkers and Listeners shall support reporting its MAC address via the 1722.1 AVB_INTERFACE descriptor information. [MRD item 9] Per the AVB_INTERFACE definition, the device's interface flags for GPTP_GRANDMASTER_SUPPORTED, GPTP_SUPPORTED, and SRP_SUPPORTED shall also be properly set.

An Endstation supporting more than one AVB-capable interface shall have a corresponding AVB_INTERFACE descriptor per AVB-capable interface.

10.4.3.4 CLOCK_DOMAIN Descriptor Information

Avnu Pro AV Talkers and Listeners shall support reporting its media clock source and lock status. IEEE 1722.1 CLOCK_DOMAIN descriptors shall be supported to report the source of the common clock signal within the entity. Refer to *10.4.3.12 GET_COUNTERS Command support* for details on required access to lock status indications.

10.4.3.5 CLOCK_SOURCE Descriptor Information

An Avnu Pro AV Talker and Listener shall support reporting its media clock(s) source and sink capabilities. IEEE 1722.1 CLOCK_SOURCE descriptors shall be supported to report available clock sources within the entity.

10.4.3.6 LOCALE and STRINGS Descriptor Information

An Avnu Pro AV Talker or Listener shall support IEEE 1722.1 LOCALE descriptors and STRINGS descriptors.

10.4.3.7 AUDIO_UNIT and AUDIO_CLUSTER Descriptor Information

An Avnu Pro Audio Talker or Listener shall support IEEE 1722.1 AUDIO_UNIT descriptors and AUDIO_CLUSTER descriptors.

An Avnu Pro Audio device shall support at least one AUDIO_UNIT descriptor with a valid *current_sampling_rate* field for the configured and supported stream format.

Certification testing will validate that the *current_sampling_rate* indicated in the AUDIO_UNIT descriptor is proper, for each certifiable stream formats. Certification testing may only verify certain stream formats. Other stream formats not verified as part of certification testing are permitted, but will not appear as verified on a device's certification.

10.4.3.8 CONTROL Descriptor Information and IDENTITY Control.

An Avnu Pro Audio Talker or Listener should support IEEE 1722.1 CONTROL descriptors. The device should support the IDENTIFY Control (IEEE 1722.1-2013 7.3.4.2).

10.4.3.9 GET_AVB_INFO Command support

An Avnu Pro Audio Talker or Listener should support the GET_AVB_INFO command to report the *gptp_grandmaster_id* field and *propagation_delay* field.

10.4.3.10 GET_NAME Command support

An Avnu Pro Audio Talker or Listener should support user-defined plain language names for media sources and sinks and shall support the IEEE 1722.1 GET_NAME command. [MRD item 14]

10.4.3.11 GET_CLOCK_SOURCE Command support

An Avnu Pro Audio Talker or Listener should support the IEEE 1722.1 GET_CLOCK_SOURCE command to report the current clock source of a clock domain.

10.4.3.12 GET_COUNTERS Command support

An Avnu Pro Audio Talker or Listener shall support the IEEE 1722.1 GET_COUNTERS command for the CLOCK_DOMAIN descriptor counters.

A device's clock lock status can be determined by examining the *counters_valid* field bits 31 (LOCKED) and 30(UNLOCKED) for the CLOCK_DOMAIN descriptor. As well as the first two quadlets of the *counters_block* for the CLOCK _DOMAIN descriptor (refer to 7.137 and 7.138 of [AVDECC]).

10.4.4 Common Avnu Pro AV Talker/Listener Configuration via IEEE 1722.1

Avnu requires all Pro AV Talker or Listener devices to be configured with the following IEEE 1722.1 commands. The following commands manipulate the configuration of the device, typically from an IEEE 1722.1 Controller.

10.4.4.1 SET_STREAM_FORMAT Command support

An Avnu Pro Audio Talker or Listener that supports more than one stream format, shall support the IEEE 1722.1 SET_STREAM_FORMAT command to select the appropriate stream format

10.4.4.2 SET_SAMPLING_RATE Command support

An Avnu Pro Audio Talker or Listener that supports more than one sample rate shall support the IEEE 1722.1 SET_SAMPLING_RATE command. This requirement is derived from [MRD item 31] which states that a professional audio device shall allow for remote configuration of its sample rate, if multiple sample rates are supported. [MRD item 31]

10.4.4.3 SET_NAME Command support

An Avnu Pro Audio Talker or Listener should support user-defined plain language names for media sources and sinks and shall support the IEEE 1722.1 SET_NAME commands. [MRD item 14]

10.4.4.4 SET_CLOCK_SOURCE Command support

An Avnu Pro Audio Talker or Listener should support the IEEE 1722.1 SET_CLOCK_SOURCE command to set the clock source for a clock domain.

