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White Paper

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Wireless Train-to-Ground Communication

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Executive Summary

As the European Commission (EC) implements its initiatives around developing a competitive European transport system to combat its dependency on imported oil and reducing its carbon footprint, it has turned its attention to dramatically improving its rail transport infrastructure across Europe by 2050. In doing so, rail transport has become very competitive and rail operators are seeking ways to differentiate themselves from one another. The primary differentiating factor is around improving service-oriented activities through the deployment of applications that provide a greater level of service to its passengers, while improving operator capacity.

This white paper explores the impact wireless is having on train-to-ground systems, including Communications Based Train Control (CBTC), Passenger Information System (PIS) and Surveillance Video (CCTV). In addition, a detailed train-to-ground application provides the reader with the framework of wireless implementation coupled by a detailed wireless product overview from Hirschmann – a leading networking technology company specializing in transport wireless infrastructures.

The Renaissance of Rail Travel

The continuing global trend of urbanization and the resulting congested suburban areas, coupled with the need for efficiency and cost effectiveness, is driving political and economic initiatives which favor rail transportation as the efficient and environmentally friendly option. Clearly illustrating this trend is the European Commission Transport White Paper[1] which details 40 initiatives aimed at implementing a competitive European transport system within the next decade. At its core is a target to reduce Europe's dependence on imported oil and cutting carbon emissions from transport by 60% by 2050[2]. Rail is seen as an environmentally friendly and efficient transport mode and the Commission aims to shift 50% of medium-distance intercity passenger and freight travel from road to either waterborne or rail modes by 2050. In Europe many major cities are within 700km of each other. That's a journey time of less than three hours by high speed rail.

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Belden.

Rail travel is currently enjoying a renaissance across Europe, no doubt in part due to these favorable conditions and initiatives. But rail operating companies also have challenges to overcome, one of which is the progressive liberalization of the European rail market; not only are they in competition with other modes of transport, they are increasingly in competition with each other. Since 2001, the liberalization of the rail market in the EU has proceeded stepwise, with the third step implemented in 2010 enacting open access rights for cross-border passenger services. Details of the fourth and final step have been published; it will lead to the opening up of domestic passenger services to new entrants and services by 2019.

Train-to-Ground Applications

One reaction of the rail operators is to identify service differentiators which make travel on their trains more desirable than their competitors whilst at the same time increasing capacity. This service differentiation is achieved through the deployment of applications that provide either a greater level of service to passengers or improved capacity for the operator. This white paper explores three such applications that rely on a wireless connection between the train and ground systems. This connection must be reliable and it must meet or exceed the required performance criteria, such as latency, bandwidth and handover times.

- Communications Based Train Control (CBTC)
- Passenger Information System (PIS)
- Surveillance Video (CCTV)

Communications Based Train Control

The trend of increasing urbanization (the UN predicts that by 2020, over 80% of the world's population will live in cities)[3] coupled with climate change, environmental concerns and increasing urban mobility mean that the demands on urban railway system capacity have never been greater.

Traditionally, increasing the capacity on an urban rail network involved large levels of capital expenditure on the rail infrastructure. Typical solutions to capacity challenges may have involved laying additional running lines, perhaps boring new tunnels and lengthening platforms to enable longer trains to be run. These large civil projects are not only expensive, they are also potentially disruptive to running an operational service.

Through the use of exact, real-time, train positioning information, CBTC provides a solution to the capacity challenges and avoids the need for many of these expensive and disruptive civil engineering capital projects. An increased utilization of the existing rail infrastructure is realized through the removal of traditional fixed signaling blocks and instead managing train headways as well as speed and acceleration profiles continuously in real time. A CBTC system managing shorter, lighter, faster trains running more closely together will result in an increase in capacity over longer trains running on a fixed block signaling system.

A large proportion of the total cost of running rail passenger vehicles is fixed for long durations (such as vehicle leasing or finance costs). Fuel or energy usage very often represents the largest proportion of costs that the operator can control. The use of a CBTC system allows energy savings to be made through the application of different driving profiles (such as coasting and reduced acceleration curves) when passenger demand is less, at off peak travelling times for example. When coupled with passenger counting technology, this management of the rail vehicles can be made fully automatic.

