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INNOTRACK

Integrated Project (IP)

Thematic Priority 6: Sustainable Development, Global Change and Ecosystems

D3.2.3 Functional Requirements for the open standard interface for electronic interlocking

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Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
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Glossary

Safety Integrity Level (SIL) is defined as a relative level of risk-reduction provided by a safety function, or to specify a target level of risk reduction. In simple terms, SIL is a measurement of performance required for a Safety Instrumented Function (SIF).

Safety case

Process to proof that a technical systems fulfills the safety requirements.

Risk analysis is the methodological process to identify and evaluate risks of technical systems.

A hazard analysis is a process used to assess risk. The results of a hazard analysis is the identification of unacceptable risks and the selection of means of controlling or eliminating them.

4-Drahtschaltung - Dedicated analog interface for control and position detection of an actuation system for switchesm which uses 2 4-wired cable.

Protocol interface - Communication interface between gidital devices based on a bus system accoording to the OSI reference model for technical communication systems.

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1. Introduction

1.1 Starting point

The interface between the interlocking system and the trackside equipment has developed historically with the components and the interlocking tower technology. Therefore very different interfaces exist in Europe today, dependent on the installed components and the applied interlocking technology. There is no single standard. All solutions show a dedicated analogous connection for controlling and driving the track components like signals, track vacancy detection and switch actuators.

For the control of switches two principal designs can be differentiated: either the power supply of the drive and the position detection of the switch are realised by separate wires, requiring at least a 6-wire cable, or the cable cores are used by change-over processes in the interlocking system for both functions.

The latter is the case with the “4-Drahtschaltung”, which is common in the German-speaking countries. This was developed in the 1930s in order to reduce the copper requirement of cabling a route, since this circuit operates with fewer wires than any other similar switching circuit.

1.2 Setting of tasks

The objective of this sub-project of Innotrack is to specify a European standard for a modern switch interface with clear benefit for the railway infrastructure companies, regarding functionality and life cycle costs, compared to the status quo. For this reason the special attention lies on creating the necessary room for innovative steps to break with the current practice. The standardisation effect promises additional scale effects with respect to cost reduction within Europe. A change of the competition environment in the supplier industry which may be implied by the standardisation is not in the focus of the Innotrack project. However, it can support the entire process.

The Innotrack project is focussed on track sections with medium to high volumes of traffic, since these have the most economical relevance for the infrastructure operator.

1.3 Outline

The interlocking system interface is regarded in this task in four directions. The separation from information flow and energy flow and the application of digital technology is always pre-supposed thereby:

1. general requirements of railway infrastructure, especially regarding the signalling and communication technology for the track components and here in particular the railway signalling technique to those Communication to the exterior installation.

2. commercial solutions with bus interface in other industries with similar requirements.

3. comparison and evaluation of commercial bus systems.

4. functional description of the switch interface.

Finally a recommendation for a new switch interface is expressed, which should be included in the further going standardisation work in the direction of a standardized interlocking system architecture with uniform European interface to the trackside equipment.

2. Requirements on interfaces and media

RAMS	Requirements	Comments
Safety	SIL 4 capability / Tolerable Hazard Rate < 10^{-9} h^{-1}	function position detection
Availability	MTBF > 10^7 h	Any failure which cause breakdown time
Robustness	• EMI resistance • Easy assembling • Intrusion protection (IP 65)	Lightning, random currents, electro-smog from power drive trains
Performance		
Temperature range	- 40 ºC to 70 ºC	No fan for cooling in devices
Network length	Maximum length of one control area 150km node distance up to 10 km	
Envelope delay	Critical events < 100ms (for example: trailing of a switch)	
No. of bus subscribers	Max. 2500 per control area / max. 250 per node	
Installation & commissioning	• Easy and simple installation • Self-configuration on the base of engineering data • Retrofit and revamp without operational interference	

Figure 1 - Requirements for communication in railway infrastructure

2.1 Environmental conditions & general requirements

In the rough environment of the railway infrastructure robust and durable solutions must be used, in order to manage the high mechanical, environmental and electromagnetic loads. Further it must be noted that the railway process must be controlled in real time. Therefore time-critical events like a lost switch end position must be send to the supervision and control centre in a very short time. This could physically mean that a signal transmission on more than 100 km is operated. The table in figure 1 gives an overview.

