New applications through axle counter communications over open networks

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Network compatible systems are nowadays used more and more frequently in railway safety technology. These new applications help decentralised architectures or transmission systems via networks to be implemented at significantly lower cost. This means that operators and system integrators alike benefit from numerous advantages such as flexible architectures, the possibility to use existing or public networks and the exchange of additional data beyond the track occupancy indication.
This article provides an overview of the available network types and shows up a number of current practical examples demonstrating the reliability of these new systems.

1 Transmission media

Communication in axle counting technology essentially requires two types of connections: those within the axle counting system itself and those to a higher level system such as an interlocking. The transmission media to be examined hereafter relate to both communication routes.

Furthermore there are systems where the internal communication of the axle counter uses state-of-the-art networking technology while relay technology provides the connection to the higher-level system. This often applies to smaller systems where the implementation of a safe protocol would be more expensive than the installation of additional hardware to enable relay-switching.

1.1 Possibilities of transmission through open networks

Most railway operators nowadays offer an existing IT infrastructure that can be used for a variety of services. Even when using existing copper line transmission lines it is possible to transmit standardised protocols. This means that wires that were originally exclusively intended for a single purpose can now fulfil a number of services at the same time.

Instead of using a dedicated wire for each axle counter, a newly created or existing line can be used for the whole axle counting system, as well as for a wide range of additional services.

If a rail operator has no own network, a public network may also be used. While this alternative transmission system facility may be cost-efficient, it nevertheless gives rise to a number of disadvantages which will be described in detail in chapter 1.3 of this article.

1.2 Infrastructure requirements

Depending on the protocol and the individual protective measures used, the network will be required to comply with a specific category in accordance with EN 50159.

Category 1	The maximum number of users and the properties of the transmission system are known and fixed. Unauthorised access is not possible.
Category 2	The maximum number of users and the properties of the transmission system are not fixed. Unauthorised access is not possible.
Category 3	The maximum number of users and the properties of the transmission system are not fixed. Unauthorised access is possible.

Category 1 defines a closed transmission system. Open transmission systems are classified in category 2 or category 3.

When configuring the transfer protocol, a maximum network delay will be assumed or established. If a delay in the network is measured by the transfer protocol, the round-trip time is decisive.

The network used must be capable of providing the required bandwidth at all times. In the case of event-oriented protocols, the data rate will be related to the frequency of the events and a (heartbeat) interval. As for the cyclical protocols on the other hand, the data rate will not be affected by the event frequency but will depend on the transfer interval. The timeout that can be achieved will depend upon the maximum permitted delay and upon a (heartbeat) interval.

The availability requirements to the axle counter system also define the transmission network availability requirements. As it is often the case, the required level of availability cannot be achieved with a single network; there may therefore be a need to plan a redundant data transfer network.

1.3 Overview of open networks

After the above presentation of the available transmission system facilities and the requirements to transmission system networks, a description of the most important transmission system media follows hereafter.

Railway Ethernet

Most major main line infrastructure managers have their own internal network. This is typically a category 2 network, in accordance with the EN 50159 standard.

In any case, when using such a network, it is important to ensure that the necessary degree of access protection is guaranteed. The benefit of this type of network is that no cost will be incurred for separate cabling. Furthermore, it is possible to ensure that the properties required for operational purposes, such as bandwidth and delay, are provided.

Fibre optic cables

An exclusive pair of fibre optic cables provides the perfect solution with respect to the bandwidth and latency characteristics. A transmission system medium of this type can fundamentally be classified in category 1. If classified in category 2, the transfer medium has the advantage that at a later stage the architecture can be altered, for example in order to achieve the necessary network redundancy. It is also easy to connect additional users that had not been identified in the first place.

2-Copper wire

If existing systems are replaced or a track section is fitted for the first time with axle counters, a 2-wire copper cable is often all that is available. When using DSL technology it is possible to transfer Ethernet data as well. Compared to the fibre optic cables described above, a copper cable admittedly offers a reduced bandwidth and a longer delay. The potential operating distance is limited as well.

