Friend or Foe?

Payload efficiency and network considerations of MOST and Ethernet

This paper discusses the payload efficiency of MOST and Ethernet and the derived influence on the network architecture of vehicles with high bandwidth needs. Furthermore, ideas for coexistence of these competing technologies are described.

By Josef Noebauer and Helge Zinner

The MOST technology is nowadays dominating the upper class infotainment systems due to its support of high bandwidth data. Fostered by the integration of consumer devices and the worldwide success of the Internet Protocol (IP), the research for the usage of IP as the common network layer in an automotive environment has already started. The results presented in this paper have been prepared within the publicly funded project SEIS [1]. In combination with IP, Ethernet is the most commonly used physical layer. Actually, the usage of a cost efficient and automotive-qualified Ethernet solution is already scheduled for implementation in series production [2]. So the competition between MOST and Ethernet is already ongoing. This paper will focus on a specific part of this competition. The payload efficiency of MOST and certain transport protocols of Ethernet AVB [3] are compared, since Ethernet AVB defines provisions to achieve Quality of Service (QoS) within an Ethernet network. However, simply looking at the payload efficiency is not sufficient, since MOST is a bus system, while today's Ethernet is a switched network that leads to a multiplication of the system-wide available bandwidth by the number of point-to-point links in the system. Hence, network utilization will also be discussed in this paper as well.

Increasing bandwidth requirements in automotive applications

Automotive infotainment networks are becoming more open to non-automotive devices like mobile phones and are supporting IP/Web based applications. High-definition video and camera based applications create higher data rates that already need to be handled today. The bandwidth requirements of certain applications in comparison to the bandwidth offered by networks, is shown in **figure 1**. The continuously increasing bandwidth requirement is a clearly visible trend.

One of the core requirements for a network is that it will deliver application data reliably and that it will provide reasonable response times for inter-node communication. In order to support QoS in asynchronous Ethernet networks, AVB extends the standard with three additional sub-standards. IEEE 802.1Qav [4] uses methods described in IEEE 802.1Q to separate timing critical and non-timing critical traffic into different traffic classes. Output port buffers are separated into different queues, each allocated to a specific class. This ensures a separation of low priority traffic from high priority traffic. Moreover, all output ports have a credit-based shaping mechanism to prevent burst cycles being used during communication. IEEE 802.1Qat [5] defines a protocol for signal reservation requests and to reserve resources for media streams. This is actually implemented by allocating buffers within switches. IEEE 802.1AS [6] is responsible for the precise time synchronization of the network nodes to a reference time. IEEE 802.1AS synchronizes distributed local clocks, referred to as slave clocks, with a reference that has an accuracy of better than one microsecond. Additionally, transport protocols like IEEE P1722 [7] and IEEE P1733 [8] are used for the actual transfer of the media streams.

Payload efficiency (PE) is defined here as ratio between the payload P and the effectively sent data D.

$$PE = \frac{P}{D} \qquad (1)$$

The available data rate of a network for media streams is defined as B.

For MOST150, the effectively sent data is the content itself without additional headers. Therefore $P_{MOST150}$ is generally equal to $D_{MOST150}$. MOST150 has an actual line speed of just 147.5 Mbit/s at a sampling rate of 48 kHz. MOST frames are sent with administrative data including the control channel, which is not related to the streaming data. Hence, the maximum available data rate for streaming data is reduced to BMOST150 = 142.9 Mbit/s.

In comparison to MOST, AVB provides similar QoS when the above introduced sub-standards are supported by the devices of the AVB network. Their bandwidth consumption is considered similarly to the MOST administrative data. IEEE 802.1Qat utilizes reservation messages that lead to a negligible background load. IEEE 802.1Qav does not utilize any messages. The time synchronization frames of IEEE 802.1AS lead to a background load of about 0.1 Mbit/s. On top of the AVB protocols, communication for setting up and controlling media streams is required. Therefore, a general background load of 1.5 Mbit/s is assumed, as this is also offered by the MOST control channel. Hence, the actually available streaming bandwidth of a 100 Mbit/s AVB network is reduced to B_{AVB} = 98.4 Mbit/s. Note that the Ethernet AVB standard limits the bandwidth of QoS supported data to 75 percent of the totally available bandwidth, since 25 percent are reserved for conventional best effort traffic.

