THE TRAIN ETHERNET BACKBONE

Executive Summary: The Train Ethernet Backbone

There is a global trend toward urbanisation1 that is causing increasing congestion in both cities and suburban areas. At the same time, fossil fuels are becoming more scarce and their use less acceptable due to their environmental impact. All of this together is driving political and economic initiatives that favor rail transportation as an efficient and environmentally friendly solution. One example is a European Commission Transport White Paper2 which details 40 initiatives aimed at implementing a competitive European transport system. At its core is a target to reduce Europe's dependence on imported oil and cut carbon emissions from transport by 60% by 2050. 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 — a journey time of less than three hours by high speed rail.

The Ethernet Train Revolution

Rail travel is currently enjoying a renaissance, 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 liberalisation of the rail market. Not only are they in competition with other modes of transport, they are increasingly in competition with each other. The competitive landscape for rail operating companies is therefore changing and will continue to become more challenging in the near future.

One reaction of the rail operators to this increasing level of competition is to identify service differentiators that make travel on their trains more desirable than their competitors, with one such service being the provision of internet access for passengers. We live in a connected world where we expect immediate, unfettered access to people, to information and even to other devices (i.e. home security systems). We want to be able to communicate (by increasingly varied methods) with whomever we want, whenever we want. And the internet is our medium of choice.

When travelling by train, gaining internet access can be a challenge. When mobile network coverage plans were developed, road users and urban areas were seen as the priority1. Therefore, on some rail routes, connections for a standard phone or smart device can often be intermittent, or non-existent. To be a credible travel alternative, train operators are increasingly looking to provide internet access for passengers via Wi-Fi and on-train WAN access points, many of which aggregate multiple GSM signals along with off-train Wi-Fi and satellite links. Currently, the provision of this service is also seen as a differentiator by passengers (particularly if it is provided free), but this situation will change as more train operators implement such services.

Concurrent with greater passenger demands, operator requirements are also changing. Top-of-mind concerns include increased fuel efficiency, increased reliability, shorter dwell times at platforms, reduced headway between trains, fewer on-board staff (perhaps no driver) and improved security. These operational mandates in turn lead to an increase in the demand for more and better diagnostic and control systems. To understand on-board equipment reliability and to ensure that the train performs as expected, it's necessary to monitor and collect data on a whole range of on-board systems.

Historically, systems installed on board trains have been self-contained, that is to say, they have had their own bespoke architecture, including a simple and reliable internal serial communications system (not usually connected to other on-board systems). But today, the data needs to flow between multiple different on-board systems; for example, it's useful for the on-board location system to tell the door system where the train is so that it doesn't open the last doors on the train when the platform is too short. Then, before the train even reaches the station, the Passenger Information System needs to notify passengers to move along the train if they want to exit at that particular station. Increasingly, the data flow does not stop at just being on board; diagnostic systems now report back to depots before the train arrives for maintenance so that spares and tools can be organised; seat reservation and ticketing systems provide information; and Communications Based Train Control (CBTC) systems allow for the control of train movements remotely.

To allow passengers to access the internet on board and to remotely manage and control increasingly sophisticated trains, the whole on-board network philosophy is changing. The whole train now needs to be connected together as one integrated vehicle. The design is moving from multiple individual communication systems supporting specific data networks to a single integrated network and the technology being used is Ethernet.

On-Train Ethernet Networks

A train is physically long and thin, which means it is not the ideal environment in which to install an Ethernet network that has to continue operation even when some equipment has failed. In a factory automation environment, this redundancy requirement can be achieved by using a ring topology and even routing cabling through different areas of buildings. Although this concept is used on trains, the routing of cabling can be challenging (particularly at the ends of Carriages). The usual architecture now being used in trains is one of an Ethernet backbone running the length of a train with each carriage having a 'local' network to interconnect all of the equipment. The backbone often consists of two separate Ethernet cable runs, with two links at the end of each carriage. Within the Carriages, there are two main topologies used:

- Linear topology, where all the equipment has one route to a single switch connected to the backbone
- Ring topology, where two switches are connected to the backbone and a redundant ring is created within each carriage so that all the equipment has more than one route to the backbone

It is usual to use a ring topology when real time or mission-critical data is present and a linear topology for less critical data.

Apart from the unique physical structure of a train, the fact that it is mobile adds additional challenges. The on-board Ethernet network needs to understand things such as the direction of travel, where the front and rear of the train (and Consists) are and the impact of train lengthening or shortening.

To help overcome these challenges, a set of IEC standards (IEC 61375 series) 3 has been issued that defines an architecture and functionality that assures both interoperability between equipment from different suppliers and the safe management of the Train's physical topology.

