Cisco Audio Video Bridging Design and Deployment for Enterprise Networks

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Audio-Video deployment trends

Audio and Video (AV) equipment deployments have traditionally been analog, single-purpose, point-to-point, one-way links. As deployments migrated to digital transmission, they continued to retain the point-to-point, one-way link architecture. This dedicated connection model resulted in a mass of cabling in professional and consumer applications that was hard to manage and operate.

Multiple mechanisms were identified to solve this problem. But all of them were nonstandard, difficult to operate and deploy, or expensive and inflexible.

Migration to an Ethernet infrastructure was seen as a means of addressing the needs of professional AV equipment in addition to lowering Total Cost of Ownership (TCO) and enabling transparent integration of new services. However, the deployment mechanism lacked flexibility and interoperability.

To accelerate the adoption of Ethernet-based AV and provide a deployment that is more flexible, IEEE developed the IEEE 802.1 Audio Video Bridging (AVB) standard. This standard defines a mechanism whereby endpoints and the network function as a whole to enable high-quality AV streaming across consumer applications to professional AV deployments over an Ethernet infrastructure.
The transition from nonnetworking (non-Ethernet and non-IP, such as HDMI) to networking (Ethernet and IP) has started. AV and production media and controller solution builders are moving to take advantage of this standards-based transition, seeking not only lower TCO—no more license fees—but also scalability—more efficient deployment, installation, and management—to enable new services and capabilities.

Many switch and endpoint vendors provide support for IEEE 802.1 AVB. Starting with Cisco® IOS® XE Software Release 16.3, Cisco supports the standard on select Cisco Catalyst® 3850 and 3650 Series mini switches, which deliver the highest-capacity 1, 10, and 40 Gigabit Ethernet ports in the industry.

This document describes AVB designs based on the IEEE 802.1 standards and deployment use cases with Cisco AVB switches.

Audio Video bridging overview

AVB is the common name for the set of technical standards developed by the IEEE Audio Video Bridging Task Group of the IEEE 802.1 standards committee. This task group was renamed the Time-Sensitive Networking Task Group in November 2012 to reflect the expanded scope of its work. IEEE 802.1 defines a set of standards that provide the means for highly reliable delivery of low-latency, time-synchronized AV streaming services through Layer 2 Ethernet networks.

The set of IEEE 802.1 standards consists of the following:

- IEEE 802.1AS: Generalized Precision Time Protocol (gPTP), which provides timing and synchronization for time-sensitive applications on Layer 2 devices
- IEEE 802.1Qat: Stream Reservation Protocol (SRP)/Multiple Stream Reservation Protocol (MSRP), which is an end-to-end traffic admission control system that helps ensure the availability of resources, such as bandwidth and latency, that are required to transport AV streams
- IEEE 802.1Qav: Forwarding and Queuing for Time-Sensitive Streams (FQTSS), which is AV traffic scheduling capability for mainstream Ethernet and other network switches
- IEEE 802.1BA: An umbrella standard for the other three IEEE 802.1 standards that defines profiles for features, options, configurations, defaults, protocols, and procedures for AVB devices
AVB network components

AVB protocols operate only in domains in which every device is AVB capable. The AVB network consists of AVB talkers, AVB listeners, and AVB switches.

The AVB talker is an AVB end station that is the source or producer of a stream. An example of this would be an AVB-capable microphone.

The AVB listener is an AVB end station that is the destination or consumer of a stream, such as an AVB-capable speaker.

In many cases, the AV endpoints (microphones or speakers) are analog devices. AVB endpoint vendors introduce Digital Signal Processors (DSPs) and I/O devices that perform extensive AV processing and aggregate the endpoints, as shown in Figure 1. Tesira from Biamp and D-Mitri from Meyer Sound are examples of such a digital audio platform. These digital audio platforms are AVB talkers or listeners on behalf of those analog devices.

Figure 1. Vendor Audio I/O system

The AVB switch, or bridge, is an Ethernet switch that complies with the IEEE 802.1 AVB standards.

The AVB stream is a data stream associated with a stream reservation that complies with SRP.

The IEEE 802.1BA specification requires an AVB talker to be grandmaster capable. In a typical deployment, a network node can also be the grandmaster, provided that it can either source or derive timing from a grandmaster-capable device. An IEEE 802.1AS network timing domain is formed when all devices meet the requirements of the IEEE 802.1AS standard and communicate with each other using the IEEE 802.1AS protocol. The clock of one device is chosen as the reference clock for synchronization purposes. This device is referred to as the grandmaster.