2.2 Requirements of other trackside components

The discussion of a Europe-wide standardised switch interface cannot be led in isolation from the trackside components, i.e. signals or track vacancy detectors. Because of economic criteria, dedicated solutions for the various component classes would make little sense.

Therefore all considerations within Innotrack regarding the interlocking interface base on the following vision (Figure 2) which implicates all trackside equipment to operate on the same interface.

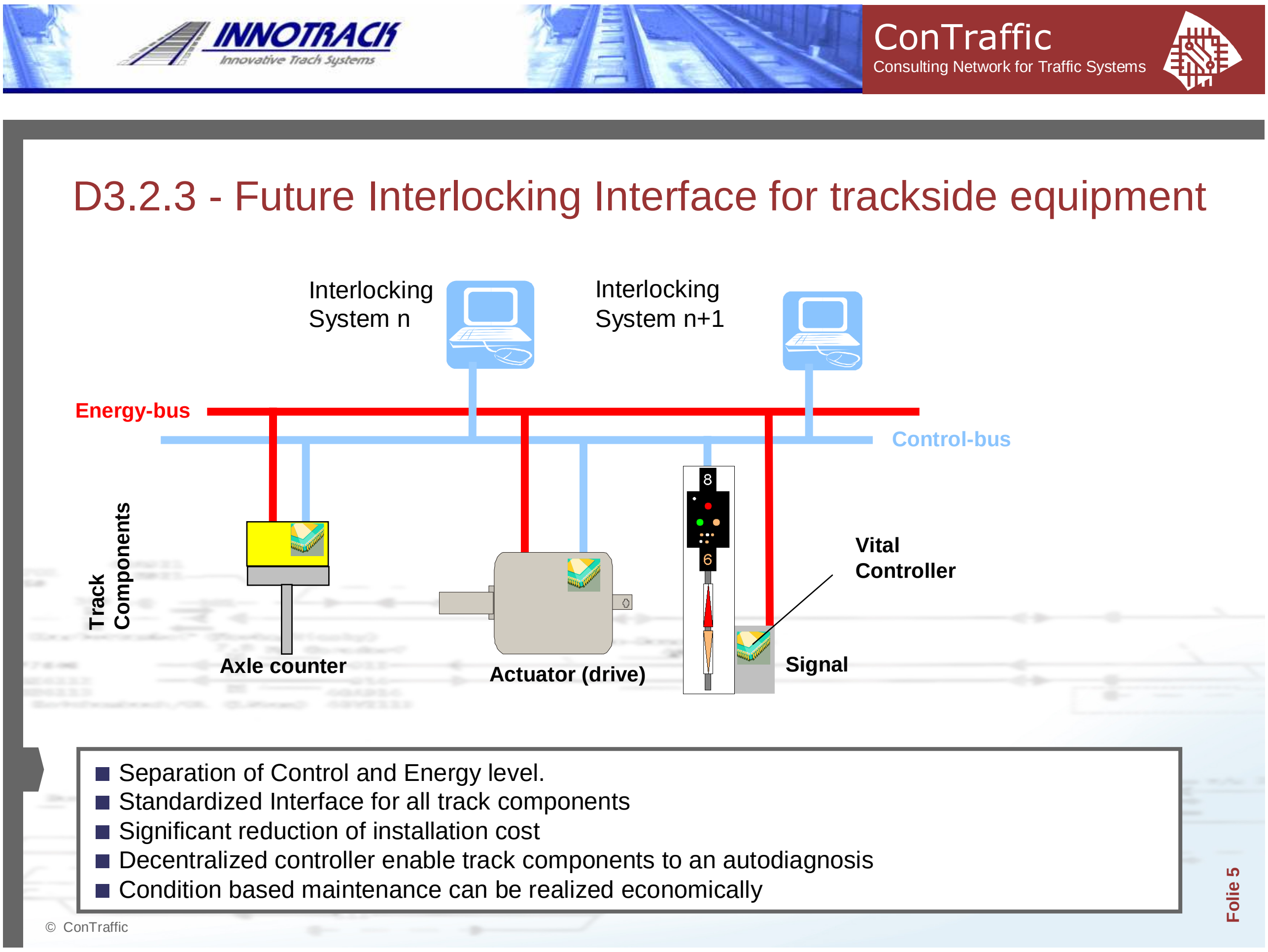


Figure 2 - Vision – Future communication in Interlocking systems

The power supply and the control signals are to be separated from each other and the control data will be transmitted digitally on a bus.

