LTE FOR METRO RAILWAY OPERATIONS

UNLOCKING NEW OPPORUNITIES TO OPTIMIZE RAILWAY OPERATIONS WITH LTE-BASED TRAIN-TO-WAYSIDE COMMUNCATIONS TECHNOLOGY

TECHNOLOGY WHITE PAPER

The mobile broadband technology — Long-Term Evolution (LTE) is ready for large-scale commercial deployment in the public telecommunications network. LTE has generated immense interest in industries because of its ability to support new applications that demand resilience or high-bandwidth real-time capabilities in the data network infrastructure. The railway industry is particularly interested in LTE because it offers an unparalleled ability to consolidate the delivery of multi-service traffic. This traffic is currently delivered through an array of fragmented legacy wireless networks.

This white paper examines the following topics:

- The value proposition of LTE as a means to support next-generation train-to-wayside communications (TWC) for urban train operations
- The challenges involved in adopting LTE technology
- How the Alcatel-Lucent LTE-based TWC solution meets the requirements for next-generation TWC
- Strategies for overcoming the challenges involved in adopting LTE

TABLE OF CONTENTS

INTRODUCTION / 1

CHALLENGES PRESENTED BY THE CURRENT TWC INFRASTRUCTURE / 1

Technology view / 1

DRIVERS AND REQUIREMENTS FOR NEXT-GENERATION TWC SOLUTIONS / 2

Improving mission-critical class reliability / 2

Securing train operations / 3

Lowering OPEX / 3

Enhancing the passenger experience / 3

Streamlining application and service introduction / 4

ALCATEL-LUCENT LTE-BASED TWC SOLUTION FOR RAILWAY OPERATIONS / 4

Why LTE? / 4

Why Alcatel-Lucent? / 5

Components of the Alcatel-Lucent LTE TWC Solution / 5

OVERCOMING BARRIERS TO SECURING LTE SPECTRUM / 7

CONCLUSION / 8

ACRONYMS / 9

CONTACTS / 10

INTRODUCTION

Over the last decade, the rail industry has begun to abandon analog communication systems and in-track cable, adopting TETRA or other proprietary digital technologies to provide communications support for metro train operations. The existing technologies have served their purpose for the rail industry, but their architecture is largely restricted to the pre-Internet Protocol (IP) era.

The rail industry, and specifically the metro operator segment, has also begun to embrace Wireless LAN (WLAN)-based networks or WLAN-like networks that include proprietary tweaks inspired by support for CBTC GoA 3 Driverless Train Operation (DTO) and GoA 4 Unattended Train Operation (UTO). These new capabilities promise more efficiency in railway network capacity but demand new supporting systems such as on-board closed circuit television (CCTV).

However, WLAN deployments are typically limited to carrying either mission-critical CBTC traffic or non-mission critical traffic such as CCTV and passenger information systems (PIS). Most deployments are incapable of carrying both types of traffic. These deployments are limited by factors such as a lack of sophisticated QoS in WiFi-based COTS products and the use of license-free bands.

Innovations or optimizations to TWC often call for the addition of a layer of new wireless network on top of a highly complex existing infrastructure. This process creates a silo-like architecture in which multiple wireless networks are each rigidly and tightly coupled with an application. — for example, TETRA for voice and data dispatch services and proprietary WLAN-based or WLAN-like networks for mission-critical CBTC traffic or CCTV (but usually not both). The use of silo-like infrastructures has an accumulative effect on support and maintenance efforts. What's more, these infrastructures do not necessarily support IP-based service natively. It can be costly, if not impossible, to integrate them with new application services.

Alcatel-Lucent appreciates the challenges and constraints a metro operator may need to overcome when embracing new TWC technologies, such as securing an allocation of licensed spectrum. This white paper explores these challenges and provides deployment strategies that can be used to address them.

CHALLENGES PRESENTED BY THE CURRENT TWC INFRASTRUCTURE

Technology view

To date, the limitations of legacy technologies have made it impossible to consolidate fragmented TWC infrastructures.

