The Future of Railway Wireless Networks: What You Need to Know

In many ways the technologies underlying train communications systems have advanced little in the time since the first modern rail systems were established 200 years ago. Many rail networks still use basic “Mark I eyeball” visual signaling systems that would not be unfamiliar to a locomotive operator from the 1800s. However, new wireless data technologies now make it possible to create train communications systems that are as advanced as the electric, maglev, and hydrail locomotives that are powering the train systems of the future.

The New Demands on Railway Communications Systems

To meet modern needs, train communications systems must improve in three key areas: bandwidth, response time, and reliability.

According to urban legend, when audiences unaccustomed to movies first saw a “moving picture” of a train pulling into a station, they panicked and ran in terror to get out of the way of the oncoming train. Driven by changing market expectations and advancing technologies, train communications technology is in the midst of undergoing a similar transition. Though the changes may not be as dramatic as the shift from static to moving pictures, industry professionals must be prepared to meet these new challenges or risk being caught equally unprepared by new realities.

Put simply, train communications systems now must do *more*. The railway applications of today, tomorrow, and beyond demand *more* bandwidth, *more* real-time response time, and *more* reliability from their communications networks—whether they be intra-train, train-to-ground, or trackside networks.

Telephony, data, and passenger infotainment systems are all bandwidth-hungry applications that tax the limits of existing networks.

Bandwidth: The contemporary traveler expects a higher level of convenience, safety, and service. To fulfill these high expectations train operators now use telephony and data systems for real-time surveillance and modern passenger infotainment systems to deliver rich entertainment and information content to passengers, including news, weather, games, and even Internet access. Naturally, all of these applications need enough bandwidth. In addition, with enough bandwidth it becomes possible to consolidate voice, video, and other operational data on one train control network, dramatically simplifying operations and maintenance.

As CBTC takes over from human operators, fast response time becomes central to smooth operations.

Response Time: The old-fashioned method of train control relied on human operators who were given directions through some combination of radio, visual signals, and track circuits. This method had a slow response time, and for safety reasons tracks were divided into long "segments" or "blocks," with only one train allowed on a block at a time to prevent catastrophes.

The introduction of Communication-based Train Control (CBTC) technology improved the efficiency of train operations by allowing operators to reduce the length of the blocks without compromising safety. However, the efficacy of a CBTC system is highly contingent on the communications response time. A system with a long response time is cumbersome to use and provides little improvement over legacy communications systems, while with real-time response time the CBTC can safely and efficiently maximize the number of trains on the track at once.

The more train operators rely on their communications networks, the more reliable those networks need to become.

Reliability in a Harsh Environment: As operators take advantage of the new capabilities of advanced train communications systems, more and more train systems depend on reliable communications. Next-generation communications systems need to be reliable enough to shoulder these new responsibilities. In particular, communications must be sufficiently resilient to overcome the unique hazards of rolling stock operations: weather, shock, vibration, and electromagnetic interference. The EN50155 and EN50121-1/2 standards are useful benchmarks for confirming that the communications devices are sufficiently robust for onboard and trackside applications, respectively.

WLAN Is the Answer

WLAN offers an optimal combination of bandwidth and cost-effectiveness for railway operations.

Wireless technology frees operators from the limitations and complications of cabling a communications system, which is a particularly arduous task in an application with as many moving parts as a train system. Of all currently available wireless technology solutions, WLAN stands out as the solution with the best balance of capabilities and cost:

	Satellite	**Cellular**	**WLAN**
Max Data Rate.	20 Mbps down/384 Kbps up	7.2 Mbps down/384 Kbps up	**54 Mbps down / 300 Mbps up**
Throughput	Fair	Poor	**Very Good**
Train Installation Cost	High	Low	**Very Low**
Infrastructure Installation Cost	Very High	High (covered by carrier)	**Low**
Service Charges	Yes	Yes	**No**
Total Cost	Very High	Very High	**Low**
Roaming	None needed, but satellite occlusion blocks coverage in some areas	ISP-dependent	**100 ms or less with fast roaming technologies**
Mobility	**300 kph**	about 150 kph	about 150 kph

WLAN is clearly a superior choice that lets you have your cake and eat it too: it offers the most bandwidth and the lowest total cost. Monthly service charges are a significant continuing expense of satellite and cellular communications. With WLAN, not only are the installation costs low, but there is also no need to pay a satellite or cellular provider for data service. For the final piece of the puzzle, mobility, the development of optimized roaming technology has made WLAN mobile enough to support train to ground communications, even at relatively high cruising speeds.

