Experiences with the implementation of the train communication network

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Abstract

The standardization of TCN has to be proceed and verified before acceptance will be achievable. In addition to simulation dnd prototypes of TCN, this goal can be reached best by operation in real applications and giving a demonstration of running vehicles. ABB Henschel provides some of the first railway applications, whereas the MICAS® communication and control system is based on the TCN defined train and vehicle bus.

1   Standardization of TCN

Integration within Europe is a challange with respect to several areas of technical standardization efforts especially in the field of railway technologies. Road traffic boarderlines are becoming highly transparent compared with those for railes where international operated vehicles are suffering from the long period of nationally dominated technical standards and preferences. Harmonization and standardization will allow to increase efficiency in operation and improve the ability of competition with non rail transportation.

One important approach is the area of train internal communication, which is widely known for example in interconnections of vehicleside signalling systems. The valid concept for harmonization of train signalling systems promoted by ERRI (European Railway Research Institute) defines the project ECTS, European Train Control System. It proposes one common control computer (EUROCAB), which is interconnected with different signalling sensors and actors by a Train Communication Network (TCN). It will thereby support

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the interoperability of rail vehicles with different types of wayside signalling equipment [1]. The responsible standardization working group of ECTS recommended to select the same solution of TCN which is elaborated by the working group WG22 of IEC TC9 [2].

As well as ECTS all the usual not safety related tasks of train and vehicle control and operation require urgently a standardized solution, suited support the complete set of possible applications like drive and brake control, air condition and power management as well as passenger information, online diagnosis and work shop intended maintainance functions. In order to fulfil all these various tasks the WG22 of IEC defined a hierarchical TCN established by a train and a vehicle bus, see figure 1.
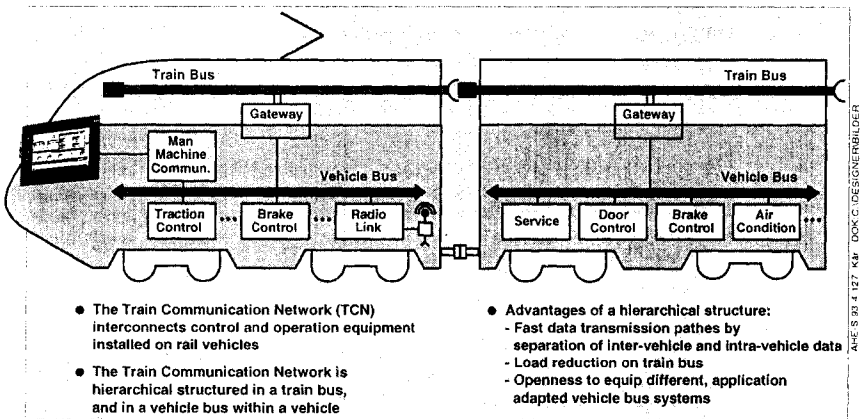

Figure 1: Structure of Train Communication Network, TCN

2   Hierarchical structured TCN

The Wire Train Bus, WTB, interconnects different vehicles by a selfconfigurating network. Changes in train configuration regarding the numbers or positions of vehicles are performed automatically in order to adapt to differrent operation or traffic requirements. Within each vehicle a fixed local network is subordinated to the train bus. For the local network a powerfull field bus solution was selected which offers the interconnection of ambitious computing stations as well as simple sensors and actors; therefore it is called Multipurpose Vehicle Bus, MVB. An alternative can be the Derived Vehicle Bus, DVB, which is a simplified version of the WTB mainly defined by skipping the selfconfiguration features. The two levels of communication are linked together by gateways. This solution allows to separate the data streams with respect to different detailled local applications inside the vehicles and the overall train control data on the upper level. Furthermore both bus levels could be specified according to the special

needs: higher distances combined with less nodes on the train bus level and vice versa at the vehicle bus.