ADSL

If the company concerned has no own lines that could be used for data transfer, it is possible (as already mentioned in chapter 1.1 above) to route the data transfer over public networks. In most such cases, DSL technologies, such as ADSL, will be used. In general, these are category 3 networks, which will require additional protection to prevent unauthorised access to the transfer system. Since the operation of this transmission system is no longer in the operator's own responsibility, restricted availability has to be taken into account.

UMTS

A connection achieved via UMTS will be classified as a category 3 network. In view of the fact that an unknown number of public users are sharing the bandwidth, communication problems may frequently occur.

Additional media

Alongside the network types referred to above, additional media, such as WLAN (wireless local area network) or professional mobile radio systems may be used as well in cases where the requirements are more relaxed.

2 Serial connection of axle counters to higher-level systems

In comparison with hardware-based interfaces, a modern interface using a serial protocol allows the exchange of a range of additional information. For instance, besides the track occupancy indication or default setting, the interface can handle such additional information as running direction, diagnosis, speed, etc. The network connection and the flexible configuration of the axle counting system offers almost unlimited opportunities for data transfer. What is more, interfaces of this type enable cost savings to be achieved when networking interlocking and axle counting systems. Indeed, serial interfaces require fewer hardware components, consequently the space needed and the applicable wiring costs would be significantly lower [1] (figure 1).

As the transmission system is generally exposed to a diverse range of threats, it is necessary to detect the information errors listed in EN 50159 by means of a suitable protocol. In the past, countless protocols were developed which contain the corresponding safety features. In that regard, there is a clear distinction between standardised and proprietary protocols.

The standardised protocols (such as UNISIG Subset-098 or RaSTA = Rail Safe Transport Application) are mostly very complex - as a result their implementation gives rise to considerable effort.

Proprietary protocols are available both in simple and complex forms. Originally, many of these protocols were developed for a different transmission medium and only later adapted for Ethernet use. This "growth" frequently gives rise to unnecessary overheads being carried forward. Another disadvantage of proprietary protocols is that despite the availability of specifications, it is necessary, to take into account hitherto undocumented issues when carrying out an implementation. The main problem, however, relates to the entitlement to implement these protocols in the first place and then to use them.

If a system integrator has implemented its own safe protocol, which he employs for interfacing between the interlockings or for communication with the field elements, he would find it the simplest and most effective solution to connect an axle counter via that very same protocol.

2.1 Frauscher Safe Ethernet (FSE)

Small and medium-sized enterprises that are active in the area of system integration, but do not have their own protocol, will not find it cost-efficient to develop a protocol or to implement a standard protocol. As an independent provider of wheel detection and axle counting systems, it is of strategic importance to Frauscher to be able to communicate signalling data with all system manufacturers and integrators via software interfaces in a safe and reliable manner.

A few years ago, the company set up its own dedicated in-house development team to exclusively work on this specific topic. Frauscher developed a safe protocol which fulfilled the communication requirements between axle counters and the higher-level signalling system. This protocol is called the Frauscher Safe Ethernet (FSE).

This freely available protocol enables communication between various systems, without excluding the option to transmit additional information. In order to take into account the criteria put forward in this contribution, the development targets were defined as follows:

- Lowest possible complexity
- Suitability to connect safety-related equipment meeting SIL4 requirements
- Suitability for all category 1 and category 2 networks
- Lowest possible implementation effort

