Connectivity in Motion

The Most Scalable and Reliable Connected Transportation on the Planet

641 River Oaks Parkway, San Jose, CA 95134

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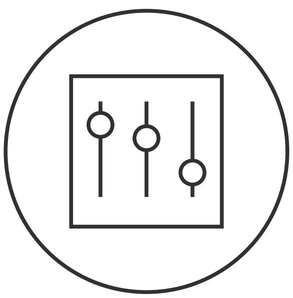
Executive Summary

People have become accustomed to having Internet access from any device, at any time, from anywhere —at home, at the office, in public areas and most recently while on the move. That is why we are seeing a growing number of commercial, private and corporate transportation services offering (mostly) free Internet services. In addition, with global warming gaining more attention and traffic and pollution getting worse every day, it is environmentally and politically advantageous to stimulate commuters and travelers to leave their car at home and switch to public and/or shared corporate transportation. As passengers increasingly desire to use their travel time to work or be entertained, high bandwidth Internet has become a default expectation. While train and bus operators are pressured to offer the service for free to grow and retain ridership, the current offerings are falling well short of expectations.

LILEE SYSTEMS' "Connectivity in Motion" platform provides a compelling business case to give your passengers the broadband connectivity they crave by integrating applications such as video surveillance, infotainment, advertising, passenger experience, and maintenance and operations into a single communications hub that consolidates hardware, software and maintenance.

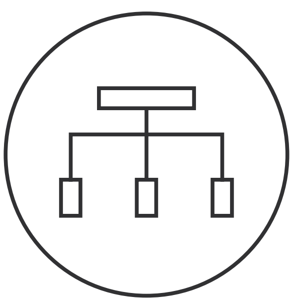
This paper serves two purposes: The first part offers a brief tutorial on how to offer a compelling connected transportation solution to your customers from a business and technological perspective. The second part details how LILEE SYSTEMS' TransAir™ service offering provides a practical way to implement an "Always ON" mobile broadband experience that grows and retains passenger loyalty in addition to offering additional monetization opportunities.



Communications Controller

At the heart of the solution is a cloud-based Communications Controller that manages multiple on-board Communications Servers located on trains, buses or other vehicles, and performs the following critical functions:

- Seamless roaming across cellular, Wi-Fi, trackside radio and future media
- Integrated network management



On-board Communications Server

The on-board Communications Servers can house up to 10 wireless network interfaces (3G, LTE, Wi-Fi, GPS) and/or appliances such as Ethernet switches and application engines and serves as the central communications hub for all passengers and services that require access to the Internet.

Management Software

The Management Software Suite is a web-based service that provides the user interface to all administrative functions running on the Communications Controller to provision, configure, manage and monitor the on-board communications servers.

Introduction

Passenger Wi-Fi in trains and buses is increasingly available, but is often of low quality for a variety of reasons. Current-generation systems are mostly unstable as they are not able to prioritize the complex needs of dynamically managing multiple connections in order to provide a stable and predictable experience similar to the one in the office or at home. LILEE SYSTEMS overcomes this limitation by delivering innovative award-winning solutions that focus on connected transportation, public safety, entertainment, and other applications through hardened, industrial grade systems. LILEE SYSTEMS customers include the world's largest transport operators on all continents.

The patented TransAir system guarantees business quality Wi-Fi, consumer grade video entertainment and other applications with the same reliability "on-the-go" as experienced in the office or at home. Related solutions include closed circuit television (CCTV), automated ticketing, advertising, emergency response, and other solutions.

Originally developed for Positive Train Control (PTC), TransAir is the only solution that simultaneously and seamlessly prioritizes passenger-facing applications, management and operations data, and safety applications, dynamically optimizing network connections to maximize application throughput.
In essence, LILEE SYSTEMS solutions create an "Always ON" mobile broadband experience by merging multiple connections, wireless or wired, into a predictable, stable and manageable network that becomes the default communications hub on buses, trains, and other commercial and emergency response vehicles to enhance safety, security, and the passenger experience.

The Value Proposition

Enabling people to extend their online activities while traveling on a train, bus or other vehicle, LILEE SYSTEMS TransAir gives you the opportunity to monetize high-bandwidth network connectivity on a moving bus or train. Our solution provides benefits to all parties in the value chain:

- The passenger has access to high bandwidth Internet connectivity.
- The crew is able to access more information and perform actions regarding the train, bus, the business or the passengers.
- The train or bus operator and potential service partners have access to information about their passengers, which could be used for marketing purposes. In addition, they will gain valuable real time information relating to the performance of their transportation assets. By integrating Transportation Management Applications that provide predictive analytics they can make "more informed" decisions that better protect the asset value and derive better long- term value.
- The manufacturer or train/bus maintenance company can improve maintenance cycles and improve miles between failures, again through the data intelligence that comes from a connected transportation system.

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The Business Case

Commuters and other travelers have an increased expectation of high bandwidth and always-on connectivity to improve their experience or to drive business efficiencies. Passengers are attracted to, and will form an allegiance to, transportation companies that provide reliable network connectivity. In parts of the world (such as Europe) where the transportation industry is more competitive, we are already witnessing passengers buying tickets on trains and buses that provide the best Wi-Fi service. Also in Europe, governments have recently begun funding the deployment of passenger Wi-Fi on public transportation to stimulate commuters to leave their cars at home and use rail, tram and/or bus to get to work. In North America we see more companies providing corporate shuttle and bus services to increase worker productivity and ease commuter congestion.

While there are a variety of technical models that can provide reliable and consistent connectivity, the biggest challenge is the business model: in an era where Wi-Fi services are cropping up everywhere, people expect it to be free. Yet, installing it on a moving vehicle like a train or a bus obviously has costs associated with it. The deployment on public transportation systems will mostly be driven by a customer loyalty and retention strategy similar to what we saw in the telecommunications industry not so long ago . This is illustrated by Amtrak losing business on the Acela route to Wi-Fi-enabled bus services. Amtrak considered free Wi-Fi essential to recapturing those customers. According to Amtrak, Wi-Fi is the most important technology amenity required by passengers; 89% of those polled said Wi-Fi influenced their decision to choose the Acela service .

However, there is more to the business case than just customer retention. Beyond growing and retaining ridership, train and bus operators can build a business case for Wi-Fi based on consolidating various applications like video surveillance, infotainment, advertising, passenger experience, voice communications for crew and employees, and maintenance and operations. While none of these would typically be enough to justify deploying a wireless network infrastructure, they form an extremely compelling business case when combined.

Once the TransAir network hub is installed to provide broadband Internet access, it becomes he default platform to launch many other services. The attractiveness of these services is what makes the platform sticky, providing value to all the stakeholders and bringing return business. For example, context information such as the status of the bus or rail network, or the current position and desired destination of the traveler can be used to improve the pre-, post- and during-travel experience. Figure 1 illustrates some of the service categories beyond basic Internet access. Beyond improving the passenger experience and building customer loyalty, the technology and applications enabled by the TransAir connected transportation solution can also dramatically improve the operational efficiency for the bus or rail operator as the crew and dispatch center can get access to real-time information that allows them to monitor and improve the performance of the train or bus, better assist passengers, and optimize the business aspects of running a bus or train company.