10.4.4.5 START_STREAMING Command support

An Avnu Pro Audio Talker or Listener that supports the STREAMING_WAIT flag in the ACMP CONNECT_RX_COMMAND and CONNECT_TX_COMMANDshall support the IEEE 1722.1 START_STREAMING command.

10.4.4.6 STOP_STREAMING Command support

An Avnu Pro Audio Talker or Listener that supports the START_STREAMING command should support the IEEE 1722.1 STOP _STREAMING command.

10.4.5 Common Avnu Pro AV Talker/Listener Operation

This section outlines common operational requirements of an Avnu Pro AV Talker or Listener.

Any common operational requirements would be defined in this section, though no such common requirements are defined in this specification currently. Refer to Talker and Listener specific operational sections.

10.5 Avnu Pro AV Talker-Specific Requirements

10.5.1 Scope

This section covers only the differences between standard Talker requirements and an Avnu Pro AV implementation. An Avnu Pro AV device shall implement all applicable Talker requirements that are not discussed in this section.

10.5.2 Avnu Pro AV Talker Major Functionality

The following sections outline additional major functional requirements of an Avnu Pro AV Talker.

10.5.2.1 No Media Format Requirement

Avnu does not currently mandate a specific media format that must be supported by an Avnu Pro AV Talker.

10.5.2.2 Talker must have Media Clock Listener Functionality

All Avnu Pro AV Talkers must be able to listen to a Media Clock stream.   This enables all Talkers to be timed to a common Media Clock, independent of gPTP grand master or Talker source.

A Media Clock stream here is defined as an IEC 61883-6 AM824/ MBLA format stream.

For every sample rate that a Avnu Pro AV Talker supports, the device should support listening to a Media Clock stream for the supported sample rate.

10.5.2.3 Multicast Address Allocation

Avnu recommends the use of the Multicast Address Allocation Protocol (MAAP) as defined by IEEE 1722. However, use of MAAP is not mandatory. If a MAAP frame is emitted from a device during certification testing, all mandatory MAAP tests must be passed to be certified. [Avnu_MAAP-2]

If a stream destination address is used by a Talker from the MAAP Dynamic Allocation Pool, then the address must have been previously allocated using MAAP. [Avnu_MAAP-1]

A device using MAAP should not use only the low 3-bytes of the address when determining address usage. [Avnu_MAAP-3] When detecting conflicts per IEEE Std 1722-2011 note b, table B.2, the device must compare the entire 48-bit address range with the block it is defending, versus the full 48-bit value of the address range of the MAAP_PROBE PDU, MAAP_DEFEND PDU, or MAAP_ANNOUNCE PDU received. A common mistake would be to assume that all MAAP address ranges used will have the same high three-bytes (0x91-E0-F0) which may not be the case if MAAP is in use for other purposes.

10.5.3 Avnu Pro AV Talker Reporting via IEEE 1722.1

Avnu requires all Pro AV Talker devices to report information with the following IEEE 1722.1 commands.

10.5.3.1 Talker ENTITY_AVAILABLE ADPDU Information

An Avnu Pro AV Talker shall properly set the IMPLEMENTED flag in the ENTITY_AVAILABLE ADPDU to indicate capabilities as a Talker. [MRD item 38]

An Avnu Pro AV Talker shall set the MEDIA_CLOCK_SOURCE flag to indicate if the Talker is the media clock source.

An Avnu Pro AV Talker which does not always set the MEDIA_CLOCK_SOURCE flag must also support Listener functionality and indicate such support in the ENTITY_AVAILABLE's *listener_capabilities* field by indicating IMPLEMENTED.

An Avnu Pro AV Talker shall set the *talker_stream_sources* field of the ADPDU properly for the supported number of streams for its current configuration.

10.5.3.2 Talker STREAM_OUTPUT Descriptor Information

An Avnu Pro AV Talker shall support the IEEE 1722.1 STREAM_OUTPUT descriptor. The number of *talker_stream_sources* indicated in the ENTITY_AVAILABLE ADPDU must match the number of STREAM_OUTPUT descriptors.