CBTC Architecture

The typical architecture of a modern CBTC system comprises the following main subsystems:

1. **Wayside equipment**, which includes the interlocking and the subsystems controlling every zone in the line or network (typically containing the wayside Automatic Train Protection (ATP) and Automatic Train Operation (ATO) functionalities). Depending on the suppliers, the architectures may be centralized or distributed. The control of the system is performed through Automatic Train Supervision (ATS) from a central command center, though local control subsystems may also be included as a fall-back.
2. **Onboard equipment**, including ATP and ATO subsystems, in the vehicles.
3. **Train to wayside communication subsystem**, now, most commonly based on IEEE 802.11 wireless radio links.

Although CBTC architecture is always dependant on the supplier and their technical approach, the following logical components can generally be found in a typical CBTC system architecture:

Onboard ATP System. This subsystem is in charge of the continuous control of the train speed according to the safety profile and applying the brake if necessary. It is also in charge of communication with the wayside ATP subsystem in order to exchange the information needed for safe operation (sending speed and braking distance and receiving the limit of movement authority for a safe operation).

Onboard ATO System. This element is responsible for the automatic control of the traction and braking effort in order to keep the train under the threshold established by the ATP subsystem. Its main task is either to facilitate the driver or attendant functions or, ultimately, to operate the train in a fully automatic mode whilst maintaining traffic regulation targets and passenger comfort. It also allows the selection of different automatic driving strategies to adapt the runtime or even reduce the power consumption.

Wayside ATP System. This subsystem undertakes the management of all the communications with the trains in its area. Additionally, it calculates the limits of movement authority for every train while operating in the control area. This task is therefore critical for operational safety.

Wayside ATO System. It is in charge of controlling the destination and regulation targets of every train. The wayside ATO functionality provides all the trains in the system with their destination as well as with other data such as the dwell time in the stations. Additionally, it may also perform auxiliary and non-safety related tasks including alarm/event communication and management or handling skip/hold station commands.