[1] **"Wi-Fi is a churn reduction strategy" (Peter Bissonette, President, Shaw)**
"The evidence we have so far suggests the correlation between churn reduction and Wi-Fi utilization" (Robert Marcus, President & COO, Time Warner Cable)
[2] **"The Connected Train Comes of Age" (Jim Baker, MuniWireless, June 10, 2010)**

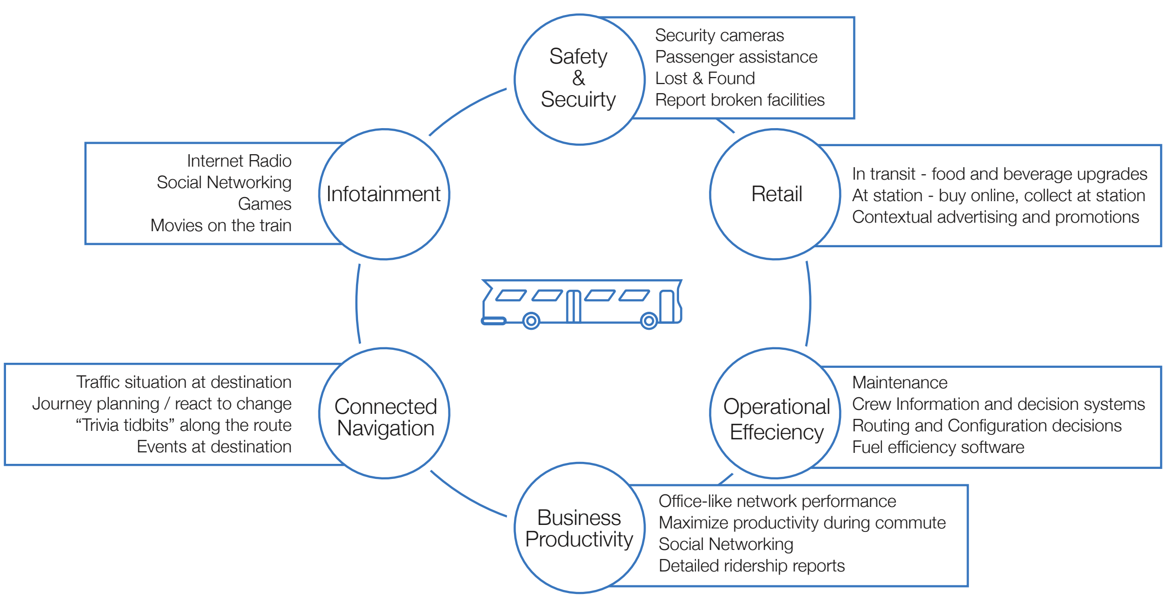


Figure 1: Connected Transportation Passenger Experience Ecosystem

The primary responsibility is always the safety of the passengers and of the bus or train. The flexibility and modularity of the TransAir platform allows it to serve as the communications network for Positive Train Control, the government-mandated failsafe that allows the train to be controlled remotely to avoid collisions or derailments due to excess speed.

Operational Efficiency	Business Profitability
• Fuel Management • Improve miles between failure • Consolidate communications requirements • Route optimization	• Automated ticketing • Pass validation • Advertising • CCTV • TransAir™ modularity • Ridership reports
Passenger Comfort/Safety	**Train/Bus Safety**
• Positive Train Control • CCTV • Information displays • Passenger communications • Passenger community portal • Emergency handling • Infotainment	• Positive Train Control • Real-time maintenance data • CCTV

Figure 2: Impact of Connected Transportation on Operational Efficiency

Additional safety functionality can be provided through Ethernet switch modules supporting power-over-Ethernet (PoE), allowing the direct connection of security video cameras to monitor passenger or driver behavior, vehicle status and incident reporting all of which can be stored locally or monitored by dispatch in real-time.

The responsibilities of the crew and operator obviously extend to passenger safety and comfort. Properly working facilities are important, but even more so is a flexible way of reporting things that have broken down. In addition, Information displays are useful only if they have the latest and accurate information. A properly functioning communications network with a dedicated portal can be instrumental in improving the interaction between the passengers and the operator and goes a long way in building customer satisfaction and loyalty. Ultimately, the facilities and services are an entire part of the brand to the passenger.

Most importantly, running a bus or train company is a business. A connected transportation system plays a critical role that can drive business profitability and improve operational efficiency. Ticketing and pass validation systems can easily be connected to the TransAir communications hub, while the passenger community portal can include a retail section that offers opportunities for contextual advertising for your partners. Detailed ridership reports can provide valuable and useful information about your customers and the websites they tend to visit, presenting a unique opportunity for targeted and contextual advertising. These reports also make it very easy to track your most loyal customers and reward them with free rides, fare upgrades, complimentary movies or retail reward cards. These are just a few examples of how a connected transportation ecosystem can lead to higher profits.

Monetization			ROI (Modularity)
Indirect		Direct	
Customer Retention	Cost Optimization		
•Wi-Fi •Free entertainment like route information, games, TV etc. •Electronic Information Displays •Automated ticketing and pass validation •Loyalty rewards program	•Automated ticketing and pass validation •On-board applications (fuel management software, route optimization, etc.) •Analytics/data mining •CCTV	•Advertising •On-board entertainment •Retail	•Lower total cost of ownership •Module reusability •Streamlined approach to configuration and maintenance •Consolidated approach to systems management •Simplified warehousing

Table 1: Business Considerations for Connected Transportation

There are many benefits from an operational perspective as well. Ridership reports provide detailed information on train and bus performance: are they running on time? How long are they idling? Where do people get on and off, and do I have enough seat capacity? Furthermore, the application engine in the TransAir platform allows integrating software that would otherwise have to run on dedicated appliances, thus saving valuable space and power. Examples include fuel management software, dynamic route optimization, and real-time maintenance data collection and reporting, to name a few.
In summary, connected transportation can be monetized in various ways. The key is to look beyond simple Wi-Fi and consider the overall communications needs on buses and trains and implement the right foundation to support all these needs. LILEE SYSTEMS' TransAir has the flexibility and modularity that makes it the de facto communications hub for all devices and applications requiring a reliable network. As illustrated in Table 1, monetization is mostly indirect, but there are several direct monetization opportunities as well. In addition, the highly modular yet hardened design provides an excellent foundation for a fast return on investment (ROI).

Connected Transportation Bandwidth Requirements

Bandwidth needs have increased steadily over the last few years, driven mostly by the ever-growing degree of connectivity and the proliferation of devices that require a network to provide the best user experience. As a result, network access speeds in the office and at home have gone up dramatically, and 10 Mb/s is now commonplace in most parts of the world with an increasing amount of people having access to 50 Mb/s or 100 Mb/s, giving people a seamless real-time and transparent user experience. Ideally, bus and train passengers would like a similar experience while traveling, giving them the ability to manage their email and calendar, but also engage in social networking, browse the Internet and even consume media. This type of user experience would require several Mb/s per passenger.