Certification testing will validate that the *current_format* indicated in the STREAM_OUTPUT descriptor is proper, for each certifiable stream format. Certification testing may only verify certain stream formats. Other stream formats not verified as part of certification testing are permitted, but will not appear as verified on a device's certification. [MRD item 12-16]

10.5.3.3 Talker STREAM_PORT_OUTPUT Descriptor Information

An Avnu Pro AV Talker shall support the IEEE 1722.1 STREAM_PORT_OUTPUT descriptor. [MRD item 12-16]

10.5.4 Avnu Pro AV Talker Configuration via IEEE 1722.1

Avnu requires all Pro AV Talker devices to be configured with the following IEEE 1722.1 commands.

10.5.4.1 Talker CONNECT_TX_COMMAND Command Support

An Avnu Pro AV Talker shall support the IEEE 1722.1 CONNECT_TX_COMMAND and the ACMP Talker State Machine per 8.2.2.6 of [AVDECC].

10.5.4.2 Talker SET_STREAM_INFO Command support

Avnu Pro AV Talkers should support the SET_STREAM_INFO command to support the setting of the *msrp_accumulated_latency* field to change the Talker's Presentation Time.

Avnu Pro AV Talkers should also support setting the stream's VLAN ID via the *vlan_id* field of the SET_STREAM_INFO command.

SET_STREAM_INFO should not be used to set Stream ID.

10.5.5 Avnu Pro AV Talker Operation

The following sections outline operational requirements of an Avnu Pro AV Talker.

10.5.5.1 Presentation Time set by Talker

A Pro AV Talker will support the ability to set the Presentation time of stream data to 2ms +125us/-250us, referenced to the gPTP grandmaster time. The device may permit lower values may be configured, but must be set to this value by default for certification testing. This requirement ensures that all certified Avnu Pro AV Talkers and Listeners can interoperate with the maximum default Presentation Time.

10.5.5.2 Talker's use of MVRP

Talkers must register an appropriate MVRP VLAN Membership request before attaching to a stream. This requirement clarifies that a Talker shall join the relevant VLAN via MVRP prior to sending any stream frames. [Avnu_SRP-17]

10.6 Avnu Pro AV Listener-Specific Requirements

10.6.1 Scope

This section covers only the differences between standard Listener requirements and an Avnu Pro AV implementation. An Avnu Pro AV device shall implement all applicable Listener requirements that are not discussed in this section.

10.6.2 Avnu Pro AV Listener Major Functionality

The following sections outline additional major functional requirements of an Avnu Pro AV Listener.

10.6.2.1 No Media Format Requirement

Avnu does not currently mandate a specific media format that must be supported by an Avnu Pro AV Listener.

10.6.3 Avnu Pro AV Listener Reporting via IEEE 1722.1

Avnu requires all Pro AV Listener devices to report information with the following IEEE 1722.1 commands.

10.6.3.1 Listener ENTITY_AVAILABLE ADPDU Information

An Avnu Pro AV Listener shall properly set the IMPLEMENTED flag in the ENTITY_AVAILABLE ADPDU indicated capabilities as a Listener. [MRD item 38]

An Avnu Pro AV Listener shall set the *listener_stream_sinks* field of the ADPDU properly for the supported number of streams for its current configuration

10.6.3.2 Listener GET_STREAM_INFO Command support

Avnu Pro AV Listeners should support the GET_STREAM_INFO command to report the *msrp_accumulated_latency* field.

10.6.3.3 Listener STREAM_INPUT Descriptor Information

An Avnu Pro AV Listener shall support the IEEE 1722.1 STREAM _INPUT descriptor. The number of *listener_stream_sinks* indicated in the ENTITY_AVAILABLE ADPDU must match the number of STREAM_INPUT descriptors.

Certification testing will validate that the *current_format* indicated in the STREAM_OUTPUT descriptor is proper, for each certifiable stream format. Certification testing may only verify certain stream formats. Other stream formats not verified as part of certification testing are permitted, but will not appear as verified on a device's certification. [MRD item 12-16]

10.6.3.4 Listener STREAM_PORT_INPUT Descriptor Information

An Avnu Pro AV Listener shall support the IEEE 1722.1 STREAM_PORT_INPUT descriptor. [MRD item 12-16]

10.6.4 Avnu Pro AV Listener Configuration via IEEE 1722.1

All Avnu Pro AV Listener devices are required to support configuration with the following IEEE 1722.1 commands.

10.6.4.1 Listener CONNECT_RX_COMMAND Command Support

An Avnu Pro AV Listener shall support the IEEE 1722.1 CONNECT_RX_COMMAND and the ACMP Listener State Machine per 8.2.2.5 of [AVDECC].