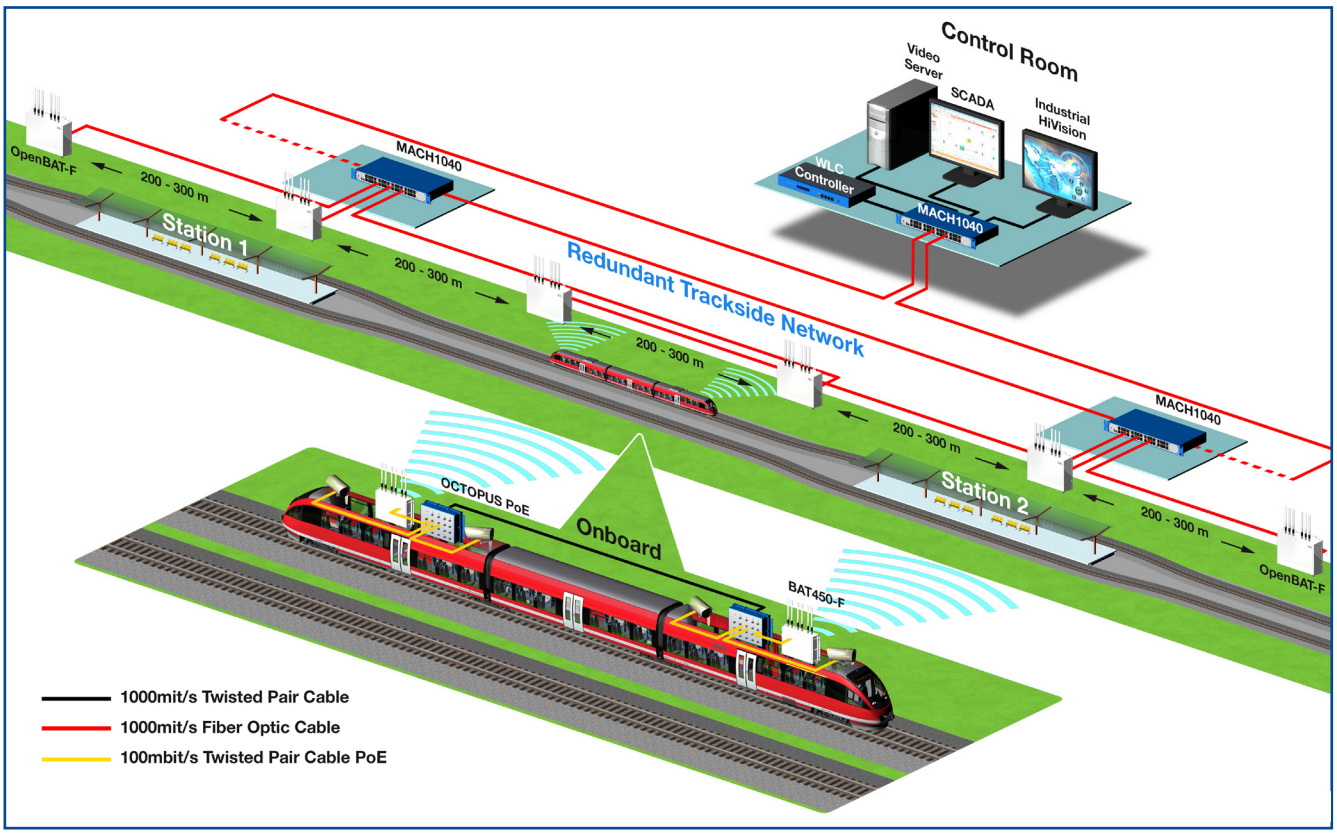

Figure 1: Communications Based Train Control (CBTC)

Requirements	Benefits
Appropriate Railway Onboard Vehicle Certification • IEC/ISO for World • EN for Europe • AAR/AREMA for North America	A pre-requisite for installation onboard train builders' vehicles or trackside and for fitment by system integrators.
Fast Secure Roaming	For safety reasons, any disruption in the CBTC service will bring trains to a stop. Because of this, a roaming handover time of <50 ms is essential to provide uninterrupted train-to-ground communication.
Error Tolerance	While the communications system for CBTC is not defined as safety-critical, loss of the data being transmitted will result in system errors, so a packet loss of less than 0.1% is required.
Sufficient Bandwidth	The communications system must be capable of carrying all of the required data from the train to the Operational Control Center for the CBTC system to be reliable in operation. To provide this service, a bandwidth of at least 4 Mbit/s is required.
Network Latency	Since the CBTC operation relies on real-time information for the control of moving trains, the maximum latency from end to end must be less than 5 ms.
High Availability	Train Control Management applications such as CBTC need communications networks with a high availability.
Security	CBTC networks require protection against malicious behavior and attacks. The network should be hardened against attacks that can threaten overall availability and performance.

Table 1: Communications Based Train Control Requirements and Benefits.

ATS System. The ATS system is commonly integrated within most of the CBTC solutions. Its main task is to act as the interface between the operator and the system, managing the traffic according to the specific regulation criteria. Other tasks may include the event and alarm management as well as acting as the interface with external systems.

Communications Network. The CBTC systems run over a digital networked radio system by means of antennas or leaky feeder cable for the bi-directional communication between the track equipment and the trains. The 2.4GHz band is commonly used in these systems (public Wi-Fi band), though other alternative frequencies such as 900 MHz (US), 5.8 GHz or other licensed bands may be used as well. (Note: The use of licensed bands is becoming more widespread to ensure that interference is less likely.)

Wireless Technology in CBTC

While the use of wireless technology for CBTC is commonplace, it is not without its challenges, many of which stem from the challenging environment and the speed of moving trains. Some key requirements of the CBTC wireless network are listed in table 1.

Passenger Information Systems

In our busy lives, we are all beginning to expect access to required information almost immediately and to be able to communicate (by increasingly varied methods) with whomever we want, whenever we want; we want a continuous connection to information and messaging systems. This expectation of immediate, up-to-date information coupled with increasingly complicated timetabling has driven a change in Passenger Information Systems. It is no longer sufficient to display or communicate timetable information on these systems.

Modern Passenger Information Systems provide real-time information; if a train is delayed, the system will show this, usually with a revised estimated time of arrival. This availability of real-time information drives the need for a train-to-ground infrastructure communications link. Next generation Passenger Information Systems build on this functionality, providing journey management information and location-dependant information or advertising.

Typically, a Passenger Information System will include some form of display system; all the way from larger LCD based displays capable of showing multiple lines of text or graphics to smaller dot matrix type displays only capable of showing one or two lines of text.

