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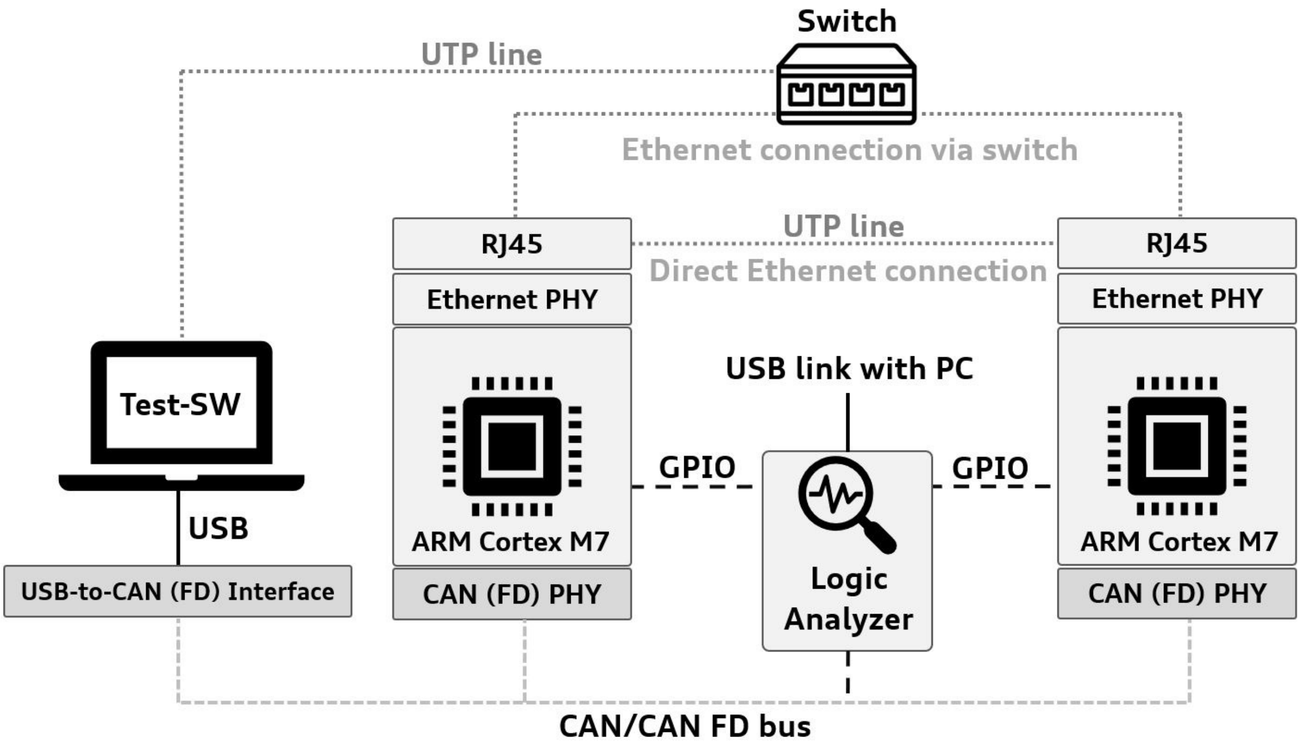
Part 1: Comparing CAN, CAN FD, and Ethernet

This analysis compares Classical CAN, CAN FD, and Ethernet communication with focus on a decentralized battery management system. This is Part 1 of the article.



Test setup for comparative analysis of CAN, CAN FD, and Ethernet (Source: OTH Regensburg)

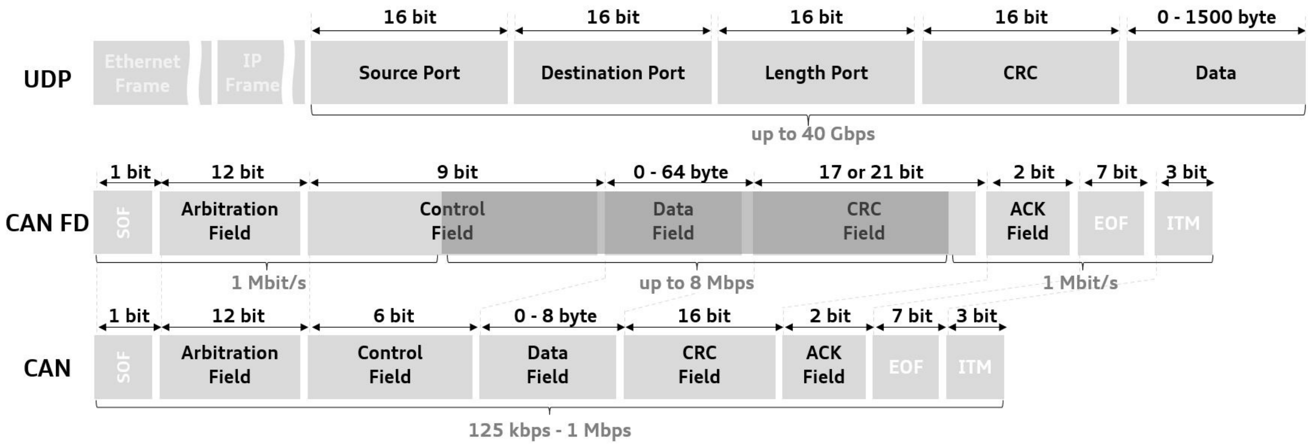
The complete article is published in the June issue of the CAN Newsletter magazine 2021. This is just an excerpt.