In the power supply the trackside components differ according to their power demand clearly - approx. 5W for an axle counter sensor up to for an electric switch actuator. Separate voltage levels could be meaningful in the field, which is a question of optimisation of the power supply for the railway infrastructure. The controlling and monitoring of the components however can be realized over a uniform interface.

2.3 Safety and availability

Beside the environmental conditions, at least the current safety level must be achieved. The relevant standards are set in the normalisation EN 50126 ff., in which safety (integrity) levels are described and the approval process is regulated.

The interlocking system interface must be assigned to the highest safety category (SIL 4), because the position of the switches and its locking and detection are part of the backbone of the entire safety concept for the railways. Therefore the failure rate of the communication systems between the interlocking and the switch must be less than 10^{-9} per hour.

Further, a high availability of field communication, particularly important in the case of a bus structure without dedicated point-to-point connections, is required in order to ensure an acceptable total availability of the signalling system. Derived from the overall expected availability of the signalling systems of 99% and better, the communication system for one signalling system should have a technical availability 10^7 h or approx. 100 years.

2.4 Data set for switches

The functionality of the interlocking interface to the switch could be described in the categories:

- Supervision
- Diagnosis
- Control and
- Set-up

The following table shows a detailed description. The basic functions are the switch movement and the detection of the switch blade position. All other functions contribute to further operational and/or cost benefits, which are in the main focus of Innotrack.

Category		Source	Remarks	Value	Safety	Cycle time
Supervision	Position of switch	Position detection sensors	Permanent supervision of switch position required	Left/right/ trailed/ processing	SIL 4	Envelop delay below 100 ms to interlocking control centre
Diagnosis	Movements	Local controller	No. of throws	No. of throws	0	weekly
	Next Maintenance date	Local controller	Cycle based Condition based	date	0 0	Weekly or trend based driven
	Actuation force	Force sensor for DC drives or current transformers in case of AC motors	Processing of sensor data by local controller	kN	0	Permanent/ weekly Permanent/weekly
	Dynamics	Acceleration sensors	Acceleration indices – average and peak values		0	Permanent/ weekly
	failures	Local controller	Wear, no end position, sensor defect, too high actuation forces,…		0	Event driven
Control	Movement	Interlocking system	Delocking of switch passively or actively	Turn left, turn right	0	2 - 8 s
Set-up		Engineering data set	ID, system data, signal dependency,…		SIL 4	

Figure 3 – Data set for switch interface

3. Functional description of the switch interface

The basic functionality of a modern switch from the view of the control and supervision system can be described as follows:

Control:
Switch movement – [move left/right]

Supervision/continuous detection:
Locked end position – [left/right/undefined]

Diagnosis:
Configuration of DLD system (No. of acutation and detection layers, type of device,…]
Number of throws made – [number]
Last maintenance – [Date or length of time]
Actuation force – [Value in kN and force trend analysis]
Dynamics, Acceleration – [mean value and acceleration spike as index in relation to reference]
Device failure – [date of occurrence, decive no., incidence)

The time and safety-relevant requirements are represented in the following table.

Header	Order	Confirmation	Data	Value	Safety	Cycle time
Switch ID / Interlocking ID	Send Status	Order received	Status	End position left, End position right, moving, trailed, undefined/maintenance required not required	SIL 4	permanently
Switch ID /Diagnosis system ID	Move left/Move right	Order received	Status	End position left, End position right, moving, trailed, undefined	0	On demand
	Send Diagnosis data set 1	Order received	Diagnosis	Force/No. of movements/date and no. of movements since last maintenance	0 0	On demand
	Send Failures	Order received	Failure list	failure code	0	On demand
	Send trend curve	Order received	Actuation force table	Table force/time	0	On demand