However, Passenger Information Systems are not in use all of the time; they are predominantly used to make announcements or display information as a vehicle nears the next station or stop. Between stations, the display (and audio) elements of the system are available for other uses; on suburban and especially inter-urban services, this period of availability can be significant.

During these periods of inactivity, the Passenger Information System can be used to display advertising content, thus creating a revenue stream for the train operator. Adding a wireless facility to an Ethernet based onboard Passenger Information System along with an associated wireless infrastructure (either at maintenance depots or terminus stations) makes it possible to download advertisement information to the system.

So, we see that to deploy a Passenger Information System that meets passenger expectations and potentially increase operator revenue, wireless train-to-ground communication is an essential element. Some key requirements of the Passenger Information wireless network are listed in table 2.

Requirements	Benefits
Appropriate Railway Onboard Vehicle Certification • IEC/EN for Europe • AAR/AREMA for North America	A pre-requisite for installation onboard train builders' vehicles or trackside and for fitment by system integrators.
Sufficient Bandwidth	The communications system must be capable of carrying all of the required data for the Passenger Information System. To provide this service a bandwidth of at least 5 Mbit/s is required.
Security	The networks carrying Passenger Information data (including the wireless train-to-ground connection) require protection against malicious behavior and attacks. The network should be hardened against attacks that can threaten overall availability and performance.

Table 2: Passenger Information Systems Requirements and Benefits.

Figure 2: Passenger Information Systems

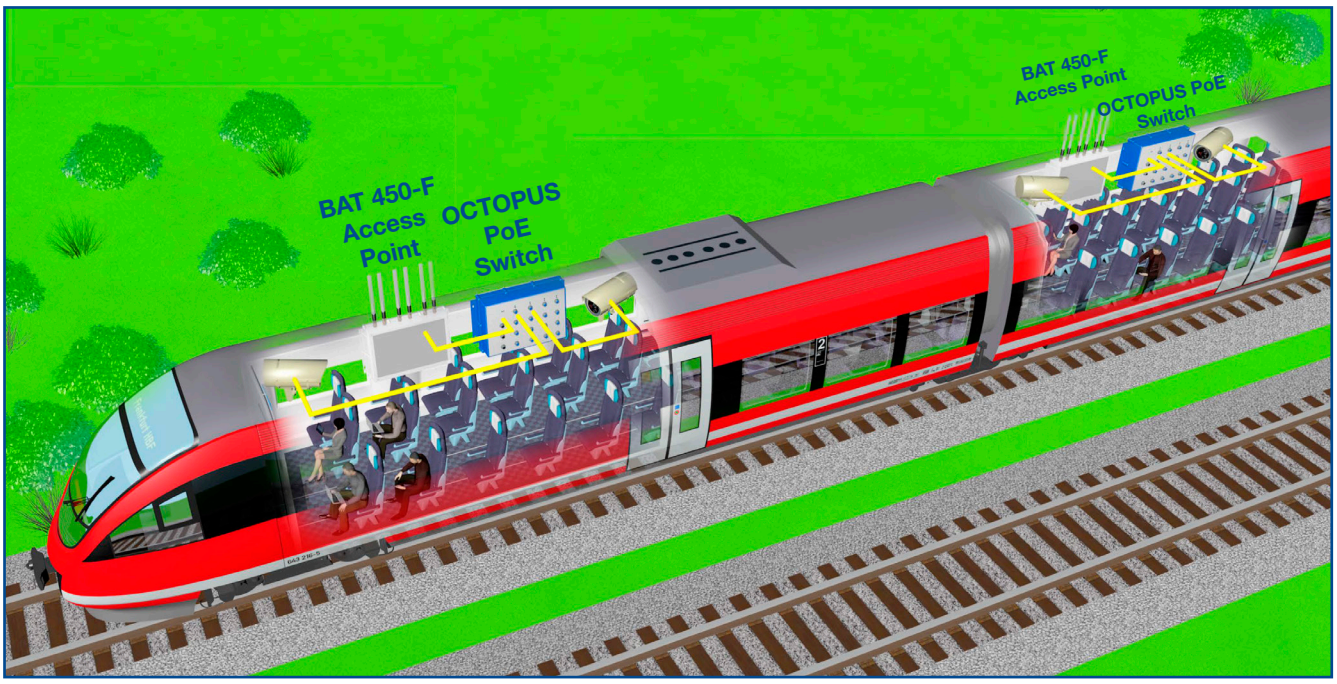

Figure 3: Surveillance Video (CCTV)