3 Milestones in the history of TCN

Communication and control systems on rail vehicles must fit the environmental conditions like temperature range, vibration and shock, humidity and further more. In addition extended life cycle duration and increased requirements in reliability and availability will only allow solutions, which are freely available, ruggadized and well proven in other applications. In the starting phase of the TCN standardization there was a detailled comparison of the different existing solutions in order to select the best suited candidates. Figure 2 reflects some of the major milestones in the candidates qualification.
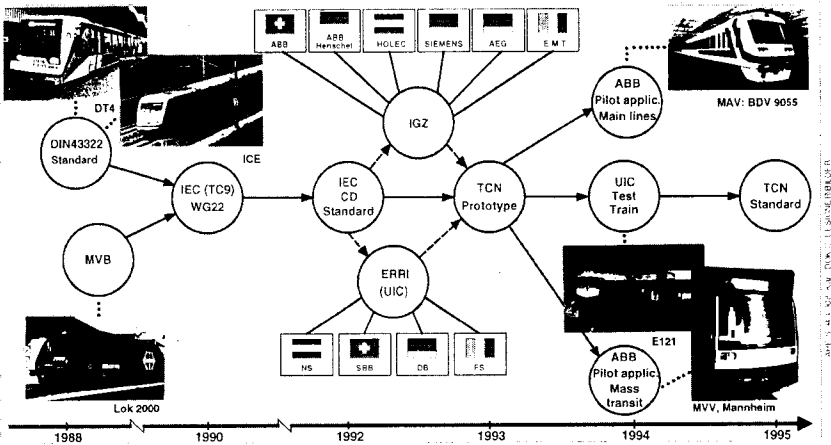

Figure 2: Milestones in the History of TCN

The first experiences with the benefits of a two level TCN were obtained by the large number of implementations of the train and vehicles busses according to the German standard DIN 43322. Among others there is one big vehicle bus application within the coaches of the ICE delivered in 1989 by ABB Henschel. 120 Bvmz185 vehicles and 700 trailors for use in ICE train sets have been each equipped with six bus nodes for the control of brakes, doors, displays, air condition, diagnosis and passenger information, diagnosis and passenger information being mutually interconnected. Real time control data are exchanged as well as service and diagnosis information, which is the necessary base for the ambitious maintenance concept [3]. One pilot application in the train bus area –the DT4– was again developed by ABB. The electrical multiple unit DT4, delivered in 1988, was equipped with the train bus according to DIN

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43322; it reduces drastically the number of wires needed for the train control and opens the doors for easy available service and diagnosis information. In addition the DT4 was one of the first vehicles which provided a powerfull sensor and actor bus by using the IFZ concept of the MICAS communication and control system [4] (IFZ= Integrated Vehicle I/O Bus). These two applications represent only a small part of the large number of DIN 43322 applications delivered by ABB as well as delivered from other companies.

In the field of locomotive control applications the concept of Loco 2000 presented a distributed digital control system, which uses for the first time consequently the advantages of light fibre techniques for vehicle bus applications. This concept combines a high performance comunication system with the reliability of fibre optic transmission especially in terms of EMI immunity [5]. This communication concept was introduced with the MICAS Vehicle Bus (MVB) and has been proven within a lot of applications equipped with the MICAS traction control system.

Based on these two types of communication solutions, WG22 (TC9) proposed the TCN, in which an enhanced version of the DIN 43322 and an extended range of the MVB – suited for mass transit vehicle applications by introducing a twisted pair physical layer – were specified.

One important application for the Wire Train Bus, WTB, is the area of boarder line crossing trains. ERRI monitors and supports the standardization efforts from the very beginning. First test of train bus implementations were performed based on the DIN 43322 implementation of ABB Henschel [6]. In order to gain the benefits of open communication system an international group of companies founded the Joint Development Project, JDP, which establishes and promotes a prototyp of the TCN. The verification of the TCN prototyp will be demonstrated in service by a test train on behalf of ERRI; the implementation will be performed by an European consortium dedicated to the TCN test train, called IGZ. In order to speed up market introduction and to gain feed back in the field of mass transit and main lines applications ABB Henschel set up two additional pilot projects: For operation of light rail vehicles respectivly intercity trains in multiple units two applications are selected for comming into service early 1994. Together with the results of the UIC test train a reliable base of practical experience will be available for the final steps in standardization of TCN.

4   Architecture of TCN with MICAS

The TCN requires support for different types of application; therefore MICAS offers a modular approach with stepwise adaptable, standardized building blocks in software and hardware due to the level of application needs.

4.1 Hardware building blocks

On the first level pure WTB nodes are preferred for economical reasons if no vehicle bus need to be subordinated; a WTB node consists of a Medium Attachement Unit, MAU, for the WTB and a CPU. In small applications direct coupled I/O devices is usefull; here MICAS offers standard analog and binary I/O.