Calculating the total bandwidth required on a bus or train is more complicated, as it depends on what you expect (or allow) the passengers to do today and what you expect them to be doing throughout the useful life of the infrastructure you plan to deploy. Offering free internet access for all passengers risks driving up bandwidth requirements as many will turn to their daily use of highly interactive services with constant traffic, such as Facebook, Twitter and other social media, and high-bandwidth video streaming from sites like YouTube and Netflix. Business people, on the other hand, will most likely use the connectivity for their essential activities like corporate email and browsing the Internet to check news headlines, stock markets and sports results.

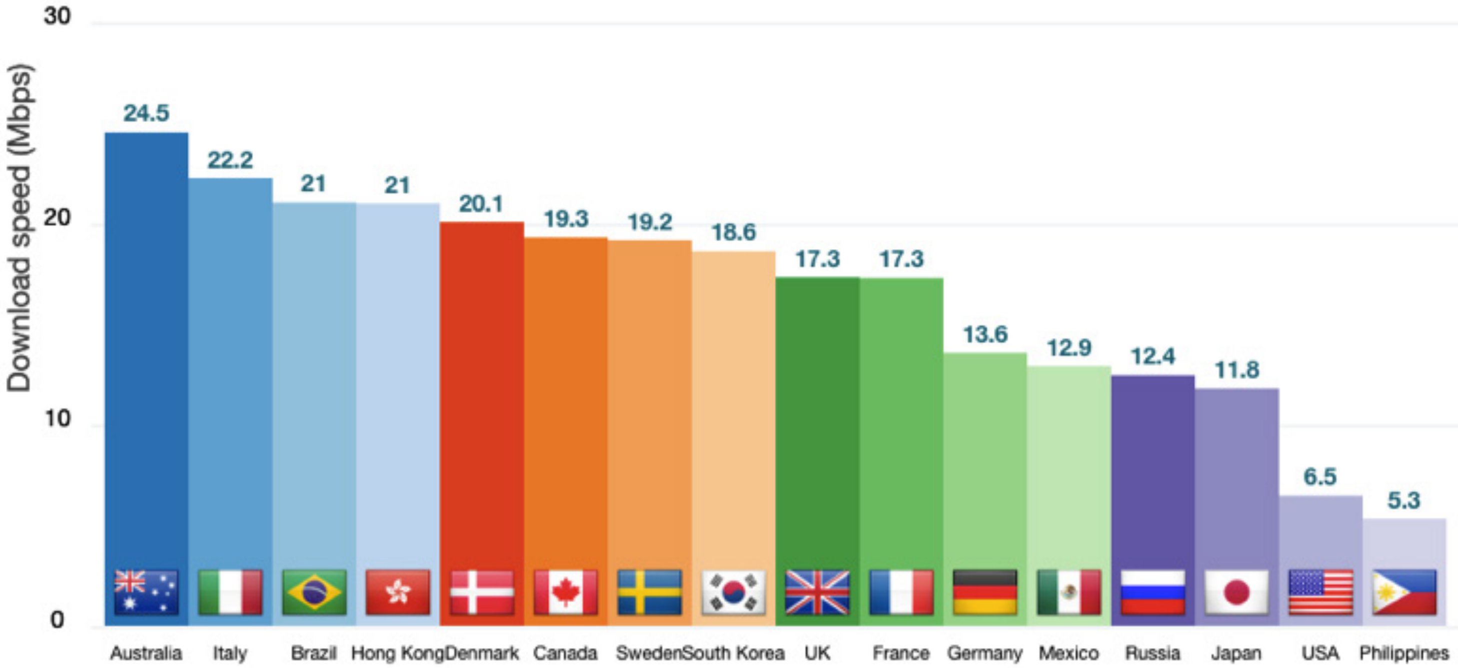
Adding all this up, uncontrolled network access will cause a leap in bandwidth requirements to a range between 100Mb/s and 1Gb/s for trains and 30 Mb/s to 100 Mb/s per bus. And since we can expect Moore's Law to apply, demand will double every two years. Given the technological limitations and cost of current and future wireless networks (see next chapter for more detail), the total amount of bandwidth that can be made available on economic grounds will likely be much less and fairness algorithms and quality-of-service (QoS) will have to be implemented to control the scarce resources and provide an adequate level of service and equal user experience to all passengers.

Using Wireless Network Technology for Connected Transportation

Various wireless connection mechanisms can be used to create a connected transportation system and most implementations will use a hybrid approach that will select the best option from multiple connection mechanisms depending on the network conditions at any given time. The most common wireless network options are listed below.

Cellular Networks

The most popular and common option to provide high-speed network connectivity in moving trains, buses and public safety vehicles is to use increasingly prevalent cellular networks, from 3G to LTE and others. The challenge, however, is that while network operators around the world are working hard to convince their users to make the jump to LTE, not all LTE networks are created equal. A recent OpenSignal study revealed that only about a quarter of networks achieve both good coverage and fast speeds and rightfully concluded that there remains much work before LTE lives up to its full potential.



This means that in order to satisfy the bandwidth requirements outlined in previous paragraph, multiple cellular channels need to be aggregated and dynamically managed. Mobile networks do not remain constant, with carriers constantly adding coverage areas and making improvements to their network. On the other side, increased users can annihilate these improvements, as increased network load brings down average speeds. This is the reason that some countries have improved since the 2013 OpenSignal report, while others have worsened. Most of the country averages have stayed broadly the same, with only minor improvement or deterioration in service. Australia and Japan have made the biggest improvements, with Australia's average speeds increasing 42% to 24.5Mbps and Japan improving 66% to 11.8Mbps. The USA suffers the biggest decline, with average speeds falling 32% to 6.5 Mbps, the second slowest global average.

[3] **"The State of LTE", OpenSignal, February 2014. OpenSignal is a crowdsourcing application that allows users to contribute to impartial coverage maps of mobile networks. Of their 6 million users, they took data from those who have LTE and focused on two key metrics: download speed, and the proportion of time spent with LTE access.**

