CANopen vehicle control for streetcars and trolley-busses

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Modern vehicles for public transport, manufactured by Vossloh Kiepe, formerly KIEPE Elektrik, have comprised CAN-based networks for control purposes since 1995. The CANopen protocol for can-based networks was introduced at Vossloh Kiepe six years ago. As a first step only the network-management and the process data objects were used. All vehicle control commands are transmitted via these objects. The master supervises the presence of all slaves by using the node-guarding mechanism. A special Process Data Object announces the state of the network. This interaction between master and slaves guarantees the detection of a faulty control unit within a time less than 1.5s. Important signals are additionally protected by a combination of time-outs, checksums and hard-wired signals, respectively. Service Data Objects have been implemented in the most recent vehicles for diagnostic and maintenance purposes. Energy consumption and event records, for example, are transmitted via Service Data Objects within the vehicle.

Introduction

Before using a CAN-based network within the vehicles a cable harness was applied. The main disadvantages were the cost of manufacturing, the heavy weight, the poor information density and especially the complex error supervision.

Modern vehicles consist nowadays of at least one CAN-based network. The motivation for implementing the CAN-based networks can be summarised as follows:

- One cable replaces almost the entire cable harness.
- The CAN bus offers high information density.
- Low cost components with built-in error supervision are available because of high volume production of CAN chips.

Principal Structure

Vossloh Kiepe produces a series of electronic control units for utilisation under railway conditions. Figure 1 shows the principal structure of the CAN-based networks within a vehicle.

The propulsion control unit (German abbreviation: ASM), the inverter control unit (German abbreviation: USM) and the propulsion bus converter (German abbreviation: ABU) constitute the core units of Vossloh Kiepe's equipment. The main task of the ASM is to cope with the drive and break control. Moreover, it processes the number of revolutions of the induction machine and acts as a gateway between the CANopen vehicle bus and the optical CAN-based propulsion bus with respect to electromagnetic interference and electrical isolation. The propulsion bus is a point-to-point-connection between the ASM and the USM, whereby the ABU manages the necessary signal conversion from electricity to light and vice versa. The USM is responsible for the generation of the firing commands for the semiconductor valves and for the realtime calculation of the induction motor model. The optical CAN-based propulsion bus additionally enables compact designs, so that the USM can be mounted on high voltage potential. Because of the importance of the bus and because of special interrupt triggered telegrams a proprietary protocol is applied on the CAN-based propulsion bus. Time-out observation secures the transmitted telegrams.

The power supply for the auxiliaries and its process control is managed by the static converter, which consists of an extra independent internal CAN-based network.