Challenges

While there are many challenges that can be overcome through the use of Hirschmann Ethernet products, this White Paper considers three in more detail:

- Coupling redundant rings within a Consist
- Wireless connectivity between Consists and Coaches
- IEC 61375 Ethernet Train Backbone Node functionality

Coupling Redundant Rings

It was noted earlier that by far the most common network topology to use within a train is the ring topology. When Ethernet ring redundancy protocols are added to this topology, we have a completely redundant method of passing data to and from connected devices. This is fine within each carriage of a Consist, but the redundancy is lost between the rings when using traditional, single-point methods of coupling.

The Hirschmann Redundant Coupling Protocol (RCP) provides you with the required functionality to couple a redundancy protocol such as MRP, DLR, RSTP or HIPERRing. RCP allows you to couple multiple secondary rings to a primary ring. Only the switches that couple the rings require the Redundant Coupling Protocol function. You can also use devices other than Hirschmann devices within the coupled networks.

The Redundant Coupling Protocol uses a master and a slave device to transport data between the networks, with only the master forwarding frames between the rings.

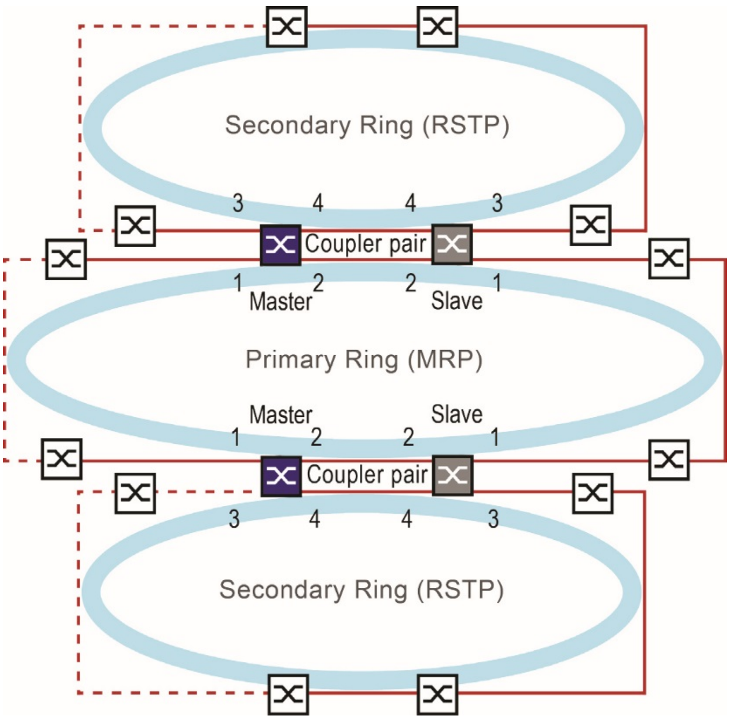

Figure 2: Coupling Redundant Rings

In Figure 2, the primary rings represent an MRP ring network within the carriage of a Consist. The secondary rings in the figure are RSTP ring networks. In this example, each ring contains four devices, but could contain more. Through the use of the Hirschmann RCP, redundancy across multiple rings is easily achieved and the redundancy functionality preserved along the length of the Train.

Wireless connectivity between Consists and Coaches

The upgrading and refurbishment of rolling stock very often includes the implementation of a high bandwidth Ethernet network providing connectivity between a variety of on-board systems. The provision of this type of network within Carriages becomes relatively straightforward thanks to Belden's broad portfolio of rail products: Belden railway Gigabit data cable and Lumberg Automation M12 Gigabit connectors, in conjunction with Hirschmann OCTOPUS IP67 Ethernet switches. However, implementing this type of high bandwidth, high availability Ethernet network down the length of the whole train, between Carriages, using existing interconnection cables (so as to not impact existing rolling stock certifications) is more challenging.

