CAN vs. Ethernet in Lift Systems

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Abstract. Modern lift control systems rely on communication networks to connect numerous components, including controllers, sensors, inverters, door drives, user interfaces, and monitoring units. Controller Area Network (CAN) bus remains a widely used and well-proven standard in lift applications, valued for its robustness and predictable behaviour. However, as lift systems increasingly require higher bandwidth and closer integration with IP-based services, Ethernet is being adopted more widely. Drawing on practical experience in the design and implementation of lift control systems, this paper compares the two technologies in terms of their architectural characteristics, network topologies, scalability, communication protocols, and suitability for different parts of the system architecture.

1 INTRODUCTION

Modern lift control systems rely on communication networks to connect many components. These include controllers, sensors, inverters, door drives, user interfaces, and monitoring systems. Each of these components has different requirements for data transmission.

Therefore, communication technologies differ in their properties and performance. Important parameters include bandwidth, real-time capability, latency, number of nodes, maximum cable length, scalability, network topology, signalling methods, and electromagnetic compatibility (EMC) robustness.

These characteristics are mainly defined by the lower layers (Layer 1 and Layer 2) of the OSI (Open System Interconnection) reference model [1]. On top of this, higher-level protocols provide additional functionality depending on the application.

Several digital communication technologies are used in the lift industry. These include RS-232 (e.g., for diagnostic interfaces), RS-485 [2], CAN bus [3, 4], and Ethernet. This paper focuses on CAN and Ethernet, as they are widely used today. It discusses their key properties as well as recent developments, especially in the CAN domain.

It should also be noted that simple hard-wired signals are still used. Examples are door contacts or final limit switches. These signals only transmit basic states, such as on/off or open/closed. In addition, analogue transmission methods exist, for example using specific voltage or frequency levels. However, these are less common in modern systems.

2 GENERAL/BACKGROUND

2.1 OSI Layer Model

The OSI (Open Systems Interconnection) reference model structures communication systems into seven layers [1], separating application-oriented functions (layers 5–7) from transport-oriented mechanisms in the lower layers [5] (see Figure 1). Communication technologies such as CAN and Ethernet are primarily specified in the physical layer (layer 1) and the data link layer (layer 2) [6]. Layer 1 (physical layer) defines the electrical and physical aspects of transmission, including voltage levels, bit rates, transmission media, and bit timing and encoding, which describe when bits are sent

and how they are represented as signals (signalling). Layer 2 (data link layer) specifies the rules for reliable data exchange over the physical medium, including frame formats, bus arbitration mechanisms, and error detection and correction.

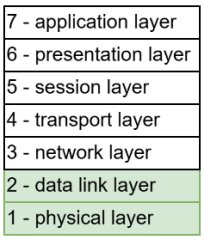


Figure 1 OSI layer model

2.2 Twisted pairs/cables

The CAN bus and modern Ethernet use twisted pairs as a transport medium. Twisted pairs are cost-efficient and robust against electromagnetic noise, as twisting supports differential transmission with strong common-mode noise rejection and reduced EMI/RFI (electromagnetic and radio-frequency interference) coupling, thereby improving signal integrity in electrically harsh environments.

Twisted pairs have individual characteristics and properties influenced, e.g. by twisting rates [7], insulation material, geometry, symmetry and tolerances [8]. Variations in these parameters lead to changes in the impedance and its uniformity along the line. This negatively affects the network's signal quality and robustness. Using high-quality cables with the right impedance is necessary, especially in networks with higher bit rates.

Twisted-pair cables require proper termination using a resistor matched to their characteristic impedance. This avoids reflections and preserves signal integrity. Twisted pair cables for data transmission usually have 100…120 ohms impedance.

2.3 Controller Area Network (CAN)

2.4 Evolution of the CAN bus

The Controller Area Network (CAN), now known as Classical CAN (CAN CC or CAN 2.0), was developed by Robert Bosch GmbH in the mid-1980s for automotive applications [6]. Its first commercial deployment was in the Mercedes S-Class in 1990 [9]. The primary objective was to enable robust and reliable communication between distributed electronic control units (ECUs), thereby reducing system complexity, wiring effort, and overall vehicle weight.

Due to these advantages, CAN was soon adopted in other embedded system domains, including the lift industry, where it has been in use since the early 1990s [3].