On the second level of application the pure WTB node can be completed to a full gateway by a vehicle bus interface. Using MICAS this can be performed by Medium Interface Boards, MIB, which are available for different types of MVB physical layer (fibre optic or twisted pair) as well as for other standard busses like DIN 43322, PROFIBUS, IBIS or point-to-point interfaces RS232/RS422. Figure 3 shows the neccessary elements, which form together the TCN stand alone gateway.

In each vehicle the gateway builds a central point of information; therefore it offers a natural location for vehicle and train control. In order to use this centre of information in a really efficient way for high level applications, the gateway must be extentable by additional computing performance and/or additional information lines. MICAS uses a powerfull Parallel Computing CPU, PCC, suited for the gateway as well as for normal control and communication purposes. The PCC can be arranged in a multiprocessor structure according to Multibus I type parallel bus. By keeping the mechanical and electrical interfaces compatibel, all existing hardware modules of MICAS can be attached as well as existing MICAS systems might be upgraded with the communication performance of TCN.
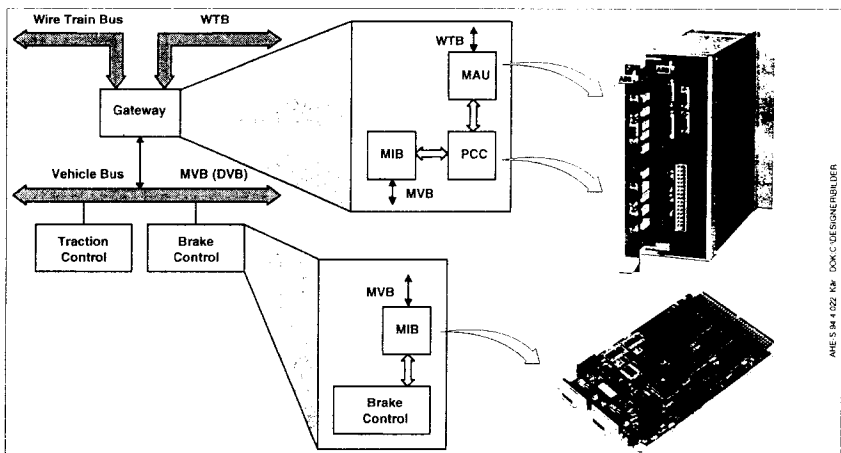

Figure 3: MICAS stand alone gateway for TCN

4.2   Software building blocks

With respect to the different needs of application performance, the TCN software is modularized according to the layer approach of the ISO modell : Figure 4. Inside the gateway two main independent real time processes are executed in parallel, train bus and vehicle bus. Both require immediate response in independent actions and events, which are represented by a number of time critical, different tasks. The number may increase if the busadministrator function of the vehicle bus is included in the gateway. In order to reduce software complexity and task switch overhead of operating sytem, the load is shared by the two parallel processors in the PCC unit.

Application programming in MICAS uses the well known building block approach for control and diagnostic functions. Building blocks performing the user interface of TCN provided in MICAS can be easily specified by the normal graphical programming tool FUPLA. They support bus configuration, send and receive of lengthy messages as well as time critical process data.
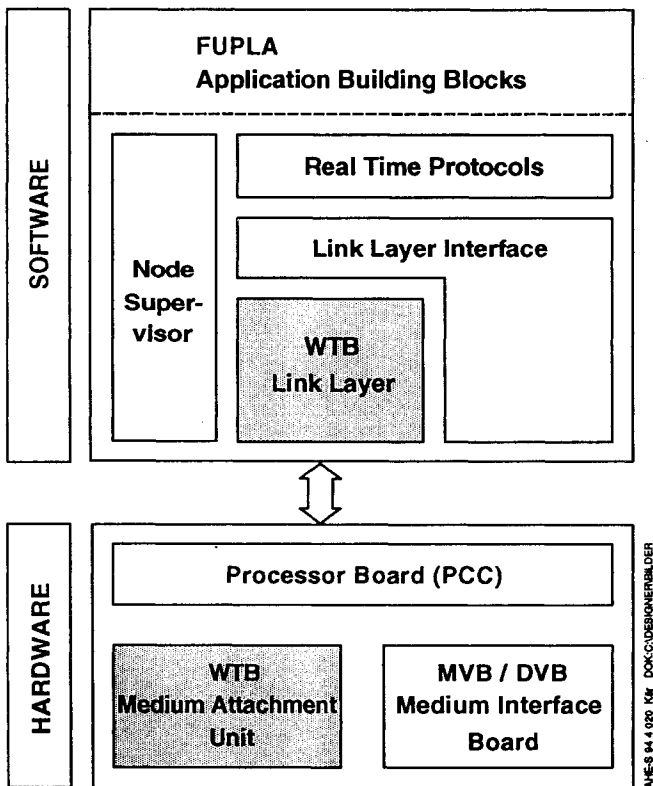

