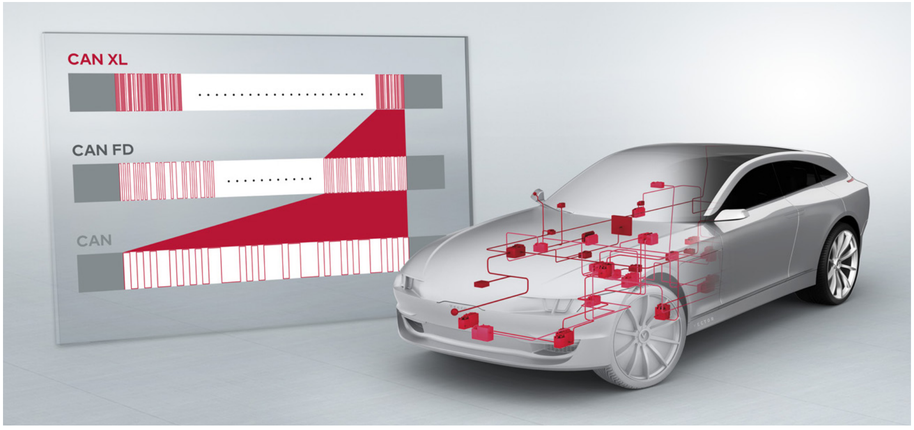
Change in automotive communication systems

The authors take a look on the transformational change of Classical CAN, CAN FD, CAN XL, Flexray, and Ethernet. CAN XL provides the basis for cooperation between IP technology and signal-based communication. It closes the gap between CAN FD and Ethernet.



(Source: Vector)

Just a few years after the market launch of CAN FD, a new CAN variant, CAN XL, is on the start – sometimes viewed with a little suspicion. In fact, CAN XL owes less to the marketing strategy of electronics suppliers than it does to the dynamic development in automotive electronics over the last few years. In particular, the advent of automotive Ethernet with IP technologies is changing some things fundamentally. Currently, service-oriented communication is establishing itself in the vehicle parallel to signal-based communication. In this context, CAN XL provides the basis for efficient cooperation between IP technology and classic, signal-based communication. With data transmission speeds of up to 10 Mbit/s, it closes the gap between CAN FD and 100-Mbit Ethernet (100BASE-T1).

Currently, development departments in the automotive industry are, for the most part, concentrating on the challenges posed by the transformation in mobility. The focus is on assistance systems (ADAS – advanced driver assistance system), autonomous driving, electric mobility, and continuous connectivity to the Internet or to the cloud. High-performance sensor systems such as radar, laser scanners, and video cameras in the vehicle are an indispensable prerequisite for autonomous driving. They generate volumes of data that were unknown in the automotive sector only a few years ago. The challenge is how to transmit and process this exploding data volume in real-time. To meet this challenge, the industry has introduced Automotive Ethernet for fast transmission of data, covering primarily the bandwidths of 100 Mbit/s to 1 000 Mbit/s (100BASE-T1, 1000BASE-T1) used initially in the ADAS area. At the lower end of Ethernet networking, development is currently focused on 10BASE-T1S, with a transmission speed of 10 Mbit/s.

Service-oriented communication goes hand in hand with Ethernet and IP technology. Applications need data and services. It does not matter who provides them. However, this does require a dynamic link connection between data sink (consumer) and data source (provider). The ability to transmit dynamic data structures is another major advantage of service-oriented communication. The volume of data to be transmitted, for example in the case of sensor data fusion applications, is generated only during the runtime of the application. Such data cannot be mapped statically; instead, the communication system must serialize the data dynamically.