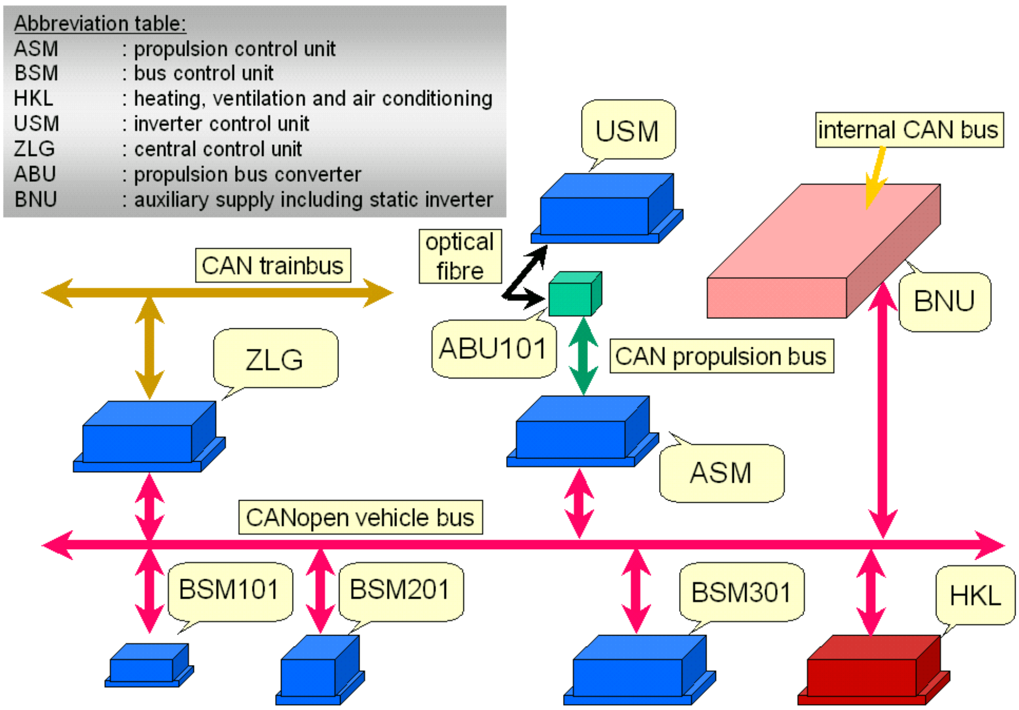

Figure 1: Principal process control structure

In order to reduce electromagnetic interference and wiring effort, many signals are gathered by so-called bus control units (German abbreviation: BSM), which are all connected to the CANopen vehicle-bus. This bus runs under CANopen, because Vossloh Kiepe considers this bus as open, which means, that independent component suppliers may connect them to this bus. The implemented CANopen services will be described in the next chapter.

The heating, ventilation and air-conditioning control unit (German abbreviation: HKL) represents this kind of third party supplied products, connected to the CANopen vehicle bus in figure 1. Door control units and the tachograph also belong to this kind.

If the vehicle can be operated within a chain, a central control unit (German abbreviation: ZLG) is used which interfaces the CANopen vehicle-bus with the CAN-train bus. Furthermore, the ZLG acts as the CANopen Master within the CANopen vehicle bus. The CAN-train bus is run under a proprietary protocol. This connection enables the vehicles to exchange data among themselves. If two or more vehicles are coupled, the sequence and the number of participating nodes at the CAN-train bus is not predictable. Single wired logical commands, which are transmitted via the coupling, secure that only one driver's cab is in operation. The ZLG which is located in the same vehicle as the driver's cab in operation, therefore initiates a launching ceremony in order to determine the number of connected vehicles and their sequence.

Figure 2 shows the evolution of the amount of installed CANopen nodes within the latest vehicles. The streetcars of the cities of Kassel and Düsseldorf are bi-directional vehicles whereas the cities of Krakau and Schwerin ordered uni-directional streetcars. This results in a different amount of third-party door-controllers, which is tantamount to a different amount of CANopen nodes. The number of CANopen nodes in trolley-busses is significantly smaller due to the smaller amount of system-functions, which Vossloh Kiepe's equipment provides.

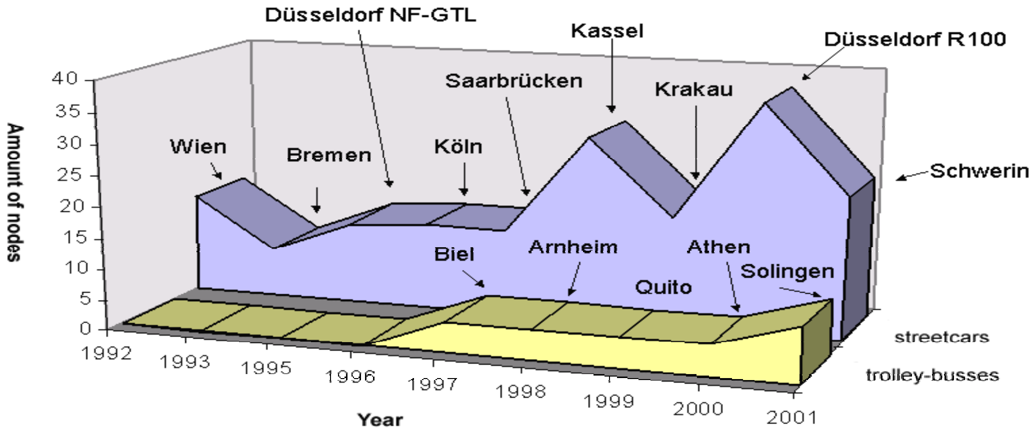

Figure 2: Evolution of the amount of CANopen nodes

The bus-constructor is responsible for the control of the breaking system of a trolley-bus whereas the break control in a streetcar is managed by Vossloh Kiepe's control units for example.

Implemented CANopen Services

Before the CANopen Standard V2.0 has been published, the company developed its own protocol, called BISS, a German abbreviation for on-vehicle information and control system. It is implemented in about 500 vehicles worldwide. Independent component suppliers tended to claim a considerable amount of money for developing an interface to the BISS protocol. Additionally, the maintenance of the code and the provision of test-equipment for the bus communication demanded financial resources.

This environment generated the desire to apply CANopen, as it offers standard interfaces for test equipment. In negotiations with independent component suppliers the implementation of CANopen facilitates the substantial argument, that the engineering effort for the development for a CANopen interface can be shared by several customers.

As a first step the Process Data Object (PDO) Service and the Network Management (NMT) Service have been used.

