Proven 1394 Technology Trumps Ethernet AVB Potential

With the automobile becoming yet another home for a network of interconnected intelligent subsystems, vehicle designers must choose a multimedia network technology. Modern automobiles need a way to move everything from video to safety data around the auto. Ethernet works well in the office and the home, and at first glance it might appear a good fit for vehicles. A detailed investigation, however, reveals that the Ethernet physical layer (PHY) is not a proper match for the automotive environment, and that no high-level protocols exist for multimedia delivered over Ethernet in the automobile. Conversely, 1394 has a more flexible PHY that supports numerous topologies (including preferred daisy-chained connections) and also includes proven protocols for passing real-time multimedia streams.

Let's take a closer look at the requirements of an automotive network. The network must connect a variety of passenger-entertainment and driver-information systems. For example, the network might need to carry video from a central DVD or Blu-ray player to video screens located at each passenger seating location. The same network might need to carry real-time video from a rear-facing camera to a driver display so that the driver can see approaching traffic or move in reverse more safely. The network might also link to storage devices such as Flash memory or hard drives that might store navigation data. With wireless WAN data networks such as WiMax emerging, the network might carry Internet traffic. And of course the network will carry streaming music.

When considering a network for the above scenario, the evaluation should include the types of media a network can use as well as the supported PHY layer performance and topologies. The evaluation should also consider the higher-layer protocols that ensure that devices interoperate seamlessly. For example, a network-connected display must be compatible with a source such as a DVD player. Unlike in the home, the DVD player won't connect directly to the display. Instead, both devices must connect and interoperate via a network. Finally, the evaluation should consider the standards body behind the network, and the roadmap for the future. See figure 1 below for examples of automotive networks.

Figure 1: Automotive Network Examples

The 1394 standard is promulgated by the 1394 Trade Association (TA). The 1394 Automotive standard includes 1394 technology developed for PC and consumer electronics applications, as well as additional auto-centric technology. For example, 1394 Automotive includes all of the auto-centric standards development originally handled in the IDB Forum, and includes a direct link to AMI-C, ISO, IEC, IEEE, SAE and USCAR standards. Consider a comparison of the 1394 Automotive standard and Ethernet Audio/Video Bridging, AVB (see Table 1).

Ethernet AVB	▪For Ethernet, design criteria and technology evolution has proceeded down a path based upon IP/UDP without the QoS required for multimedia. ▪The new Ethernet AVB standard is being added to support QoS for multimedia applications. ▪Unknown if existing software base can adapt to Automotive and time critical applications.
1394℠ TRADE ASSOCIATION	▪Virtually every OS supports 1394 ▪Robust Open Source community ▪Rich 3rd party developer environments exists ▪Abundance of software exists for 1394 for multimedia

Table 1 Comparison of the Standards

Ethernet AVB is being promulgated by the AVnu Alliance. The alliance will promote A/V transmission using the established Ethernet PHY and Link layers combined with the AVB addition developed in the IEEE 802.1 standards body. Specifically, Ethernet AVB will use the new 802.1Qat Stream Reservation Protocol and 802.1AS Precision Time Protocol to add multimedia capabilities to the Ethernet LAN.

Let's start the detailed comparison with the maximum data rates supported by 1394 and Ethernet. Today, 100-Mbps and 1-Gbps Ethernet ICs designed for IT applications are readily available. In the case of 1394, 400-Mbps (S400) and 800-Mbps (S800) automotive grade ICs are readily available and the technology is broadly deployed in computer products. 800-Mbps 1394 is essentially equal to1-Gbps Ethernet in usable bandwidth due to the fact that Ethernet uses 8b/10b data encoding and incurs what's essentially a 20% performance hit in terms of actual data rate. While both Ethernet and 1394 offer plenty of raw bandwidth for automobile multimedia network needs, the evaluation must go beyond data rate to topology considerations and cost.

Topology and Weight in the Automotive Network
It's fair to question why we need an automotive network. Why wouldn't point-to-point connections like the ones most broadly used in consumer A/V systems work perfectly well? Automakers in recent years have used point-to-point connections such as LVDS to carry video. The answer to why a network is better lies in the weight of the cable. Automakers are constantly seeking to reduce vehicle weight to increase both fuel efficiency and performance.

Wiring harnesses contribute significantly to vehicle weight. Lower-speed networks (like CAN), which connect driveline systems such as braking and engine control, came about largely based on the desire to minimize the wiring harness. Now, automakers seek a similar solution for multimedia data. The 1394 Automotive technology has demonstrated that a network can carry the multimedia data that in many cases today still traverses point-to-point connections.