Classical CAN remained the dominant standard for over 25 years until the introduction of CAN FD (Flexible Data Rate) (see Figure 2) [9]. While Classical CAN supports bitrates of up to 1 Mbit/s with a maximum payload of 8 bytes, CAN FD increases data rates to 2 Mbit/s, and up to 8 Mbit/s when using signal improvement capability (SIC) transceivers. CAN FD also extends the payload size to 64 bytes. CAN FD retains a low bitrate during arbitration while allowing higher bitrates during the data phase, preserving reliable communication over longer cable lengths.

Since 2023, products implementing the latest CAN standard, CAN XL, have become available on the market. CAN XL further extends performance by supporting data rates of up to 20 Mbit/s and payload sizes of up to 2048 bytes per frame. Moreover, it enables efficient tunnelling of Ethernet OSI level 2

frames, allowing the use of higher-layer networking protocols such as TCP/IP over CAN-based networks.

In addition, CAN XL introduces built-in security mechanisms at the OSI Layer 2, including support for confidentiality and authenticity. This advancement simplifies implementing secure communication in CAN networks by reducing the need for security protocols at higher OSI layers, such as the application layer.

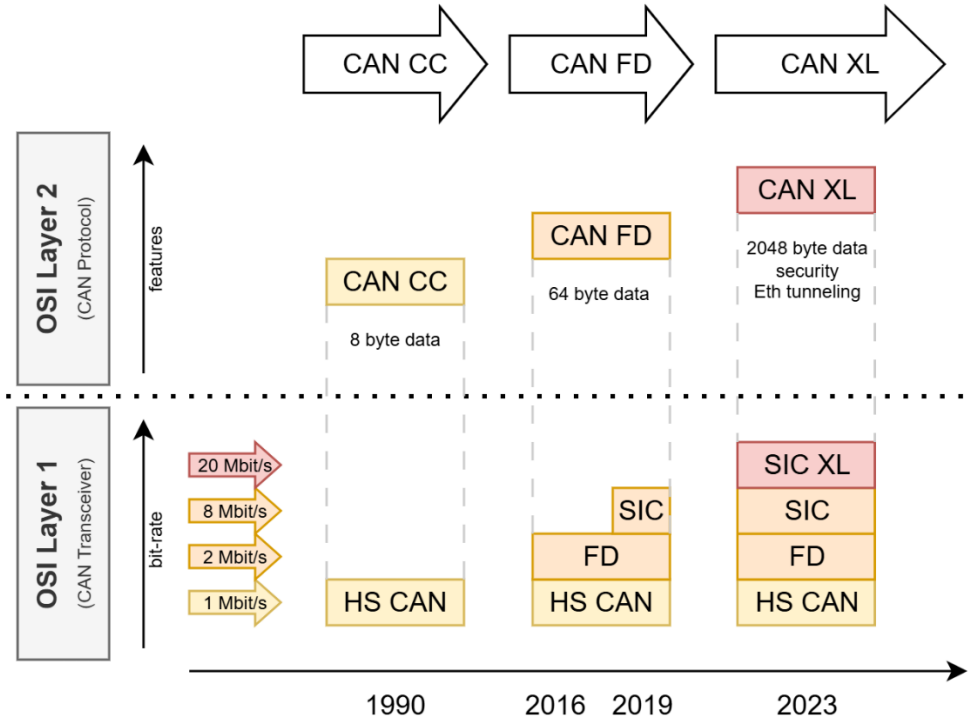


Figure 2 History of CAN standards

2.5 Network topology

The CAN bus applies a classical bus topology. Multiple nodes/devices are connected to the same wires (twisted pairs). When multiple nodes share a communication medium, arbitration mechanisms are required to prevent or resolve transmission collisions (OSI layer 2). A mechanism used by CAN is the CSMA/CR. CSMA (Carrier Sense Multiple Access) means that nodes transmit only when the medium is idle. CR (Collision Resolution) realises a non-destructive arbitration based on message priority. Simultaneous transmissions are resolved bitwise; the frame with the highest priority (lowest identifier) continues, while others abort and retry. This is an efficient bus arbitration method.

The bus topology (an example is shown in Figure 3) requires proper termination at the “main” ends of the wires (N1 and Nn). Only short stubs without additional termination resistors are allowed for additional nodes (N2…N6).