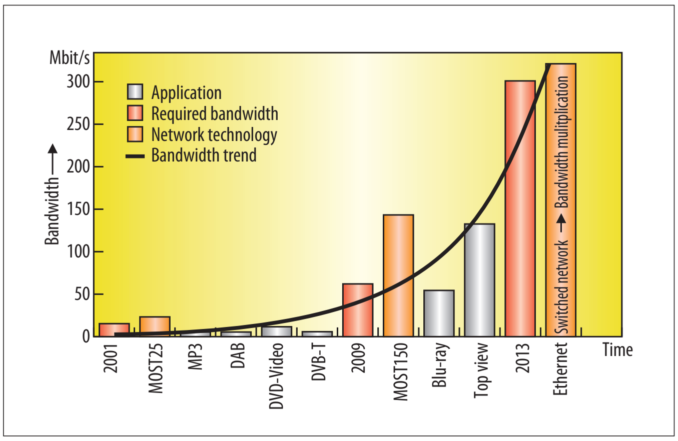


Figure 1. Bandwidth requirements and network capabilities over time.

As the preferred AVB transport protocol for media streams, P1722 has been examined. The P1722 frame structure is depicted in **figure 2**. The sent data D_{AVB} for media transport over P1722 is constructed by Ethernet header (preamble + layer 2) + P1722 header + CIP header (Common Isochronous Packet) + payload + CRC. D_{AVB} differs depending on the type of the payload.

Introduction to solution

P1722 encapsulates media content into Ethernet frames and also adds a presentation timestamp. In the case of audio or video data, P1722 transports the stream sample clock information from the sender (speakers) to the receivers (listeners) via multicast. With the presentation timestamp included in the frames, a playback time is given to the listeners, which allows a synchronous playback to multiple listeners. As visible in figure 2, P1722 embeds several media stream formats, e.g. the IEC 61883 based formats, to an IEEE 802 network.

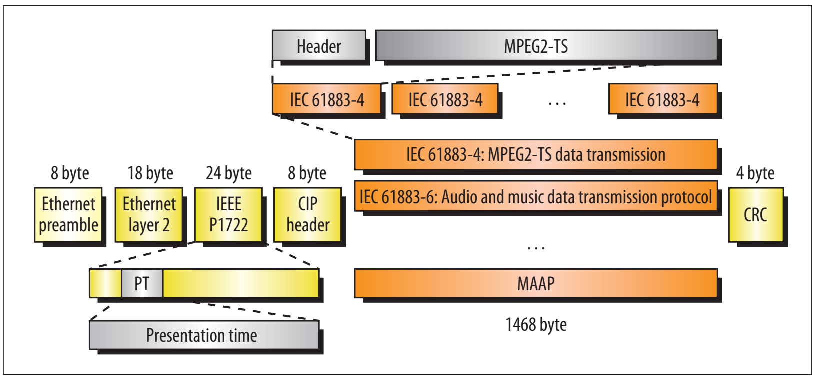
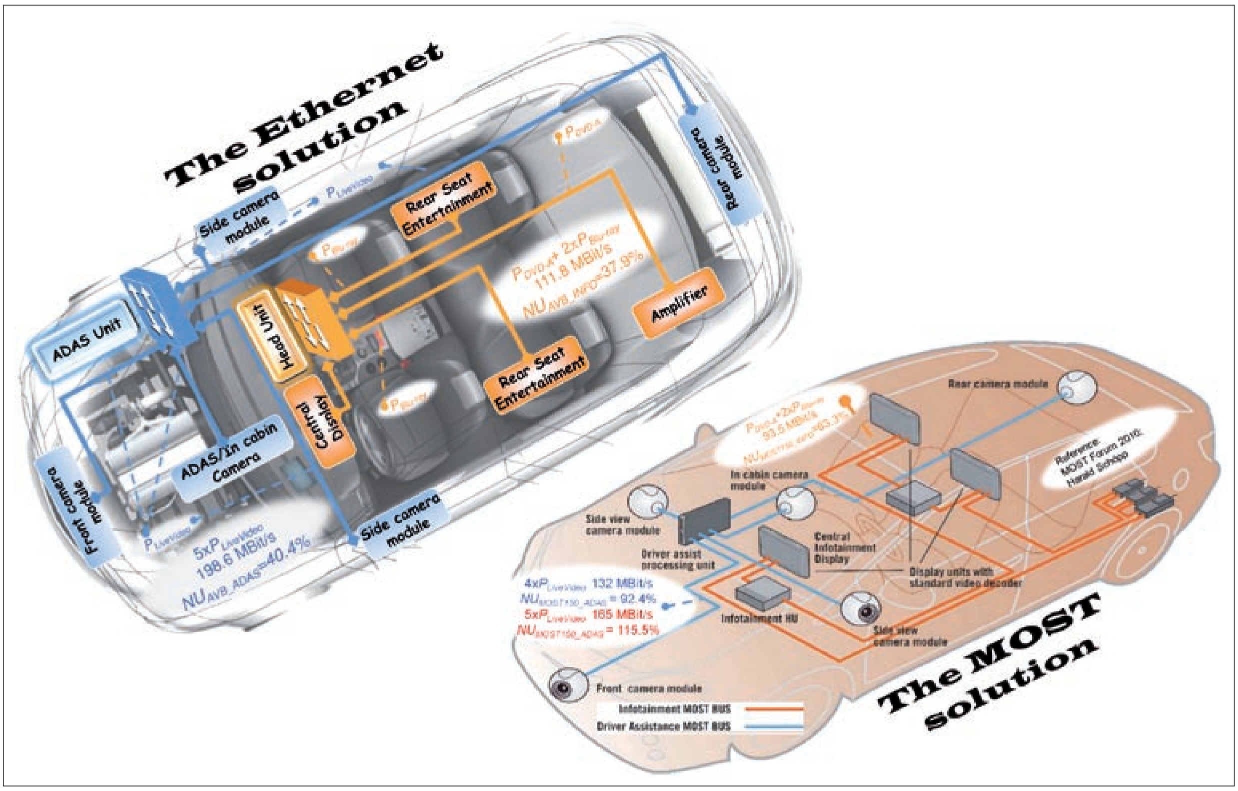