In fact, 1394 offers far more flexibility in topology than does Ethernet, and that advantage translates into simpler, more flexible and lighter-weight wiring harnesses. The 1394 Automotive standard inherently supports star, tree, ring, or daisy-chained topologies. In most automotive cases, the daisy chain choice delivers the desired simplicity in the wiring harness. Table 2 below illustrates some of the basic topology differences.

Ethernet AVB	Star – switch centric
1394	Flexible – Bus, Ring, Tree, Star

Table 2 Shows the Comparison of Topologies

Ethernet, as broadly used in office and home applications, depends primarily on a star topology. A switch forms the center of each connected star. A network can consist of one or many stars. In a vehicle application, the star approach requires that all nodes on the network must be wired to the switch, and generally results in much heavier and more complex harnesses.

The Impact of Topology on Cost
Let's dig a bit deeper into topology and bring cost into the equation. Ethernet proponents claim that Ethernet is a better choice from a price perspective, based on the huge installed base of the technology. But widely available Ethernet ICs designed for the IT space don't support Ethernet AVB. New ICs will be required to handle Ethernet AVB.

Some Ethernet proponents claim that 100-Mbps Ethernet is suitable for auto network needs. In a star configuration, a 100-Mbps network may or may not suffice, given today's auto network requirements. But even if it has sufficient bandwidth, the aforementioned problem with the complexity and weight of the wiring harness can't be ignored.

Some Ethernet advocates have proposed a new daisy-chain topology. In reality, this daisy chain scheme does nothing more than place a full-fledged Ethernet switch at each node. You can daisy chain switches just as you would in a home or office network, connecting multiple star clusters.

Placing a switch at each node, however, creates a multitude of potential problems. For starters, you certainly could not use 100-Mbps Ethernet in such a daisy-chain configuration. The advantage of a switch-based Ethernet is that the switch directly links each pair of nodes communicating at any one time. So a switch supports multiple full-speed links simultaneously. But a daisy chain with a switch at each node would result in a situation where a single pair of nodes that contended for and won the bus would block other nodes from access.

A daisy-chain configuration might work based on 1-Gbps Ethernet because the network would have enough raw bandwidth to still operate with each node contending for what is essentially a single bus. But 1-Gbps Ethernet uses 4 twisted pairs of copper wire; 100-Mbps Ethernet and 1394 use only two twisted pairs. A daisy-chained 1-Gbps Ethernet implementation would still require heavier and bulkier harnesses.

The Impact of Topology on Performance
There is also a performance issue with the daisy-chained Ethernet concept. There is some amount of latency associated with each Ethernet switch. While small, the latency could be a problem with a safety-related function such as a rear-facing driver-assistance camera. The slight delay in getting the video stream from the source camera to the driver display could prove dangerous.

Conversely, every 1394 node has a hard-wired repeater and daisy-chain support. The technology may not match Ethernet in terms of price at the IC level, but you can buy 1394 ICs for less than $1 and be assured of a reliable, latency-free daisy chain any time the network is powered on.

Command and Control Protocols in the Automotive Multimedia Network
Let's now move up the network stack and consider how nodes in an automotive multimedia network might interoperate. The 1394 technology has been broadly proven in consumer AV products. The 1394 TA defined the AV/C Digital Interface Command Set that allowed audio and video products from different manufacturers to interoperate. A source such as a Blu-ray player or camera could use AV/C to link with a display device with plug-and-play ease.

Ethernet AVB currently has no high-level command and control protocol for plug-and-play connectivity. Ethernet has not been deployed in such a capacity, and that capability must be developed and proven workable before Ethernet AVB can serve in an auto multimedia network.

The 1394 Automotive standard has gone one step further in formalizing video compression techniques that must be used in the automotive application. None of the other candidate automotive networks can carry sufficient uncompressed video to serve the application at hand.

At first glance, you might wonder why we need yet another different video codec. But remember that a key function of the auto network will involve carrying safety-oriented data such as video streams from multiple cameras positioned around the vehicle.

Video codecs such as the various MPEG flavors that are prevalent in consumer electronics use discrete cosine transforms (DCT) encoding of pixel blocks and motion vectors to compress video. The technique works well in entertainment applications because it provides a high compression ratio. But the scheme requires extreme processing power on the encode side of the process and adds latency.

There are both safety and logistics issue with an MPEG-style codec in the auto. First, a safety application that relies on a camera can't tolerate the hundreds of milliseconds of latency in the MPEG encoding process. Whether a human or an automatic system was reacting to the encoded video, the reaction could come too late to avoid an accident.