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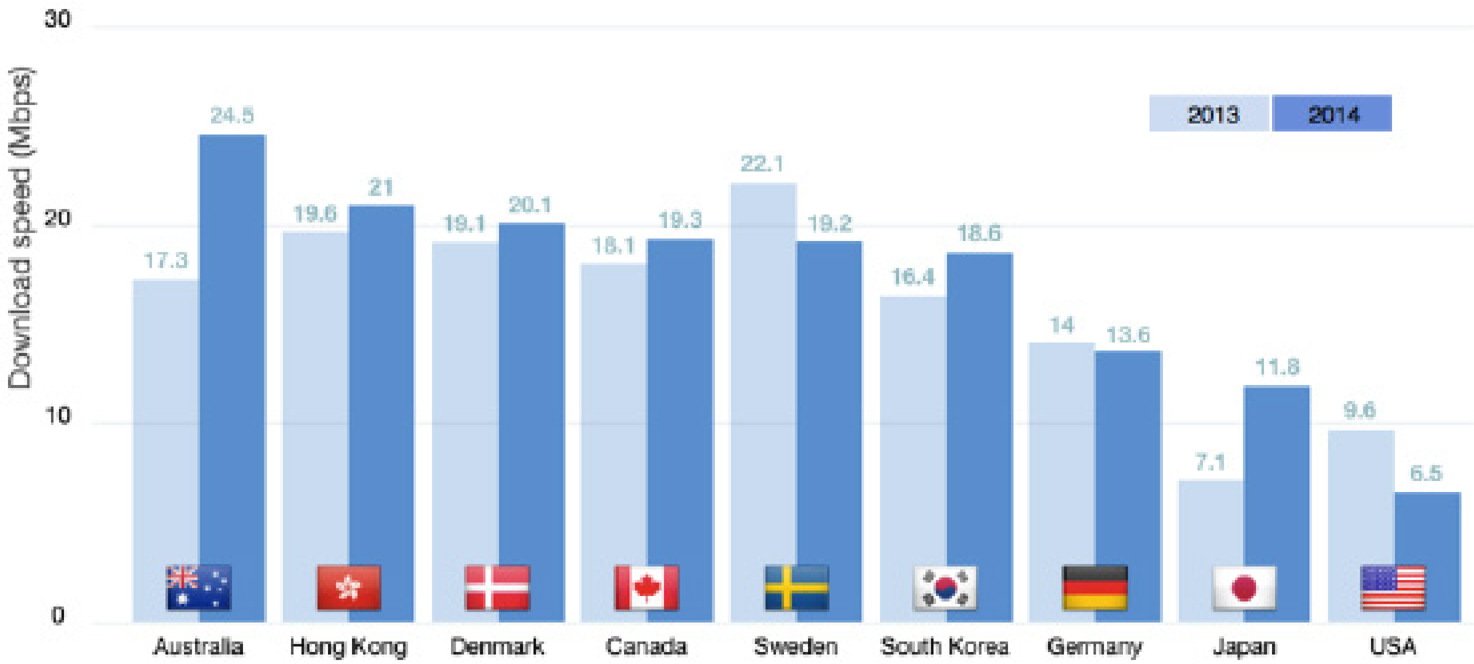


Figure 4: Comparing Yearly Download Speeds by Country (Source: Open Signal)

Wi-Fi

Trains and buses will naturally pass through areas that are covered by high-speed WiFi. Wi-Fi uses the 2.4GHz or 5 GHz spectrum and can deliver very high bandwidth, but typically has reduced range. Wi-Fi signal range depends on the frequency band, radio power output, and antenna gain and type. Line-of-sight is the thumbnail guide but reflection and refraction can have a significant impact. An access point compliant with either 802.11b or 802.11g, using a standard antenna, might have a range of 100 m (330 ft). The same radio with an external semi parabolic antenna (15db gain) might have a range over 20 miles. IEEE 802.11n and 802.11ac, however, can more than double the range. Range also varies with frequency band. Wi-Fi in the 2.4 GHz frequency block has slightly better range than Wi-Fi in the 5 GHz frequency block used by 802.11a (and optionally by 802.11n). Hence, Wi-Fi is a popular option for stations, terminals and trackside base stations.

Since practically every device has built-in Wi-Fi, this is the preferred method of access in the connected transportation world. Wireless network access points have a range of about 20 meters (66 feet) indoors and can easily be deployed in a central location in a train car, bus or van.

WiMAX

WiMAX (Worldwide Interoperability for Microwave Access) is a wireless communications standard designed to provide 30 to 40 Mb/s data rates, with the 2011 update providing up to 1 Gb/s for fixed stations. Mobile WiMAX (originally based on 802.16e-2005) is the revision that was deployed in many countries, and is the basis for future revisions such as 802.16m-2011.WiMAX is sometimes referred to as "Wi-Fi on steroids" and can be used for a number of applications including broadband connections, cellular backhaul, hotspots, and more. It is similar to Wi-Fi, but it can support much greater distances.

Initially hailed as a replacement technology for cellular networks, WiMAX adoption has stalled with the recent upgrades to 4G, LTE and 5G in the near future. Sprint (probably the biggest proponent of WiMAX in the U.S.), for example, recently announced it will shut down its WiMAX network in November 2015. However, the technology remains very viable for private trackside networks.
Trackside Radio

While cellular networks are the most popular and common option to provide high-speed network connectivity in moving trains, private trackside networks are a viable option in areas where cellular coverage is not sufficient or of low quality. Trackside networks use private base stations mounted on towers or poles that are interconnected by a trackside fiber network and are capable of delivering up to 100Mb/s to trains traveling at speeds up to 250 km per hour (160 mph). While several radio technology options exists, Wi-Fi and WiMAX based trackside solutions are very popular as they use unlicensed spectrum.

Satellite

Satellite communication is another interesting option to deliver train-to-ground communications as it has a number of distinct advantages:

- Easy coverage of a wide geographical area
- Broadband connectivity
- Lower CAPEX than private trackside networks (if using an existing satellite service. Private satellite would be economically unviable)
- There are, however, also several constraints that have to be considered:
- Satellites require line-of-sight to the antenna to achieve broadband speeds. Any obstacle passing in the way (bridges, but also bad weather like fog, heavy rain and snow) will cause fading in the signal
- When using a high-gain antenna, its beam-width will be very thin, requiring a very accurate pointing and tracking system. Given that a high-speed train is subject to a lot of movement (acceleration/deceleration, curves, lateral movements and transversal shifts) sophisticated (hence expensive) antennae will have to be used. We believe, however, that this technology will become economically viable in the next 12 to 18 months.
- Latency needs to be taken into consideration for latency-sensitive applications

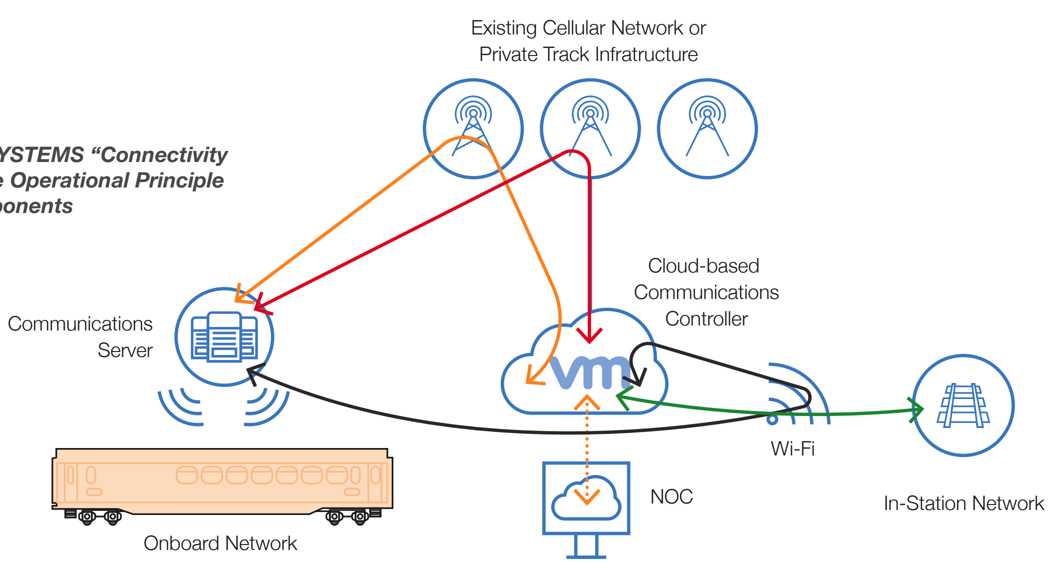
OPEX also needs to be considered with satellites, as it is directly tied to the contracted satellite capacity. If we assume that bandwidth requirements double every two years, the business case may not be viable. While there are a few operators that use satellite-based connectivity, we believe this option will only be viable in military and homeland security applications where some of these economic concerns are dwarfed by the need to safeguard national security.
In summary, the ideal connected transportation platform needs to leverage a combination of network technologies in a seamless and transparent way in order to maximize availability, performance and efficiency. A "vertical roaming" capability will be critical to dynamically and transparently switch between physical network bearers and provide an "Always ON" mobile broadband experience.