Benefits of WLAN for Trackside Communications

WLAN eliminates cabling headaches for trackside networks, such as theft, maintenance, and damage.

Trackside networks consist of numerous wayside cabinets that share data up and down a length of track. These networks contribute to the operation of track elements such as axle counters, track switches, cameras, and railroad crossings. In addition, the trackside network provides the access points for a train-to-ground communications network.

Existing trackside networks often rely on cables between wayside cabinets to deliver communications. This fragile cable can become a weak link in the trackside infrastructure, as it can be targeted by vandalism or damaged by the weather. In addition, the valuable metal is a frequent target of thieves, and the many meters of cable needed to support a true trackside network represent a significant ongoing replacement and maintenance cost. Replacing the cables with WLAN units in each wayside cabinet eliminates this vulnerability.

Benefits of WLAN for Intra-Train Communications

Compared to couplers, WLAN has higher throughput and lower maintenance costs.

Train operators are calling upon intra-train networks to support more applications, including passenger information, public announcement, video surveillance, intercom, HVAC, and data-driven train control systems.

Conventional wired intra-train communications relied on couplers between carriages to send data down the line. These couplers would need to be regularly replaced as the constant motion of the carriages wore out the contacts. Even worse, couplers have a fixed bandwidth and limited data rate, which places severe constraints on the upgradeability of an intra-train network. WLAN is a natural fit for intra-train networks that can reduce maintenance costs while increasing throughput to support more applications today and in the future.

Benefits of WLAN for Train-to-Ground Communications

WLAN can comfortably support advanced CBTC and passenger infotainment systems.

As the key link between the trackside network infrastructure and the intra-train network, train-to-ground communications is the lynchpin that enables revolutionary, next-generation railway applications such as rich passenger infotainment systems and Automatic Train Operations (ATO) through CBTC.

These systems simply would not be possible with conventional train-to-ground communications systems. ATO coordinates trains to maximize track utilization and increase the service efficiency and frequency beyond that which is possible without central control. In order to safely do this, the control center must receive and send a dizzying amount of data, including train status, passenger status, video data from cameras, and emergency controls. In addition, the Passenger Infotainment System must transfer real-time video, ads, news content, and more. 10 Mbps (or greater) is a reasonable estimate of how much throughput is needed to sustain these next-generation applications.

Clearly, the sheer magnitude of throughput required is far beyond the capabilities of radio, a technology from the 1950's which is able to transmit only a trickle of data. This level of demand even strains the capacity of modern satellite and cellular data technology such as GSM and HSDPA. The IEEE 802.11 WLAN standard can transfer up to 300 Mbits of data to comfortably enable all the applications envisioned today, with plenty of throughput left over for applications of the future.