Within the planning-period of a new project the communication matrix, which describes every control unit and its Input/Output ports, is designed first. As a second step the communication relations between the control units are established. By that Vossloh Kiepe neglects the usage of the predefined connection set. The trolleybus and streetcar respectively represent a system that is not emerging during its lifetime as for example a production plant. A mapping procedure performed by an extra configuration tool can be integrated in this process of the architectural design. At Vossloh Kiepe this process is supported by an intranet application.

Based on the communication relation database, which is one result of the architectural design, the application software for each CANopen node is configured by using a graphical interface [1]. All process-relevant data are communicated by periodically sent PDOs.

The overall security of the whole control system is secured by additional CRC-checksums for e.g. the driving command. Moreover, hard wired logical commands can vote down the signal distributed via CAN-bus in case of any discrepancy

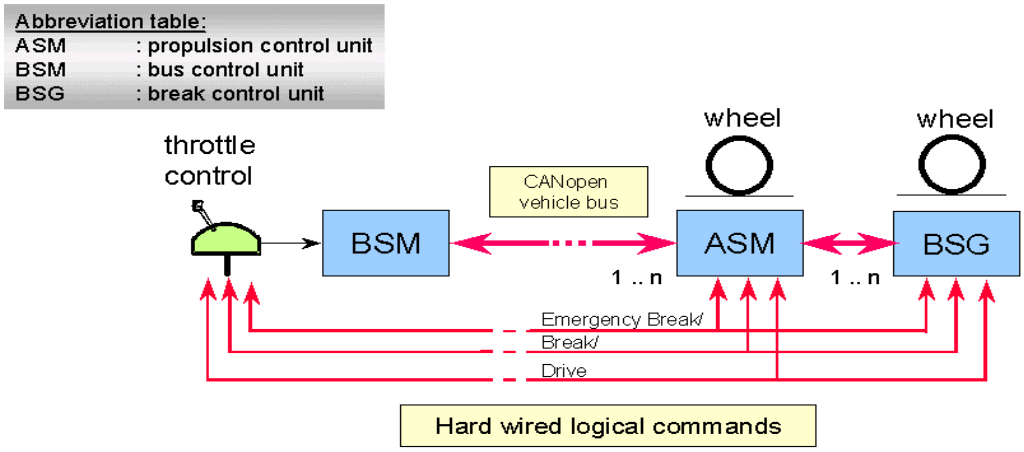

Figure 3: Safety mechanisms

between them and the CAN bus information. Finally an emergency stop loop is implemented. Figure 3 gives an overview over the mechanisms described above.

The CANopen NMT state machine [2] is implemented in each node. The node-guarding mechanism secures the supervision of the nodes. Each node is guarded every 500ms by the CANopen master. The CANopen master receives the state of each node by the guarding answers. In order to communicate this knowledge to all slaves, a special PDO is transmitted, which announces all nodes in the state ‘operational’ by setting off a bit within the telegram. Additionally, this telegram transports bits which enable the slaves to temporarily disconnect from the CANopen vehicle bus in case of a diagnosis enquiry by the service interface of the control unit. Each node can validate received PDOs by checking the presence of the sender in the special telegram mentioned above. If the sender is not logged on there, the content of the telegram is omitted because of security reasons.

Each PDO is represented by one object in the object directory, so that the consumption of memory of the control unit can be minimised.

Implementation of the Service Data Object (SDO) mechanism

The most recent orders include an extra feature, called vehicle data management (German abbreviation: FDM). It consists of a control unit, which acts as a gateway between the wireless local area network (abbreviated by WLAN) client and the CANopen vehicle bus, a WLAN access point, a WLAN client at the workshop of the maintainer and various pieces of software. If a malfunction occurs within a control unit, the occurrence is registered in an event recorder.

The FDM control program, located on the computer in the maintainer’s workshop and connected with the WLAN client, initiates the transfer of the event recorder to the workshop (e.g.). The request is transmitted via the access point to the addressed streetcar or trolleybus respectively. The control unit with the gateway functionality then acts as a SDO client. The control unit with the event recorder functionality puts the gathered data at the occurrence of the event into one object of its object directory within the manufacturer-specific area. This way, the SDO client can access the information, requested by the FDM control program via WLAN.

This additional feature of Vossloh Kiepe vehicles offers the customer an excellent benefit. He can monitor his vehicles just before entering the workshop and is able, for example, to decide, based on information transferred from the vehicle, which track to use and which maintenance team with which equipment should inspect the vehicle. Another benefit is the chance to build up a fleet database, which can be inspected with statistical methods. In addition the implemented WLAN allows wireless and cost-free transmission of large quantities of data without a permission of the local authorities. For easy access to the gathered data Vossloh Kiepe has developed a browser-based visualisation tool. This tool can be run in several entities and operates independently of the FDM control program, which supplies new data to the fleet data base as soon as vehicles with new data enter the maintainer's workshop area. FDM has been implemented for the latest streetcar fleet of the cities of Düsseldorf, Schwerin and Cologne.