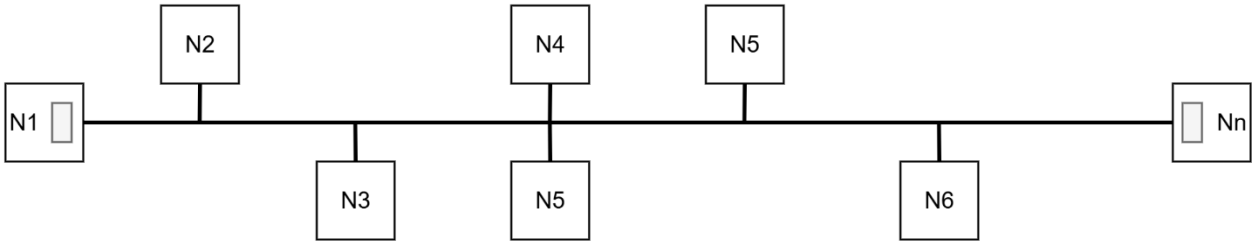


Figure 3 Bus topology

The bus cable length is limited by the arbitration bitrate. The arbitration bitrate is up to 1 Mbit/s for all CAN standards. The higher the arbitration bitrate is, the shorter the CAN bus cable must be. The maximum bus cable length, dependent on the bit rate, is shown in Table 1 [10]. With CAN FD or CAN XL, there can be a low arbitration bit rate but a high data transmission bit rate. This means that once bus arbitration is successful, CAN FD/XL can switch to higher bit rates for the data-byte transmission. The arbitration bit rate and the data transmission bitrate can be configured in CAN networks.

Table 1 CAN - Max cable length

Arbitration bit rate	Max cable length
1 Mbit/s	25m
800 kbit/s	50m
500 kbit/s	100m
250 kbit/s	250m
125 kbit/s	500m
50 kbit/s	1000m

If classical CAN nodes use new transceivers, CAN CC, CAN FD and CAN XL can be used on the same CAN bus (as long as CAN XL operates <=8 Mbit/s).

2.6 Wires

The CAN transceivers are optimised for a cable impedance of 100-120 Ohms (CAN CC and CAN FD). CAN XL is optimised for 100 Ohms. That requires twisted-pair cables of the same impedance, and likewise the bus termination. Mostly, CAN bus cables are unshielded because transmission frequencies are relatively low and CAN frame transmission is very robust. Power over the data-twisted-pairs, like Power over Ethernet PoE, is not possible.

3 ETHERNET

3.1 Evolution of the Ethernet

Ethernet (now standardised in IEEE 802.3), dating back to the 1970s, has a longer history than the CAN bus. Originally, it focused on interconnecting personal computers (workstations) and commonly used printers as shared resources in a building/office [11], with the first specification in 1980 [12]. The system was based on a shared communication medium, a coax cable (the “Ether”). Early Ethernet

used CSMA/CD (Carrier Sense Multiple Access/Collision Detection), a potentially destructive arbitration method. Nodes detect collisions during transmission, abort the transmission, and retransmit after a random backoff time. The first Ethernet had 10Mbit/s.

The Ethernet connection evolved over the years [13]. While some characteristics remained unchanged, such as frame formats on OSI layer 2, the physical layer kept evolving and expanding. The different Ethernet standards are named with the following naming convention:

<rate><BASE/BROAD>-<medium/variant>

The most common variants nowadays use twisted pairs (medium = "T"), have different bit rates, and use different signalling.

The most common variants are shown in Table 2.

Table 2 Common Ethernets standards

No	ETH variant	Wires	Signalling	Type	Max cable length
A	10Base-T	2 twisted pairs	Manchester	Point to point	~100m
B	100Base-TX	2 twisted pairs	MLT/3	Point to point	~100m
C	1000Base-T	4 twisted pairs	4D-PAM5	Point to point	~100m
D	10Base-T1L	1 twisted pair	PAM-3	Point to point	~1000m
E	10Base-T1S	1 twisted pair	DME	Multidrop (shared medium)	~15 - 25m

The point-to-point Ethernet variants mentioned above support full-duplex operation. Historically, half-duplex operation has also been possible, but it is no longer relevant. Depending on the specific Ethernet standard and data rate, Ethernet employs different signalling schemes. The signalling complexity increases to achieve the higher bit rates.

