History and trends:

CAN on rails

CAN serves in many rail vehicles as embedded and deeply embedded network. Often CANopen is used as higher-layer protocol. CiA has developed several profiles, which need to be revised according to new feature requests.

Already in the early days of CAN in Automation (CiA) in mid of the 1990s, some members used CAN in rail vehicles. One of them was Kiepe Elektrik Today, the company belongs to the Knorr-Bremse group. An early bird in applying CAN in special train utility vehicles was Windhoff. Both companies adapted CANopen, when this higher-layer protocol was handed over to CiA. Selectron (today part of the Knorr-Bremse group) and Luetze, two other CiA members, started end of the 1990s to provide CANopen devices for locomotives and coaches. At the same time, Knorr-Bremse developed CANopen solutions deeply embedded in its railvehicle brakes. IFE (today a part of the Knorr-Bremse group) submitted a CANopen profile for rail vehicle doors to CiA, which was released as CiA 424.

From research projects to IEC standardization

In 1994, Deutsche Bahn (German railway company) and STZP technology transfer center initiated the Ebas system development project for CAN-based data acquisition, monitoring, and control in freight trains. The system should shorten train assembly procedure including train rearrangement, identification, and configuration of the vehicles, as well as the check and determination of train's braking performance. Ebas also supported all train operating phases providing brake and traction control, and monitoring the vehicle functions. CAN fulfilled the communication requirements providing high data integrity, low implementation costs, resistance in harsh environments, and minimal power consumption especially during the long idle times. The system could be deployed in trains made of up to eight 900-m segments, each consisting of up to 60 vehicles. Considering these lengths and communication delays of the CAN repeaters, the chosen bit rate of 10 kbit/s was sufficient for real-time requirements while the train operation. CAL (CAN application layer), the predecessor of CANopen, provided required objects and services for network management, vehicle configuration, transmission of high-priority braking and traction control commands, and emergency notifications. In 1996 first trains were equipped with Ebas by Mannesmann Rexroth. Later, the successfully-introduced system was also deployed in Deutsche Bahn locomotives. The well-documented specification of the CAN-based communication paved the way for further usage of CAN(open) in railway applications and for international standardization.

Public transport vehicles for from Vossloh Kiepe have comprised CAN-based networks since 1995. The use of CANopen was introduced in 1997. On the iCC (international CAN Conference) 2003, the company presented the principles of the CANopen-based control for streetcars and trolley-busses. Figure 1 shows the structure of the CAN-based networks within a vehicle. As a first step only the network management and the process data objects (PDOs) were used. The network-managing device supervised all connected CANopen devices using the node-guarding mechanism. The control and status data were transmitted via PDOs. The more recent vehicles implemented service data objects (SDOs) to exchange diagnostic and maintenance information. ▷
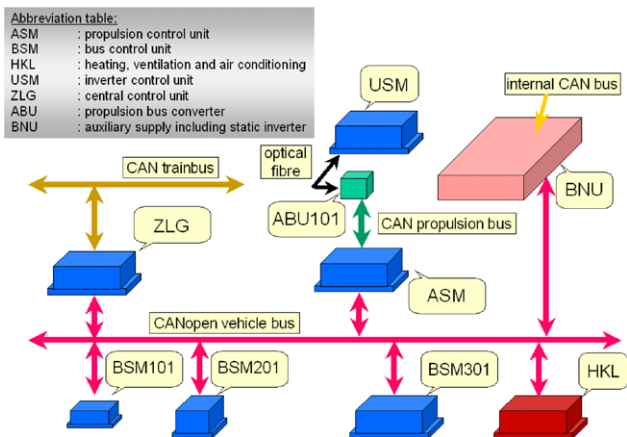
Figure 1: In-principle structure of the CAN-based networks within a vehicle (Source: Vossloh Kiepe)

On the same conference Knorr-Bremse spoke about the use of its CAN-based sub-systems (e.g. brake equipment, anti-skid system, door control, passenger information) in trams, metros, locomotives, and high-speed trains. As the base for its developments, the manufacturer used the Esra (electronic system for railway application) – a central electronic micro-processor system. At that time, the company implemented a proprietary higher-layer protocol similar to CANopen.

An expert from Deuta shown on the iCC 2005 how the company realized the CAN-based communication within the driver's desk comprising displays, dashboards, and control switches. The application implemented redundant CAN networks. A demonstration driver desk has been exhibited on the Innotrans 2004. In those days, the company considered to implement the CANopen Safety (EN 50325-5, former CiA 304) or the CANopen-based redundancy mechanism (former CiA 307) in its driver desks.