The device also must provide the timing to the AVB network using IEEE 802.1AS. Figure 2 shows a simple AVB network with its components.
Cisco Audio Video bridging design

From a high-level perspective, AVB works by reserving a fraction of the available Ethernet bandwidth for AV traffic. AV streams are established upon successful reservation of bandwidth within latency requirements. All the nodes in the system share a virtual clock. AV packets have a presentation time that defines when the media packet should be played.

**Time synchronization (IEEE 802.1AS)**

IEEE 802.1AS gPTP is based on the IEEE 1588 Precision Time Protocol (PTP). It defines clock master selection algorithms, link delay and network queuing measurement and compensation, and clock-rate matching and adjustment mechanisms for Layer 2 network devices.
Each grandmaster-capable device broadcasts its clock parameters through announce messages. The best master clock selection algorithm is used to select the master and slave states of the port on each link using the announce messages. The best clock selected as the master depends on the quality of the clock and configurations such as gPTP priority. Figure 3 shows an example of an AVB network with the grandmaster and AVB switch gPTP port status. The master port is the source of the time on the path. The slave port synchronizes its time with the master port.

Figure 3. AVB Network time synchronization

To use IEEE 802.1AS, streams must include a presentation time. All devices in the network can then align their playback by comparing the presentation time information in the stream packets with the IEEE 802.1 AS common time base. One advantage of this approach is that with IEEE 802.1AS and presentation time encapsulated streams, an AVB network inherently supports multiple simultaneous sample rates and sample clock sources. This support allows, for example, video and audio streams to be synchronized even though they travel on different paths with different sample rates. A second advantage of using presentation time is that if two devices are outputting the same stream, they are precisely locked in their playback even if they are on different networks at different distances from the source.

**Multiple stream reservation protocol (IEEE 802.1Qat)**

IEEE 802.1Qat Multiple SRP (MSRP) provides mechanisms for reserving stream bandwidth that allow endpoint applications to configure the routes automatically, eliminating the need to manually configure Quality of Service (QoS) across network devices. MSRP checks end-to-end bandwidth availability before an AV stream starts. The bandwidth allocated for AV streams is limited to a maximum 75 percent of the total port bandwidth. If bandwidth is available, it is locked down along the entire path until it is explicitly released.
MSRP signaling is based on a set of talker and listener declarations. MSRP-aware switches register and deregister talker and listener declarations on the switch ports to set up the AVB sessions and automatically generate deregistration of stale registrations to tear down the AVB sessions.

A talker declaration is forwarded over output ports that can potentially lead to the destination MAC address of the reservation. The talker declarations are advertise and failed, which are propagated by MSRP so that the listeners and switches are aware of the presence of talkers and their streams (Figure 4).

- An advertise declaration is an advertisement for a stream that has not encountered any bandwidth or other network constraints along the network path from the talker. The listeners that register with this stream are likely to create a reservation with the described QoS. Talker advertise messages contain the following information necessary to make a reservation:
  - Stream ID (48-bit MAC address associated with the talker plus a 16-bit ID)
  - Stream destination address (a multicast group MAC address)
  - VLAN ID
  - Priority (used to determine the traffic class)
  - Rank (emergency or nonemergency)
  - Traffic specification (maximum frame size and maximum number of frames per class)
  - Measurement interval
  - Accumulated latency

- A failed declaration is an advertisement for a stream that is not available to the listener because of bandwidth constraints or other limitations somewhere along the path from the talker.

Figure 4. AVB talker declaration message propagation
The listener declarations are asking failed, ready, and ready failed. These declarations convey the results of the bandwidth allocation along its path back to the talker (Figure 5):

- A ready declaration means that one or more listeners are requesting attachment to the stream. Sufficient bandwidth and resources are available along the paths to the talker for all listeners to receive the stream.
- A ready failed declaration means that two or more listeners are requesting attachment to the stream. At least one of those listeners has sufficient bandwidth and resources along the path to receive the stream. One or more other listeners cannot receive the stream because of network bandwidth or resource allocation problems.
- An asking failed declaration means that one or more listeners are requesting attachment to the stream. None of the listeners can receive the stream because of network bandwidth or resource allocation problems.

Figure 5. AVB listener declaration message propagation

End-to-end stream reservation is successful only when an AVB listener receives an AVB talker advertise message, and the AVB talker receives an AVB listener ready message.