Variants A and B (using two twisted pairs) assign a dedicated transmission direction to each pair. In contrast, variants C and D use all twisted pairs bidirectionally in full-duplex mode (see Figure 4). This is enabled by echo cancellation, where the device's own transmitted signal is removed so that only the remote signal is received.

Variants A-C usually use the same PHY (physical layer transceiver) and are used in office computers and switches (also in industrial environments) and, as a standard, in many embedded devices. 10Base-T1L, as a variant of Single Pair Ethernet (SPE), focuses on process and building automation and enables the connection of sensors to Ethernet networks, including Power over Data Line (PoDL). Special switches are necessary and available.

For longer distances, where it is not possible to have intermediate switches, e.g. the lifts' travelling cable, Ethernet standards for fibre optics exist (e.g. 100Base-FX).

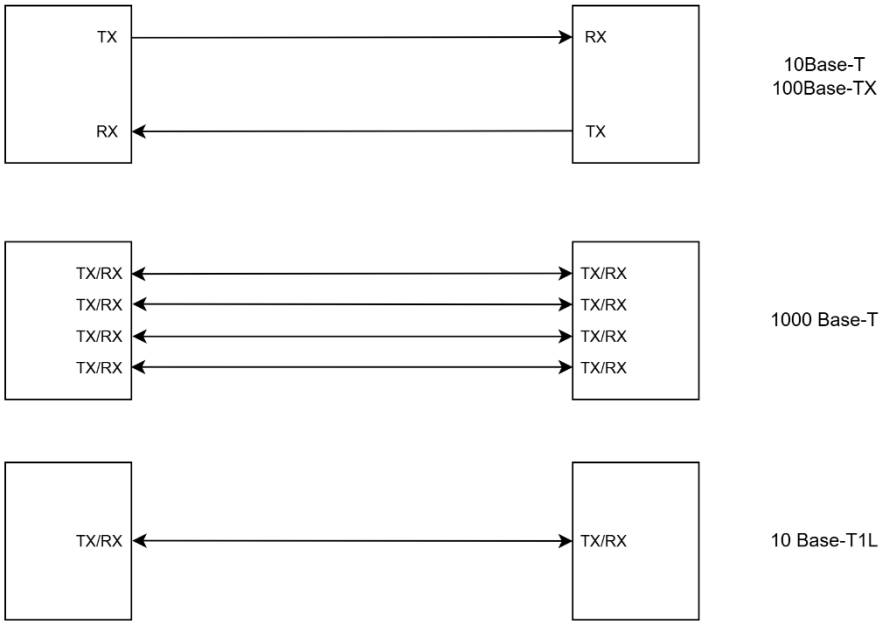


Figure 4 Ethernet full-duplex connections

3.2 Network topology

10BASE-T1S supports multidrop operation using a bus topology similar to a CAN bus (see Figure 3 above). However, it employs Physical Layer Collision Avoidance (PLCA) for bus arbitration. A central coordinator assigns transmission time slots, effectively preventing collisions. 10BASE-T1S is primarily used in the automotive industry. Due to its limited maximum cable length, it is less relevant for lift applications.

Variants A–D use point-to-point connections, so switches are required to form networks. Different concepts of network topologies exist. Their properties, advantages, and disadvantages form a field of their own, and their detailed discussion is beyond the scope of this paper.

However, some basic ideas (ring, star, tree) are shown in Figure 5 below.

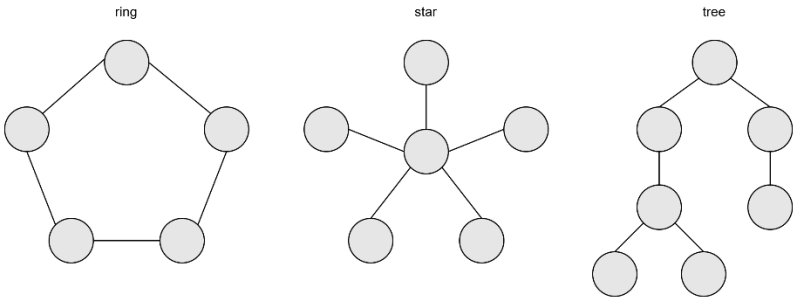


Figure 5 Ethernet network topologies (ring, star, tree)

Hybrid topologies can be used (see Figure 6) to enable efficient adaptation to application-specific requirements. With Virtual Local Area Networks (VLANs), a physical network can be divided into several virtual networks. Therefore, managed switches are necessary.

