CAN XL as backbone for body application

CAN XL, the third CAN generation, provides high-layer protocol management functionality. This allows running multiple applications using different higher-layer protocols on a single CAN XL backbone network. A typical application is commercial vehicle backbone network for body applications.

Some commercial road vehicles, trucks, and trailers, provide a gateway device for body builders. The gateway is connected to the in-vehicle networks often based on Classical CAN J1939 networks and provides on the other side a Classical CAN port to be connected to body applications. Body applications include tail-lifts, truck-mounted cranes, tippers, refrigerators, etc. There are also complex body applications with more than one control unit. Especially, refuse-collecting trucks and fire-fighting vehicles implement even several CAN body application networks. Most of the CAN interfaces for the body builder provide J1939 parameter groups (PG); an exception is Iveco offering a CANopen-based interface. In order to backbone multiple body application units with optional deeply embedded CAN networks, the DIN 4630 standard has been developed. The first edition was published in May 2022. It is based on Classical CAN using J1939 or CANopen as higher-layer protocol.

CAN XL possibilities

In 2018, CiA members started to develop the third CAN generation, also known as CAN XL. The CAN XL protocol (CiA 610-1) separates the ID functionality represented by two independent protocol fields: the 11-bit Priority ID field and the 32-bit Acceptance field. The data field has a length of 1 byte to 2048 byte. The CAN XL SIC physical medium attachment specification (CiA 610-3) uses optionally a PWM (pulse-width modulation) coding enabling dataphase bit rates of above 10 Mbit/s. Applying linear topologies, up to 20 Mbit/s have been achieved. CiA has already submitted its CAN XL lower layer specifications (CiA 610-1 and CiA 610-3) to ISO for international standardization.

The CAN XL data link layer protocol features embedded OSI layer configuration as specified in ISO 7498-4 (Information processing systems – Open Systems Interconnection – Basic Reference Model – Part 4: Management framework). This includes the PCS (traditional non-return to zero (NRZ)) coding or the optional PWM coding, the data link layer (Classical CAN, CAN FD, or CAN XL frame formats), and the higher layers. The higher-layer configuration possibility by means of the SDT (Service Data Unit Type) field is new. It allows the transmitter to indicate in the CAN XL data frame, which higher-layer protocol is used. This enables the network designer to run different higher-layer protocols on the same cable. The usage of the 8-bit SDT field is specified in the CiA 611-1 document. The receiver of a CAN XL data frame knows from the SDT value, how to interpret the CAN XL data field.

Additionally, the CAN XL protocol provides the VCID (Virtual CAN Network ID) field. This 8-bit field indicates to which virtual network the received data frame belongs to. With this approach, the system designer can implement several network applications on one network cable, if such a backbone network provides sufficient bandwidth. Combined with the SDT field one can run even multiple instances of the same higher-layer protocol on such a backbone network.

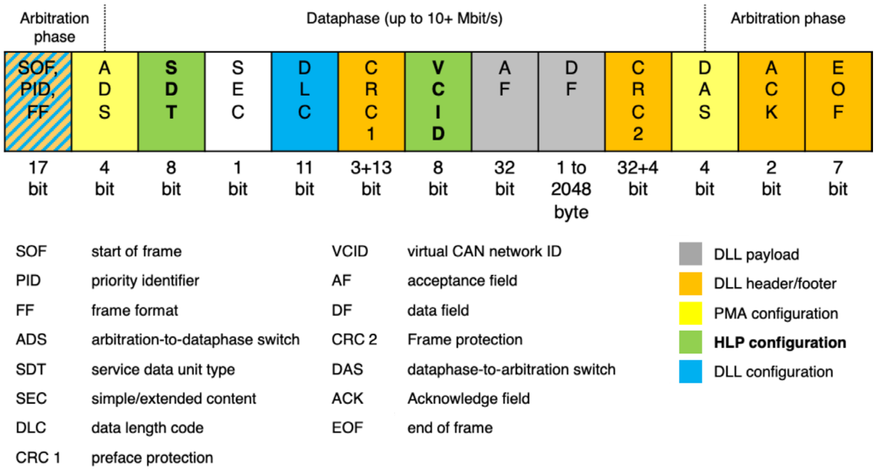

Figure 1: The CAN XL frame embeds higher-layer protocol (HLP) management information: the SDT and the VCID fields enable to run multiple instances of different HLPs on the same network segment (Source: CAN in Automation)

Example: Fire-fighting body application units

Fire-fighting trucks are equipped with body application units (BAUs). Some of these BAUs need to communicate with the in-vehicle networks provided by the truck or chassis manufacturer by means of an IGU (in-vehicle network gateway unit). Optionally, there are additional units connected to this body builder network such as a TGU (telematic gateway unit) or an FMU (fleet management unit). Each BAU may also comprise a deeply embedded ▷