Figure 4 - Data set for switch interface

4. Commercial bus systems in comparison

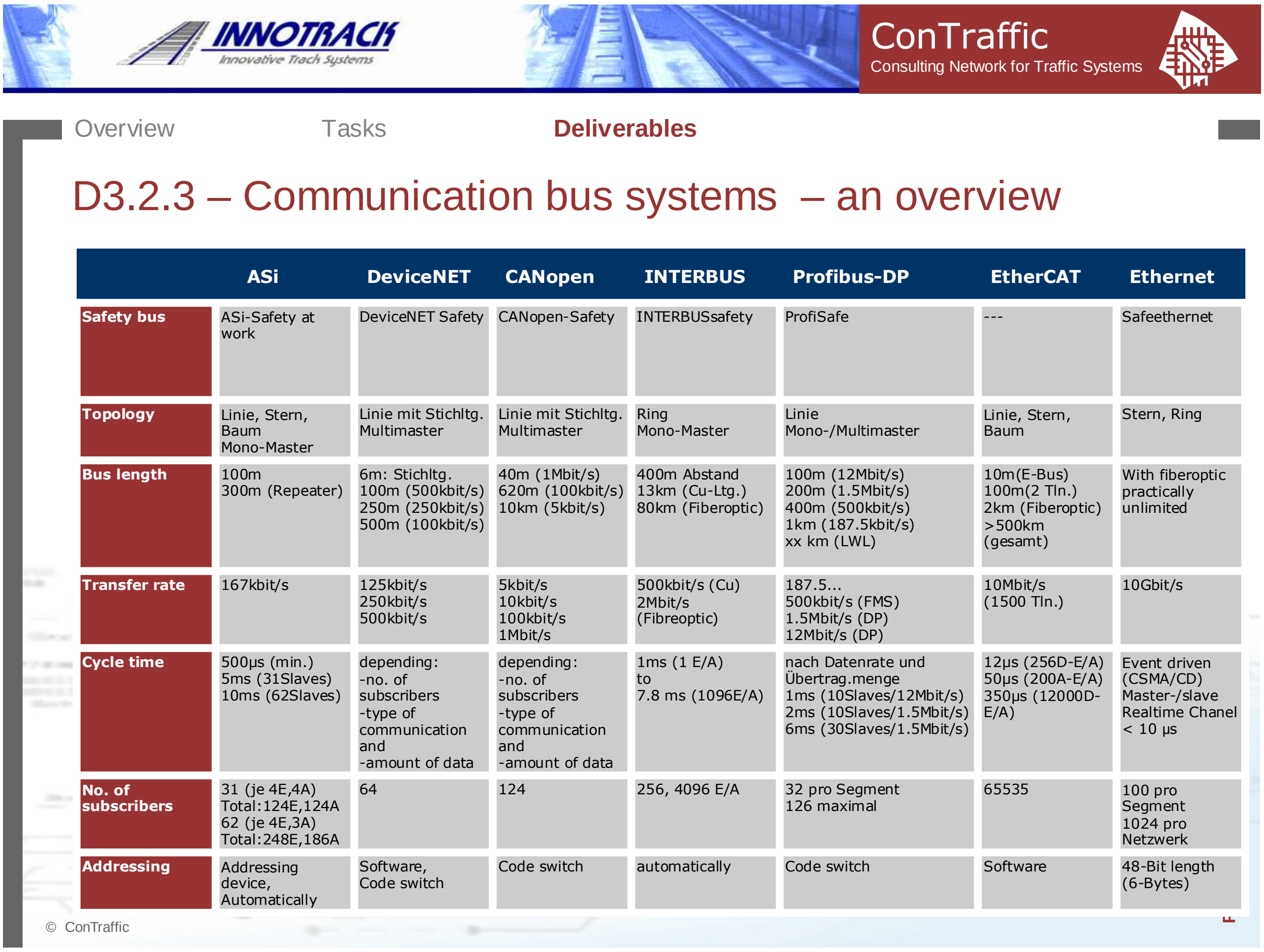
Cost reduction via economies of scale are more difficult to achieve in the railway infrastructure compared to other areas such as telecommunication, industrial automation and the automotive industry. For this reason the introduction of new technologies in the railway branch should draw on standards from other industries, in order to be able to hold the development, component and product care costs within an acceptable range.