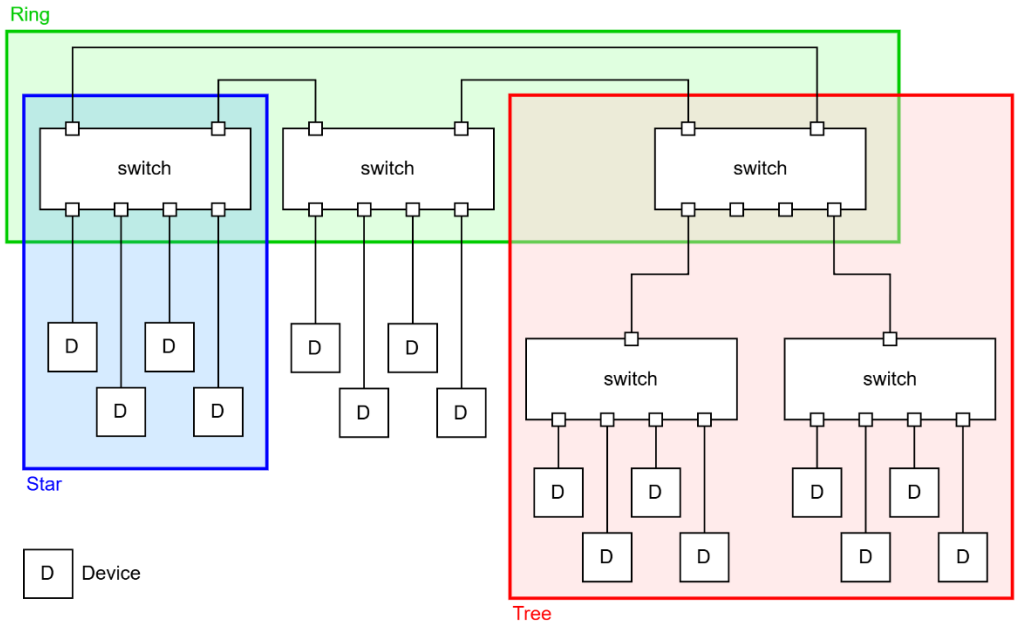


Figure 6 Ethernet hybrid network topology (example)

4 PHYSICAL ASPECTS

4.1 Wiring, EMC and signal quality

Reliable communication requires good signal quality. The higher the transmission frequency or bit rate, the more sensitive the signals become to interference. But countermeasures are possible.

One important source of interference in lift systems is electromagnetic and radio-frequency interference (EMI/RFI). The use of twisted-pair cables helps to mitigate negative impacts (see section 2.2). In applications with very high data rates or particularly harsh electromagnetic environments, shielded cables are recommended. However, interference can also originate from the system's physical design. For example, low-quality cables with large manufacturing tolerances or temperature-sensitive insulation [9] may lead to variations in the characteristic impedance. Similar issues arise from poorly designed or mismatched connectors and patch panels. Such impedance discontinuities along the transmission path can cause signal reflections and degrade overall signal integrity. Furthermore, even when high-quality components are used, improper installation practices can significantly reduce robustness. Common issues include incorrect or missing bus termination, long, untwisted "twisted" pairs, very small cable bending radius, and insufficient large-area grounding for cable shielding.

Every transition between cables through connectors introduces potential impedance discontinuities and represents a source of signal integrity degradation. Different signalling methods and bit rates result in different levels of robustness.

In the case of the CAN bus, often unshielded twisted pair cables are used. Even simple terminals are sometimes used to connect CAN cables, especially at low data rates. With its robust protocol and signalling, systems are operationally stable. With increased data rates and increased signalling complexity, good wiring and installation quality become more important.

For example, using standard terminals to connect Ethernet cables (see Figure 7) is very likely to cause issues. Using RJ45 connectors or dedicated Ethernet patch panels helps to connect, e.g. the twisted pairs of travelling cables, to the control cabinet/machine room cabling. However, especially for

Ethernet cables, it is important to keep the twisted pair twisted as long as possible. Figure 8 shows a patch panel, but with untwisted twisted pairs once they are uncovered outside the sheath/shielding.