Requirements	Benefits
Appropriate Railway Onboard Vehicle Certification • IEC/EN for Europe • AAR/AREMA for North America	A pre-requisite for installation onboard train builders' vehicles or trackside and for fitment by system integrators.
Fast Secure Roaming	Any delay in handover will result in a loss of video data which could result in the critical moment of an incident being missed.
Sufficient Bandwidth	The communications system must be capable of carrying all of the required video from the train to the Operational Control. The quality of the video streams is related to the available bandwidth of the wireless connections and the amount of video streams. The quality of the video streams can be adjusted by changing the frames per second and the resolution to fit the application.
PRP	When roaming, single radio clients lose their connection, leading to Packet losses or delays. Conventional dual radio clients can use two connections but need to switch between both connections (quality degradation before or after switch) Using PRP compensates for loss and avoids quality degradation during handover. Seamless transition between access points without switchover effects: • Zero authentication delay • No/reduced quality degradation
Security	The networks carrying Surveillance Video (including the wireless train-to-ground connection) require protection against malicious behavior and attacks. The network should be hardened against attacks that can threaten overall availability and performance.

Table 3: Surveillance Video Requirements and Benefits.

Surveillance Video

The use of video systems within rail vehicles is becoming more widespread; both for operational reasons and to help meet the passenger expectations of safety and comfort when travelling. Traditionally these video systems would have recorded to a high capacity onboard storage system, which could then be downloaded at a later date to support the investigation of an incident. Increasingly operators want to stream the video (often HD) live off the moving train to allow an incident to be dealt with as it happens. This video is either streamed on a continuous basis or only when some trigger event occurs; typical triggers for enabling the live stream are:

- A passenger pressing a help or panic button
- Fire detection systems
- Driver action
- Video analysis software used to detect incidents automatically

In addition to passenger related surveillance systems, there are also operationally related video systems such as

- Pantograph video
- Front and rear facing camera systems
- Driver only operation cameras

The currently deployed systems increasingly utilize network/IP based cameras rather than analog, and a recent study showed that the majority of public transport authorities and operators will only be acquiring network/IP based camera systems in the future.

For video transmission, the wireless train-to-ground communications system needs to meet the challenges shown in table 3.

Choosing the Right Wireless Infrastructure

Network engineers need a complete solution for Wireless train-to-ground communication applications, from the cables, connectors, patch cords and patch panels, to a broad portfolio of wired and wireless switches, routers and firewalls for harsh environments.

What should engineers look for when choosing the right solution?

Industry-specific portfolio with proven track record

In a sector where domain knowledge is vital, Belden offers an innovative dedicated product portfolio that has a proven track record within the industry.

Safety and reliability without compromise

The Belden product portfolio is designed to meet the uncompromising safety and reliability requirements of the transportation industry. Belden is able to provide your network system as a fully integrated solution, compliant with your exacting requirements.

Dedicated future-proof solutions

Whether implemented through fiber or copper, a Belden supplied network solution can be designed to provide data rates for the future, thus eliminating the need for any upgrades to cope with system innovations in the future.