Figure 1: FAdC with Ethernet interface

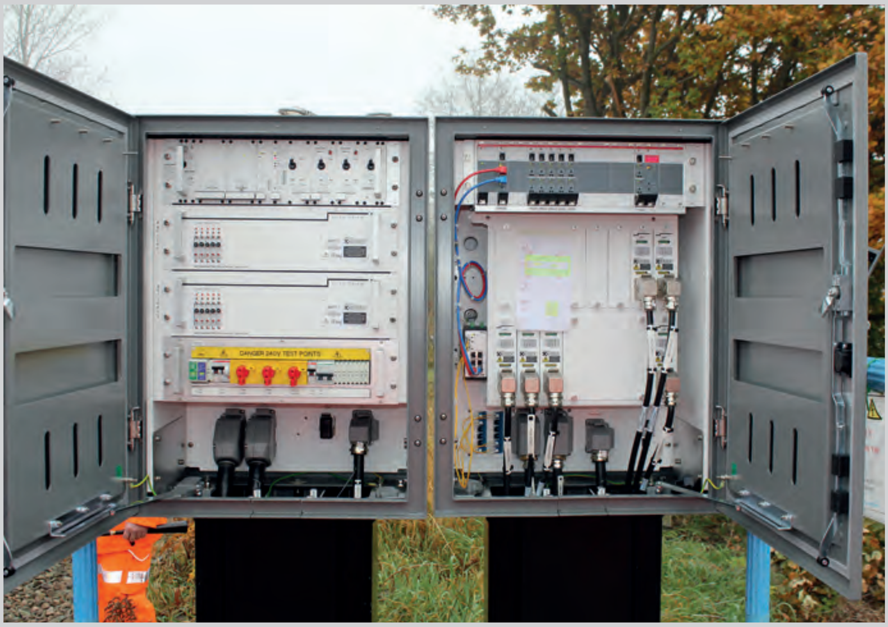

Figure 2: Modular-signalling-project: Track-side object-controller cabinet

- Suitability for various applications
- Suitability for redundant transmission.

Safety reports confirm fail-safe operating method

An essential objective of the FSE protocol development was to ensure the fail-safe transmission of data fulfilling CENELEC standards and SIL4. This should make it possible to guarantee that the protocol can be used in conjunction with safety-related applications. Various assessments have confirmed that the Frauscher Safe Ethernet protocol possesses the necessary properties.

Minimising the integration effort

Frauscher provides the FSE protocol free of charge and uses its know-how and wealth of practical experience to support users during its integration. Care has been taken to reduce the implementation effort by keeping it uncomplicated and by providing the following support tools:

- Protocol specification
- Extracts from the source code of a reference implementation
- Simulator
- Test specification.

As the FSE can be used to transmit any type of application data, its potential uses are not limited to axle counter information alone. This means that once implemented, the protocol can be used to communicate a variety of data types.

Technical features

In the FSE protocol, data packets are cyclically transmitted in both directions. As each package contains the full range of information, it is not necessary for any lost packages to be repeated.

Addressing is carried out using 32-bit source and destination IDs. Over 4 billion users can be addressed in this way. Using 8-bit port numbers, it is possible for sub-addresses to be allocated within a specific communication partner. Each user can therefore initiate several outgoing communication channels.

The round-trip-time (timeout), the sequence and the recognition of repeated messages are monitored by means of 32-bit TX and RX timestamps. This enables the redundant transfer of data to be carried out, without involving an additional mechanism. With a timestamp increment of 10 milliseconds there will be no data overflow until after one year.

Data integrity is ensured by means of two CRCs, each of which is 32 bits long.

3 Practical examples with open networks

The serial connection and flexible configuration of the Frauscher Advanced Counter FAdC axle counting system opens up almost unlimited opportunities [2]. In addition to customer-specific protocols for various interlocking types, the FAdC additionally offers the standard Frauscher FSE protocol for those applications that have not yet implemented a fail-safe Ethernet interface.

A number of projects involving various transmission media is meanwhile in successful operation.

3.1 Application example 1: Implementation of an interlocking protocol

In the UK, Network Rail worked with major rail industry players to develop a concept primarily aimed at modernising regional lines in a cost-efficient and sustainable way. The deployed modular signalling concept is based on a decentralised approach. Field elements such as axle counting systems, point machines and signalling equipment are positioned along the line in ‘object controller’ cabinets [3] (figure 2).