For example, TETRA, typically used for private mobile radio (PMR) voice operations, supports only narrowband data services. Its sibling, TETRA Enhanced Data Service (TEDS) technology, provides moderate improvement (< 100 kbps range) but still falls well short of addressing the demands presented by the array of metro operations applications. These technologies are sufficient for current CBTC and PMR applications but will not provide adequate support for future railway operations.

Over the last few years, many railway operators have included WiMAX in their TWC deployments, primarily as a means to deliver best-effort passenger Internet service. WiMAX has gained traction in the railway environment. However, the technology — in particular, the 802.16m standard with mobility support — is being made obsolete by LTE, which is backed up by a far stronger market ecosystem.

WLAN-based and WLAN-like technologies provide broadband data capabilities that can be used to deliver the most demanding train operation traffic. For example, these technologies can be used to support CCTV or deliver of multiple types of non-mission critical application traffic.

WLAN-based technologies can incorporate some features of the 802.11e standard. For example, the use of traffic prioritization and marking features allows for the differentiation of traffic by QoS class. It also offers partial support for allowing highly important traffic to preempt lower-ranked traffic. However, WLAN-based technologies lack comprehensive QoS features, such as end-to-end resource management, traffic admission and traffic policy enforcement capabilities. This limits their potential to support a multi-service delivery network in a mission-critical environment.

This limitation implies that a WLAN-based TWC solution cannot be trusted to support mission-critical traffic under degraded network conditions. Because of these deficiencies, the WLAN-based solutions deployed to date have been customized to deliver either mission-critical, low-capacity CBTC traffic or non-mission-critical high-capacity traffic — but not both.

Although WLAN capabilities will increase through 802.11ac and beyond, issues in key areas like security and prioritization will continue to affect critical infrastructure operations. The implementation of WLAN handover capabilities will likely continue to be proprietary in nature. This will limit the possibility of supporting multivendor user equipment (UE).

DRIVERS AND REQUIREMENTS FOR NEXT-GENERATION TWC SOLUTIONS

This section identifies five business drivers that reflect a general view of the demand for next-generation TWC solutions within the metro railway industry:

1. Increasing mission-critical class reliability
2. Securing train operations
3. Lowering OPEX
4. Enhancing the passenger experience
5. Streamlining application and service introduction

This section also describes the enabling applications associated with each driver to demonstrate the driver’s dependency on the TWC network capabilities.

Improving mission-critical class reliability

In a next-generation TWC network, the mission-critical class reliability target is primarily driven by the requirements of the CBTC system. To a certain extent, the target is also driven by operational voice services such as intercom and PMR.

A CBTC system demands stringent availability. It typically tolerates a communication loss of no more than a few seconds. The actual tolerance duration depends on the CBTC system's implementation and failure scenarios.

Operational voice services are considered to be mission-critical applications. They play a key role in maintaining security and sustaining train operations in manual contingency mode in case of a failure of the CBTC system. Despite their mission-critical role, voice services typically have a higher tolerance for communication loss than the CBTC system does. For example, voice services can tolerate a momentary service loss caused by a failover.

Until recently, the CBTC and operational voice services were most often supported on separate networks. The inspiration for consolidating both mission-critical services onto the next-generation TWC network is to aggregate their reliability requirements.

Securing train operations

On-board CCTV and operational voice services are TWC applications that can help secure train operations. The on-board CCTV infrastructure provides support for new analytics applications that offer enhanced security management capabilities.

Both services require real-time data delivery within the TWC network to prevent buffering in video delivery and ensure good voice quality.

The on-board CCTV service requires high uplink throughput, while the platform CCTV service requires high downlink throughput. Due to the intrinsic nature of a mobile network, the uplink spectral efficiency is typically lower than the downlink spectral efficiency. Of all types of application traffic relating to train operations, CCTV traffic is probably the most dominant in a capacity budget. For example, the loss of platform CCTV service could prompt a fallback to manual inspection of door closure procedures. This, in turn, could cause departure delays.