Figure 2. IEEEP1722 frame structure.

AVB supports two QoS classes. Class A provides a maximum latency of 2 ms and Class B provides a maximum latency of 50 ms over 7 hops. For Class A, P1722 frames are sent each 125 µs, which allows collecting six stereo audio samples at a sampling



I Figure 3. Possible MOST and Ethernet based vehicle architectures.

rate of 48 kHz. For Class B, P1722 frames are sent every 250 µs.

The streaming use cases defined in the left column of **table 1** were used for the comparison of MOST and AVB. The Blu-ray disc is specified with a maximum data rate of 53.95 Mbit/s for audio and video and will soon enter the infotainment domain. Due to the maximum support of 50 Mbit/s for a single transport stream of the MOST INIC transceiver [9], a reduced media content for the calculation composed of Dolby Digital Plus audio (1.7 Mbit/s) and video (38.5 Mbit/s) was used. This leads to an actual transport stream payload $P_{Blu\text{-}ray}$ of 41.1 Mbit/s considering the transport stream header.

The PE for the use cases is shown in column PE of the respective network in table 1 and was calculated using equation (1).

As mentioned above, MOST150 has a payload efficiency of 100 percent. When transmitting an audio stream with P1722, the overhead (including CRC) is about 62 byte. This causes bad payload efficiency when transmitting a small amount of data, as is the case with CD audio streams. Since the P1722 payload for a single packet can be up to 1472 byte long, the payload efficiency also reaches values beyond 90 percent, as visible in table 1. Unlike audio, video packets sent via P1722 have a better balance between payload and header information. Applications needing lots of bandwidth generate better payload efficiency because larger frames need to be used. The substantial overhead of each frame is spread out over more payload packets.

However, just looking at the payload efficiency is not sufficient. Additionally, the network utilization (NU) needs to be considered. NU is defined by the ratio of the required to the available bandwidth of the complete network.

$$NU = \frac{D}{B} \qquad (2)$$

Mapping the use cases above to a MOST [10] and Ethernet based vehicle architecture, as shown in **figure 3**, leads to network utilizations as sum-

Streaming Use Cases	Payload [MBit/s]		MOST150 Sent Data [MBit/s]		MOST150 PE	AVB 1722 Class A Sent Data [MBit/s]		AVB 1722 Class A PE	AVB 1722 Class B Sent Data [MBit/s]		AVB 1722 Class B PE
CD-A Stereo 16bit audio stream Sampling rate 44,1kHz	$P_{CD\text{-}A}$	1.41	$D_{MOST150\_CD\text{-}A}$	1.41	100%	$D_{AVB\text{-}A\_CD\text{-}A}$	6.8	20.8%	$D_{AVB\text{-}B\_CD\text{-}A}$	4.8	29.3%
DVD-Audio, Dolby Digital 5.1 24bit audio stream, no DTCP Sampling rate 48kHz	$P_{DVD\text{-}A}$	6.91	$D_{MOST150\_DVD\text{-}A}$	6.91	100%	$D_{AVB\text{-}A\_DVD\text{-}A}$	13.2	52.4%	$D_{AVB\text{-}B\_DVD\text{-}A}$	11.2	61.7%
Live Video (from Camera) Resolution 1280*800, 30fps MJPEG (compression factor 15)	$P_{LiveVideo}$	33	$D_{MOST150\_LiveVideo}$	33	100%	$D_{AVB\text{-}A\_LiveVideo}$	39.7	83.1%	$D_{AVB\text{-}B\_LiveVideo}$	35.7	92.5%
Blu-ray Compr. audio and video stream with constant bit rate	$P_{Blu\text{-}ray}$	41.1	$D_{MOST150\_Blu\text{-}ray}$	41.1	100%	$D_{AVB\text{-}A\_Blu\text{-}ray}$	45.9	89.5%	$D_{AVB\text{-}B\_Blu\text{-}ray}$	43.9	93.6%

