

Gbit Ethernet - The Solution for Future In-Vehicle Network Requirements?

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ABSTRACT

In-vehicle communication faces increasing bandwidth demands, which can no longer be met by today's MOST150, FlexRay or CAN networks. In recent years, Fast Ethernet has gained a lot of momentum in the automotive world, because it promises to bridge the bandwidth gap. A first step in this direction is the introduction of Ethernet as an On Board Diagnostic (OBD) interface for production vehicles. The next potential use cases include the use of Ethernet in Driver Assistance Systems and in the infotainment domain. However, for many of these use cases, the Fast Ethernet solution is too slow to move the huge amount of data between the Domain Controllers, ADAS Systems, Safety Computer and Chassis Controller in an adequate way.

The result is the urgent need for a network technology beyond the Fast Ethernet solution. The question is: which innovation will provide enough bandwidth for domain controllers, fast flashing routines, video data, MOST-replacement and internal ECU buses? And of equal importance, which one is able to fulfill the standard automotive requirements such as

- Cost efficiency (for cables, connectors)
- Functional safety
- Security (separation, application filtering, secure switching)
- Real-time behavior (latency, delays)
- EMC requirements.

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INTRODUCTION

In-vehicle communication faces an increasing bandwidth requirements, which cannot be fulfilled by today's MOST150, Flex-Ray or CAN networks as depicted in [Figure 1](#). In recent years, Fast Ethernet has gained a lot of momentum in the automotive world, because it promises to bridge the bandwidth gap.

Ethernet and IP technology are often mentioned together and are closely related. Both standards have evolved in the last decades to become the basic networking technologies utilized in the IT industry. Furthermore, both technologies have evolved further and have become general, cross-industry technologies. Even in the fields of industrial automation and avionics, IP technology has been introduced in recent years.

For this reason, it seems logical to introduce Ethernet and IP technology in the automotive domain as well, in order to achieve a technological continuity for the in-vehicle networking. At the same time, the automotive industry can use the industry-proven standards in the field of networking technologies.

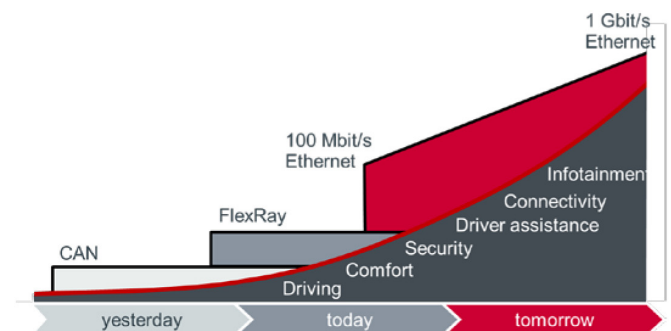


Figure 1. In the future, the fast-growing demand for bandwidth makes Ethernet necessary [4]

The paper is divided into three parts. The first part gives a dedicated view on application requirements from the OEM perspective, with specific focus on the applications which account for the highest bandwidth and complementary requirements. The question “What standard is appreciated?” will be discussed, as well as several detailed scenarios, such as AVB, QoS, RTP and UDP. There will also be an outlook into the future of high bandwidth technologies for in-vehicle communications.

The second part examines the backbone network itself and considers solutions for the network partitioning and placing of PHYs and switches. It provides answers to the question of the potential benefit in case several elements are merged together in one package.

In the third part, the semiconductor vendor's view is covered. Since up to now, very few standards have been claimed by OEMs and TIER1s, the semiconductor vendors have a variety of options that can be implemented in silicon. This risk of heading in the wrong direction is very high. The chapter will have a closer look on the most likely solutions. Different hardware topologies and silicon implementations and their effect on the network will be discussed. The emphasis in this part is mainly on actual silicon implementations and further enhancements. Dedicated microcontroller solutions will be presented.

Finally, this paper gives a summary on how the most urgent issues can be solved in order to have automotive qualified parts, which support Fast Ethernet, available on first SOP.

ETHERNET; THE NEXT IN-VEHICLE NETWORK

In the automotive industry, there is a strong movement toward using standardized, fast, proven and open network solutions in order to drastically reduce development and employment costs. Ethernet is a promising candidate for the next vehicle network system. Using Ethernet as an upcoming network standard helps automotive manufacturers to focus on developing differentiating car function.

Bandwidth

High-end cars are equipped with dozens of ECUs providing driving comfort to the driver. The driving comfort is mainly based on new software-based functions, which are typically bandwidth-intensive. During the last year, we have seen an increase in required bandwidth. The trend toward a piloted driving system will increase the bandwidth requirements further. A new network solution needs to be scalable in order to fulfill the rising bandwidth requirements. This means that Ethernet networks can start with a 100 Mbit physical layer and in future systems easily be changed to the 1 Gbit physical layer.

TYPICAL USE-CASES FROM THE OEM PERSPECTIVE

The introduction of 100 Mbit Ethernet and 1 Gbit Ethernet is driven by a lot of different use cases. In this chapter, some of the most important will be discussed.