Thus a comparison of the commercial bus systems used today is a good starting point for the further specification work.

In particular industrial solutions have a high relevance for a solution in railway industry, because the installed basis in that industry is very high, the technical requirements are similar and the life time of production plants are several decades, so that long-term product planning and product care must be operated on the part of the suppliers. These facts suggest that an application of industrial automation solutions in the railway infrastructure is promising.

Further industries, like the energy industry with similarly extensive infrastructure equipment look obviously exactly the same on industrial automation, as the recently adopted standard IEC (International Electrotechnical Commission) 61850 shows, in which on the basis of Industrial Ethernet a standard for communications networks in the energy business is fixed.

In the following chart the bus systems, used today, with its determining characteristics are represented.



	ASi	DeviceNET	CANopen	INTERBUS	Profibus-DP	EtherCAT	Ethernet
Safety bus	ASi-Safety at work	DeviceNET Safety	CANopen-Safety	INTERBUSsafety	ProfiSafe	---	Safeethernet
Topology	Linie, Stern, Baum Mono-Master	Linie mit Stichltg. Multimaster	Linie mit Stichltg. Multimaster	Ring Mono-Master	Linie Mono-/Multimaster	Linie, Stern, Baum	Stern, Ring
Bus length	100m 300m (Repeater)	6m: Stichltg. 100m (500kbit/s) 250m (250kbit/s) 500m (100kbit/s)	40m (1Mbit/s) 620m (100kbit/s) 10km (5kbit/s)	400m Abstand 13km (Cu-Ltg.) 80km (Fiberoptic)	100m (12Mbit/s) 200m (1.5Mbit/s) 400m (500kbit/s) 1km (187.5kbit/s) xx km (LWL)	10m(E-Bus) 100m(2 Tln.) 2km (Fiberoptic) >500km (gesamt)	With fiberoptic practically unlimited
Transfer rate	167kbit/s	125kbit/s 250kbit/s 500kbit/s	5kbit/s 10kbit/s 100kbit/s 1Mbit/s	500kbit/s (Cu) 2Mbit/s (Fibreoptic)	187.5... 500kbit/s (FMS) 1.5Mbit/s (DP) 12Mbit/s (DP)	10Mbit/s (1500 Tln.)	10Gbit/s
Cycle time	500µs (min.) 5ms (31Slaves) 10ms (62Slaves)	depending: -no. of subscribers -type of communication and -amount of data	depending: -no. of subscribers -type of communication and -amount of data	1ms (1 E/A) to 7.8 ms (1096E/A)	nach Datenrate und Übertrag.menge 1ms (10Slaves/12Mbit/s) 2ms (10Slaves/1.5Mbit/s) 6ms (30Slaves/1.5Mbit/s)	12µs (256D-E/A) 50µs (200A-E/A) 350µs (12000D-E/A)	Event driven (CSMA/CD) Master-/slave Realtime Chanel < 10 µs
No. of subscribers	31 (je 4E,4A) Total:124E,124A 62 (je 4E,3A) Total:248E,186A	64	124	256, 4096 E/A	32 pro Segment 126 maximal	65535	100 pro Segment 1024 pro Netzwerk
Addressing	Addressing device, Automatically	Software, Code switch	Code switch	automatically	Code switch	Software	48-Bit length (6-Bytes)

Figure 5 - Comparison of bus systems

5. Evaluation and selection recommendation

Among all the requirements of the railway industry,

- spatial network expansion

and

- long-term availability

are the most decisive for the selection.

Communications techniques for road vehicles follow however different requirements. Here it is important to improve further the efficiency of the intra-vehicle bus systems regarding the real time processes driving (assistance and safety systems) and the drive-train management, in order to increase safety and energy efficiency. Spatial expansion plays no role. In addition, the product cycles are clearly shorter in the automotive industry than in the railway industry. The CAN-Bus is the bus system with the highest production volume because of its widespread application in passenger cars. However, it is expected to be superseded within the next 10 years by Flexray.