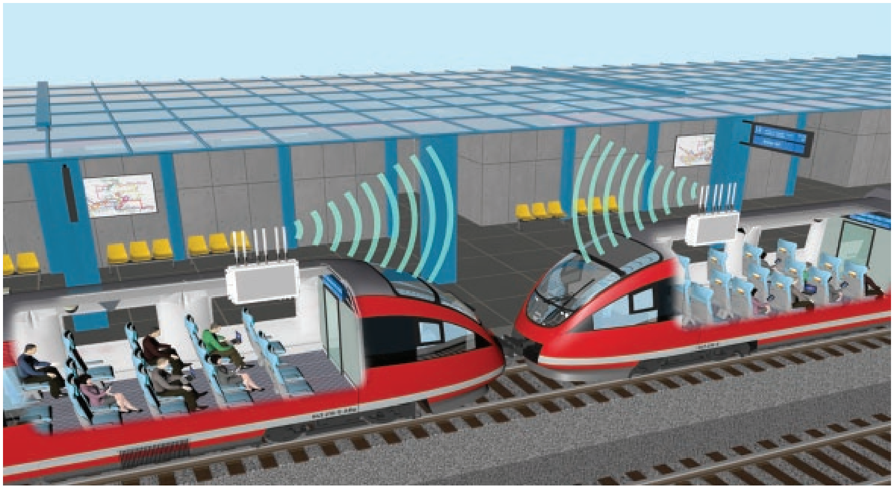

Figure 3: Wireless Connectivity between Coaches

Using wireless technology for the connection between Carriages overcomes the problem of connectivity, but one of the challenges of using wireless connectivity is how to avoid incorrect connections between access points. Hirschmann has designed a unique solution to this problem using more IEC 50155 and EN 45545-2 certified products: the Hirschmann BAT450-F and Open BAT-F wireless router and access points.

The Hirschmann coach-to-coach (C2C) functionality automatically connects the two correct access points via a point-to-point (P2P) link, thus avoiding the need for a wired serial link between the two WLAN devices. In addition to the standard automatic mode, a serial link interface has been implemented to allow an on-board Train Management System to trigger the access point to search and discover the correct P2P partner. Since each Hirschmann wireless device is capable of supporting two wireless connections, they can be deployed to achieve Ethernet backbone functionality between Carriages and between Consists.

Using the Hirschmann wireless C2C functionality allows Carriage and Consist upgrades to be achieved in a more cost effective manner and connectivity between in-service Consists to be achieved risk free.

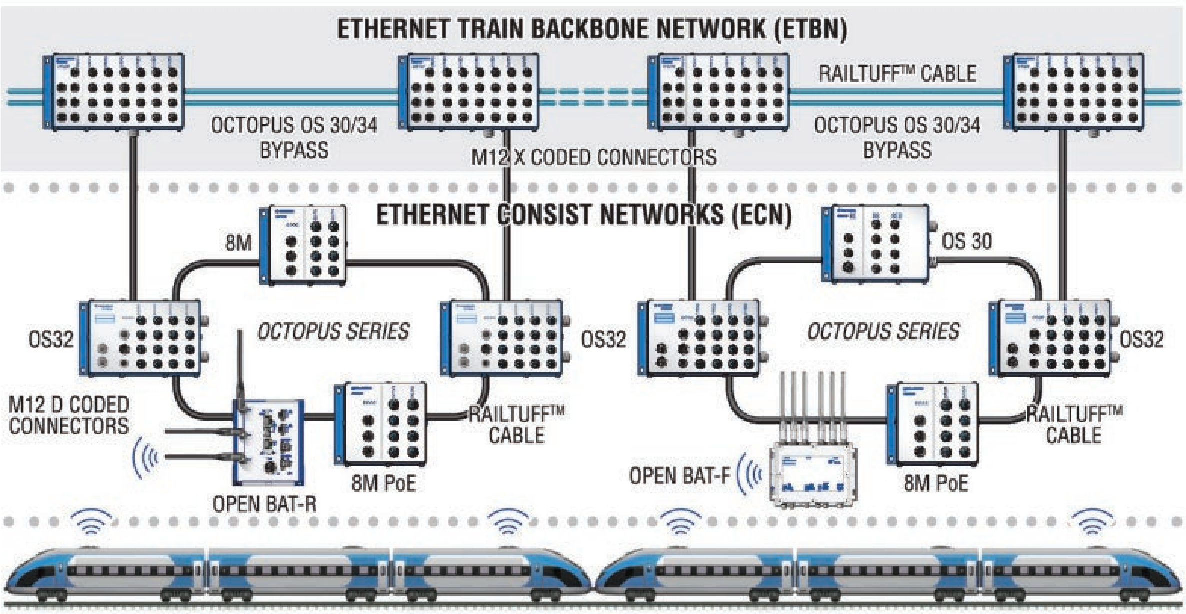

Figure 4: Ethernet Train Backbone Network

IEC 61375 Ethernet Train Backbone Node (ETBN) functionality

The objective of the IEC 61375 standards is to specify a Train Communications Network that can be used by multiple types of equipment and applications along the whole length of a train, with Ethernet being one of the technologies defined.

The Train Communications Network (TCN) runs along the whole length of the train and is referred to as an Ethernet Train Backbone (ETB), the interface between this Ethernet backbone and local (within Carriages or sets of Carriages) networks is via a new device (product) called an Ethernet Train Backbone Node (ETBN).