Figure 2: Demonstration driver desk exhibited on the Innotrans 2004 (Source: Deuta)

CiA profiles based on UIC leaflets

Based on UIC (international union of railways) leaflets, which specify process data for different rail-vehicle sub-systems, CiA members developed CANopen application profiles. These profiles standardize CANopen interfaces for logical units. The PDO (process data object) mapping is not specified. This enables an easy adaption by config-uring the PDOs individually for each project. The following several-part profiles have been released:

Order to equip 130 regional trains

Alstom has commissioned Knorr-Bremse to equip at least 130 new regional trains from the Coradia Stream fam-ily with multiple systems, starting in 2023 and extending through to 2029. In addition to the contract for the entire braking systems, doors, and HVAC systems, it is also the first major contract for Knorr-Bremse in Europe to deliver integrated sanitary cabins from its brand Evac. The Cora-dia Stream high-capacity trains will operate in and around Stuttgart (Germany).

The electropneumatic braking systems for the trains will include Pistonsupply-Eco compressors, flexible brake control systems from the Flexcontrol-Modular fam-ily, Syscontrol brake electronics, and Sandgrip sanding systems. Knorr-Bremse will also be supplying pressure-tight, weight-optimized, low-maintenance entrance sys-tems with sliding steps from the group's IFE brand, and modular, scalable, HVAC (heating, ventilation, air-condi-tioning) systems. Some of this equipment use embedded CAN networks. Additionally, Knorr-Bremse will be supply-ing Sansys sanitary systems from the Group's Evac brand, with three units to be installed in each trainset. The Sansys units include customized cabins comprising vacuum sys-tems, tanks, and electronic control functions.

(Source: Knorr-Bremse)

The order was placed with Knorr-Bremse under the long-term framework agreement concluded between Alstom and Knorr-Bremse in 2021. Under the terms of the agreement, until at least 2025, whenever rail operators raise an order for trains in Alstom's Coradia Stream family, Knorr-Bremse will be a systems supplier for the trains. For Knorr-Bremse, this is the fourth order to be awarded under the Coradia Stream framework agreement by an Alstom customer in Germany, following orders for Coradia Stream trainsets from Expresskreuz Bremen and the Kinzigtal as well as Main-Weser regions.

Alstom's Coradia Stream design is a state-of-the-art low-floor electric multiple unit (EMU). As a matter of course, the train family offers specific technical configu-ration options that can be adapted to individual operators' requirements. At the same time, Alstom's efforts to further improve standardization have resulted in a single, versatile train family capable of acting as the ideal platform for both regional and intercity trains.

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- ◆ CiA 421: CANopen application profile for train vehicle control networks
- ◆ CiA 423: CANopen application profile for rail vehicle power drive systems
- ◆ CiA 424: CANopen application profile for rail vehicle door control systems
- ◆ CiA 426: CANopen application profile for rail vehicle exterior lighting control

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- CiA 430: CANopen application profile for rail vehicle auxiliary operating systems
- CiA 433: CANopen application profile for rail vehicle interior lighting control

CiA is going to revise these specifications. Therefore, a free-of-charge CiA webinar (open to the entire CAN community) and a CiA workshop (limited to CiA members and invited guests) have been scheduled. Additionally, CiA exhibits on the Innotrans 2022 trade show in Berlin (Germany) in hall 27, stand 290.

Internationally standardized

Since 2005, CiA experts joined the Working Group 43 of the IEC (international electrotechnical commission) Technical Committee 9. Reiner Zitzmann (now CEO of CAN in Automation GmbH) edited the IEC 61375-3-3 document named "Electronic railway equipment – Train Communication System (TCN) – Part 3-3: CANopen Consist Network". The existing CANopen-based profiles were submitted to IEC and were considered, when the CANopen Consist Network was standardized. The standard was finally approved in April 2012 and published in June 2012. IEC 61375-3-3 specifies the data communication based on CANopen, inside a single rail vehicle or a consist, in which several vehicles share the same vehicle bus. A standardized gateway, also defined in the document, enables the full integration of CANopen-based consists in trains that follow the TCN architecture (TCN: train communication network, see IEC 61375-1/-2).
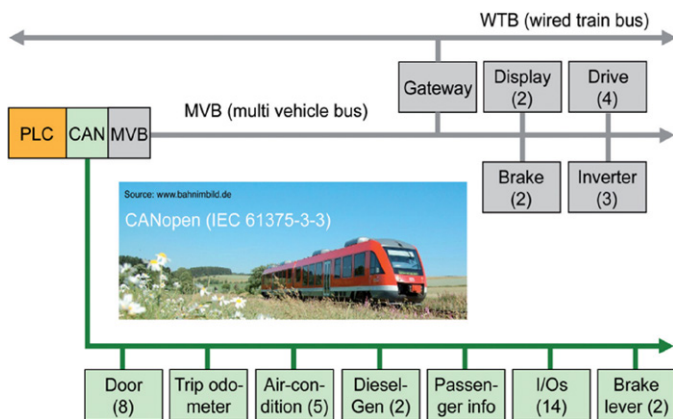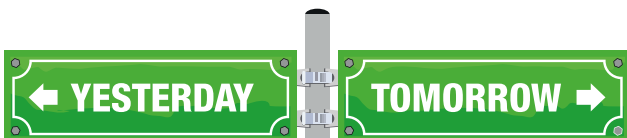
Figure 3: TCN architecture with CANopen (Source: CiA)

