AVnu™ Alliance White Paper

AVB for Automotive Use

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Executive Summary

With the explosion of demand for connectivity and multimedia in the automobile, the need for standards-based A/V networking that can be easily deployed is now well-established. The IEEE 802.1 Audio/Video Bridging (AVB) task group and the IEEE 1722 Layer 2 Transport Protocol Working Group for Time-Sensitive Streams have developed a series of network enhancements that provide the components for highly reliable audio and video applications. The AVnu Alliance has taken these standards, documented a profile for automotive use, and developed certification tests in its automotive Certification Test Subgroup (CDS). This paper outlines these new technologies and their benefits when used for in-vehicle applications.

About AVnu Alliance

The AVnu Alliance enables deterministic networking via certification of compliance and interoperability for devices using open IEEE standards. The AVnu certification program ensures interoperability of networked devices in a broad range of applications including professional AV, automotive, industrial control and consumer. The organization works with standards bodies and alliances to create an open path to deterministic networking based on 802.1 Audio Video Bridging (AVB) / Time Sensitive Networking (TSN) base standards, enabling designers and engineers to architect these standards into their product plans.

Introduction

Over the last ten years, consumer demand had driven a large increase in audio and video features and options in the automobile. Once only found in luxury cars, features such as DVD playback, backup cameras, and navigation have become commonplace options in many mainstream automobiles. Rear Seat Entertainment (RSE) units are growing in sophistication with more sources and choices at your fingertips. Each of these options has added to the need and desire for a common networking architecture in the automobile.

While automotive OEMs around the globe have embraced the concept of low-bandwidth vehicle communication networking with Controller Area Network (CAN) being adopted almost universally, the unique and varied challenges in vehicle multimedia networking (e.g., bandwidth, QOS, scalability, cost, economies of scale, open vs. proprietary, and supplier choice) has left the door open for much debate over the best solution for multimedia from both a technical and commercial perspective.

Historically, the implementation of packet-switched networks has been avoided for vehicle multimedia applications due to their non-deterministic nature. The recent work of the IEEE 802.1 Audio Video Bridging (AVB) task group and the IEEE 1722 AVTP working group, offers a standards-based approach for highly reliable networked transmission for low-latency applications like those found within an automobile. While AVB protocols can be used on more than one physical layer type, this paper will focus on the application of AVB over Ethernet. Wired Ethernet networks employing AVB protocols are very well suited to automotive deployment due to both simplified cabling and reliability of a hard-wired solution.

A primary market focus of the AVnu Alliance is the successful deployment of AVB for streaming audio/video into the automotive space. This whitepaper outlines the features and benefits of in-vehicle networking using the AVB technologies.

Ethernet AVB at-a-glance

AVB is an enhancement to the Ethernet suite of open standards. It provides quality of service (QoS) guarantees, a network time synchronization service, and a related transport protocol for transmission of time-sensitive traffic that together allow a network to handle audio-visual (AV) data. In the automotive environment, it can also satisfy more generalized time-sensitive networking requirements, opening up the possibility of a single network that handles infotainment, body control, driver assistance and even safety-critical functions.

To do this, AVB uses a number of important concepts. It introduces “priority”, to specify that some data streams are time-sensitive and distinct from ordinary traffic that gets carried on a best-effort basis. The idea of “reservation” means that the network can set aside a certain amount of guaranteed bandwidth to handle this high-priority traffic. The concept of “network time”, along with rigorous latency specifications, enables synchronized AV playback through simultaneous packet delivery. Standard traffic shaping and forwarding rules are also included.

Finally, there are standardized methods for discovery, enumeration and control, allowing systems to be built and configured quickly and easily.

More details about the individual parts of the standard and associated technologies can be found in the technology overview at the end of this document.

AVB Benefits for automotive markets

Simpler cabling lowers weight and increases reliability

A networked approach to cabling reduces the component cost and design complexity of the in-vehicle wiring harness. It boosts reliability by cutting the number of interconnects, while reducing weight and hence increasing fuel efficiency.

The use of multiplexed or networked based control communication in vehicles is already commonplace, starting with basic control messaging and the widespread adoption of the CAN protocol. As the A/V content associated with infotainment systems has increased, it has become impractical to continue with point-to-point dedicated connections such as shielded LVDS cables.

A healthy ecosystem

The creators of AVB chose to base it on Ethernet for more than just sound technical reasons. Ethernet is the most robust, most deployed, most familiar networking technology on earth. The decision to create an open, standard technology was intended to build on these advantages. Open standards foster strong, competitive ecosystems, and multiple silicon providers have already deployed AVB into their products. Further, the work of the AVnu Automotive CDS has defined a usage profile for AVB and is developing an associated certification process. This will allow OEMs to specify compliance and interoperability requirements that can be met by a variety of Tier-1 automotive suppliers, who in turn can architect their solutions without dependence on a single technology provider.