The standards go further than specifying hardware and a simple transport layer; they define a set of communication protocols that have the objective of making sure that the ETBNs operate together and provide some intelligence to the TCN – such as working out which ETBNs are active and where the front of the train is for example. Within these standards, there are some definitions that relate to the physical make-up of trains:

Train: a composition of one or more Consists that can be operated as an autonomous unit (containing motors and at least one driver's cab)

Consist: a train set, rake of coaches, single vehicle or group of vehicles that are not separated during normal operation, that can contain no, one or several Consist Networks; for example, the vehicles of a Consist are permanently connected together in a workshop, automatic couplers are mounted at both ends of the Consist to facilitate the coupling and de-coupling of complete Consists during operation

Train Communication Network (TCN): a data communication network for connecting electronic equipment on board rail vehicles

Train Backbone: a bus that connects the vehicles in a train and conforms to the Train Communications Network protocols

Train Backbone Node: a device that is connected to the Train Backbone; a Train Backbone Node connects Consist Networks to the Train Backbone; an Ethernet-based TBN is termed as an ETBN (Ethernet Train Backbone Node)

How these various elements of the IEC 61375 standard come together can be seen in Figure 4.

Hirschmann is a key member of the IEC working group responsible for the IEC 61375 series of standards. Through our contributions to this multi-national group, we have been instrumental in formulating this industry-wide on-board rolling stock communications standard. This group continues to drive the development and standardisation of vehicle-based broadband communications technology by maintaining the IEC 61375 standard.

As a long-standing member of the working group, we have been party to early drafts of the standard. But unlike some of our competitors, we have not rushed to implement the functionality. Instead, we have waited and implemented the final agreed functionality and have also reviewed and updated the hardware platform for our ETBN switch implementation within our OCTOPUS product range. We believe that the advantages of this measured approach will become quickly apparent in the market:

- IEC 61375 qualified hardware and software that are future-proofed provide the highest level of reliability and robustness required by the railway industry
- Running ETBN functionality at full Ethernet line switching speeds
- Double switched backbone lines protected by a bypass relay ensure high levels of fault tolerance in the case of a power failure
- Routing and address translation rules (NAT) for multiple Consist networks interconnections are automatically defined during train inauguration
- Meets market-specific regulations, including EN 50155 for operating conditions in railway vehicles, EN 50121-4 for use on railway lines and EN 45545 for fire protection in trains
- The PoE+ capabilities reduce cabling, saving both space and associated costs
- Port count up to 28, fibre or copper port options

Products for Effective Ethernet Train Backbone Implementation

	OpenBAT-F	The OpenBAT-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 wireless communication.
	BAT450-F	The BAT450-F industrial wireless LAN access point family features multiple interface configurations and connection options. With its ruggedised, compact design and high IP rating this product can be installed almost anywhere, both on-board rolling stock and along the trackside.
	OCTOPUS OS30	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 on-board 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.
	Railway Gigabit Data Cable	Meeting or exceeding the highest railway industry standards, this highly specialised Gigabit Ethernet data cable reliably delivers real time information for operators and passengers, on-board as well as in terminals and control rooms. Moreover it is fully compliant with the high standards for safety, fire performance, quality and reliability.
	M12 Gigabit Connector	The M12 Gigabit connectors are designed for use in transportation systems in rolling stocks – in accordance with Europe's stringent DIN EN requirements – where vibration and inflammability pose constant challenges to the consistency of transportation systems, which is an absolute must for the safety of the people traveling.

Figure 5: Products for Effective Ethernet Train Backbone Implementation

Summary

Rail travel is enjoying a renaissance, but the challenges facing operators have never been greater. Ethernet and IP technology is becoming the standardised solution for on-board data networks and with more applications aimed at increasing safety, capacity and passenger engagement. That means bandwidth requirements continue to increase.

The challenges of deploying an Ethernet network over a dynamic train topology can be overcome through the use of products and solutions specifically designed for this environment. New standards will continue to be issued as technology and innovation become more deeply embedded in the rail transport industry. Choosing a partner who is involved with the inception of these standards will become increasingly important.

References

1. World urbanisation Prospects. Published by the United Nations. Revised 2014
2. White Paper Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system. European Commission, Published 2011
3. IEC 61375 Standard - Electric Railway Equipment - Train Communication
4. IEC 50155 Standard - Railway applications - Electronic equipment used on rolling stock
5. EN 45545-2 Standard - Railway applications - Fire protection on railway vehicles - Part 2: Requirements for fire behaviour of materials and components