Figure 4: TCN software building blocks of MICAS

4.3   MICAS tools with TCN

TCN supports the design of function oriented distributed control systems based on a powerfull open communication standard. In MICAS, train and/or vehicle bus are used as the central service and maintenance access points for a computer aided project engineering environment for control systems, CAPE/C [8]. On the tooling side, CAPE/C integrates all design phases of the vehicle control system by using a function related top down approach and object oriented database, which fits just directly to the goals of the TCN on the target side. Each PC-based CAPE/C workstation is directly connected to the TCN, by using the standard components, provided for protocol analysis and data line monitoring: Figure 5 shows an example for the WTB.
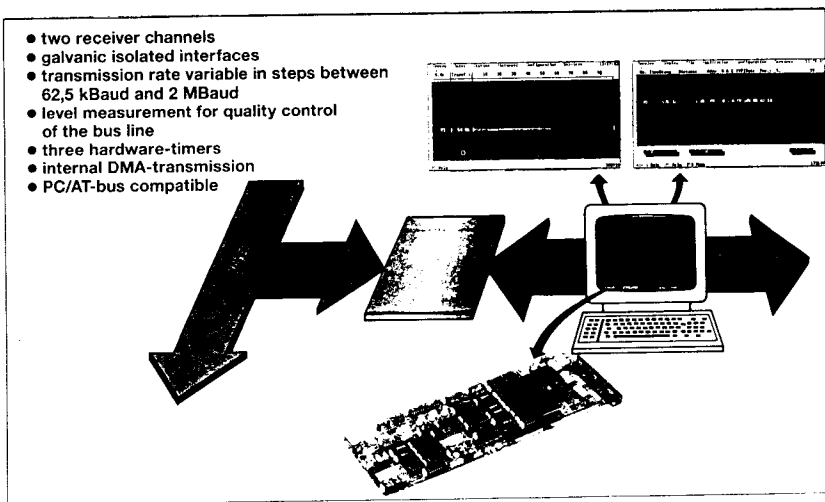

Figure 5: Data Line Monitor (DLM) for protocol analysis of WTB

At the application layer the TCN provides a functional view on different tasks like drives, brakes, air condition, doors and further more. The implementations of these functions may use equippment of different suppliers in various types of vehicles, in any case the TCN can provide a common view on identical functional objects. They can be standardized in application profiles, which are useful objects for CAPE/C function libraries. Each function consists of functional design, hardware components, software and documentation; a function may be concentrated within one computer or distributed among several control stations interconnected via the TCN. All features and views of any object are available in the database of CAPE/C, all communications relations between the objects are based on the TCN and accessible for any service, maintance tasks used in the vehicle. Navigation through the functions of a project is enabled by the tooling system, TCN offers the possibility to perform it online with respect to real time conditions: Figure 6.
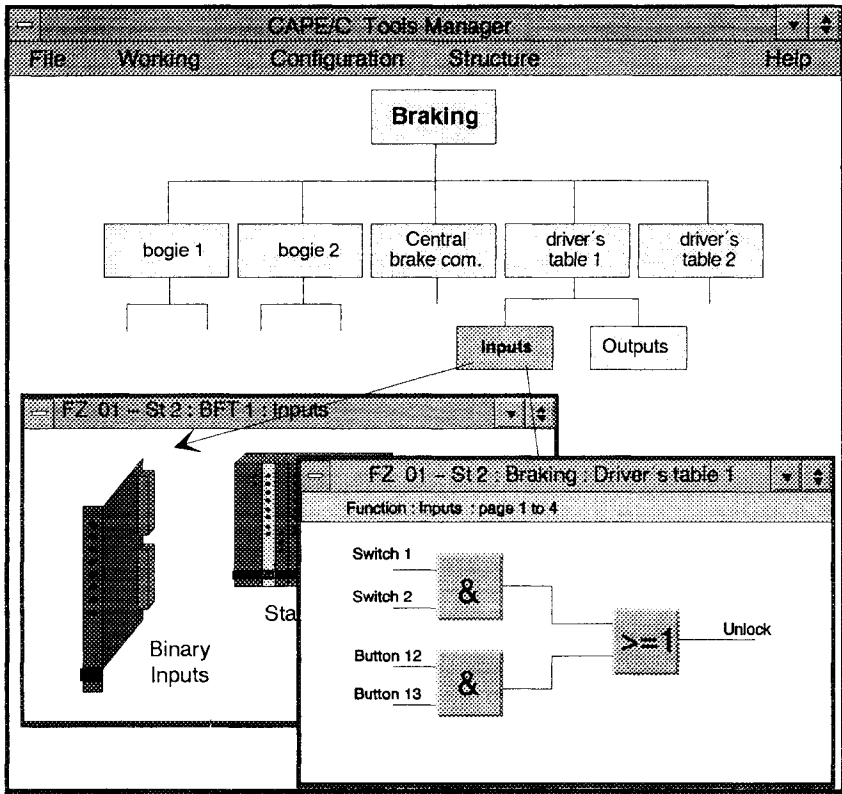
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Figure 6: Multiple Views on Process Objects by TCN based Tooling in CAPE/C