Figure 4 shows a screenshot of the browser-based user interface of the event recorder module. The window is divided into three sections. On the left hand side the maintainer can operate through his fleet. In the central part of the screen he can access the single events. If he wants to gain more information about a certain event, he can get additional information, which is displayed in the bottom section of the screen. The depicted event for the dump of additional information is printed in blue (light grey).

Summary and Outlook

The implementation and usage of the CANopen standard has offered Vossloh Kiepe many advantages.

The company can use counter off the shelf software for the CANopen stack itself and software and tools for testing and diagnosis purposes. Furthermore, the implementation of open standards

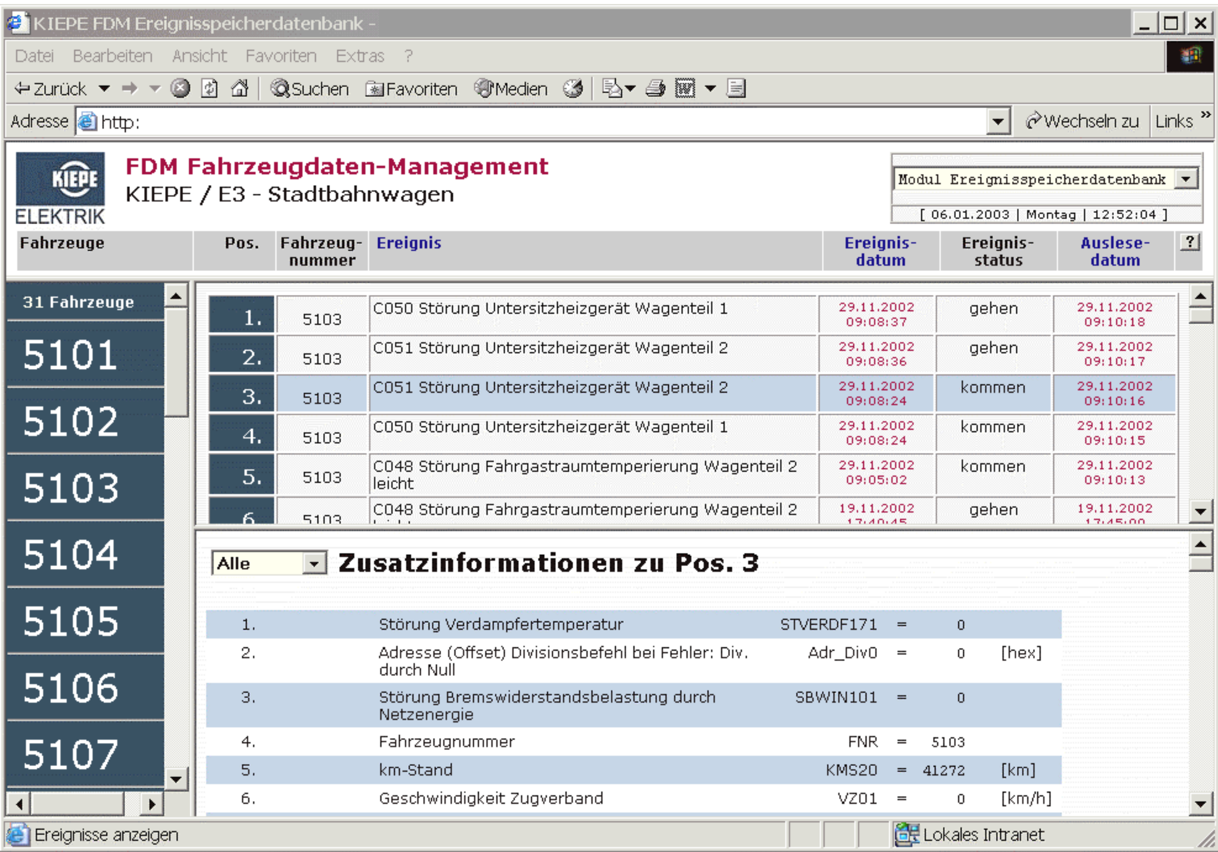

Figure 4: Screenshot of the event recorder function at the maintainer's computer at his workshop

improves the motivation of independent component suppliers to develop new applications.

By implementing all CANopen Services within the vehicles, more benefits can be added to Vossloh Kiepe's vehicles in order to accomplish future market demands.

References

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