Equipping Vehicles with "Connectivity in Motion" Service

LILEE's "Connectivity in Motion" service is designed to solve all the challenges identified in the previous section. Originally developed for Positive Train Control (PTC), TransAir is the only solution that simultaneously and seamlessly prioritizes passenger-facing applications, management and operations data and safety applications, dynamically optimizing connections according to content type, flow size, and system requirements. In addition, its flexible architecture makes it the default communications foundation on buses, trains, and other commercial and emergency response vehicles to enhance safety, security, and the passenger experience, all while offering several monetization opportunities to solidify the business case. LILEE SYSTEMS' "Connectivity in Motion" mobile broadband solution consists of three components as depicted in Figure 5:

- An on-board Communications Server
- A Communications Controller
- A Management Software Suite

Figure 5: LILEE SYSTEMS "Connectivity in Motion" Service Operational Principle and System Components



At the heart of the solution is the Communications Controller that typically resides in the cloud, although some customers will prefer it to run on dedicated hardware in their data center. One Communications Controller can manage multiple on-board Communications Servers that are located on trains, buses or other vehicles, and performs the following critical functions:

- Seamless roaming between cellular, Wi-Fi, trackside radio and future media
- Integrated network management for centralized provisioning, monitoring, and management

The on-board Communications Servers can house up to 10 wireless network interfaces (3G, LTE, WiFi, GPS) and/or appliances like Ethernet switches and application engines and serves as the network access point and central communications hub for all services that require access to the Internet.

The Management Software Suite is a web-based service that provides the user interface to all administrative functions running on the Communications Controller to provision, configure manage and monitor the on-board communications servers. It also supports a suite of troubleshooting and diagnostic tools and provides a comprehensive reporting tool that accumulates all network and passenger statistics that are collected by the Communications Controllers and renders them in easy-to-use reports that provide detailed insight on device performance, network performance down to individual networks, connections and user sessions, usage statistics, ridership reports and much more.

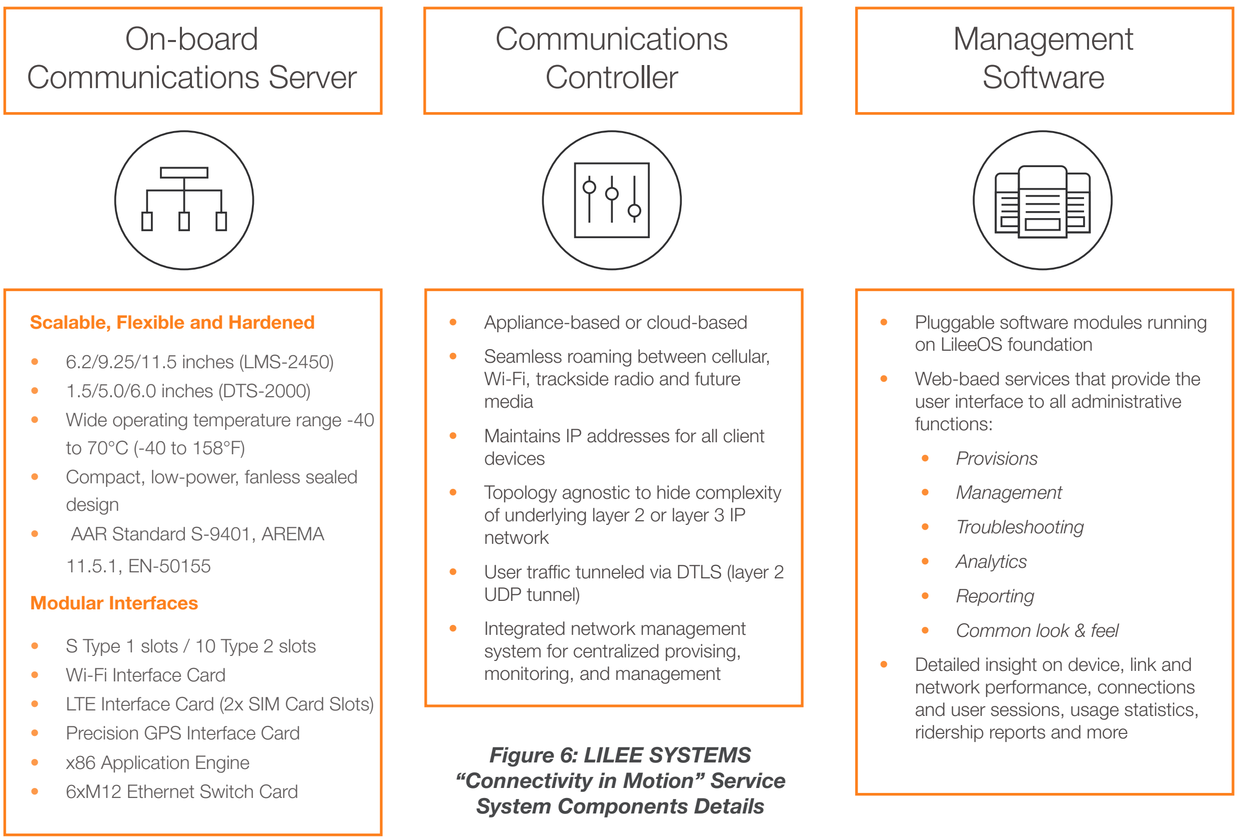


Figure 6: LILEE SYSTEMS “Connectivity in Motion” Service System Components Details

LMS-2450 and DTS-2000 On-Board Communications Servers

LILEE’S on-board communications servers are hardened from years of providing mission-critical applications under the stringent requirements of Positive Train Control (PTC). The modular LMS system supports up to 10 wireless interface cards, WiFi, GPS location services, a 6-port Ethernet switch, an application engine, and is field-upgradable to handle future generations of cellular and other wireless technologies. The DTS supports two modular slots that can accommodate SIM cards and/or GPS modules cards, and includes an embedded application engine. The LMS-2450 and DTS-2000 share compatibility with the interface card (IC) modules listed in Table 2 for a lower total cost of ownership.

Multiple wireless Networks

Supporting WiFi, 3G and 4G technologies, our solution uses multiple broadband connections on major carrier, municipal, service providers and private networks to connect to the Internet and support entertainment and business services as well as applications that optimize operations and/or provide on-board such as security and surveillance, automated ticketing, information displays, advertising and infotainment. The various wireless network connections are managed transparently by the Mobility Controller, which will be discussed in the next section.