5   Applications of TCN with MICAS

The implementation of TCN starts on the vehicle bus side with a number of control applications in locomotives like Loco 2000 for SBB in service since 1991 [9]; these applications use the MICAS Vehicle Bus (MVB) based on a fiber optic physical layer. The WTB is obviously based on a twisted pair medium, which is even on the vehicle bus level a crucial precondition, if it comes to mechanically segmented types of rolling stock. This is valid for nearly all kind of mass transit vehicles like light rail, multiple units etc. . Another advantage of the twisted pair medium compared with light fibre is the independence of an active central star coupler, which is normally to be designed redundant in order to avoid single point of failures. The fist products for the MVB twisted pair version can be expected in 1995.

   In the meantime a large number of vehicles has to be designed and delivered, which can make use of the TCN benefits by taking the WTB approach even on the vehicle bus level. In the MICAS control system this solution is

possible by using standard communication hardware according to DIN 43322 and adding layer 2 - 7 functionality of WTB, which is sometimes called Derived Vehicle Bus (DVB). In this combination a homogeneous network for train and vehicle bus is acchieved providing a robust, EMI-proven, powerfull and economic implementation of all TCN functionality. This choice - WTB + DVB - is taken for a number of mass transit projects of ABB Henschel.

5.1 TCN for light rail vehicles

One of the several light rail vehicles delivered in 1994 by ABB Henschel is the type 6MGT for Mannheim. It uses the WTB for double traction purpose, thereby the number of train lines are reduced by more than 50% while on the other hand the possible flow of information is increased drastically compared with conventionally equipped vehicles. Figure 7 shows the principle design of the communication and control system with MICAS.

Light rail vehicles take part in high density traffic systems and are expected to provide traction effort even at events of single faults in order to prevent stops. Therefore traction and control systems are designed carefully in terms of redundancy and retroactive free communication. The design provides a symmetrical structure with redundant central control stations, CCS, attached to the WTB. Each CCS works as a gateway to the vehicle bus and the sensor/actor bus IFZ [10]. The CSS perform all train control and diagnostic tasks as a centre of information which is directly available for any monitoring purpose on the driver's cab display. Depending on the amount of informations between subsystems for traction, brake and door control, these systems can interconnected via the vehicle bus or via the IFZ bus. If diagnostic features in subsystems increase, the vehicle bus is recommended. Mass transit vehicles are usually separable into 3,5 or up to 7 segments coupled by hinges. Depending on such a mechanical layout, connector interfaces must be provided at each segment boarder even for the communication lines of any bus system like WTB, MVB, DVB or IFZ. Any interruption on the physical layer may cause distortions of signal quality.As a result the requirement of robust and economic design using a twisted pair medium which is nonsensitive against reflections is obvious. Calculations for usefull types of masstransit vehicles have shown, that the number of bus connectors caused by segmentation is in the same order as the number of bus stations thereby the minimum noise level is increased. For such environmental conditions the DFT based filter algorithmen in WTB receivers (same on DVB) support noise immunity as well as the digital pulse width modulation of IFZ.