Classic automotive serial bus systems

In contrast, the classic automotive networks such as Classical CAN/CAN FD and Flexray employ signal-based communication technology. In most applications, CAN operates at a transmission rate of 500 kbit/s and is used in automotive areas such as engine management and body control. The capabilities of CAN, a pioneer in automotive networks, are extended upwards by CAN FD and Flexray, whose transmission rates range from 1 Mbit/s to 10 Mbit/s. ▷

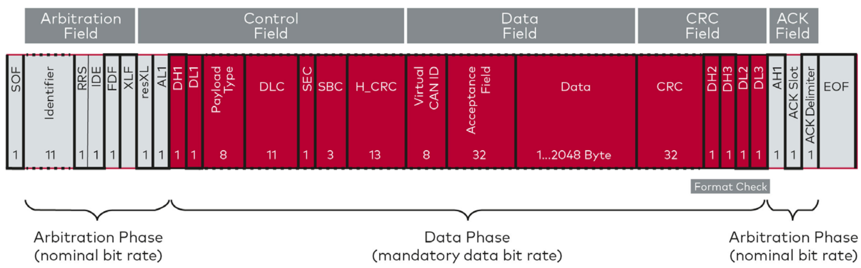


Figure 1: CAN XL frame (current status of development); With data lengths of up to 2 048 byte, CAN XL also lays the groundwork for future transportation of Ethernet frames and for the use of IP communication (Source: Vector Informatik)

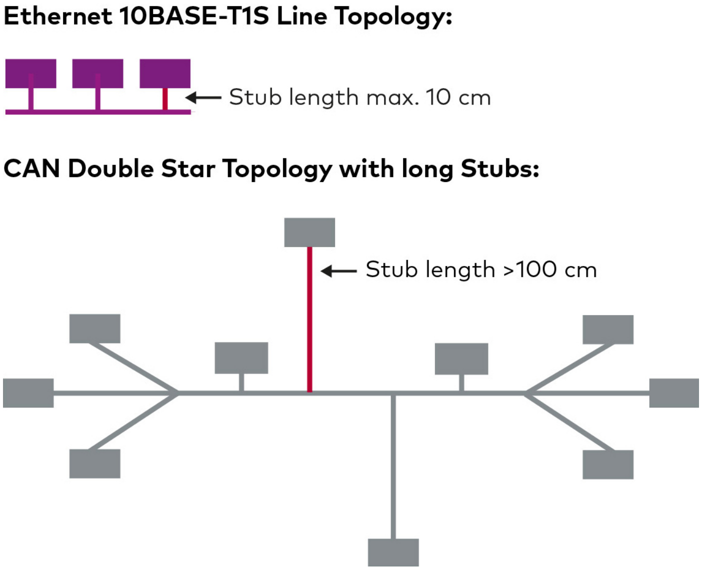


Figure 2: Network topologies of 10BASE-T1S and CAN XL; CAN XL enables other topologies to be used, with a star and long stubs (Source: Vector Informatik)

These newer systems are predestined for time-critical applications in engine management, body control, and chassis control, where they are used, for example, in the brake system. Lastly, Most, which is responsible for infotainment applications, covers the 25 Mbit/s to 150 Mbit/s range.

Given the rise of automotive Ethernet and in view of the growing variety of communication systems, a consolidation appears reasonable to limit complexity and costs. Since the fields of application of Flexray and Most can also be sufficiently covered by Ethernet, these systems will likely be replaced in the medium term. This would leave CAN and Ethernet, with Ethernet now handling infotainment, ADAS, telematics and connectivity at 100 Mbit/s to 1000 Mbit/s. Classical CAN and CAN FD operate in the range of 0,5 Mbit/s to 5 Mbit/s and are responsible for engine management and body control. In the future, CAN XL or 10BASE-T1S could be used for chassis control systems, running at 10 Mbit/s.

Considering that about 90 % of all network nodes communicate at speeds of up to 10 Mbit/s, the 10 Mbit/s domain covers a wide field of applications. It extends from audio applications to radar and ultrasonic sensors all the way to chassis control. From the technical viewpoint, the first applications mentioned focus on the streaming and serializing of data as well as on the principle of service orientation. In contrast, for applications in chassis control, signal-oriented communication dominates. As indicated above, CAN XL and the Ethernet variant 10BASE-T1S are competing in this sector.