Logistics issues reside in the complexity of the electronics in each display in the auto, and some high-end autos could have a display at every seating location. Theoretically, auto designers could rely on a decoder in the displays to handle a variety of different codecs. For instance, the MPEG stream, assuming copy protection issues could be mitigated, could be piped directly from a DVD player to a display for decoding at the display.

Realistically, auto companies can't afford the rapidly multiplying maze of different codecs and want to settle on one video compression scheme for all video in the auto, so the 1394 Automotive group defined the type of video encoding that would be used with the network. A line-by-line, lightweight compression scheme specifically for the auto application is found in 1394TA Standard #TA2006020 (BT 601, rev 1.4), a new revision released in June 2010 to address the “analog sunset” directive.

Ethernet AVB currently has no provision for a lightweight video compression algorithm. An MPEG flavor will simply not fit the application at hand. The AVnu standards body and Ethernet proponents would have to address the codec issue before the technology can find broad use in a vehicle.

Cabling Options for Ethernet AVB and 1394 Auto

Moving along, our comparison will finish with a look at materials appropriate for the PHY layers and a look to the future. Both 1394 and Ethernet can be used with a variety of optical and fiber cables. In the case of Ethernet AVB, it's unclear what type of cable might be usable in the auto application.

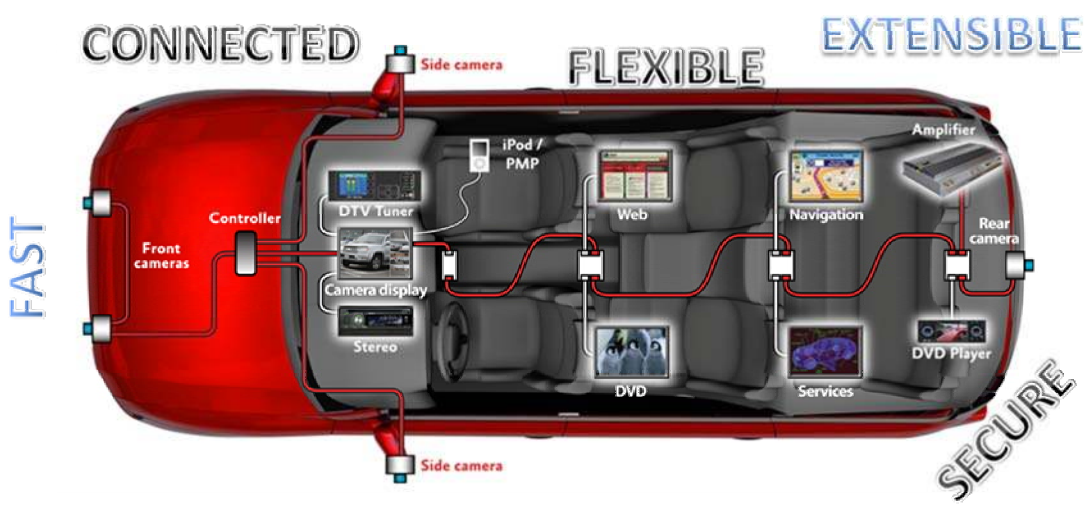
Ethernet offers the convenience of copper Cat-5 and Cat-6 cables in offices and homes but it's very doubtful that such cable would work in the noisy EMI and RFI environment of the auto, and has yet to be clearly defined for automotive use.

The 1394 Automotive standard allows a mix of media types designed for the automotive application. Shielded 4-conductor cables can serve over 8-meter distances with multiple in-line connections. A special coax cable can work over 20-meter distances. Those two options would handle the majority of auto requirements – especially given that 1394 would use a daisy-chained topology for some or most nodes. 1394 Automotive also defines plastic- and glass fiber options for longer distances and unique applications should the need arise.

The Future of 1394 Auto and Ethernet AVB
In terms of the future, 10-Gbps Ethernet is being used in data-center applications, but won't become broadly used any time soon. In fact, 10-Gbps Ethernet almost certainly requires optical media even for relatively short cable runs. It's unlikely that 10-Gbps will be suitable for auto networks.

The 1394 TA has developed S1600 (1.6 Gbps) and S3200 (3.2 Gbps) specifications and ICs are now available. It's projected that S1600 and S3200 will be able to use copper cable for applications, including auto networks.

In summary, Ethernet simply wasn't designed for the automotive environment. The cost advantages don't translate to the automobile, where simple and light-weight cables trump the advantage of lower-cost ICs. Manufacturers utilizing 1394 Automotive can readily provide cost-effective ICs that meet or exceed automobile designers' needs for topological flexibility, PHY layer, command and control protocols, and video capabilities.



For a complete review of the 1394 Automotive specification, benefits, available products, technical and design background, and other related resources, please visit http://www.1394ta.org/industry/Automotive.html