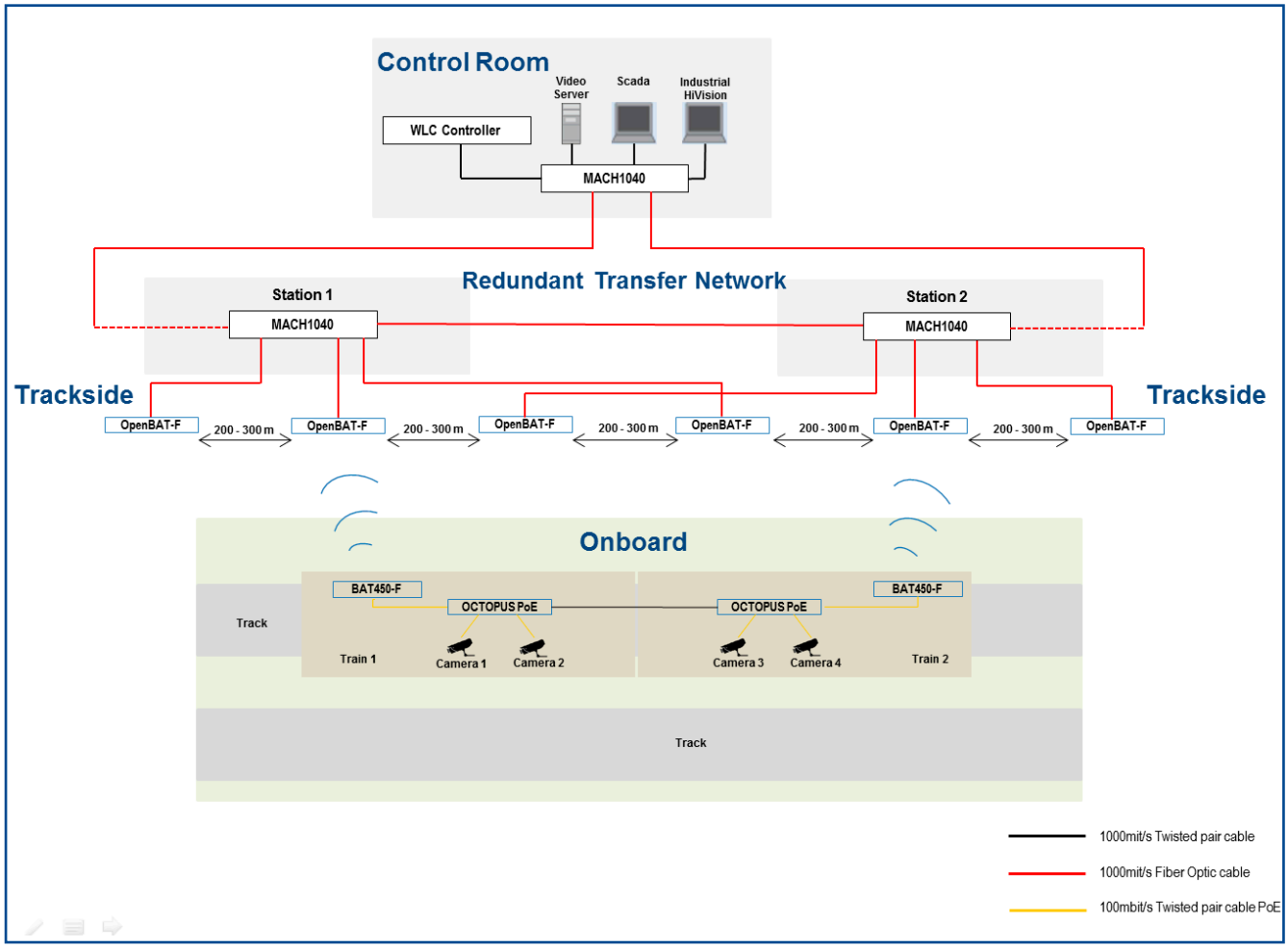

Figure 4: Architecture example with Hirschmann products.