During stream reservation, MSRP interfaces with gPTP to set up the correct timing profile. MSRP requires two pieces of information from gPTP:
• Per-port status indicating whether the port is gPTP capable: This information is used to determine the SRP domain boundary.

• Per-port peer delay: Peer delay and residence delay on AVB switches are used to accumulate delays along each hop of a reservation to help ensure that latency requirements are met. A stream session is set up only when end-to-end latency meets the requirements.

During stream session creation, MSRP also interfaces with QoS to trigger allocation of hardware resources:

• Add end-to-end per-interface AVB switch QoS configurations, including bandwidth allocation for AVB streams and traffic shaper configuration based on IEEE 802.1Qav.

• Add the Layer 2 multicast route to distribute AVB streams from talkers to listeners.

AVB streams are forwarded only upon successful creation of an AVB stream session. After AVB streams stop, MSRP automatically releases reserved resources on AVB switches and tears down the AVB session.

**Forwarding and queuing for time-sensitive streams (IEEE 802.1Qav)**

IEEE 802.1Qav defines forwarding and queuing rules for AVB traffic: the type of AVB stream classes, corresponding QoS properties, how to schedule delivery of time-sensitive AV streaming data, and so on. IEEE 802.1Qav works together with MSRP. MSRP manages the bandwidth and admission control. It interfaces with IEEE 802.1Qav to determine and allocate the required bandwidth for the stream. IEEE 802.1Qav schedules time-sensitive AV streaming data, helping ensure timeliness through the network. Regular non-AVB traffic is treated in such a way that it cannot interfere with reserved AVB traffic. Using the AVB protocols, intelligent devices communicate with the network to provide reliable AV streaming without the need for the installer to perform extensive manual tuning of the network.

An AVB network has different classes of traffic. Here are some examples:

• Stream Reservation (SR) class A: This class has the highest priority in the AVB network. The worst-case latency requirement in a network is 2 milliseconds for SR class A traffic. MSRP uses the per-port peer-delay information provided by gPTP and AVB switch residence delay to calculate the accumulated delays along each hop of a stream reservation to help ensure that the latency requirements are met.

• SR class B: This class has the second highest priority in the AVB network. The worst-case latency requirement in a network is 50 milliseconds for SR class B traffic.

• Control traffic: This class has the third highest priority in the AVB network. It includes gPTP and MSRP traffic.

• Best-effort traffic: This class has the lowest priority in the AVB network. It consists of non-AVB traffic.

On ingress, traffic is classified into different ingress queues based on the Class-of-Service (CoS) field. Sometimes non-AVB ingress traffic to a non-AVB port carries a CoS value that is the same as the SR class CoS value. To prevent non-AVB traffic from being misclassified as AVB traffic, ingress QoS remarking is performed on all non-AVB ports to help ensure that non-AVB traffic traverses the AVB network as best-effort traffic.

On egress, frame forwarding behavior is based on the priority. The SR class traffic is mapped to the egress queue that supports the credit-based traffic shaper algorithm. The credit-based traffic shaper algorithm is used to shape the transmission of the SR class streams. Traffic shaping is the process of smoothing out the traffic for a stream, distributing the stream’s packets evenly in time. If traffic shaping is not performed at sources and switches, then the packets tend to bunch, or agglomerate, into bursts of traffic, which can overwhelm the buffers in subsequent switches. Traffic shaping helps reduce or eliminate network congestion for AVB traffic.

The QoS configuration on AVB switch ports is initiated by MSRP when bandwidth is reserved. The QoS configuration is removed automatically when the bandwidth is released by MSRP.
Cisco AVB deployment use cases for enterprise networks

This section discusses several Cisco AVB deployment use cases and network designs for an enterprise network. The goal of a Cisco AVB enterprise network is to limit the analog AV signal as much as possible and push the Ethernet-based AV network as far as possible within the enterprise. AVB can be used in many different environments where timing and clarity of Audio/Video traffic is critical. Below are some common AVB deployment use cases:

**Contained AVB deployment**

In a contained AVB deployment, the space is built using discrete and local equipment closets with the AVB systems and the AVB switches. Auditoriums and multiple-purpose rooms are examples of contained AVB deployments. Figure 6 shows the analog microphones and ceiling speakers that are aggregated by AVB I/O devices. These are then converted to Ethernet AV traffic to be passed through the AVB switches.