Lowering OPEX

All steps taken to optimize the efficiency of train operations are measured against process simplification and operating cost reduction. Optimization can be achieved in two ways:

1. By introducing new applications and services that automate or simplify current operating processes (for example, CBTC, real-time train monitoring and remote diagnosis)
2. By consolidating fragmented TWC networks with a unified TWC architecture that is capable of supporting multiple services

Enhancing the passenger experience

Passenger information and multimedia entertainment applications are common examples of applications that could enhance the passenger experience. For instance, passenger information applications can provide route information, weather forecasts or the time of day. Entertainment applications can provide video streaming with buffering.

This type of "infotainment" traffic is typically of low-end priority. It may consume a low to moderate amount of network capacity. The tolerance for network latency is also considered high with this type of traffic.

However, passenger Internet service could eventually become the single highest contributor to the traffic profile. Support for on-board passenger Internet service will be discussed in a separate white paper.

Streamlining application and service introduction

In the traditional metro railway environment, many services are implemented in a non-IP environment and tightly coupled with the communication network. For example, the network may include a TETRA system that supports voice- and circuit-switched data services. The introduction of new applications is difficult, costly and sometimes impossible in this type of network environment.

Wireless packet data technologies like WLAN and LTE are based on all-IP architectures, and provide native IP-based service support. Integration with IP-based applications should be relatively simple and straightforward. For example, there should be no need for the gateway function to harmonize the differences between the network service interface and the application interface.

As discussed previously, the next-generation TWC network should support sophisticated QoS capabilities. These capabilities should logically segregate traffic from various QoS classes to ensure appropriate resource contention and provide assured protection for high-priority traffic. This segregation will alleviate the integration risk when new application traffic is introduced to a live network.

ALCATEL-LUCENT LTE-BASED TWC SOLUTION FOR RAILWAY OPERATIONS

Next-generation communication network technologies like LTE will transform the current ICT infrastructure for train-to-wayside communications (TWC). This transformation will lead to new operational service capabilities and improved operational efficiency.

Why LTE?

The key value propositions of LTE are summarized below:

1. With a user-plane latency as low as 10ms LTE supports a more capable CBTC system, leading to higher efficiency in train operation.
2. Sophisticated QoS built into LTE guaranteed delivery of critical traffic over a multi-service network, leading to OPEX reduction.
3. The all-IP architecture and superior broadband capacity performance of LTE opens up the possibility of supporting new kinds of operational or infotainment services and lowers the integration barrier.
4. As the leading-edge mainstream mobility technology, LTE offers a platform for future evolution and growth. Its strong ecosystem support will deliver the best possible performance–value ratio in the long term.
5. LTE is a commercial off-the-shelf solution (COTS). It does not need to be modified to meet the stringent requirements for carrying mission-critical services.
6. Despite its status as the newest of the 3GPP standards, LTE's evolutionary nature shares the benefits of many of the proven mobility technologies and architectural concepts defined in preceding standards. A January 2013 LTE market summary by the Global Mobile Suppliers Association (GSA) projected that 234 commercial LTE networks would be in place in 83 countries by the end of 2013.[*]

* "Evolution to LTE Report."Global Mobile Suppliers Association (GSA), January 2013. http://www.gsacom.com/downloads/pdf/GSA_update_LTE_developments_worldwide_050213.php4

Why Alcatel-Lucent?

Alcatel-Lucent is a leading end-to-end LTE solution vendor. It offers one of the industry's most complete LTE product portfolios. The Alcatel-Lucent LTE portfolio encompasses the radio access network, the core network, applications, and network and device management.

Backed by the renowned Bell Laboratories, Alcatel-Lucent is also pioneering a groundbreaking wireless technology called lightRadio®, which promises a higher performance wireless network at an up to 50% lower total cost of ownership.

The IP backhaul also plays an important role in LTE deployment. Alcatel-Lucent is one of the market leaders in the carrier service switch market.

An experienced partner for tunnel and metro railway environments

Alcatel-Lucent has in-depth experience in providing communications solutions for tunnels and metro railways. The company understands the challenges presented by harsh tunnel environments.

Alcatel-Lucent's previous railway and tunnel experiences include:

1. Eurotunnel, the longest undersea tunnel in the world. Alcatel-Lucent was the lead integrator for deploying the tunnel's radio propagation infrastructure.
2. Gotthard Base Tunnel, the longest rail tunnel in the world, set to open in 2016. Alcatel-Lucent was the lead integrator for deploying the tunnel's propagation infrastructure.