Therefore it makes more sense to look on the telecommunications and industrial automation industries as the requirements there are more similar to what is needed in the railway industry. The following table gives an overview of the basic requirements and the long-term development trend in those branches:

	Automotive Industry	Telecommunication	Industrial Automation
Main driver	Cost, performance	Network extension Transport capacity	Network extension, Real time operation, availability
integration	No integration of other networks, Multimaster architecture	Horizontal – integration of IP-based communication networks in different locations to one virtual network (example: Metropolitannet)	Vertical – Integration of office communication and control networks with the factory process layer on IP-based solutions (Industrial Ethernet)
Expected changes	Replacement of CAN by Flexray for performance reasons	10 – 100 Gigabyte Ethernet to improve the transport capacity of networks	Replacement of classical Field bus technology by Industrial Ethernet solutions

Figure 6 - Trends in Communication technology

Obviously, there is a trend towards extending IP-based Ethernet solutions in both industries spatially (**horizontal integration - Metropolitannet**). In the industrial automation industry it can be noticed that on the other end IP-based communication are brought more closely to the process level (**vertical integration - Industrial Ethernet**). The driver is in both cases the same. Data storage, data communication and process control were realised by IP-based computer networks in the last decade. On the receiver side, IP-capable computer systems or PC solutions have been implemented, with resulting communications approaching elimination of protocol breaks in the transmission. For this reason, it is unlikely that Ethernet will be replaced in the near future. On the contrary: the end of the classical Field buses, which so far played an intermediary role between the control and process levels in industrial automation, is approaching.

The continuous advancement of the Ethernet technology and the extension of the standards in the IEEE committee confirm this view clearly.

Industrial Ethernet, which will likely replace Field buses in the near future in factories, has meanwhile only little to do with the 25-year-old CSMA/CD protocol (carrier sense multiple access/ collision detection).

Also the classical bus topology, with which many participants had to divide the broadband range, leading to bottlenecks and collisions, are only rarely used in modern industrial networks. In contrast to this shared Ethernet, modern switching technology offers the possibility of scaling the broadband range as well as the network extension with almost no limit. Beyond that, system behaviour regarding, for example, real-time data transfer or redundancy, has significantly improved.

The original Ethernet (10 MBit/s) needs 1,518 bytes for the transmission of a large package, taking a maximum of 1200 µs. Today this time can be reduced by the use of Fast Ethernet to 120 µs and by Gigabit Ethernet even down to 12 µs . This is not the limit for Ethernet innovations. The standard for 10 Gigabit Ethernet has been announced and work is ongoing on even higher speeds.

The preceding remarks suggest that the railway infrastructure should follow the trend in the industrial automation and telecommunication industries. It is therefore recommended to define a communication standard for the railway industry on the basis of Industrial Ethernet, with which the entire communication infrastructure can be included in one vertically and horizontally integrated system.

Data communication along the railway infrastructure should be realised using optical fibres, because they are immune to the high levels of EMI, of various types, which are found in the railway environment. The fibre-optic cable is, as it were, electrically not at all existent, and therefore EMC is not a problem for this transmission medium. Fibre-optic cables are also a proven technology and have been in use for decades.

The summarised recommendation for the interlocking interface is shown in figure 6.

	Recommendation	**Comment**
Communication architecture	Master/slave	
Architecture	Ring or redundant tree	For high availability
Bus-System Base	Industrial Ethernet	Standard solution with long-term availability
Safety	Signalling Safety protocol	Specific enhancement in Layer 6 of ISO-reference to fulfil the safety requirements
Physical medium	Fibre-optic along track	Media-converter in sub-stations for distribution and plug-in of the trackside-components with RJ45 electrical connection
Telegram	Standard data scheme with specific data fields depending on the track component functionality	Unified interface for all trackside equipment
Data transfer	Time-critical processes on real-time channel, Other operational data and diagnosis on regular Ethernet data flow	One network for all applications needed for operating the railway infrastructure

Figure 7 - Recommendation interlocking interface

6. Conclusion

The standardisation of the interlocking interface is a must to achieve the possibility of an independent innovation of the actuation system. Regardless of the current status quo this interface must be based on a significant higher level of technology, otherwise the projected savings in LCC can't be realised. The core driver to reduce operational cost is the diagnosis techniques integrated in the actuation system. A bus system for the communication is therefore recommended. For cost reasons a dedicated bus system for railway applications only will not pay off. Thus applying the Industrial Ethernet standard to the need of the railway industry is the best solution.