APPLICATION	ON-BOARD SERVER INTERFACE CARDS	
IC-WIFI-11N	WiFi Interface Card	
IC-GPS-P	Precision GPS	
IC-LTE	LTE Network Card (USA)	
IC-LTE-G	LTE Network Card (Global)	
IC-LTE-GPS	Combo LTE/GPS Card	
IC-4S	4-port Serial Interface Card	Roadmap
SM-GE-6M	6-port GE Switch Module	
SM-GE-6M-4P	6-port GE Switch Module	4 ports with POE Support (802.3at)
SM-AE-AK	Application Engine / 8GB Storage	DTS-2000 has embedded AE Industrial grade
AM-AE-AK-2T	Application Engine / 2TB Storage	Commercial grade Roadmap
IC-AD-IO	Analog/Digital I/O Card	DTS-2000 has embedded A/D I/O Roadmap

GPS

The GPS modules provide precise location tracking, accurate to within 3 feet, with a trace that indicates the direction of travel. Current and historical positions are available at all times and are recorded by the Mobility Controller, or third-party tracking systems. In addition to location tracking, the GPS data can be used for passenger information systems (such as ridership reports), carrier network coverage surveys and "heat maps" and for safety applications like HLCS (HyRail Limits Compliance System).

Ethernet Switch

The SM-GE-6M and SM-GE-6M-4P Gigabit Ethernet Switch cards allow appliances that require network connectivity to get access to the "Connectivity in Motion" broadband network. Combined with the platform's modularity, this functionality is a critical component of the business case as it accelerates the return on investment by consolidating all network requirements into one hub and reducing the infrastructure and cellular network costs. A typical example is security; most transportation systems use some form of closed-circuit video (CCTV) for passenger safety and system security. Cameras mounted either on-board or at terminal stations can be utilized by fleet operators during transit, or recorded and always available for offline analysis. These systems can be connected directly to LILEE's LMS system, allowing for inbound access to a digital recorder, even while the vehicle is in transit. Other examples include information displays, automated ticketing and pass validation systems, and on-board computers.

Application Engine

The application engine allows integrating software that would otherwise have to run on dedicated appliances, thus saving valuable space and power. Examples include fuel management software, dynamic route optimization, video storage and real-time maintenance data collection and reporting, to name a few. Other applications that can be supported are content caching, radius proxy, integrated network test tool, and many more.

LMC-5500

LILEE SYSTEMS' LMC-5500 Series Mobility Controller handles the registration of the radio interfaces equipped in the LMS and DTS Mobility Servers and coordinates network connectivity management and seamless vertical roaming to maintain continuous communications with the Internet host while moving from one LTE base station to another or from one medium to another. With handovers of less than 50ms, connectivity appears to be stationary for all users. The LMC also manages link aggregation and provides a comprehensive web-based monitoring and management tool that collects and reports all statistics required to support detailed performance analysis and ridership reporting. LILEE's onboard mobility solution maintains sessions in the face of IP address changes, because the connections are at Layer 2. LILEE hides the complexity of roaming to the user and presents one stable, predictable and manageable network, just like in the office or at home. Furthermore, our solution works with a "make before break" algorithm that that moves flows to alternate links before the current connection is abandoned. We also supports a "vertical roaming" capability wherein multiple tunnels can be established between the LMC and the LMS through different networks. And these tunnels can be grouped into a single logical link. User traffic is distributed across tunnels in a group for load balancing and failover.

With link monitoring and dynamic weighted load balancing, each tunnel monitors the link quality between the LMC and LMS and determines the weight for user traffic load balancing in the tunnel aggregation group. The weight changes dynamically when the link quality changes.

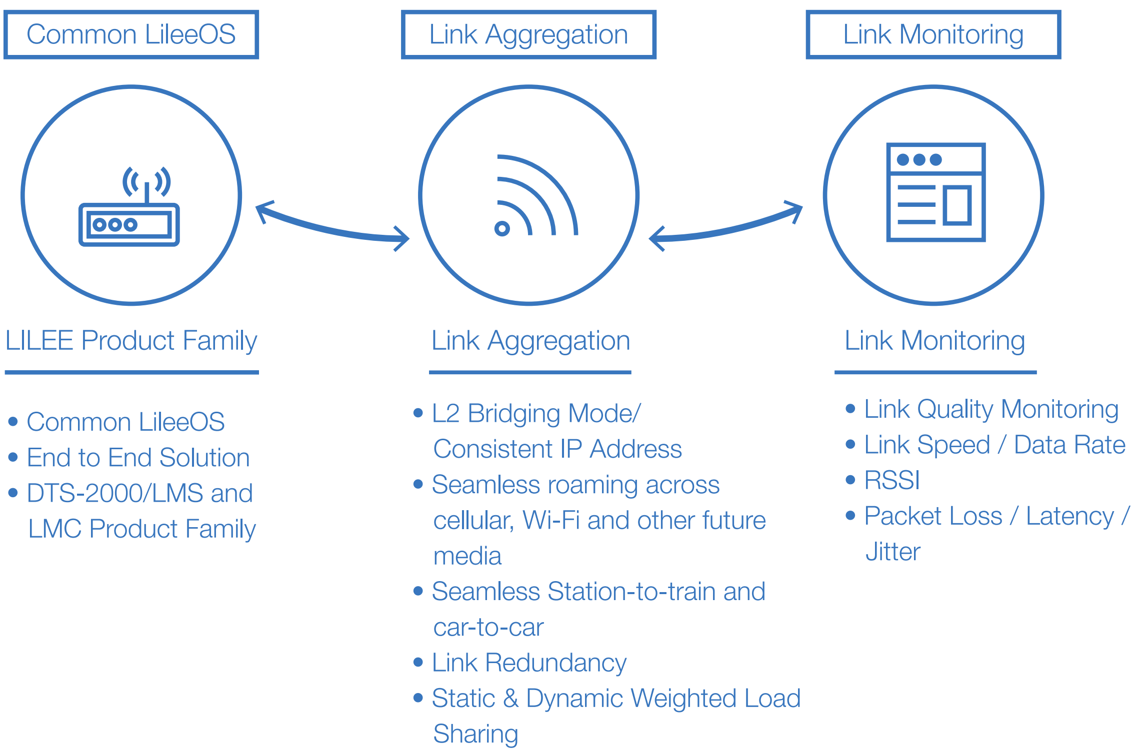


Figure 7: LILEE SYSTEMS Link Aggregation and Monitoring

TransAir™ supports both per-packet and per-flow load balancing. With per-packet load balancing the router sends one packet to the destination over the first path, the second packet for (the same) destination over the second path, and so on. This guarantees equal load across all links. Flow-based load balancing identifies different flows of traffic based on the key fields in the data packet and sends the entire flow over the link with highest quality.