Communication with the central interlocking takes place via a fibre optic network. In terms of its modular signalling projects, the systems that Network Rail ultimately selected included the Siemens Westrace Mk II interlocking (formerly Invensys) and the FAdC axle counting system. The decisive reasons for this choice were the network-compatible interfaces of the axle counting system as well as the software configuration which is optimally adapted to projects with a decentralised architecture and designed to be implemented in a particularly cost-efficient way. In order to ensure that the communication with the interlocking is as efficient as possible, Frauscher implemented the WNC protocol that is used in the Westrace Mk II (figure 3).

The use of a decentralised architecture in combination with of fibre optic network instead of individual copper cables considerably reduced the investment, thereby significantly lowering the life cycle costs.

3.2 Application example 2: Transmission via FSE

The track system in Vostochny port, the largest harbour in the far-eastern part of Russia, underwent a full logistical modernisation in 2013. The aim was to introduce a system that enabled coal wagons to be distributed automatically onto different tracks, depending on the quality of the coal they are carrying [3] (figure 4).

Based upon the Ethernet connection between the interlocking and the axle counting system, two protocols were implemented to enable internal logistics to be supplied with essential data. As part of that process, the Frauscher Safe Ethernet (FSE) provides the fundamental safety-related data, whilst a diagnostic protocol is used to provide additional data for the purpose of logistics management. The information collected from

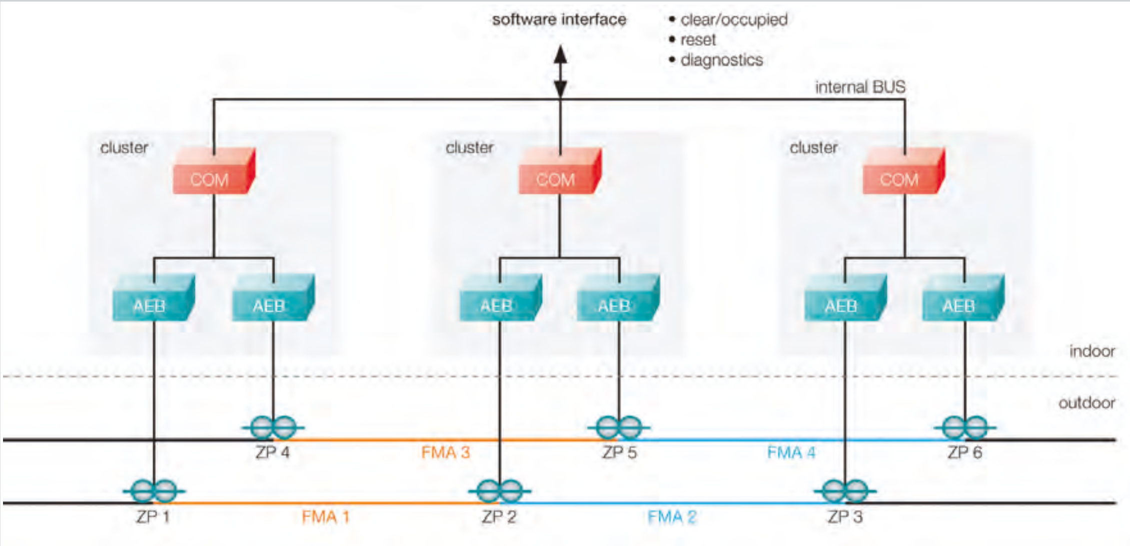

Figure 3: FAdC deployed within decentralised architecture: The single clusters communicate via Ethernet.

the system in that way enables the internal software to sort the wagons according to the quality of the coal. What is more, the additional information regarding maintenance and operations can be analysed and optimised (figure 5).