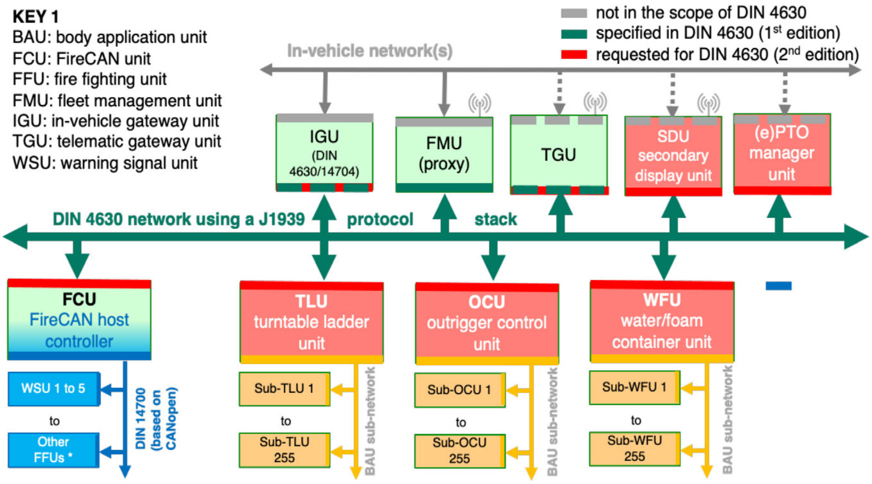

Figure 2: Example of the body application of a fire-fighting truck using Classical CAN networks (Source: CAN in Automation)

network. Typically, all these networks are based on Classical CAN. Most truck OEMs (original equipment manufacturers) provide a J1939-based IGU, to which the fire-fighting truck suppliers connect their BAUs.

The body builder network for commercial vehicles is standardized in DIN 4630 (Road vehicles – Data parameter specification for body application units in commercial vehicles) in English language. It specifies a generic IGU, the TGU, the FMU, and several BAUs. The first edition of this document does not standardize specific BAUs for fire-fighting vehicles.

Depending on the fire-fighting vehicle's functionality, there are different proprietary BAUs connected to the body application network. Normally, fire-fighting trucks are produced in low quantities. They provide more or less a unique functionality. This is not cost effective. Each vehicle needs to be equipped individually. This is why the fire-fighting industry (vehicle OEMs and suppliers) developed the DIN 14700 series standardizing fire-fighting devices such as battery chargers, frequency inverters, pumps, signal warning units, etc. This approach is also known as FireCAN. The specified communication interface for the devices is based on CANopen, but not compliant to the above-mentioned standards and specifications. To overcome this weakness, the DIN 14700 series is currently in review. One objective is to harmonize the communication optionally with the CiA 301 CANopen application layer and communication profile. The DIN 14700 parts will be integrated into a single standard also published in English language. The DIN 14700 host controller manages the communication with the fire-fighting units (FFU). These FFUs are virtual entities. This means a real device can host one or more FFUs. They are directly connected to ▷

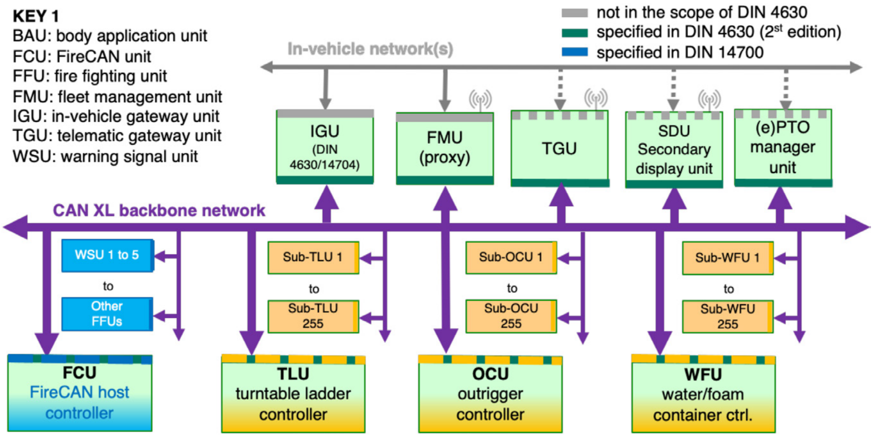

Figure 3: Example of a fire-fighting truck body application with a CAN XL backbone network (Source: CAN in Automation)

the body application network. The host controller acts as a gateway communicating with the IGU, TGU, and FMU by means of the body builder network (in the future based on DIN 4630). In order to standardize the IGU specifically for fire-fighting trucks, DIN has developed a special document. The DIN 14704 (Fire-fighting and fire protection – Fire-fighting-specific parameters for in-vehicle gateway units) standard is based on DIN 4630 using a J1939 mapping of parameters. It specifies the mandatory and optional suspect parameters (SP) and the parameter groups (PG).