DESCRIPTION	NOTES
L2 tunneling with UDP and DTLS encapsulation	The tunnels between LMC and LMS provide a transparent L2 bridged transport for Ethernet frames from user devices
Handoff Handling	Make before break" algorithm moves flows to alternate links before connection breaks (based on RSSI/jitter/drop/link speed/throughput)
Vertical roaming	Multiple tunnels can be established between LMC and LMS through different networks. Connectivity is maintained transparently for user data by switching traffic to another tunnel when a link fails
Tunnel link aggregation	Multiple tunnels can be grouped into a single logical link. User traffic is distributed across tunnels in a group for load balancing and failover
Link monitoring and dynamic weighted load balancing	Each tunnel monitors link quality (throughput, RSSI, latency, etc.) between LMC and LMS and determines the weight for user traffic load balancing in the tunnel aggregation group. The weight changes dynamically with link quality

Table 4: Link Aggregation and Load Balancing Functionality

Mobility Manager: Comprehensive Centralized Management

LILEE Mobility Manager is a cloud-based managed service that is hosted by LILEE SYSTEMS and provides detailed up-to-the minute reporting on the status and performance of all deployed and operational LILEE devices.

Mobility Manager displays information including device status and uptime, firmware version, number of users connected and network signal quality. The system also tracks device positioning, throughput, applications being run, data usage, and various fleet management reports. These reports identify trends for ridership and usage, and can provide valuable background information that can be used to optimize the device configuration to maximize throughput and minimize costs. Ridership reporting statistics include: throughput, packet loss, and usage by vehicle, network, SIM, or MAC address. These definitive summaries give you an at-a-glance sense of how your WiFi services are being used, and you get important feedback from which to calculate ROI. You can determine how many people used the service over specified periods of time, how much data was transferred, etc.

Figure 8 depicts a high-level operational view of the Mobility Manager. At the highest level (Level 1), the admin machine can create virtual machines (VM) in the datacenter where the virtual LMC (vLMC) is hosted (Level 2). A single admin can manage all assets and all on-board users at any time, although it is possible to assign one vLMC for each user account. Furthermore, a history of onboard usage is maintained in the database. Data is available for immediate on-line access for three months, and archived for off-line retrieval for up to 2 years.

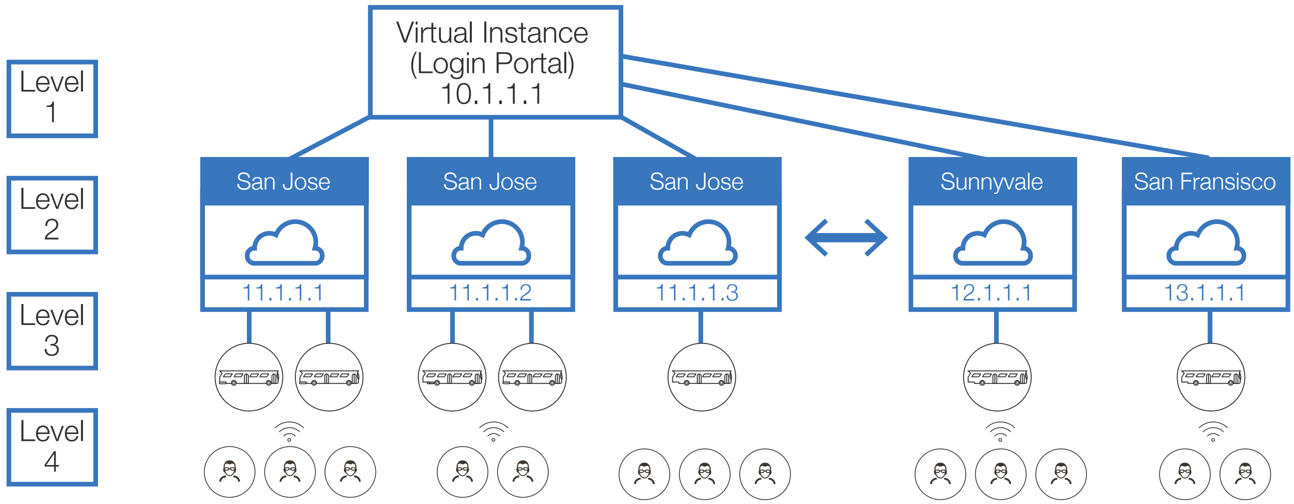


Figure 8: LILEE Mobility Manager Operational View

Mobility Manager also integrates easily with existing 3rd party management software through RESTful APIs (Application Programming Interface). As an example, Figure 9 illustrates the SIM dashboard created from statistics and analytics collected and exported by the LMC.

LILEE MOBILITY MANAGER HAS 9 PRIMARY REPORTING LEVELS:

SIM Management

Mobility manager retrieves data from SIM cards and makes it available to the admin who then may act based on usage, traffic shaping needs, or alarm handling; you can avoid overage, control allocation and understand geo-differences in billing (roaming).

User Management

This report tells you how many users are online, monitors individual usages and includes the ability to throttle traffic per MAC address to ensure fair bandwidth usage across all passengers. Saving this information lets you track user history and loyalty. The system can track users connected to either the Wi-Fi service or an Ethernet interface.

Fleet Management

Tracks ridership details that could then be used for dispatch or for real-time management of fleet resource. This could include e-ticketing, route scheduling, fuel management etc.

Asset Management

Inventory and control/configuration of field equipment (DTS/LMS), including line cards and interface cards, SIMs, application engines, LMCs (virtual and physical), third party access points, etc. With Asset Management, you can see what devices are online, how many users are online, what the connection strength is, and other details.

Event Management

Logging, notification and alarms are associated with status lights. The status lights may indicate that a device has dropped out of coverage for a specified period of time. Low receive signal strength may also trigger an event.

Application Management

Allows to balance or throttle traffic based on application, and to block certain applications and/or websites that may consume too much bandwidth.

System Management

Displays information including device status and uptime, firmware version, memory and CPU usage. Allows uploading the latest firmware to the on-board units.

Landing Page

A built-in captive portal with customizable screens that include a branded landing page, splash screen, login and authentication, and an editable survey for gathering market research.

History

The analytics shown here may include number of users at certain times on certain routes. How long they were connected, etc. You can look at number of sessions at different points in time and different locations, and determine whether these were new or returning users. This information can be used to analyze system uptake and evaluate ROI. Another of the historic views is the location history. You can track a certain device's (LMS/ DTS) journey within a specified time frame.