Mass transit applications require automatic coupling of vehicles repeatingly each day. The heavy coupling connectors are exposed to dust, humidity and vibration. In order to provide reliable electrical connections for the WTB, a dc fritting voltage is superimposed to the manchester coded ac signals of

transmission. Faults on the physical layer of WTB are managed by line redundancy up to the transmitter/receiver line interface; transmission takes place simultaneously on both lines, the receiver selects the first non distorted frame.

On the train bus level process data can be refreshed every 25ms, using frame lengthes of about 128 byte (broadcasted). During the process data poll sequence an efficient data transmission rate of approximately 70% at a nominal rate of 1MBit/s is achieved by using standard microcontrollers INTEL 80C186/16MHz. It shows really sufficient spare capacity for future extentions; even if the number of nodes is doubled. In some seldom events of failures the duty cycle for process data exchange will not exceed 60%, which offers a highly sufficient bandwidth for message data.

On the vehicle bus level the frame length varies between 32 (doors or brakes) and 128 bytes (drives and CCS); this includes plenty of online diagnostic data, which can be evaluated immediately for operative purposes. The transmission rate will be normally identical to the train bus (1MBit/s); it can be reduced to 500 kBit/s if application requirements are low. Normally the DVB makes use of the inclusion of process data within the master poll frame (32Byte). Based on a refresh period of 25ms the duty cycle of DVB process data reach about 65% at an average efficient data rate in the same range. In order to simplify application programming, all the process data frames are designed from the very beginning with sufficient spare data; in combination with the self configuration procedure of WTB/DVB the programming of bus administrator and bus nodes does not need any update during the whole engineering phase.

Sensors and actors are highly distributed among the vehicle in mass transit applications. The IFZ sensor/actor bus supports most economically distributed I/O sytems; vehicles like 6MGT for Mannheim need about 80 different IFZ substations located at about 15 separated places. Communication based on fibre optics like MVB will be applicable when passive starcouplers are available; in the mean time the twisted pair version for MVB will provide a high performance solution which combines the requirements of vehicle bus and sensor/actor bus into the ideal flat communication structure.

5.2   TCN for main line applications BDV mot 9055, MAV

Compared with light rail or metro applications main line applications of TCN have to serve different types of vehicles within one train or train set. The intercity trainset BDV mot 9055 combines one motorized unit, two coaches and a trailor; three of these trainsets can be interconnected depending on operation demands. The overall communication inside the trainset as well as in multiple units is performed by the WTB; the local communications systems inside the vehicles requires only a point-to-point link for drive control or coach control. The main communication takes place on the train bus level. The TCN application profile distinguishes between motorized units and an operated trailor

on one side or coaches and non operated trailors on the other side. The train inauguration of WTB will define the number, sequence and direction of each vehicle in the configuration phase and in addition it will determine the position of the driver. The driver served vehicle will get the position of WTB master and activates the drivers desk control elements.
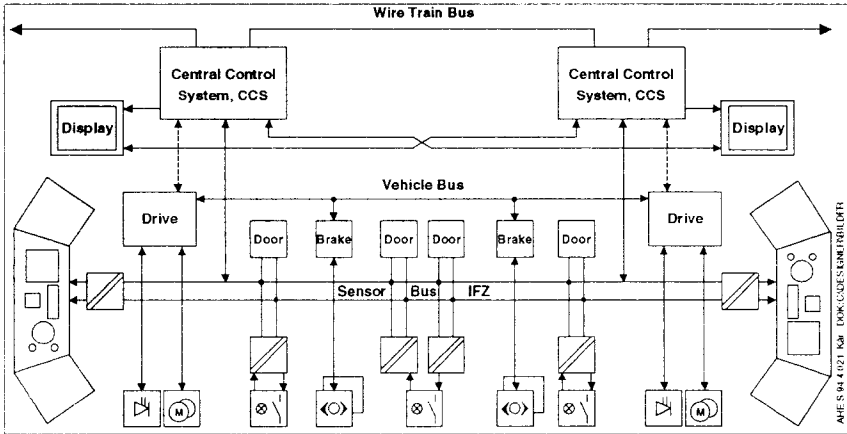