I Table 1. Payload efficiency of streaming use cases

Vehicle Architectures	MOST150 $B_{MOST150}$ 142,9 MBit/s		AVB 1722 Class A B_{AVB} 98,4 MBit/s		AVB 1722 Class B B_{AVB} 98,4 MBit/s	
	Total Bandwith [MBit/s]	NU	Total Bandwith [MBit/s]	NU	Total Bandwith [MBit/s]	NU
Infotainment Domain	90.5	63.3%	111.8	37.9%	103.8	35.2%
ADAS Domain 4 Cams	132	92.4%	158.8	40.4%	142.7	36.3%
ADAS Domain 5 Cams	165	115.5%	198.6	40.4%	178.4	36.3%

I **Table 2. Comparison of the available bandwidth for different applications**

marized in **table 2**. Looking into the infotainment domain, this leads to one exemplary combination of streaming use cases to (3)

$$NU_{info} = \frac{D_{CD-A} + D_{DVD-A} + 2 \times D_{Blu-ray}}{B}$$

i.e., actually to $NU_{MOST150\_INFO} = 63.3\ \%$ and $NU_{AVB\_INFO} = 37.9\ \%$.

Looking at advanced driver assistance systems (ADAS), with a top-view system as a possible application generating a bird‘s eye view of the vehicle, this requires at least four live video streams. For MOST, this leads to (4)

$$NU_{MOST150\_ADAS} = \frac{4 \times D_{MOST150\_LiveVideo}}{B_{MOST150}} = 92{,}4\ \%$$

since the available streaming bandwidth is shared. For Ethernet AVB this leads to (5)

$$NU_{AVB\_ADAS} = \frac{4 \times D_{AVB\_LiveVideo}}{4 \times B_{AVB}} = 40{,}4\ \%$$

since each link also multiplies the available streaming bandwidth. Because figure 3 shows a fifth camera used, e.g. for driver observation, bird‘s eye or traffic sign recognition, the $NU_{MOST150\_ADAS}$ is more than 100 percent, which is not the case for NU_{AVB_ADAS}: that remains at 40.4 percent.

MOST provices optimum bandwidth efficiency

Since MOST was originally designed for automotive infotainment, it is using the available bandwidth in an optimal way for all kinds of media streaming and is, in this respect, superior to Ethernet and other physical layers. However, MOST is designed as a bus system that shares the available bandwidth, rather than a switched network that multiplies the available bandwidth. Another upcoming topic is the communication between the driver assistance and Infotainment systems. With MOST, there is no simple layer 2 bridging, as is the case with Ethernet by simply connecting the driver assistance ECU and a head unit. An alternative approach is to implement an efficient MOST/Ethernet gateway, maintaining the main advantages of Ethernet (higher total network bandwidth, scalability, flexibility) and MOST (highly efficient media streaming). Due to the IEEE 802.1AS protocol, Ethernet AVB simplifies the implementation of a MOST/Ethernet gateway, since it allows to maintain the synchronous MOST timing on the Ethernet side. Furthermore, a media source on the Ethernet side can stream synchronously using MOST as a reference clock. A demonstration system, which was built up in line with the SEIS project, was successfully used to validate this MOST/Ethernet AVB gateway concept.

Both MOST and Ethernet have the capability to address the bandwidth needs of the future using alternative system architecture approaches. The suggestion is to use Ethernet for applications that will need high bandwidth, like the different kinds of video streaming. *sj*

Literature + Links

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Josef Noebauer

is team leader at Continental and an expert for the cross divisional usage of automotive network technologies like MOST, Ethernet and FlexRay. He is coordinating Continental’s activities around the introduction of Ethernet as automotive bus system.

josef.noebauer@continental-corporation.com

Helge Zinner

is working a Continental and also a Ph.D. student at the Institute for Communication Networks, University Ilmenau (Germany). He has been with Continental as a development engineer for infotainment systems since 2004.

helge.zinner@continental-corporation.com