Figure 6. Contained AVB deployment
Figure A. Courtroom example (example from Biamp.com)

Figure B. Lecture/Classroom example
• Multifloor scaled audio deployments

**Note:** Each device between the source and the destination of the AVB stream needs to support AVB. Ensure to deploy AVB supported devices between the source and destination AVB streams.

**Interconnected multiple-floor AVB deployment**

In an interconnected multiple-floor deployment, multiple spaces or rooms across floors in a building have installed AVB systems and AVB switches interconnected across multiple floors. Figure 7 shows an example of a multiple-floor building with AVB switches connected across different floors.

**Figure 7.** Interconnected multiple-floor AVB deployment
Video distribution deployment

Video can also be distributed over an AVB network. One deployment example is a video recording and distribution system. The cameras record the events and then send compressed/uncompressed video over the AVB Ethernet network to the recording center in a central location. The deployment can range from small scale (one-floor courtroom) to large scale (multiple-floor service building). Other video distribution examples include video media delivered to a lobby or a video wall and video broadcast from an auditorium to a cafe.

Cisco AVB hardware and software support for enterprise networks

Audio Video Bridging is supported on select Cisco Catalyst 3850 and 3650 Series mini switches. Either an IP Base or IP Services license is required. Note that currently AVB is not supported on stacking switches.

The Cisco Catalyst 3850 Series is the next generation of enterprise-class access and aggregation layer switches. The Cisco Catalyst 3850 models that support AVB are:

- **WS-C3850-12x48U**: For Cisco IOS XE Software 16.3.1, AVB is supported on the 36 1 Gigabit Ethernet copper ports and uplink fiber ports. From Cisco IOS XE Software 16.3.2, AVB is supported on the other 12 mGig copper ports as well. WS-C3850-12x48U supports full IEEE 802.3at Power over Ethernet Plus (PoE+) and Cisco Universal Power over Ethernet (UPOE), which can power the AVB endpoints that are POE capable.
- **WS-C3850-24XU**: The 24 copper ports on WS-C3850-24XU are mGig ports. AVB is supported on all ports with Cisco IOS XE Software 16.3.2. WS-C3850-24XU supports full IEEE 802.3at PoE+ and UPOE, which can power the AVB endpoints that are POE capable.
- **WS-C3850-12XS/WS-C3850-16XS/WS-C3850-24XS/WS-C3850-32XS/WS-C3850-48XS**: These C3850 models are 10 Gigabit Ethernet SFP+ models. AVB is supported on all ports with Cisco IOS XE Software 16.3.1.

The Cisco Catalyst 3650 Series mini switches are reduced depth (11.62-inch deep) next-generation enterprise-class access-layer switches. The Cisco Catalyst 3650 Series mini switches support full IEEE 802.3at PoE+, which can power the AVB endpoints that are POE capable. AVB is supported on all ports with Cisco IOS XE Software 16.3.2. The models that support AVB are:

- **WS-C3650-24PDM**
- **WS-C3650-48FQM**
- **WS-C3650-8X24PD**
- **WS-C3650-8X24UQ**
- **WS-C3650-12X48FD**
- **WS-C3650-12X48UQ**
- **WS-C3650-12X48UR**
- **WS-C3650-12X48UZ**
Conclusion

Audio and video equipment deployments have traditionally been analog, single-purpose, point-to-point, one-way links. As deployments migrated to digital transmission, they retained the point-to-point, one-way link architecture. This dedicated connection model resulted in a mass of cabling in professional and consumer applications, which was hard to manage and operate. Migration to an Ethernet infrastructure was recognized as a way of addressing the needs of professional AV deployments in addition to lowering TCO and enabling transparent integration of new services.

Audio Video Bridging is a set of technical standards developed by the IEEE 802.1 standards committee. IEEE 802.1 defines a set of standards that provide the means for highly reliable delivery of low-latency, time-synchronized AV streaming services through Layer 2 Ethernet networks. The standardization helped accelerate the adoption of Ethernet-based AV deployments in enterprise networks.

With an AVB-capable endpoint and switch, analog AV signals are aggregated at AVB endpoints and transmitted on shared Ethernet infrastructure. The design is flexible, scalable, simple to operate, and cost effective.

With a Cisco AVB enterprise network solution, professional AV installations that previously required extensive time and resources to connect proprietary or noninteroperable network elements now benefit from a simplified network, reduced implementation costs, unified management, converged infrastructure, and standards-based designs for audio and video application integration.

For more information

- AVnu Alliance: http://avnu.org/knowledgebase/