Figure 7: Design of communication and control structure for light rail vehicles

In main line applications the real time reqirements depend on the vehicle type; coaches and comparable ones are polled by the WTB busmaster normally every 50ms, motorized units within half of the period. The main control tasks inside the latter are performed by central control stations, CCS, similar to light rail applications with the exception of non redundant lay out. Each CCS includes a WTB node extended by additional application processors and directly coupled with a sensor bus IFZ inside driving trailors and motorized units. The vehicle bus is replaced by a point-to-point connection. Time critical control signals are refreshed every 25ms, in combination with the sampling delay (25ms) inside source and sink computer the overall delay between input command and output action may not exceed 75ms. Control commands using subordinated communication links will be delayed in addition by the related refresh period. Depending on this period overall delays of 100 - 150 ms may be considered without any measurement of synchronization inside the gateways respectively the interconnection of communication and computation inside the end nodes of a communication link. By using careful designs of process data application interface, delays can be minimized; the TCN implementation with MICAS provides optimized buffering algorithmen inside the MICAS building block interface for TCN in order to reduce the delay time.

6 Extentions of TCN for open communication

The TCN design is intended to establish an international standardized open communication system for the near future. At the moment there are a lot of other proprietary solutions as well as national standards are used for existing products and systems. For economical reasons it will not be possible to change immediately the implemented communication solutions into TCN compatible ones. Within a migration period communication standards like DIN43322, PROFIBUS DIN19241, IBIS defined in VÖV publication 300, 7/91 by VDV in Germany or other solutions will exist in parallel with the TCN solution.
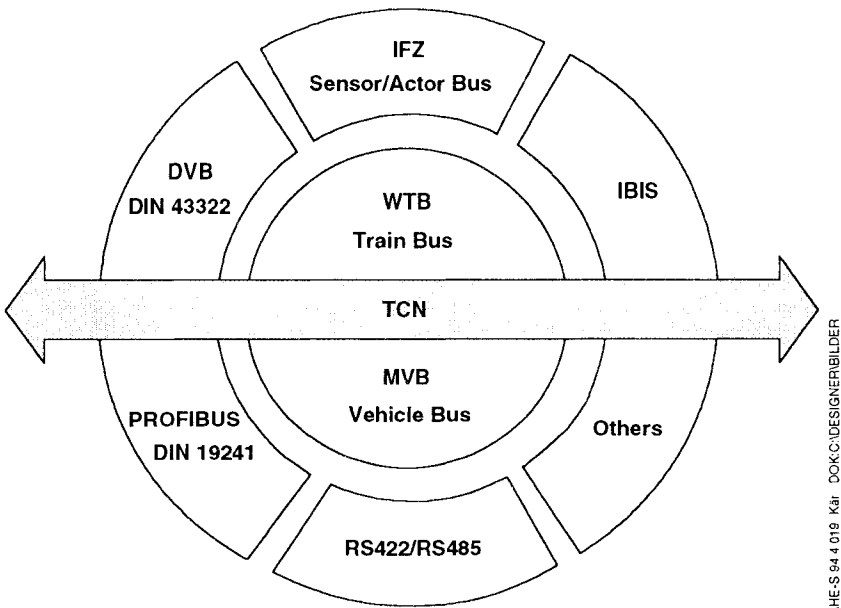

Figure 8: Extentions for TCN Communication

This reflects the interests of operators which usually prefer continuity of product interfaces as well as the interest of suppliers interested in keeping minimum product life cycles with respect to pay back reasons.
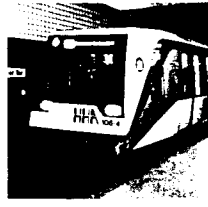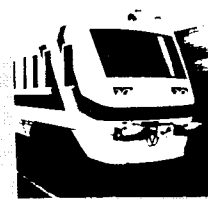
In order to start the migration phase from local and proprietary system to international standards coexistence must be possible and supported. Therefore ABB Henschel provides a set of modular communication interfaces for most of the important standards beside TCN: Figure 8 shows the possibilities of TCN extentions which might be used if required for interfacing existing products with TCN. The hardware design for all interfaces uses building blocks attachable as mezzanine boards to the gateway CPU, PCC, in order to concentrate the different links of communication in one location. The number of intermediate links, respectively the cascadation of TCN-external serial communication links, is

restricted to one in each direction of TCN, either WTB or MVB. Thereby during the migration phase in direction of pure TCN communication and control systems the combination with existing products and those based on TCN can be solved by an economic step by step concept.