This approach contrasts sharply with the previous situation in the automotive industry. The predominant technology for in-vehicle infotainment networking has traditionally been MOST®, but many have felt that the proprietary nature of the MOST technology has slowed development and hampered its adoption. As early as Nov 2008, the Hansen Report observed that "...industry players today believe that compared with CAN, LIN, and FlexRay, MOST is not nearly open enough." The report goes on to predict that "Without more openness and greater affordability, MOST could in several years give way to alternatives, for example Ethernet." This prediction is now coming to pass, as MOST gets overtaken by newer, more open technologies."

Certified interoperability

AVB is not just open – it is a set of IEEE standards backed by a robust and rigorous set of conformance and interoperability (C&I) defined in its respective Protocol Implementation Conformance Statements (PICS). AVnu C&I extends IEEE PICS to include those specific to the Automotive use case. AVnu Alliance certification programs include independent testing ensuring interoperability across a broad ecosystem of A/V devices.

The result is that OEMs get assurances that their products will work with other AVB-certified devices; and auto makers get a fertile ecosystem of suppliers that grows and quickly reaches critical mass.

Predictability and high reliability

The AVB core technologies of prioritization, reservation, traffic shaping, and universal timing allow the construction of networks with the demanding predictability and reliability requirements of the automotive industry.

The IEEE 802.1Q Queuing and Forwarding Protocol (Qav) is key to this predictability. It schedules high-priority traffic through the network, ensuring that lower-priority data does not interfere with time-sensitive content.

Bandwidth Reservation reserves end-to-end bandwidth availability across the network before an A/V stream starts, guaranteeing that bandwidth until it is explicitly released. Bandwidth reservations can be preconfigured statically for a minimal startup. A system configured with Static Reservations for the expected traffic patterns and thereby reserving the required network resources is the default functionality in automotive use cases.

The IEEE 802.1Q Stream Reservation Protocol (SRP) can be used to add a further layer of flexibility. It allows endpoints to dynamically reserve and release stream bandwidth, enabling reliable A/V streaming without the need for the OEM to perform extensive hand tuning of the network for every different option package or future configuration of the vehicle. Implementation of SRP is option in automotive use case.

Many-to-many configuration flexibility

Creating an in-vehicle network that deals with a broad range of content and control signals is a challenging task. The network needs to play back AV program material from a variety of sources to a number of destinations, provide features such as program muting in the event of an incoming cellphone call, and deliver content like warning indicators and turn-by-turn navigation commands that must be assured a timely delivery. This requires a network that is configured with reservations to cope with these requirements from the outset.

Implementation of SRP is optional and not required in automotive use case. The need for many-to-many communication is one of the fundamental attractions for auto makers of moving to a networked AV system and away from point-to-point connections.

Low Latency

Many automotive applications require very low latency. Devices such as back-up or driver assist cameras, Bluetooth microphones and various signal tones are obvious examples. Just as important are the constraints imposed by outside-world systems – for instance a handsfree car kit needs to conform to the latency requirements of the cellular network. The AVB protocols can deliver against the most rigorous latency requirements.

Precise Synchronization

The overall aim of an automotive AV network is to deliver a high-quality listening and viewing experience to the user in the vehicle by allowing AV streams to be reconstructed faithfully at the end points. In addition, the auto maker gains the opportunity to build a flexible network that can accommodate a diverse range of content types, sources and playback nodes.

The key to both of these requirements is synchronization.

Technically, synchronization has two primary purposes: first, it provides a common time base for sampling data at a source device and presenting that data at one or more destination devices with the same relative timing; second, it allows multiple streams to be synchronized with each other (for example front and rear audio).

AVB achieves this via IEEE 802.1AS Precision Time Protocol (PTP). This provides a common time-reference base to all nodes on the network, called the “wall clock”. IEEE 1722 AV Transport Protocol then introduces the concept of “presentation time”, derived from the common “wall clock”, allowing the sending node to specify when (in network time) a packet should be presented at the receiving end.

Network nodes retain their own local clock: but by exchanging timestamp information, they track “where they stand” in relation to network time. At the receiving end, the original sample clock can therefore be reconstructed, not only allowing an accurate, low-jitter delivery of the content, but also allowing a single AVB network to accommodate any number of different sample rates and device types.

Fast boot

One of the most testing requirements placed on automotive multimedia systems is the need to provide “early audio” and “early video”. The system must boot fast and be ready to provide audio and video functionality on the order of a second after the car is started. Audio is used to play safety chimes; video is used for rear-view cameras. Both use cases are mandated by NHTSA to be available within 2 seconds after starting the car.