Products for Effective Train-to-Ground Communication

Customer benefits of the Hirschmann products		Communications Based Train Control (CBTC)	Passenger Information System (PIS)	Surveillance Video
 The OpenBAT family is comprised of the BAT-R (IP30) and BAT-F (IP65/67) series of WLAN access points, compliant with the required railway standards. Their built in ClearSpace™ and PRP functionality means that they can be installed in challenging environments and still provide reliable error free wirless communication.	OpanBAT-F	✔	✔	✔
	OpenBAT-R	✔	✔	✔
 The BAT450-F industrial wireless LAN access point family features multiple interface configurations and connection options. With its ruggedized, compact design and high IP rating this product can be installed almost anywhere, both onboard rolling stock and along the trackside.	BAT450-F	✔	✔	✔
 The BAT Controller WLC is used for centralized management of large WLAN networks, making the management and running of a large wireless network stress free. During set up, the Controller will locate all the access points, and configure them as appropriate, saving the administrator a great deal of time. During operation a faster, seamless handover between access points is assured since key management as well as channel and interence management are dealt with centrally with no operator intervention required.	WLAN Controller	✔		✔
 The managed Industrial Ethernet switches in the OpenRail family provide an optimum degree of flexibility. They are suitable for a variety of transportation application and manufactured to the customer's specifications which means that the price paid exactly reflects the functionality needed to achieve reliable network connectivity.	OpenRail RS20/30	✔		
 Due to their extremely robust design, the IP67/54 OCTOPUS switches can withstand the most severe stress. This ensures fail-safe data communication even in the demanding onboard rail environment - whether installed in an equipment cabinet or within the roof space. The product range provides many different numbers of M12 ports from 100Mbps to 1GBps which means that the correct device can be specified for every different application.	OCTOPUS 8M PoE	✔	✔	
	OCTOPUS 16M PoE	✔		
	OCTOPUS 24M PoE			✔
 The workgroup switches in the MACH100 range are available in different full Gigabit versions. They are highly specialized multifunctional devices, since they can assign ports to different subnetworks and deliver specifically targeted data packets within these networks making them a cost effective solution. Because they tolerate temperatures from 0°C to +50°C, these workgroup switches can be installed in control cabinets without any need for powerful cooling systems. For an increase in reliability, fanless versions are also available.	MACH102 + SFP			✔
	MACH104 + SFP	✔		
 The MACH1040 switches are designed specifically for use in harsh industrial environments such as the rail industry. They can be connected to form sub-networks, which in turn can be linked up to each other. Thanks to their fanless design, their ability to withstand temperatures from -40°C to +70°C and their Fast HIPER Ring redundancy mechanism, these switches guarantee the highest degree of availability. Moreover, they also support Profinet and EtherNet/IP.	MACH1040 + SFP	✔		
 The entry-level rail switches in the SPIDER range allow economical solutions for a variety of applications. There are more than 25 variants which means that there will always be a perfect solution to the switching requirements of different applications and at a relatively low acquisition cost per port. Startup is simply plug-and-work – no special IT skills are needed. LEDs on the front panel indicate the device and network status.	SPIDER 1TX/1FX-SM			✔

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Summary

As high-speed train travel enjoys rejuvenated popularity, the market is seeing increased demand for secure, reliable connections between moving trains and ground systems. In this white paper, we have explored some typical applications in more detail and also identified and quantified the associated performance requirements for the train-to-ground connection. It is clear that the communications link between the train and the ground infrastructure is critical to the success of many onboard applications and even the running of the train service. In the future, as passenger expectations and the demand on railway systems continues to increase, the performance and reliability of this link and the associated Ethernet-based systems will become even more vital. Even as this demanding environment evolves, the impact of a system failure will continue to affect thousands of people and have serious financial consequences. Therefore, choosing the right network components, like those from Belden, takes on even greater importance to ensure reliability, availability and network resilience.

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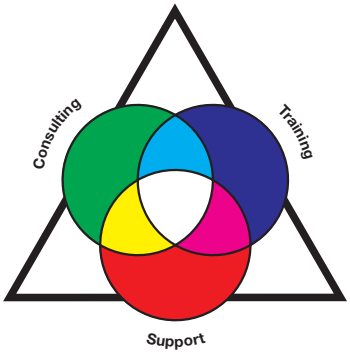

Belden Competence Center

As the complexity of communication and connectivity solutions has increased, so have the requirements for design, implementation and maintenance of these solutions. For users, acquiring and verifying the latest expert knowledge plays a decisive role in this. As a reliable partner for end-to-end solutions, Belden offers expert consulting, design, technical support, as well as technology and product training courses, from a single source: Belden Competence Center. In addition, we offer you the right qualification for every area of expertise through the world's first certification program for industrial networks. Up-to-date manufacturer's expertise, an international service network and access to external specialists guarantee you the best possible support for products. Irrespective of the technology you use, you can rely on our full support – from implementation to optimization of every aspect of daily operations.

About Belden

Belden Inc., a global leader in high quality, end-to-end signal transmission solutions, delivers a comprehensive product portfolio designed to meet the mission-critical network infrastructure needs of industrial, enterprise and broadcast markets. With innovative solutions targeted at reliable and secure transmission of rapidly growing amounts of data, audio and video needed for today's applications, Belden is at the center of the global transformation to a connected world. Founded in 1902, the company is headquartered in St. Louis, USA, and has manufacturing capabilities in North and South America, Europe and Asia.

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