Alcatel-Lucent also has proven experience in serving industrial, public sector and government needs. In particular, it continues to serve the needs of railways and metro operators, supporting more than 80 customers worldwide, including RATP, Network Rail and Shanghai Metro.

Components of the Alcatel-Lucent LTE TWC Solution

Shown in Figure 1, the Alcatel-Lucent LTE TWC Solution encompasses the distributed 9914 eNodeB architecture, the wireless packet core, over-the-top mission-critical service entities, and network management and diagnostics tools.

Distributed eNodeB architecture

The distributed 9914 Evolved Node B (eNodeB) architecture is composed of the Remote Radio Head (RRH) and the 9922 Baseband Unit (BBU). The lightweight RRH is normally mounted on the telecom mast with an X-pol macro antenna. The BBU is centralized in the telecom room of a station along with the IP/MPLS equipment.

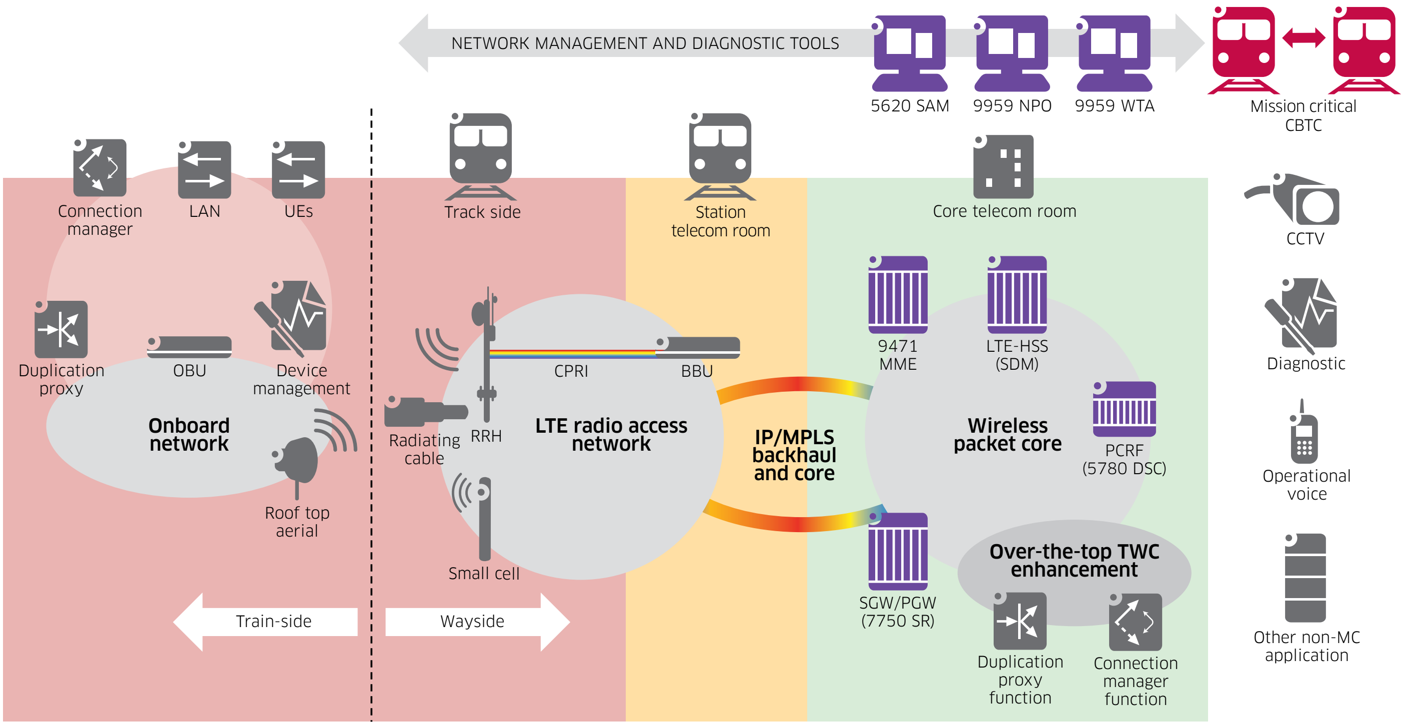
The Common Public Radio Interface (CPRI) link is a fiber link that connects the RRH and BBU. It has a reach of up to several kilometers, depending on the air interface configuration.