To satisfy these needs, the AVnu Alliance has created a dedicated automotive profile that streamlines the startup process of automotive Ethernet AVB products. In particular, the profile uses a pre-configured fixed clock tree for fast network time synchronization, and preconfigured traffic stream configurations, eliminating the delay associated with dynamic set up of AVB stream reservations.

Scalable, versatile topologies

Unlike MOST, where the total network bandwidth is shared among all connected devices, AVB networks utilize bandwidth only between source and destination node connections. This conservation of bandwidth allows substantially more data to flow on an AVB network vs. a MOST network even at equivalent network bitrates. Topologies such as stars and trees are easily supported. The availability of a multicast service, for one-to-many transmission, further increases bandwidth efficiency.

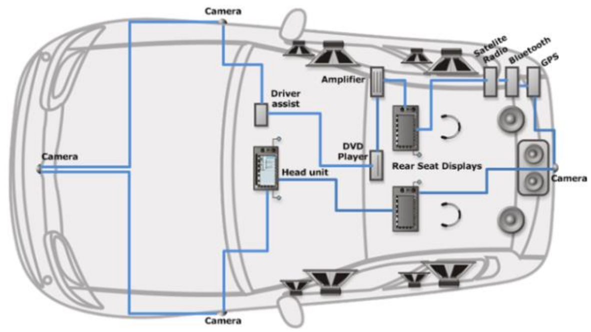


Fig 1 MOST ring topology. All devices see entire network traffic from every other devices

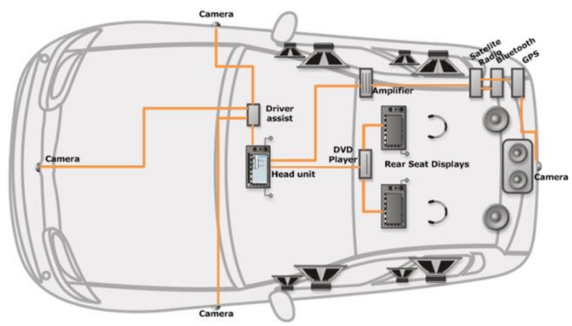


Fig 2 Possible AVB architecture. In this example, the camera signals from the front of the car only pass to the drives assistance module.

Designers also have a flexible choice of compatible speeds. For example a given vehicle design can easily mix and match high-bandwidth gigabit links with lower-bandwidth 100Mbps. Substantial technological investment by the networking community has ensured this interoperability at the same time that speeds have been pushed upward to 10Gbps and even 100 Gbps. By comparison, the three published speeds of MOST - MOST25, MOST50, and MOST150 - are not compatible. The entire network must be at the same speed, reducing flexibility and adding unnecessary cost into the low-bandwidth devices to meet the needs of high-bandwidth devices.

Ethernet AVB Use Cases

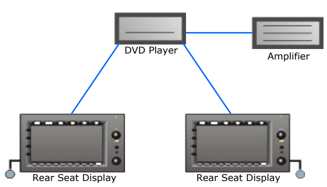
Lip-synced Multimedia Playback

Providing truly lip-synced playback of AV content across the various multimedia devices in a car environment is a core automotive use case for Ethernet AVB.

The content, whether from a pre-installed DVD player in the front console or from a wireless mobile device, can be delivered simultaneously to multiple front and rear seat displays, the car's primary audio amplifier and even connected headsets. This ensures an enjoyable AV experience for all passengers, regardless of the content being played or the desired playback constellation.

The following figure shows an example with two RSE displays showing the video playback of a DVD whilst the audio is transmitted on a totally separate path to the amplifier. Ethernet AVB allows all three to be precisely synchronized.

Fig 3. DVD player with multiple audio/video paths



Connected Car Applications

In a connected car, the availability of and the inevitable dependency on external data is high. Whether it is streamed AV content, online maps for navigation, general Internet media coming into the car or various telematics data and service requests being sent out of the car, the demand for network bandwidth is high.

The ability to leverage a single vehicle network for delivering all of this data as well as internal AV data, while still respecting the significantly different QoS requirements for different data is a powerful advantage of Ethernet AVB.

Advanced Driver Assistance Systems

The flexibility and high bandwidth of an AVB network enables the realization of many modern Advanced Driver Assistance Systems (ADAS).

For example, an array of cameras can be connected to provide a synchronized 360° surround view of the vehicle's environment. This view can be further enhanced with additional sensor data, sent and synchronized over the same network, to provide an augmented driver awareness system to increase safety for both motorists and pedestrians.

Diagnostics

Vehicle diagnostics are highly desired by automotive OEMS to troubleshoot vehicle problems at automotive OEM assembly lines and dealer service stations. No physical diagnostics exist for CAN and only ring break diagnostics exist for MOST.

