AUTOSAR Learns Ethernet

Ethernet is a new and yet old and familiar network technology that is making its way into vehicles. At first, it is just being used for diagnostic applications and intelligent charging of electric vehicles, but onboard Ethernet networks are now being implemented as well. This article describes the properties and advantages of Ethernet and discusses the special aspects of integrating the technology in AUTOSAR. Finally, useful extensions are presented for an AUTOSAR Ethernet Stack which can be used to implement new applications.

Until just a few years ago, CAN and LIN were the only bus systems being used in vehicles. The desire for more bandwidth and growing requirements in the safety field, especially with regard to X-by-wire systems, led to the development and introduction of FlexRay. The MOST standard also became established for high-end applications in the multimedia field. Unlike CAN, FlexRay and MOST are complex and expensive bus systems. Because of this, and due to the lack of a service-garage network for these bus systems, CAN was still used for external access in vehicle diagnostics. However, the time required to program ECUs increased dramatically due to the limited bandwidth of CAN and the increasing amount of software content. The Diagnostics over Internet Protocol (DoIP) was developed several years ago to resolve this problem. This protocol is the first to be based on Ethernet as the network technology in the vehicle environment, and it is standardized in ISO 13400. Ethernet offers the advantage of high bandwidth, and it has primarily taken hold in the office and Internet worlds. It makes it easy to integrate a DoIP-based diagnostic tester in an existing service-garage network. DoIP laid the foundation for the use of Ethernet in vehicles. When electric mobility became a central topic a short time later, the focus shifted towards Ethernet-based Vehicle-to-Grid applications. In the charging process, the electric or hybrid vehicle communicates with an energy provider’s charging spot. The communication is based on TCP/IPv6 and a dedicated Smart Charge Communication (SCC) protocol, in order to exchange such information as the charging type (AC/DC), date and time of charging, duration of charging and rate and payment information.

The standard shielded Ethernet cable with its high wiring costs prevented widespread use of the technology for in-vehicle networks. However, introduction of the new BroadR-Reach physical layer has made the option of Ethernet interesting for in-vehicle communications as well. Using twisted pair lines, BroadR-Reach offers a bandwidth of 100 MBit/s which represents a 100-fold increase in speed compared to CAN.
without increased costs for wiring. It also offers the benefits of a switched network, which enables implementation of a backbone architecture, for example (Figure 1). Other applications that are currently of interest to automotive OEMs and their suppliers include Audio Video Bridging (AVB), network management and new gateway ECU concepts.

Ethernet in combination with the Internet Protocol (IP), Transmission Control Protocol (TCP) and User Datagram Protocol (UDP) also enable the transition from a data-oriented to a service-oriented communication schema. BMW has developed a serialization protocol, the Service Oriented Middleware over Internet Protocol (SOME/IP), which among other things can be used for remote procedure calls. It is complemented by the Service Discovery (SD) protocol that was also specified. ECUs use Service Discovery to inform communication partners of the availability of their services. ECUs can also use it to search for services and register their events.

**Ethernet and AUTOSAR**

Ethernet has been part of the AUTOSAR standard since Version 4.0. In the AUTOSAR architecture, the Ethernet communications stack is laid out in parallel to the CAN, LIN and FlexRay stacks. However, unlike them, it exhibits a number of special aspects – which relate to the higher protocol layers IP, UDP and TCP in particular. The Ethernet Transceiver Driver (EthTrcv) and Ethernet Driver (Eth) modules are comparable to those of other network technologies. The Ethernet Interface (EthIf) module, on the other hand, is different. While the interfaces for CAN, LIN and FlexRay implement the AUTOSAR Protocol Data Unit (PDU) interface directly, the Ethernet Interface routes raw data to the TCP/IP stack or receives data from it. The IP, UDP and TCP protocols are processed in the TCP/IP stack, which however is not fully specified in AUTOSAR 4.0. The use of a common off-the-shelf TCP/IP stack is recommended here.