The distributed eNodeB (rather than the conventional integrated eNodeB) architecture is recommended because it minimizes the amount of equipment (only the RRH) installed outdoors. This architecture simplifies access procedures and reduces the number of components that are subject to stringent railway environmental compliance regulations.

Radiating cable or free-range radiating antenna may be supported in the tunnel environment.

Note: The RAN architecture is determined based on customer requirements. Alcatel-Lucent can provide RAN options that address each operator's unique needs.

Figure 1. Overview of the Alcatel-Lucent LTE-based TWC solution



Small cell solutions for future railway applications

A small cell solution differs from the traditional macro cell architecture because it offers lower radio power (< 5 W) output that results in smaller cell coverage. It can also integrate the baseband processing unit (BBU) and radio amplifier component within a single unit that is small in dimension (< 20 L) and light enough (< 20 kg) for a single installer to handle. Gigabit Ethernet backhaul is supported by way of a built-in BBU.

Another small cell differentiator is the ability to support self-organizing network (SON) capabilities. These capabilities greatly simplify radio commissioning compared to macro cell commissioning, which traditionally requires highly skilled radio planners and drive testing. With small cell deployments, an installer can be sent to the field, and commissioning can be managed remotely. This could significantly reduce commissioning time and limit disruption of train services.

The commercial deployment of small cells has already begun in public mobile networks. Alcatel-Lucent is currently exploring the feasibility of applying the small cell architecture to the metro railway environment.

Wireless packet core

The wireless packet core includes the 3GPP Evolved Packet Core (EPC) components. It is composed of:

- 9471 Mobility Management Entity (MME), which supports LTE control-plane mobility management and connection management functions
- 7750SR Serving Gateway (SGW) and Packet Data Network Gateway (PGW), which supports user-plane session management functions
- 5620 Subscriber Data Manager (SDM), which hosts the LTE-Home Subscriber Server (LTE-HSS) function. The LTE-HSS function supports the subscriber (UE) data profile database, UE authentication and authorization, and the UE location database.

- 5780 Dynamic Service Controller (DSC), which provides PCRF support for network-wide flow control. Managing millions of service data flows, it supports detection, gating, QoS and flow-based charging, and authorizes the use of QoS resources across the network.

Mission-critical service enhancement entities

The Alcatel-Lucent LTE solution incorporates complementary "over-the-top" mission-critical service enhancement entities, including a packet duplication and filtering proxy function and connection management capabilities.

Network management and diagnostics tools

The LTE RAN and wireless packet core are managed end to end by the Alcatel-Lucent 5620 Service Aware Manager (SAM). The SAM provides element, network and service-aware management capabilities for all Alcatel-Lucent products encompassed by the LTE solution while expanding its management capabilities to the underlying backhaul and transport networks.

The 9958 Wireless Trace Analyzer (WTA) supports the troubleshooting of specific subscriber problems with detailed end-to-end call analysis.

The 9959 Network Performance Optimizer (NPO) simplifies the monitoring and accelerates the optimization of radio performance by storing, post-processing and analyzing vast amounts of measurement data provided by the E2E LTE network elements.

OVERCOMING BARRIERS TO SECURING LTE SPECTRUM

Despite many promising benefits of LTE, a key prerequisite for adopting LTE in railway environments is to secure the necessary licensed spectrum.

The demand for LTE spectrum by the public mobile telecom industry is very high. As a result, the expectation is that it would be very difficult for a railway operator to compete with the mobile network operators to secure "sweet spot" frequency bands such as the 800 MHz–2.6 GHz bands.