On the other hand, modern Ethernet PHYs have substantial physical layer diagnostic capabilities which include: automatic detection and compensation of swapped pairs, cable breaks, and detection and compensation for kinks and impedance mismatches which can reduce bandwidth. Utilizing these established and proven Ethernet diagnostics, both assembly and service issues can be more quickly found and fixed.

Brief Technology Overview

For a more thorough treatment of the AVB technologies, see technical resources available on AVnu website Knowledge Center and Council Material.

The IEEE 802.1 AVB and IEEE 1722 standards form the foundation of the technology promoted by the AVnu Alliance and—like other IEEE standards—describe interworking/bridging between various network link technologies. It's important to note, however, that this is not intended to imply that the services provided by the AVB standards over every kind of network link are identical, since each link technology has different characteristics.

Below are the foundational standards.

- IEEE 802.1AS (PTP): "Timing and Synchronization for Time-Sensitive Applications in Bridged Local Area Networks." This auto-selects a device to be the master clock, which then distributes time throughout the bridged LAN / IP subnet to all other nodes. The 802.1AS clock is not used as a media clock. Rather, the 802.1AS time is used as a shared clock reference between nodes which is used to port a media clock from talker to listener. Such a reference removes the need to fix the latency of packet delivery, or compute long running averages in order to estimate the actual media rate of the transmitter in the presence of substantial network jitter. IEEE 802.1AS is based on the ratified IEEE 1588-2008 standard.
- IEEE 802.1Q-2012 (SRP): Developed as a P802.1Qat project, "Virtual Bridged Local Area Networks - Amendment 9: Stream Reservation Protocol (SRP)." This allows a stream reservation to be established between a talker and listener in a bridged LAN / IP subnet.
- IEEE 802.1Q2012 (FQTSS): Developed as a P802.1Qav project, "Virtual Bridged Local Area Networks - Amendment 11: Forwarding and Queuing for Time-Sensitive Streams." This describes a token-bucket method for shaping network traffic such that the latency and bandwidth of reserved streams can be controlled.
- IEEE 802.1BA: "Audio/Video Bridging (AVB) Systems" This references and defines relevant IEEE 802.1 and other standards for use in building AVB systems.
- IEEE 1722 "Layer 2 Transport Protocol for Time-Sensitive Applications in Bridged LANs." This specifies the protocol, data encapsulations, and presentation time procedures used to ensure interoperability between audio- and video-based end stations that use standard networking services provided by all IEEE 802 networks meeting quality-of-service requirements for time-sensitive applications.

By precisely time-stamping special packets as they leave and arrive at the interface or PHY, PTP can measure and compensate for all queuing and time-of-flight transmission delays. To make use of 802.1AS, streams are expected to include a presentation time which then is used to regenerate the sample clock by means of cross-time stamping with the network time. With 802.1AS and presentation time-encapsulated streams, an AVB network inherently supports an arbitrary number of different media sample rates and clock sources as the destination devices will each synchronize to their corresponding source device. An AVB network also then provides the mechanism to synchronize different paths through the network.

The IEEE 802.1Q Stream Reservation Protocol (SRP) provides mechanisms for reserving stream bandwidth that allows endpoint applications to dynamically configure the routes. SRP is an optional feature for automotive. In order to simplify end-points and achieve faster network startup, the default behavior is instead a fixed network that is pre-configured with the outcome that SRP would have arrived at had it run. Whether pre-configured stream reservation or SRP used, both works hand-in-hand with the IEEE 802.1Q Forwarding and Queuing Time Sensitive Streams Protocol (FQTSS). FQTSS schedules time-sensitive A/V streaming data, ensuring timeliness through the network. Regular non-streaming traffic such as IP-based control or meters is treated in such a way that it cannot interfere with reserved AVB traffic.

The AVnu Automotive Ethernet AVB Functional And Interoperability Specification takes these standards and defines configuration and options optimized for the automotive use case, including: -

- A fixed pre-configured 802.1AS clock tree with built in timing redundancy
- Pre-configured traffic streams
- Startup meeting NHTSA requirements
- AVB traffic classes optimized for Automotive Audio
- Mechanisms to optimize AVB performance in low-cost ECUs and end-point.
- Diagnostics

Conclusion

The new technology from IEEE 802.1 AVB task group provides a critical component for successful deployment of Ethernet in the vehicle for applications such as infotainment and driver assistance. AVnu Alliance provides interoperable automotive use profile and certification tests to validate embodiment of these requirements. The reliable delivery of low-latency precisely synchronized audio and video combined with the massive industry investment provides a compelling solution for next-generation systems. The AVB protocols are an open standard, allowing multiple suppliers to deliver silicon solutions for automotive usage. For more information, please contact the AVnu Alliance at www.AVnu.org.