CAN XL – the latest and fastest CAN

CAN XL is a further development of Classical CAN and CAN FD and operates largely on the same principle. A CAN frame can be divided into arbitration and data phases. While CAN XL uses low transmission speeds of 500 kbit/s to 1 Mbit/s in the arbitration phase, the speed in the data phase is ▷

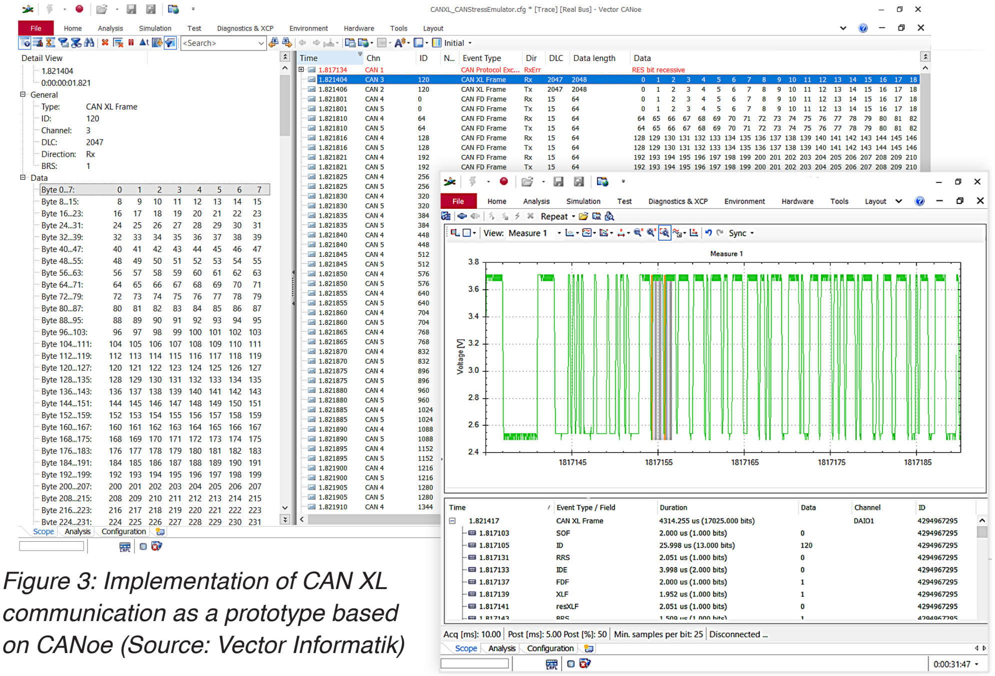


Figure 3: Implementation of CAN XL communication as a prototype based on CANoe (Source: Vector Informatik)

scalable over a wide range of 2 Mbit/s to 10 Mbit/s. This bit-rate-switching is now mandatory with CAN XL.

Once again, the access method used is CSMA/CR (carrier sense multiple access/collision resolution), which resolves competing write access through bit arbitration. In this way, CAN XL follows a strict priority concept that allows the more important frame to be transmitted with no delays. CAN XL now only supports 11-bit identifiers, and 29-bit identifiers are no longer in use. Furthermore, CAN XL features a high level of data transmission reliability. With Hamming Distance 6 for headers and frames as well as format checks, it actually outperforms Flexray and the capabilities of Ethernet CRCs.

However, for future applications, it is not just the increased speed of data transmission that is important. A key motivating factor for the development of CAN XL is also the scalable length of useful data, which can extend to as much as 1 byte to 2 048 byte. Where necessary, this enables future automotive communication systems to package Ethernet frames in CAN XL frames, and/or to use IP communication via CAN XL (figure 1).

Network topology with controlled network access

The new 10BASE-T1S also operates at a transmission speed of 10 Mbit/s. With the automotive 10-Mbit/s Ethernet variant considered here, the “S” stands for short distance or short range and exists explicitly for automotive applications. It covers short distances of up to 25 meters and should not be confused with the 10BASE-T1L variant (L – long distance), which provides ranges of up to 1 000 meters and is typically employed in industrial applications.