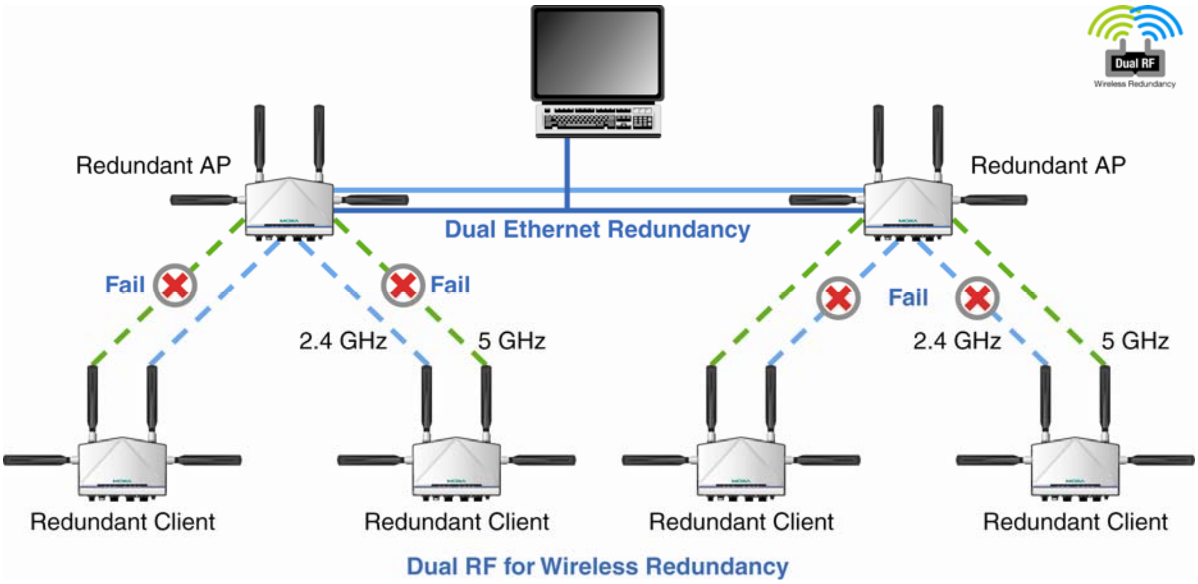
Unique Challenges of Train-to-Ground Communications

WLAN can draw from a large toolbox of different antenna strategies to accommodate different environmental challenges.

A reliable and capable train-to-ground communications link is the foundation of many valuable next-generation train systems, but creating such a link can seem like a daunting task. How is it possible to maintain a consistent, uninterrupted link between fixed trackside access points and a quickly moving train that traverses many different operating environments? Luckily, WLAN technology has a large toolbox of solutions.

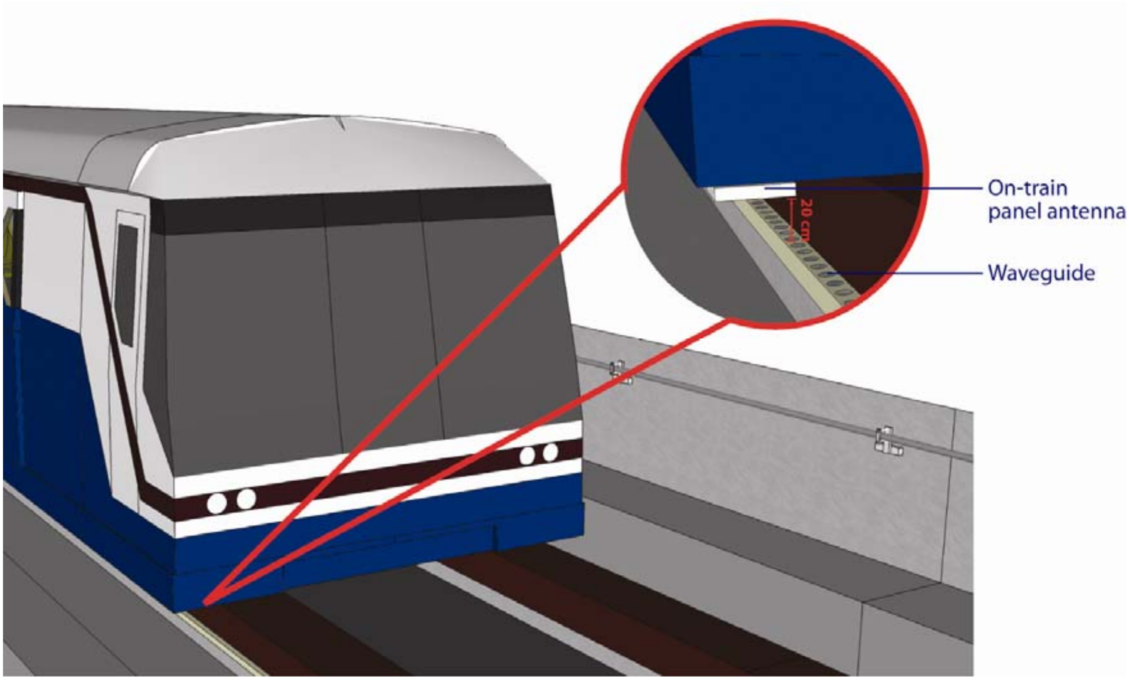
Train tunnels are a clear environment with limited interference. Antennas are a cost-effective coverage solution for this kind of environment. There may be additional complications when the track goes through sharp twists and turns, but simply increasing the AP density will ensure continued wireless coverage in this environment.