Alcatel-Lucent believes that a number of options are available for consideration by metro railway operators. For example:

- A metro operator could use LTE 400 MHz, which provides alternative spectrum that can carry mission-critical traffic.
- A metro operator could adopt mobile virtual network enabler (MVNE) role in which it:
  - Establishes spectrum partnerships with MNOs for leasing spectrum usage rights for DTP tracks, lines and stations
  - Builds and manages the wireless network to ensure that it meets the key performance indicators (KPI) for railway operations
  - Resells or leases out spare data capacity to MNOs

This strategy establishes cooperation between MNOs and the metro operator. Both sides can share costs, maximize the investment return and avoid the complexity inherent in deploying multiple wireless infrastructures to fulfill similar needs.

CONCLUSION

The new LTE-based TWC solution addresses metro railway operators' key business needs. It consolidates multiple legacy TWC infrastructures while supporting an array of metro railway operation applications with different reliability and QoS requirements, including the ultra-high availability requirements of CBTC.

The versatile TWC solution also provides an environment that enables fast and easy introduction of new applications by leveraging the all-IP based mechanism and its inherent traffic quality protection capabilities.

LTE stands out from other existing wireless technologies because it offers key benefits such as:

- An unparalleled ability to supporting various railway operational applications for metro railway promising potential of reducing network operating cost, and paving path to potential passenger services
- A sophisticated end-to-end QoS architecture and coherent application-layer QoS control, which enables efficient management of precious air interface resources while allowing a defined level of application service quality
- Off-the-shelf standard technology that requires no modification, and that is supported by a well-developed and still-growing ecosystem

To overcome the difficulty of securing spectrum, Alcatel-Lucent recommends that metro operators consider other possibilities, such as LTE 400MHz, forming partnerships with mobile network operators for pursuing spectrum sharing strategies, and deploying a hybrid LTE/WLAN TWC solution.

ACRONYMS

AF	application function
AMBR	aggregate maximum bit rate
APN	access point name
ARP	allocation and retention priority
ATO	Automated Train Operation
BBU	baseband unit
CBTC	communications-based train control
CCTV	closed-circuit television
COTS	commercial off-the-shelf
CPRI	Common Public Radio Interface
DAS	distributed antenna systems
DL	downlink
DPI	Deep Packet Inspection
DSCP	Differentiated Services Code Point
DTO	driverless train operation
EPC	Evolved Packet Core
EPS	Evolved Packet System
eNodeB	Evolved Node B
E-UTRAN	Evolved Universal Terrestrial Radio Access Network
FDD	frequency-division duplexing
GBR	guaranteed bit rate
GoA	Grade of Automation
HARQ	hybrid automatic retransmission request
HSS	Home Subscriber Server
IP	Internet Protocol
LAN	local area network
LTE	Long Term Evolution
MBR	maximum bit rate
MC	mission critical
MIME	multiple-input multiple-output
MME	Mobility Management Entity
MTBF	mean time between failures
NPO	Network Performance Optimizer
OBU	on-board unit
OFDM	orthagonal frequency-division multiplexing
OSS	operations support systems
PCC	policy control and charging
PDN	packet data network
PCEF	Policy and Charging Enforcement Function
PCRF	Policy and Charging Rules Function
PGW	PDN Gateway
PMR	private mobile radio
PS	packet switched
QCI	QoS class identifier
QoS	quality of service
RRH	remote radio head
SAM	Service Aware Manager
SAE	System Architecture Evolution
SGW	Serving Gateway
SON	self-organizing network
SPOF	single point of failure
TDD	time-division duplexing
TEDS	TETRA Enhanced Data Service
TETRA	Terrestrial Trunked Radio
TP	throughput
TWC	Train-to-Wayside Communication
UL	uplink
UTO	unattended train operation
V+D	voice plus data
VoIP	Voice over IP
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	wireless LAN (WiFi)
WTA	Wireless Trace Analyzer

CONTACTS

Technical contacts

Henry Chor, Solution Architect, Strategic Industry Department – Transportation
(henry.chor@alcatel-lucent.com, +44 7973 234575)
Yves Vidal, Solution Architect, Strategic Industry Department – Transportation
(yvidal@alcatel-lucent.com, +33 1 3077 9614)

Commercial contact

Emanuele Di Liberto, Business Development Manager, Strategic Industry Department – Transportation
(ediliber@alcatel-lucent.com, +39 06

Alcatel·Lucent