In general, the lower communication layers as well as the application layer are based on well-proven standards for CAN (ISO 11898-1/-2) and CANopen (EN 50325-4). This allows to use available CAN components (transceiver, controller) and tools, CANopen protocol stacks, CANopen configuration and diagnostic tools as well as CANopen off-the-shelf devices (I/Os, host controller, drives, etc.). Well-defined communication interfaces simplify system design and maintenance.

Proven in innumerable applications

Embedded and deeply embedded CAN(open) networks are not visible for the passengers, even if they travel daily by commuter trains, metros, or trams. CAN(open) networks do their duty already since many years, because rail vehicles have a long lifetime. In the CAN Newsletter we reported about a lot of developments for rolling stock applications. Here are several examples:

Railway computer
Compliant with EN 50155

Duagon provides CAN-enabled communication solutions for train networks, control, monitoring, and information systems.

Read on

Decentralized applications
Programmable logic controller for rail vehicles

The rail technology provider Luetze Transportation presented the Lion MicroPLC logic module for decentralized applications on rail vehicles.

Read on

Traction converters
For light rail vehicles

The Bordline CC400 series by ABB is dedicated for trams, metros, streetcars, trolleys, and monorails. The products provide CANopen connectivity.

Read on

Exhaust after-treatment
Modular control system

Heinzmann has developed the Xios hardware platform to manage engine control tasks in special-purpose and rail vehicles, construction machines, ships, and stationary generators.

Read on

Driver assistance system
Electronic co-driver for trams

Bosch released a system, which warns of collisions and even brakes independently. The company uses its CAN-connected radar and video sensors from the automotive sector in rail transport.

Read on

Rail vehicles
Control of hybrid drives with J1939

When used on rail vehicles, the Luetze Dioline PLC compact controller enables decentralized and autonomous preprocessing of functions below the main control level. The main control is thus relieved and becomes more reliable.

Read on

Interior lighting system
For rail vehicles

The Interior lighting control (ILC) by Teknoware (Finland) uses an embedded CANopen network and communicates with the TCMS (train control and management system). It is intended for use in rail coaches.

Read on

CAN over powerline

At the iCC 2002, Selectron introduced the CAN powerline application for rolling stock. Every time a train is composed, a new communication network has to be formed and set up. To achieve a reliable communication through a serial bus line, which has to be routed via a large number of contacts (from wagon to wagon), the serial bus line has to be operated at a higher voltage (50 V_{DC} to 60 V_{DC}). Using the powerline-communication principles, the CAN nodes are communicating via a loaded DC-line. A special power line transceiver was designed to achieve required bit rates and fulfill the immunity and emissions demands according to EN 50155. Two powerline communication principles (base-band method and signal-carrier method) were considered while development. Test results prove successful function of a CAN powerline system that is based on the base-band principle. Nowadays, for example, the new vehicles from Stadler are equipped with CAN powerline and CANopen solutions from Selectron.

Summary and outlook

CANopen networks embedded in railway vehicles' subsystems do their duty already since many years, because rail vehicles have a long lifetime. "For retrofit projects and new developments, CANopen FD could be a candidate," said Holger Zeltwanger, CiA Managing Director. "In the long-term also CAN XL is a good opportunity to be adapted in rolling stock for coach backbone applications."

The international standardization (IEC 61375-3-3 for train communication networks) provides CANopen the necessary acceptance in the application field of rail vehicles. Additionally considering the existing CiA specifications for diesel engine control, door control, light control etc. railway operators and vehicle manufacturers can benefit from a high degree of standardization. They are no longer dependent on one single supplier. Regarding system integration and maintenance, they can choose from a broad range of available tools of different manufacturers. Suppliers of single devices or entire sub-systems are enabled to sell their identically-configured products in several projects. This can reduce the diversity of device variants and the administration effort. ◄

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