Domain Controller

As seen in many publications, there is a strong movement to integrate different functionalities into a so-called domain controller. Typical examples for such systems are domain controllers for:

- Central advanced driver assistance functions
- Chassis control systems
- Powertrain and hybrid systems
- Central gateway
- Body and Comfort domain
- Telematics and Infotainment

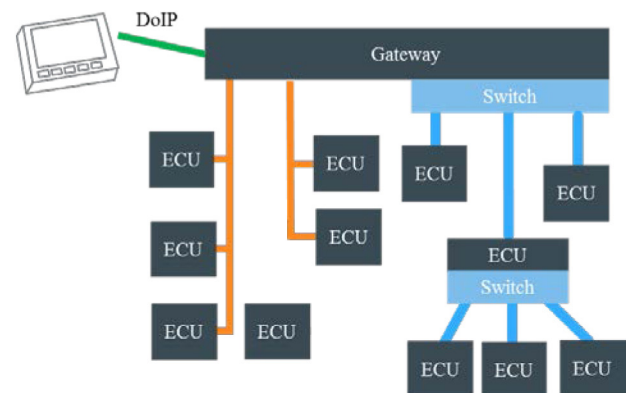


Figure 2. Some examples of a car network architectures

Such domain controllers require communication of control data amongst each other with a high data rate, since the new applications are typically very bandwidth-intensive and require short latencies. In some cases, predictability is also required. The demand for inter-ECU communication is expected to continue to grow in the future.

End-of-Line Programming - Fast Flashing

The size of programming data at end-of-line systems is growing constantly, so the time required for reprogramming (also known as flashing) is becoming more important and is a cost factor during production due to programming time.

The increased speed and bandwidth of 100 Mbps Ethernet or even 1 Gbit Ethernet could reduce programming times significantly. Also, diagnosis applications during vehicle service will benefit from fast access to diagnosis data. Additionally, the optional direct seamless connection of the car to a garage network improves usability [5].

Video Data

In order to increase comfort for the driver, many different Advanced Driver Assistance Systems (ADAS) are under development. ADAS is quickly becoming an integral part of the vehicle, with interfaces to many different domains within the car. Such systems are typically based on video data, radar data and ultra-sonic data. Furthermore, ADAS needs data from different car systems such as steering, braking, ESP and airbag.



Figure 3. Example of different sensor sources (including video)

Since cameras are deployed in different locations around the car, the video data must be transferred to the master ECU in order to fulfill the functional requirements, where in the past proprietary systems were used. The required bandwidth depends on the resolution and frames per second. It is expected that at least a 1 Gbit network will be needed for sufficient video quality. Furthermore, the latency requirements must be fulfilled.

MOST Replacement

MOST is a popular infotainment networking technology. Currently, MOST 150 is the latest version and is already in use in the new Mercedes-Benz S-Class. MOST is a proprietary standard and often the hardware does not meet the cost requirements of automotive manufacturers. Ethernet is now a promising alternative to MOST for infotainment network systems, as it can offer important benefits. First of all, the penetration of Ethernet for infotainment applications in the consumer market helps to minimize the overall system cost. Also, the available speed and bandwidth is scalable.

For audio and video data, time synchronization is important to ensure the quality level of audio and video data flow within an Ethernet network. The AVB standard can ensure the required quality parameters.

Internal ECU Bus

For high-speed internal ECU connections, Ethernet is an interesting concept. As a common technology, Ethernet enables fast and easy interconnection between different microcontrollers inside an ECU. The required software is available as standard software.

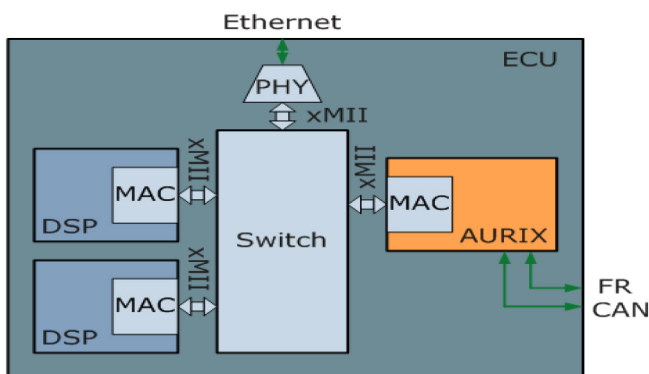


Figure 4. Example internal ECU bus realized with Ethernet

OEM REQUIREMENTS

In this chapter, the basic requirements from the OEM point of view will be listed. The basic requirement is quite easy. For the OEM, a new network technology must be based on open standards to allow the interoperability of multiple vendors on one network. The strong focus on standards helps to define a solid strategy for backward compatibility for typically very long lifecycles, which is usually not a requirement for consumer electronics.

Standards

By using Ethernet-based technology, the automotive industry is able to use a well-established IT standard in the field of in-vehicle networking. There is therefore no need to define new standards, but rather a careful selection of suitable automotive-specific subsets of the existing Ethernet specifications.

The use of specialized networking technologies (CAN, LIN, FlexRay, Most) for a specific application has an acceptable cost / benefit ratio. However, the result is the existence of many technology breaks at system and domain boundaries. This is especially seen in high-end cars. As mentioned previously, future systems have significant cross-system interaction, which means that this technology break represents a growing challenge.

Safety for Future Requirements

The above-mentioned idea applied to the car development means that electronic car systems can be designed to be flexible and scalable. If the range of functions scales up and therefore requires more bandwidth, most of the existing infrastructure can be re-used, since only the physical layer of the connected ECU is affected.

Security Aspects

During the development for the well-known automotive networks (CAN, LIN, FlexRay, MOST), security aspects were not the main goal, since the car was seen as a closed system. Nowadays there are several reasons why security is becoming increasingly important. The most important reason is the communication demand to and from external sources. In order to keep the automotive system secure during the development of new cars, security must be taken into account [3].

The huge payload length compared to old-fashioned bus systems allows a relatively easy addition of cryptographic data to different layers to provide authentication, authorization or encryption.

Secure Switch

The switch in an Ethernet-based network assumes an important role, since the switch is the central connection point for car networking and represents the heart of every Ethernet network. A switch must fulfill different tasks, without which the network would function properly. The switch is responsible for fulfilling the required quality of service and also controls the access to the network. Furthermore, a