The exchange of data via this protocol between the interlocking system based on a Simatic S7-400 and the Frauscher axle counting system offers a range of advantages. For instance, besides the basic track occupancy indication and default status, data regarding the number of axles, the direction of travel and diagnosis information can as well be transferred. Another advantage is the fact that no additional components are required

Figure 4: Loading of coal at Vostochny port

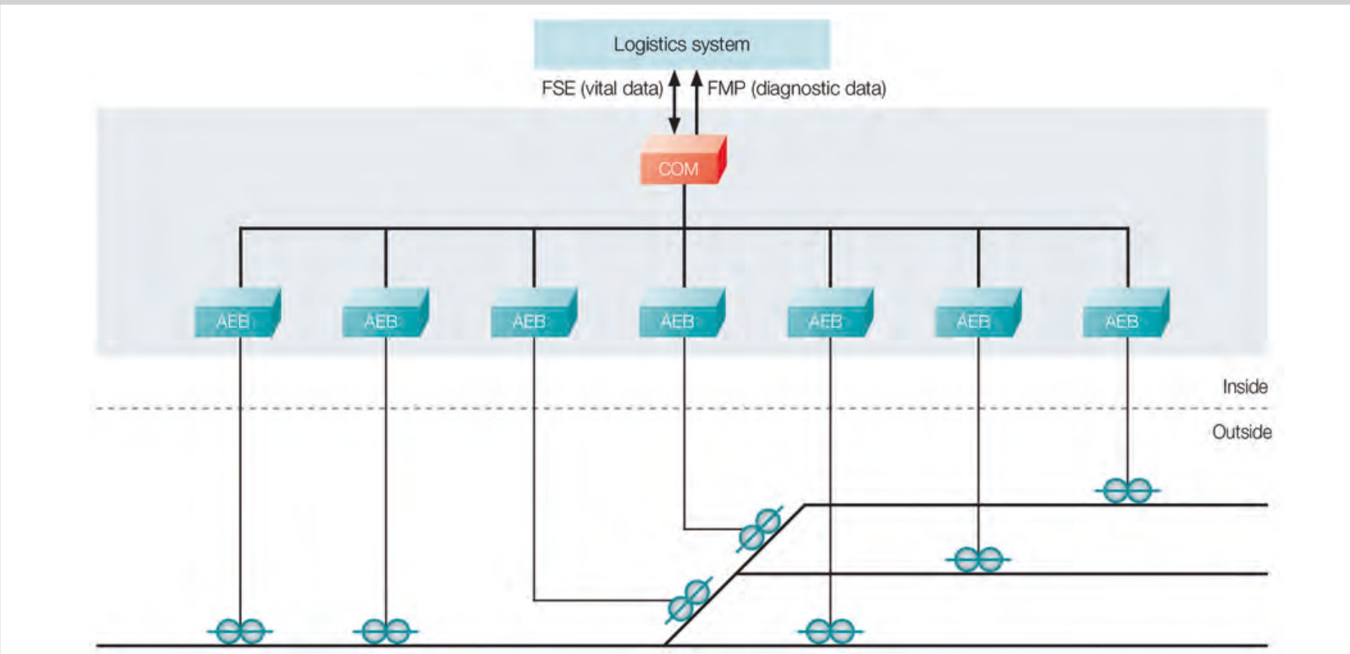

Figure 5: The FSE protocol and the diagnostic protocol FMP are providing all data necessary for a higher-level system.

Figure 6: The train control system of the Oberweissbacher Schwarzatalbahn (OBS) railway has been modernised.

for the relay interfaces. This reduces the investment and the amount of wiring.

The system integrator, Automated Systems and Complexes (ASC), was able to implement the FSE protocol and integrate it on-site into the project within two months, demonstrating how easily system integrators can use the FSE protocol.

In this particular context, the Frauscher Advanced Counters, notably the FAdCi version that was specially developed for less demanding requirements, such as those of industrial railways, were used in the project implementation and demonstrated their advantages. Having been designed according to CENELEC standards up to SIL3 and a maximum speed of 80 km/h, this model offers all benefits of the FAdC axle counting system in terms of functionality, flexibility and optimal integration.