7   Conclusions

Train communiccation networks were implemented first by using tailor made and proprietary techniques like the train bus Time Devision Multiplex, TDM, delivered resp. orderd in more than 1200 installations inside european railway vehicles. Increasing requirements on the application side and advantages in communication technology resulted in national communication standards, on which now open communication sytems can be based on to support integration efforts in international railway vehicle operation. ABB Henschel provides long term experience in the field of train communication systems see figure 9.

FSK-Train Bus	ZWS ZDS ZMS		
	UIC cable FSK		
Double traction Push-pull trains Multiple units	Stations Data rate Cycle	2-6 1.2-2.4 kBd 50-150 ms	

DIN-Train Bus	DIN 43 322		
	Twisted pair PCM		
Subway trains	Stations Data rate Cycle	4-8 (32) 125 kBd 50 ms	

Wire Train Bus	WTB IEC (305) CD		
	Twisted pair PCM		
Trams Metros, S-Trains EMU, DMU Loco's, Coaches, UIC High speed trains	Stations Data rate Cycle	10-22 1 MBd 25-50 ms	

Figure 9: Train bus products and applications of ABB Henschel

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In parallel with the proceedings in train communication, the performance of computerized control systems was supported successfully by the introduction of vehicle bus standards for interconnection of different control applications. The growing number of electric sensors and actors was followed consequently by the development of I/O busses like IFZ which will in the future be supported by standardized communication interfaces even in this area. The open system of Train Communication Network TCN covers all the possible and necessary fields of application; the TCN approach is directly supported by MICAS® products and implementations as shown in figure 10.

Sensor-Actor-Bus	**IFZ, Integrated Vehicle I/O Bus** Twisted pair power on the line DPWM		
	Stations	80	
	Data rate	16 kBd	
	Cycle	50-500 ms	

Derived Vehicle Bus DVB	**TCN IEC (305) CD or DIN 43 322** Twisted pair PCM		
	Stations	32	
	Data rate	0,5-1 MBd	
	Cycle	25-50 ms	

Multi purpose Vehicle Bus MVB	**TCN IEC (305) CD** Optical fibres or twisted pair PCM		
	Stations	32	
	Data rate	1,5 MBd	
	Cycle	16-50 ms	
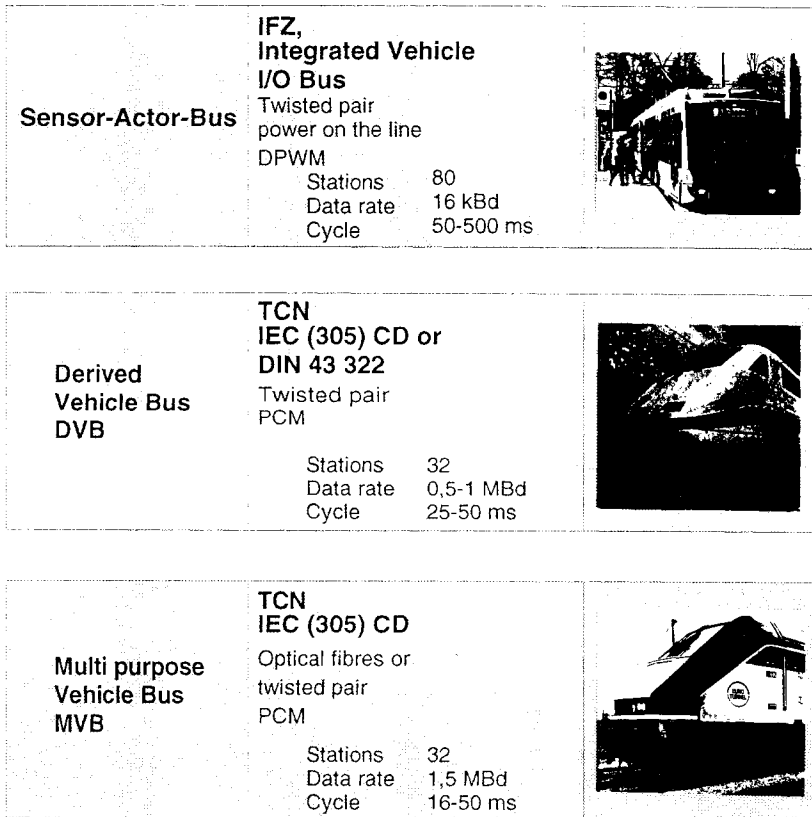
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Figure 10: Products and applications of vehicle and sensor/actor busses

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