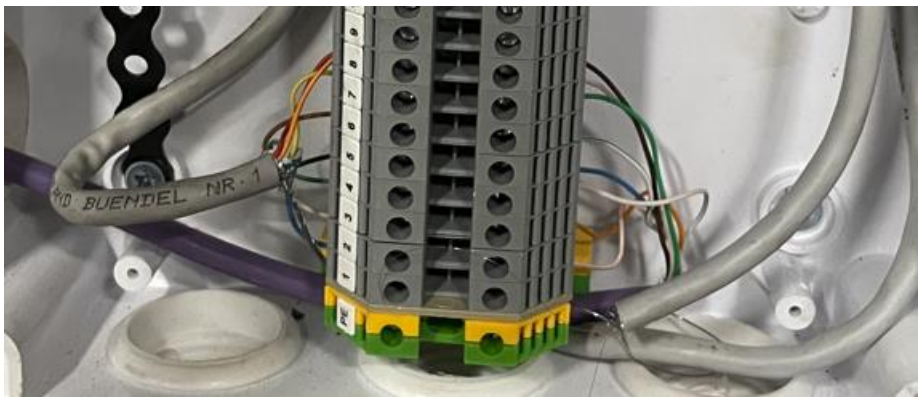


Figure 7 Ethernet connection with standard terminals

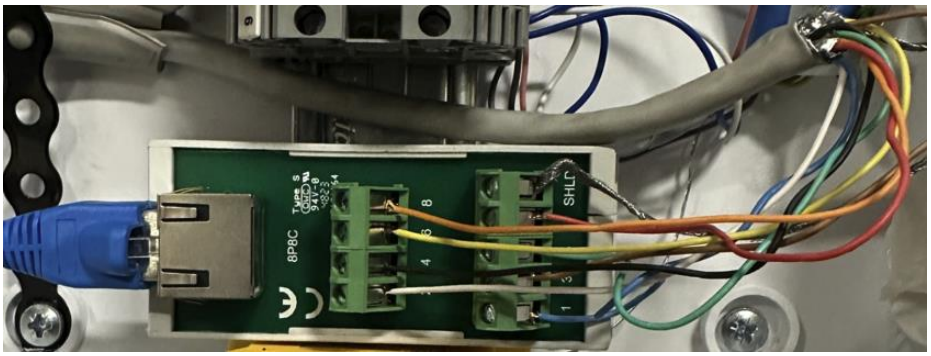


Figure 8 Ethernet patch panel with untwisted "twisted" pairs

An example of a differential CAN bus signal with an FD receiver (early generation) on a bad-terminated bus is shown in Figure 9 [14]. Reflections reduce signal quality and limit the bitrate. The logical 1 (0V) signal is ringing and oscillates beyond the threshold for a logical 0 (>0.9V). Note: New transceiver generations, such as SIC or SIC XL, improve signal quality and are more "forgiving" to poor wiring/cables, as oscillation is lower and the "signal margin" is much higher.

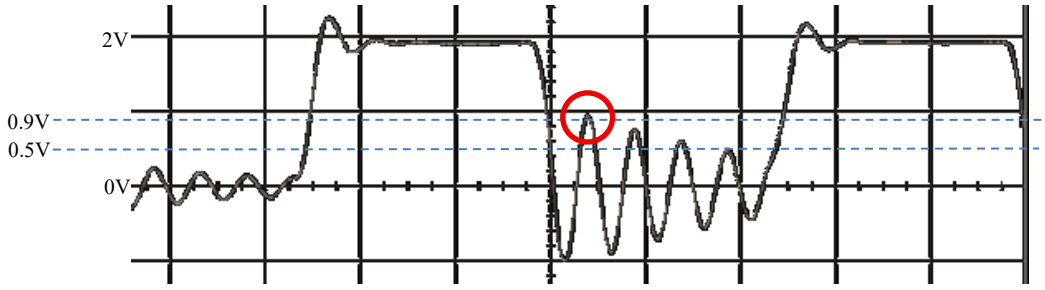


Figure 9 Ringing bus signal

This is just an example, as it is the same with other bus systems, like Ethernet. It outlines the importance of good wiring and termination.