There is far more interference aboveground, especially in busy urban areas. Still, WLANs can use a number of strategies to create networks that remain reliable in these conditions. Rugged outdoor wireless APs with fast roaming and dual RF redundancy are well-suited for meeting this scenario, especially when deployed with high AP density.

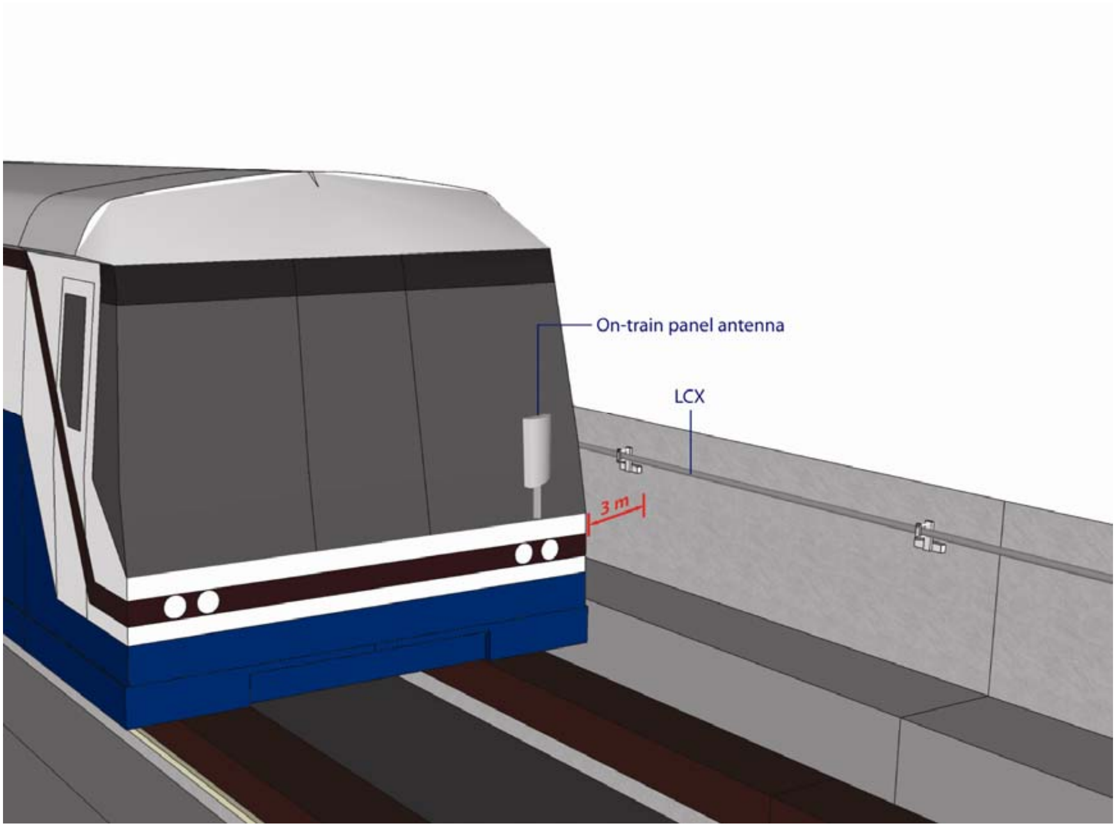


Concurrent Redundant Wireless Connections

For truly exceptional operating environments, waveguides or leaky (or leakage) coaxial cables (LCX) provide an even more secure link between client and access point, albeit at increased cost. A track lined with waveguides or LCX cables offers wireless clients very stable, interference-proof access.



Wave guides: the antenna will remain within 20 cm of the waveguide strip on the ground



LCX lines: the antenna will remain within 3 m of the LCX line