3.3 Application example 3: DSL communication

In order to increase safety, the Oberweissbacher Berg- und Schwarzatalbahn railway (OBS) incorporated a technically supported train control system. Until then, train control had been carried out without any technical means. In order to keep the overall system cost down, data between the stations should be transmitted over a public network instead of building an own network [3] (figure 6).

OBS opted to install the AZB plus system produced by the engineering company V+S Ingenieurgesellschaft and FES Bahntechnik. As a central component of train detection, the Frauscher Advanced Counter (FAdC) axle counting system was used. Data transfer takes place via a DSL broadband internet connection, with encryption being provided by a VPN tunnel.

On the basis of the Ethernet interface and the easily adaptable software configuration, the data transfer of the FAdC can be precisely adjusted in response to the various requirements – including communication via DSL or directional radio. This means that no cabling system is needed for the data transfer between the various operating points and life cycle costs will therefore be considerably lower. Data are transferred at each operating location via a Lynx switch produced by the company Westermo, as well as via the DSL broadband internet connection supplied by the providers Telekom and Newone (figure 7).

Although the DSL network is briefly interrupted when it re-establishes the connection once a day, there is no adverse effect on the axle counting system. Thanks to the software configuration facility, parameters such as modem and communication delays can be taken into account and timeouts in the FAdC can be set up easily and quickly. Another significant benefit is the ability to adjust the data volume transmitted per second, thereby enabling a more stable transfer with greater availability. Using the latest diagnostic tools means that the transmitted data will not be confined to track occupancy information, but data relating to the power supply to the individual cabinets, the battery level or power failures can also be transmitted.

3.4 Application example 4: Communication via UMTS

When modernising the line between Spencer Junction and Tarcoola, the Australian Rail Track Corporation (ARTC) chose radio as one of the methods of transmitting block information. This project saw the existing track circuits replaced with state-of-the-art axle counting systems. To ensure network compatibility, ARTC chose the FAdC axle counting system. The primary means of trans-

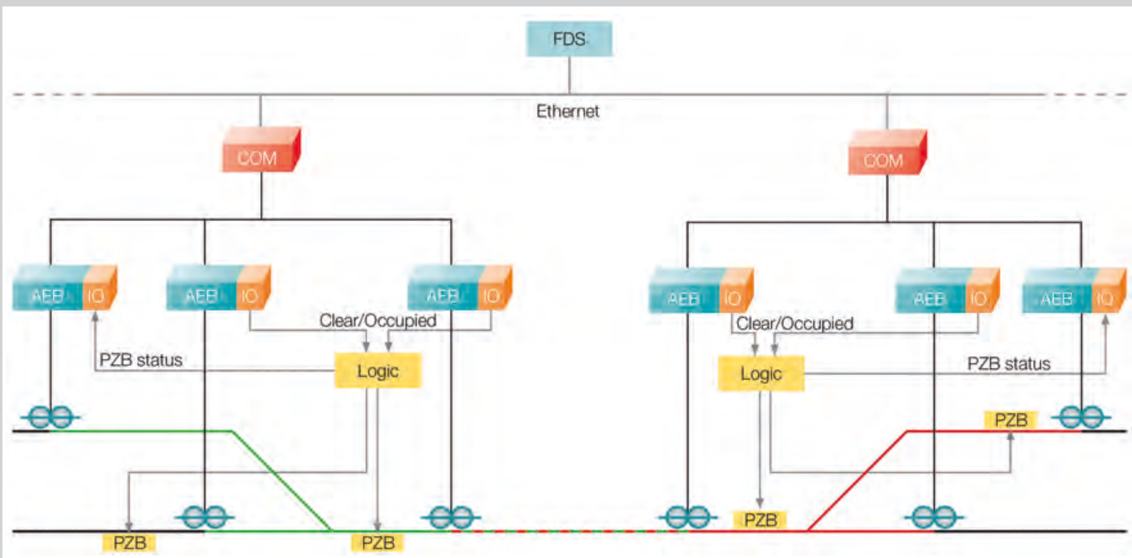

Figure 7: FAdC: Connection via a public DSL network

mitting block information is a fibre optic network [3] (figure 8).