5 DATA PROTOCOLS

Since the classical CAN bus uses simple frames, proprietary protocols at OSI level 7 running over CAN are needed. Standardised protocol definitions at OSI level 7, such as CANopen for lifts, exist [15]. CAN XL, able to tunnel Ethernet frames, make the CAN bus ready to transmit IP protocols and increases the range of applications. Ethernet, originally developed for office applications, supports network- and transport-layer protocols (TCP/IP). Plenty of OSI layer 7 protocols are available.

Internet Protocol (IP) (OSI layer 3) is an unreliable connectionless protocol that employs a best-effort delivery model. Data packets can be lost or duplicated and can be delivered in a different order than they were transmitted. Transmission Control Protocol (TCP) (OSI layer 4) builds a reliable, connection-oriented communication channel on top of IP. Data arrives in-order, duplicate packets are discarded, lost packets are re-sent, and the protocol includes mechanisms to deal with traffic congestion. To achieve this reliability, TCP gives up any guarantee of latency, and so it may not be suitable for hard real-time applications and should be used with care in soft real-time applications.

Numerous application layer protocols are built on top of TCP/IP - e.g. Domain Name System (DNS), Dynamic Host Configuration Protocol (DHCP) and Hyper Text Transfer Protocol (HTTP).

6 APPLICATION/EXAMPLE

In a lift controller system [16], multiple communication technologies are employed to interconnect components according to their specific requirements. The simplified/stripped-down example shown in Figure 10 comprises three distinct networks. An Ethernet (ETH) network connects the group controller to destination call input terminals (“kiosks”) and displays used for traffic information in the cabin. Ethernet enables these screens to operate as browser-based terminals for visualising HTTP content and receiving passenger inputs (destination calls). In addition, the lift controllers are interconnected with each other and with the group controller via a CAN network. A dedicated internal CAN bus within each lift connects components such as the lift controller, the inverter, and sensors. Only a small amount of data is exchanged over the classical CAN, but it fulfils real-time requirements.

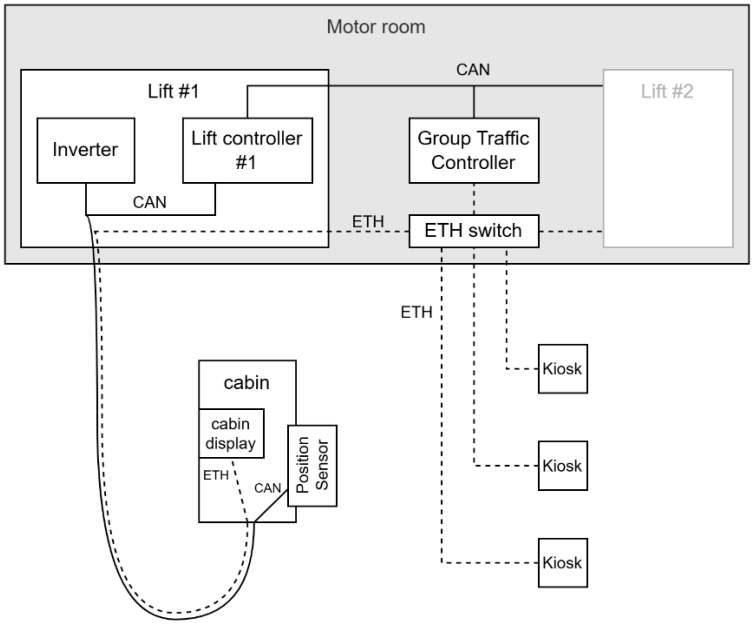


Figure 10 Simplified/stripped-down example application

7 CONCLUSION

Both CAN and Ethernet are used in lift controller networks. Both lead to stable and robust systems. However, good wiring/installation quality, along with high-quality cables and connectors, is needed, especially for higher bit rates and higher signalling complexity. The new CAN XL standard offers an option for applications that require robustness, higher data rates, and benefit from a bus topology. Additional features, such as Ethernet tunnelling and security mechanisms, help bridge the gap toward Ethernet-based communication. It will be interesting to see how Single Pair Ethernet and CAN XL will be used in future. However, Ethernet, in the context of the 10/100/1000Base-T standards, is a well-established technology for high-data-rate communication and forms the basis for IP-based networking. Moreover, many embedded components natively support the 10/100/1000Base-T Ethernet standard, resulting in the widespread availability of cost-effective off-the-shelf components.

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