An unshielded twisted wire pair serves as physical layer for 10BASE-T1S ("T1"). In contrast to today's other switched Ethernet versions, the topology for 10BASE-T1S is a network. All users are connected to a common Ethernet cable (multi-drop bus topology) by short tap lines (“stubs”) measuring maximal 10 centimeters in length. This immediately raises the question of network access: In the Ethernet-PHY, a round-robin approach is implemented that allows collision-free network access via PLCA (physical layer collision avoidance). This guarantees deterministic response times for each network user, and provides real-time capability in the application. Collision-free access further allows complete use of the entire bandwidth of 10 Mbit/s. 10BASE-T1S offers only half-duplex operation, for which only one PHY per ECU (electronic control unit) is needed instead of two per connection.

With these characteristics, 10BASE-T1S is also suitable for applications found in classic automobile networks. Whereas Ethernet 10BASE-T1S is positioning itself from above in the 10-Mbit/s domain, CAN XL, coming from below, is expanding up into the 10-Mbit/s domain. Both, 10BASE-T1S and CAN XL domains, could frequently operate as network branches under a 100BASE-T1 domain. Coupling of 10BASE-T1S to 100BASE-T1 is possible without problems through use of a switch. In contrast, a gateway is required to connect CAN XL branches. With their different approaches, both models have advantages and disadvantages, and theoretically could exist in parallel to each other. The decision as to which communication system will play a predominant role in this area in the future depends on cost considerations as well as on technical factors and, last but not least, on reverse-compatibility with Classical CAN and CAN FD.

Signal-based CAN communication

A powerful argument for CAN XL remains the high dominance of Classical CAN variants with signal-based communication in numerous vehicles. For typical control tasks, the signal-based approach has been tested and proven for almost three decades. Together, with the priority principle used with CAN, the system ideally satisfies the necessary real-time requirements. A major feature of signal-based communication is the predefined static communication matrix. Signals such as temperatures, pressures, speeds or revolutions always represent the same fixed parameter, which is mapped to an established CAN frame and sent to ECUs (electronic control unit). In addition, so-called PDUs have been introduced, which form an intermediate layer and make communication more flexible.

In contrast to 10BASE-T1S, CAN XL offers the ability to use more complex topologies with a star and long stubs. For this reason, the proven topologies of existing CAN solutions cannot be replaced on a one-to-one basis with 10BASE-T1S networks, given their considerably more restrictive network topology. Their restrictive network topology only permits stubs with a length of 10 cm. On the other hand, nothing stands in the way of upgrading from Classical CAN/CAN FD to CAN XL in this regard, since a great deal of know-how and development time has already been invested in wire routing and the careful design of ingenious cable harnesses (figure 2). ▷

It is precisely this migration path that makes CAN XL interesting for those automakers who focus primarily on compact and midsize cars. In this mass market, autonomous driving will not be found for some time. At best, you will find simple assistance systems that have already been in common use for years, for example anti-lock brake systems. Without radar sensors, high-resolution cameras, and the like, there is no compelling need for an Ethernet-based network; instead, the classic systems will predominate, led of course by CAN. For such vehicles, CAN XL offers the ideal platform for further development on the basis of the existing vehicle architecture. No redesigns of cable harnesses, controllers, and protocol stacks are necessary. The simpler protocol stack for CAN compared to that for IP allows use of smaller and thus lower-cost controllers. One goal for CAN XL would be to continue this tradition.

Summary and prospects

CAN XL is a CAN variant that constitutes a simple migration path for existing Classical CAN and CAN FD networks and that also closes the gap in transmission speeds between Classical CAN/CAN FD and Ethernet. In appropriate fields of application, CAN XL communication can facilitate smaller and therefore less expensive controllers than Ethernet. With useful data lengths of up to 2 048 byte, CAN XL also delivers what will be required in future to transport Ethernet frames and to utilize IP communication. At some future date, this could mean that CAN XL and 10BASE-T1S could together provide a link between signal-based communication on the lower levels and service-oriented communication on the higher systems. With appropriate extensions in the various protocol layers, this will open up some interesting options. Some very promising initial CAN XL prototypes have already been developed, including ones by Vector (figure 3).

On page 32 (IP concepts with CAN XL), the authors take a look on the transformational change of communication systems. CAN XL provides the basis for cooperation between IP technology and signal-based communication. It closes the gap between CAN FD and Ethernet. ◀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