This network is characterised by high transmission rates, low costs, and easy integration. In remote areas with no fibre optic connections, the Australian Rail Track Corporation decided to use the Next-G (UMTS) radio network from Telstra. The decentralised control cabinets communicate via this network using a secure VPN tunnel (figure 9).

The required efficiency of train operations was improved by the introduction of FAdC without needing costly cables in the sections fitted with wireless communication facilities.

Figure 8: Modern signalling technology along the track in South Australia: ARTC aims for more efficiency by using open networks

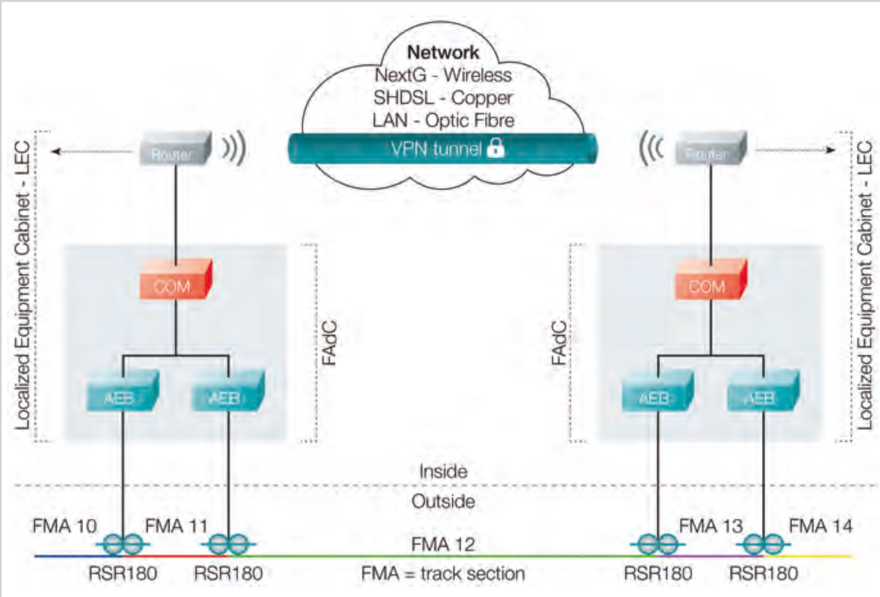

Figure 9: Connecting the clusters via a secure VPN tunnel

Conclusion and Outlook

In the area of railway safety technology network-compatible systems are becoming more and more common. Both operators and system integrators benefit from a number of advantages, such as flexible architectures, the use of existing and public networks and the exchange of additional data beside the clear/occupied status information. As shown in this article, current projects demonstrate that this new generation of systems operate reliably and significantly reduce the life cycle costs.

LITERATURE

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ZUSAMMENFASSUNG

Neue Anwendungen durch Kommunikation von Achszählern über offene Netzwerke

Immer mehr moderne Geräte bieten die Option, über standardisierte Netzwerke miteinander zu kommunizieren. Daraus ergeben sich zahlreiche neue Ansätze und Möglichkeiten. Diese Technologien kommen auch in der Leit- und Sicherungstechnik verstärkt zum Einsatz. Bis vor wenigen Jahren war es notwendig, für die Gleisfreimeldung exklusive Leitungen zur Datenübertragung zu verwenden. Mittlerweile ist es modernen Achszählanlagen möglich, verschiedene Übertragungsmedien für den Betrieb zu nutzen. Sich daraus ergebende Möglichkeiten für Betreiber und Systemintegratoren konnten in diesem Artikel zusammengefasst dargestellt werden. Die eingebrachten Praxisbeispiele bestätigen die Funktionalität dieser Systeme und veranschaulichen zugleich die Vielfalt neuer Anwendungsmöglichkeiten durch den Einsatz netzwerkfähiger Komponenten.