In Part 1 of the article, the test environment setup as well as the evaluation criteria for the comparative analysis is introduced. Part 2 provides related results and discussion.

Networked control systems such as battery management systems, smart grids, or vehicular systems, consist of sensors, actuators, and controllers linked via a common communication line. The system control can be distributed among several nodes thus building a decentralized control system enabling a communication-based coordination of the control tasks. Nodes can be added or removed even after an initial installation, which offers the required flexibility for different applications.

A communication network can cause unpredictable delays which can affect the system control. For CAN communication, e.g., only the latency of the highest prioritized data frame can be determined. For the remaining data frames, the delay depends on the situation on the network and is not predictable. These network-induced delays may increase the time jitter of the control loop, which consequently can lead to instability. In addition, possible data or information loss or data manipulation, endanger the control coordination. Therefore, the data rate and the reliability of the underlying communication network are key factors of the networked control system. In addition, the processor load caused by the communication is relevant as it affects the calculation of system states and the setting of control parameters.

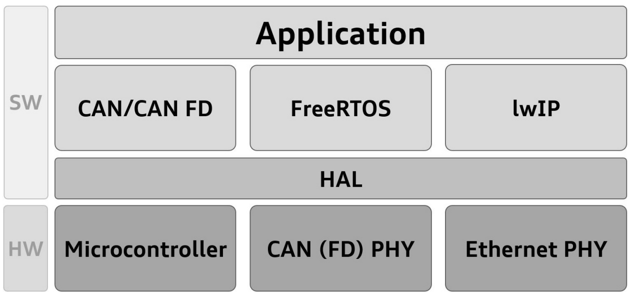
Energy required for the communication network influences the system efficiency in a respective application. Energy efficiency, small latency, and reliability are the key features for the communication networks. The decentralized battery management system (DBMS) is an example application for networked controlled systems. The DBMS consists of renewable energy generators, a variable number of different batteries, and varying loads. For battery control, battery-specific condition parameters are communicated regularly, which allows to adjust the required charging/discharging power of the batteries. Additionally, current, voltage, and temperature values are measured in millisecond intervals. Each data packet comprising few bytes contains a time stamp and is sent to all participating nodes forming the basis for the collaborative system control. Within the DBMS, it is therefore required to regularly send frames with few data bytes quickly, reliably, and without errors in order to achieve system-wide data consistency.



Structure and size of the UDP, CAN FD, and CAN frames and the maximum transmission rates (Source: OTH Regensburg)

Examined networks

Classical CAN is widely used in distributed embedded systems. Its limited communication bandwidth (up to 1 Mbit/s) and payload (user data) size (up to 8 byte) restrict the applicability in increasingly complex electronic systems (Figure 2). CAN FD comes with higher data- transfer rate (up to 8 Mbit/s) and larger payload size (up to 64 byte). Ethernet offers data rates up to the Gbit/s-range via a twisted pair (TP). In embedded systems, 100BASE-TX with 100 Mbit/s is most common, since higher data rates also increase processor and memory requirements. It offers a payload size of up to 1 500 byte and provides low latency but is also more complex compared to Classical CAN and CAN FD. Ethernet-based solutions offer various protocols. In this article the user datagram protocol (UDP) is considered as it is a relatively simple compared to the transmission control protocol (TCP). It avoids confirmation of correct frame reception and thus supports unicast, multicast, and broadcast communication. The size of the UDP message header (8 byte) is significantly reduced compared to the up to 60-byte header of the TCP. In the scope of this article, the UDP/ IP protocol stack is examined and is only one of several options.



Software components and the interface between them and the hardware (Source: OTH Regensburg)

For the evaluation of the energy efficiency, the maximum power consumption of the communication technologies is measured. To evaluate the transmission reliability, the bit error rates (BER) and the residual error rates (RER) are determined. Furthermore, the frame processing time and the processor load of each communication technology are measured as both influence the system control. Since networked control systems may consist of numerous participants, the behavior of the communication technologies under high network load is investigated. In this article, theoretical comparisons have been made for a substantiated evaluation of the communication technologies. Data sheets, existing literature, and simulations are referenced. In addition, comparative tests within a hardware test setup enabled practical, realistic results, especially for transmission speed, error susceptibility, and behavior under high frame load.

Test environment setup

The basis for the comparative analysis is the software implementation (Figure 3) of the communication technologies and a test environment (Figure 1). The test setup consists of software and hardware components.

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