10.6.5 Avnu Pro AV Listener Operation

The following sections outline operational requirements of a Avnu Pro AV Listener.

10.6.5.1 Presentation Time supported by Listener

An Avnu Pro AV Listener shall support the ability to receive a stream with a Presentation time of 2ms +125us/-250us, referenced to the gPTP grandmaster time.[FWAV-22] This requires all certified Avnu Pro AV Listeners to support buffering requirements of 2ms, allowing the Listener to be placed anywhere in the supported AVB network topology (eg: adjacent to the Talker, or 7 hops away from the Talker).

Nothing in this specification prevents the coordinated use of a lower Presentation time between certified Pro AV Talkers and Listeners when lower latencies are desired.

11 Avnu Pro Bridge Requirements

Sections 7 through 9 of this specification identified device requirements by protocol (gPTP, FQTSS, or MRP). In this section, additional requirements specific to a Bridge are addressed. The IEEE 802.1 standards define the requirements for an Avnu Pro Bridge, especially IEEE 802.1Q-2014.

11.1 Scope

This section covers differences between a standard 802.1Q Bridge requirements and an Avnu Pro AV implementation as well as clarifications or emphasis on key standard-defined requirements.

An Avnu Pro Bridge shall implement all applicable IEEE 802.1Q Bridge requirements that are not discussed in this section.

11.2 Avnu Pro Bridge Major Functionality

The following sections outline additional major functional requirements of an Avnu Pro Bridge.

11.2.1 Stream Reservation Class Support

All Avnu Pro Bridges shall support SR class B. Any Bridge with 2 or more IEEE 802.3 ports shall support SR class A.

11.2.2 Spanning Tree Functionality

All Avnu Pro Bridges shall support Rapid Spanning Tree Protocol (RSTP), and may support Multiple Spanning Tree (MSTP).

11.3 Avnu Pro Bridge Configuration

The following sections outline configuration requirements of an Avnu Pro Bridge.

11.3.1 Mandatory Bridge Configuration Method

In this specification, no mandatory method is specified for Avnu Pro Bridge configuration. A future specification may add requirements to ease discovery, enumeration and configuration.

For some certification test cases to be applicable, a manufacturer defined mechanism must be provided, either command line interface (CLI), Web GUI, or similar means to configure Bridge parameters. One example of such needed Bridge configuration is the need to enable and disable gPTP functionality either globally or per port on the Bridge for testing purposes.

11.4 Avnu Pro Bridge Operation

The following sections outline operational requirements of an Avnu Pro Bridge.

11.4.1 MSRP Propagation Performance

For certification purposes, a Bridge is expected to complete any propagation of attributes within 1.5 seconds.

11.4.2 Maximum Number of support VLANs

For certification purposes, a Bridge's maximum number of support VLANs must be identified.

11.4.3 Maximum Number of Talker Registrations

For testing purposes, a Bridge's maximum number of Talker Registrations must be identified. The following values must be provided, given default timer values for the MSRP protocol.

$Tdense_{port}$ = Number of densely encoded Talker registrations supported per-port.

$Tdense_{global}$ = Number of densely encoded Talker registrations supported on the Bridge as a whole.

$Tsparse_{port}$ = Number of sparsely encoded Talker registrations supported per-port.

$Tsparse_{global}$ = Number of sparsely encoded Talker registrations supported on the Bridge as a whole.

NOTE: Larger values can be supported by a device when non-default timer values are utilized (eg: modifying leaveTime network-wide to a larger value). Certification testing does not address non-default timer configurations.

11.4.4 Maximum Number of Listener Registrations

For testing purposes, a Bridge's maximum number of Listener Registrations must be identified. The following values must be provided, given default timer values for the MSRP protocol.

$Ldense_{port}$ = Number of densely encoded Listener registrations supported per-port.

$Ldense_{global}$ = Number of densely encoded Listener registrations supported on the Bridge as a whole.

$Lsparse_{port}$ = Number of sparsely encoded Listener registrations supported per-port.

$Lsparse_{global}$ = Number of sparsely encoded Listener registrations supported on the Bridge as a whole.

NOTE: Larger values can be supported by a device when non-default values are utilized. Certification testing does not address non-default configurations.

11.4.5 Maximum Number of Active Streams Supported

For certification purposes, a Bridge's maximum number of supported active streams must be identified. An active stream indicates a reservation is active, with a corresponding Talker Advertise registration and Listener registration on the bridge, and that bandwidth is now actively reserved for the stream.