But there are still several not standardized interfaces for fire-fighting BAUs. This includes the FireCAN unit (FCU) interface, the water/foam container unit (CU), the outrigger control unit (OCU), the turn-table ladder unit (TLU), the aerial working platform unit (AWPU), etc. For e-vehicles, additional equipment such as power battery units (PBU) and an energy management unit (EMU) is required. There is also a desire to use the vehicle's second dashboard for body application purposes.

Implementing multiple Classical CAN networks leads to complex wiring harnesses and additional hardware for bridges, routers, and gateways. The effort to tailor the body application functionality is high. Even with standardized units the integration of fire-fighting equipment is somehow challenging. When implementing a single backbone network, the integration task would be much easier.

CAN XL provides suitable features

CAN XL is a candidate for such body application backbone networks. It provides sufficient bandwidth to substitute multiple Classical CAN networks. Additionally, it features the necessary functionality to migrate from a multiple Classical CAN approach to a single backbone network approach. The protocol-embedded higher-layer protocol configuration function, the SDT field, allows to indicate the used higher-layer protocol (e.g. CANopen, J1939, or proprietary ones). This enables running CANopen and J1939 applications on the same network. In combination with the VCID field indicating a dedicated virtual network, one can even run multiple CANopen or multiple J1939 networks on the same network cable. In total, one can assign 255 virtual network IDs.

Applying virtual networks and virtual functional units allows implementing multiple virtual communication interfaces on a single CAN XL hardware port. Implementing multiple functional units is already supported by classical CANopen: up to eight logical devices can share one node-ID. If more functional units need to be realized, multiple CANopen nodes with different node-IDs can be implemented. Another option is the implementation of an application profile. CANopen application profiles enable the implementation of virtual devices as the J1939 application profiles are doing. But the mixing of CANopen devices and J1939 devices in a single Classical CAN network is only possible in theory. The limited bandwidth is one practical challenge. Another one is that J1939 allows proprietary use of data frames in CBFF (CAN base frame format). This could lead to double-use of 11-bit identifiers. CANopen supports optionally the use of data frames in CEFF (CAN extended frame format), which could lead to conflicts with J1939 parameter groups. If multiple proprietary higher-layer protocols need to be integrated, a single Classical CAN network with a harmonized network layer is required.

Conclusions

Body builder networks based on CAN XL overcome all described limitations and challenges. Especially, the above-mentioned higher-layer management options (SDT and VCID) embedded in the CAN XL data frame enable the integration of heterogeneous higher-layer protocol approaches. The separation of arbitration and addressing functions in the CAN XL protocol is another important feature to enable the integration of heterogenous higher-layer protocols, which can be instanced, too.

The data-phase bit rate of more than 10 Mbit/s allows the straight-forward integrations of multiple Classical CAN network segments without communication optimization. However, this high bit-rate requires the use of so-called SIC XL transceivers, which limit the arbitration bit rate. But this is not a real limitation, because the required network length limits the nominal bit-rate to 500 kbit/s (125 m) or even lower to 250 kbit/s (250 m).

Adapting an MPDU (multiple process data unit) concept mapping several application layer PDUs in a single CAN XL data frame can optimize the communication, because the data link layer (DLL) header/footer is shorter and the DLL payload is longer (up to 2048 byte). Of course, such an MPDU concept requires an additional header/footer in the communication middleware mapped to the application layer payload. But this protocol overhead is mapped into the CAN XL data field, which is transmitted with the configured data-phase bit rate. ▷

Coming back to the example of the fire-fighting vehicle: The legacy body application integration network (legacy backbone) can be integrated with the BAU-specific embedded networks (e.g. DIN 14700). The legacy hardware gateways become virtual gateways folded on a single CAN XL port. This allows to use a single wiring harness optimized to the vehicle's constructions and to pre-install connectors at places, where generic electronic control units (ECU) with CAN XL connectivity can be placed. The ECU functionality is software-configurable as well as gateway functionality. This reduces the effort for the wiring harness as well as number of CAN XL ports.

The described fire-fighting vehicle example is applicable to other complex vehicle body applications ("machines on wheels"). This includes, for example, refuse collecting trucks and trucks with multiple BAU functions (e.g. refrigerator and tail-lift or truck-mounted crane and tipper). The presented backbone approach integrating several legacy networks is also suitable for other commercial off-highway and off-road vehicles as well as agriculture, forestry, mining, and earth-moving machinery. Container-handling equipment, forklifts, and road pavers are other examples. ◀

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