A paradigm upon which the TCP/IP protocol family is based is the use of sockets. A socket is uniquely identified by the combination of IP address and port of the remote and local end nodes. Via a socket, packet-oriented UDP and connection-oriented TCP user data are routed from the TCP/IP stack to the application or in the opposite direction. This paradigm is incompatible with the PDU concept of AUTOSAR. Transformation of socket-based communication into PDU-based communication and in reverse is the task of the Socket Adaptor Module (SoAd). It provides the familiar PDU interface to higher level modules, which fully integrates the Ethernet stack in the AUTOSAR architecture. The Ethernet stack specified in AUTOSAR 4.0 has established a foundation for receiving and sending PDUs over Ethernet. It also considers the use case DoIP. The implementation of the DoIP protocol shall be realized as Socket Adaptor plug-in. Moreover, this AUTOSAR version supports ECU calibration via XCP over Ethernet and network management over UDP, and it offers an interface for connecting AUTOSAR Complex Drivers (Cdd). Automated data parameterization of the Ethernet stack is only partially covered in AUTOSAR 4.0. The user can represent Ethernet networks, frames and PDUs in the AUTOSAR System Description or in the ECU Extract of System Description.
The TCP/IP stack is now an AUTOSAR module. Besides version 4 of the Internet Protocol, version 6 is also supported. The two IP versions can be operated either individually or in parallel in one ECU. It is now possible to use Virtual Local Area Networks (VLANs). PDU-based data transmission over the Socket Adaptor is much more efficient. In its new version, the Socket Adaptor offers a generic interface to higher level modules. Implementation of the DoIP protocol was removed from the Socket Adaptor and relocated to a separate DoIP module. The Service Discovery protocol is also specified as a new AUTOSAR module.

The SOME/IP protocol and the use cases SCC and AVB are still not covered in AUTOSAR. The description of a sample implementation of SOME/IP is available as a supplemental document to the current standard. In practice, only FIBEX 4.1 has been used so far as the description format for in-vehicle Ethernet networks. It has now been harmonized with AUTOSAR 4.1.1. This means that although the two description formats are not identical, their contents can be transformed from one format to the other without loss of information. To a large extent, this enables automated data parameterization of the Ethernet stack per AUTOSAR 4.1.1 (Figure 2).

Pre-filling of data for higher protocol layers, e.g. definitions of IP addresses and ports, is not specified.

**Extended Ethernet Support in AUTOSAR 4.1**

With the introduction of in-vehicle Ethernet networks, new requirements have evolved, which an AUTOSAR 4.0 Ethernet stack does not fulfill. It is very difficult to implement efficient transmission of multiple PDUs, for example. Therefore, the Ethernet stack was revised significantly in AUTOSAR 4.1.1:

![Figure 2: An Ethernet stack is configured with an AUTOSAR 4.1 description file.](image)

**Figure 2:** An Ethernet stack is configured with an AUTOSAR 4.1 description file.

![Figure 3: The AUTOSAR Ethernet stack MICROSOAR IP from Vector contains AUTOSAR modules and useful supplements.](image)

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= Standard AUTOSAR Modules  = Additional modules available from Vector
Useful Supplements from Practice

As already mentioned, some applications of the Ethernet stack, such as Smart Charge Communication, are not covered by AUTOSAR specifications. For this purpose, there are ISO and DIN standards, which Vector helped to create. Producers and suppliers of electric and hybrid vehicles need the protocols specified in these standards for intelligent charging. Ideally, the protocols would be seamlessly integrated in an AUTOSAR Ethernet stack.

Per specification, the Universal Measurement and Calibration Protocol (XCP) does not have routing capability. When Ethernet is used for vehicle access, it is also necessary to calibrate all ECUs that are not directly connected to the Ethernet network over XCP. Vector developed a mechanism that enables this in cooperation with a German automotive OEM.

Routing of DoIP over a gateway to a sub-Ethernet network is not standardized in the ISO 13400 specification. Nonetheless, solution approaches have already been worked out with various automotive OEMs.

The Ethernet stack defined in AUTOSAR is available from Vector as ECU software under the product name MICROSAR IP (Figure 3). It contains the functionality specified in AUTOSAR 4.0.3 and 4.1.1 and is also available for AUTOSAR 3.x projects. The extensions mentioned above are included, as well as a resource-minimizing implementation of SOME/IP. The architecture of MICROSAR IP permits implementation of customer-specific extensions without any problems.

Outlook

One feature of AVB is that it enables time-synchronous transmission of audio and video streams over Ethernet. The IEEE 1722 transport protocol that is needed for this is already available from Vector. AVB support is currently being extended, e.g. by integrating time synchronization with the Generalized Precision Time Protocol.

In AUTOSAR version 4.2.1, there will presumably be some extensions related to the Ethernet stack. Current efforts include adopting data serialization via SOME/IP into the standard. These plans also include supporting data serialization for sender-receiver communication. Currently, this is only possible for client-server connections. Another document describes the introduction of a second communication module, which is specially designed for efficient sending and receiving of serialized data. Other concepts currently under discussion relate to the allocation of IP addresses and global time synchronization across different networks.

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