The Future of Railway Wireless Communications Networks

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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.

New Demands on Railway Communications

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.

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

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

**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.

**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.

**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 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:

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

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

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

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

Challenges of Train-to-Ground Communications

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.

For truly exceptional operating environments, waveguides or leaky (or leakage) coaxial (LCX) cables 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 a very stable, interference-proof access.

1 To learn how concurrent dual RF redundancy overcomes wireless collisions, weak signals, and environmental interference, see the "Using Redundant Wireless for Reliable Industrial Automation" white paper: www.moxa.com/support/request_catalog_detail.aspx?r_id=2445
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.
The Railway Networks of Today and Tomorrow

Moxa offers a complete suite of communications solutions that includes Ethernet switches and IP cameras with EN50155 and EN50121-1/2 certification to confirm their resilience in harsh railway environments, and the rugged wireless devices to bring it all together. The AWK-6222 outdoors wireless AP/bridge/client features fast Turbo Roaming technology as well as the dependability provided by dual independent RF modules, power redundancy, and a weatherproof, dustproof, wide operating temperature design.

These highly rugged features and turbo roaming technology provide railway operators with the perfect formula for seemingly formidable railway applications. With two AWK-6222 units at each wayside cabinet, a railway can replace trackside cabling and its attendant maintenance headaches with dual redundant RF links. The AWK-6222 units connect to a solar-powered Moxa Power-over-Ethernet (POE) switch that supports an IP camera and a third wireless device, an AWK-4121, acting as a local wireless AP. As is, this system can give station staff out in the field convenient wireless access to system maintenance tools. These advanced, rugged components can also provide the foundation for a future train communications network with the addition of even more advanced wireless technology, complete with fast train-to-ground WLAN communications.
Future Rail Networks Can Be Built Today

The future of railway communications is coming, and operators need to be ready. Moxa offers a full suite of industrial WLAN products with fast Turbo Roaming, wide operating temperature, weatherproofing, dual RF redundancy, as well EN50155 and EN50121-1/2 certifications to build future-proof systems that possess the bandwidth, response time, and reliability required for railway applications.

See how railway operators are already taking advantage of Moxa’s products or request pricing information at www.moxa.com/event/vertical_markets/railway. US customers can quickly and conveniently obtain evaluation units with our Moxa Online ordering service, available at store.moxa.com.