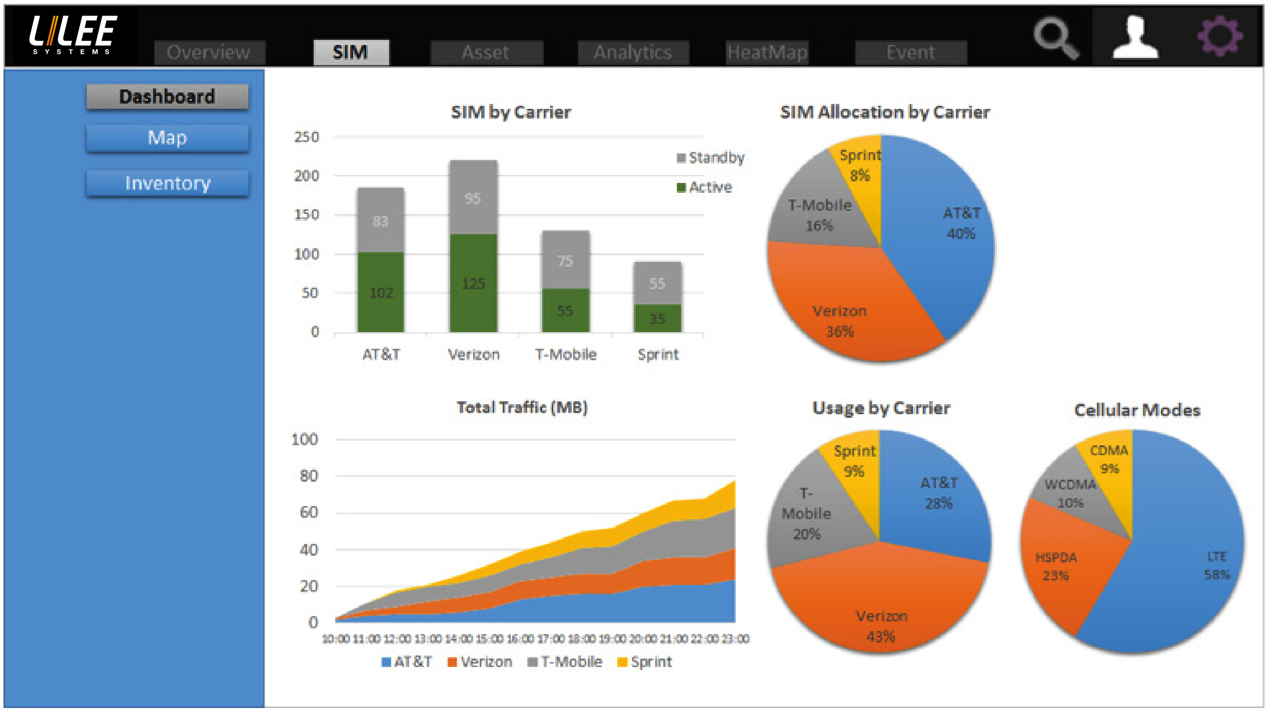


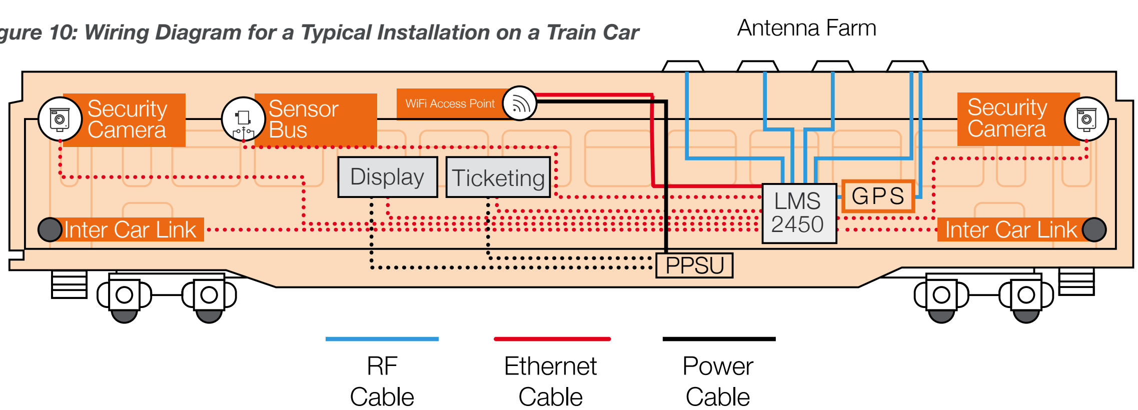
Figure 9: SIM Dashboard

Physical Installation

Requiring a 10 to 30 VDC power source from the vehicle's electrical system, combined with a fanless design and total power consumption of less than 200 Watts, LILEE's on-board systems can be installed practically anywhere on board: overhead compartments, under seats or behind paneling, in luggage storage, even in the engine compartment. For best performance, roof antennas should be used and connected directly to the wireless interface cards outfitted in LMS-2450 or DTS-2000 chassis. For trial purposes, window antennas or antennas mounted inside directly behind the windows can be used, although performance can be impacted if the windows are treated for privacy or sun screening as these treatments typically contain metallic substances. The LMS or DTS systems can be preconfigured before deployment, and remotely updated when new features are available.

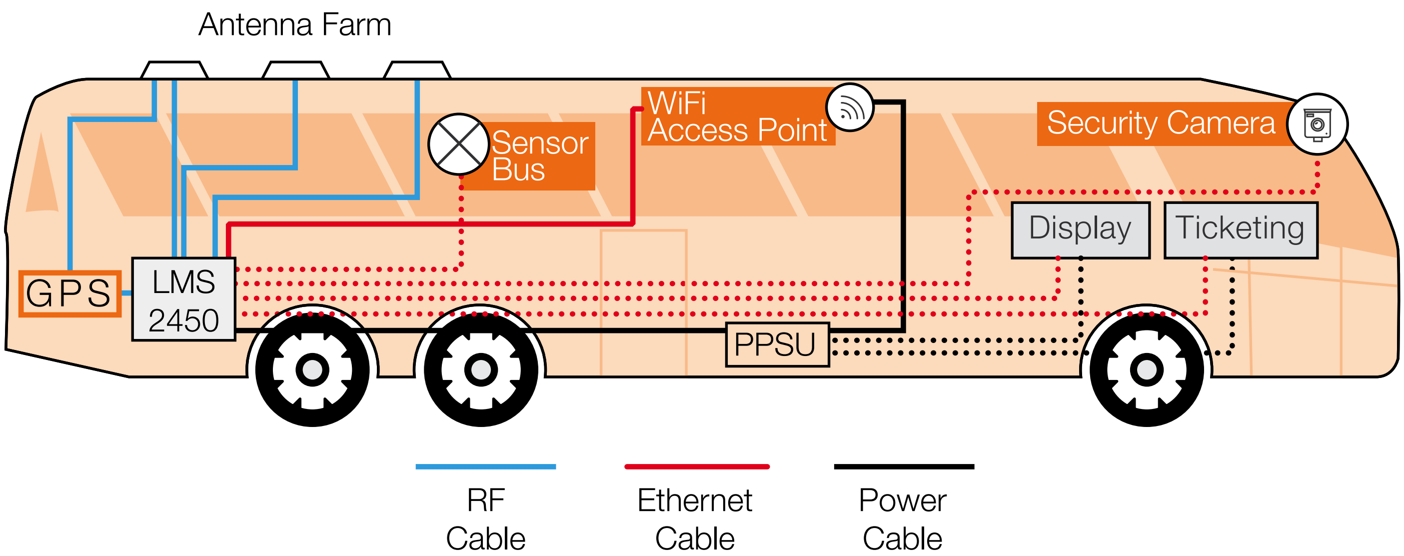
Figures 10 and 11 illustrate a typical installation diagram for deployment of an LMS-2450 on a train car and bus, respectively.

Figure 10: Wiring Diagram for a Typical Installation on a Train Car



The solid lines represent the minimum wiring that needs to be done to connect power, WiFi access point and the antennas. A protected power supply isolates the "Connectivity in Motion" infrastructure from the other electrical components of the carriage, protects the system against power surges and provides a battery back-up when the main power supply is interrupted. This is particularly useful in environments where vehicles cannot idle beyond a minute (e.g., San Francisco) and the system needs to operate continuously even when the engine is shut off.

Figure 11: Wiring Diagram for a Typical Installation on a Bus

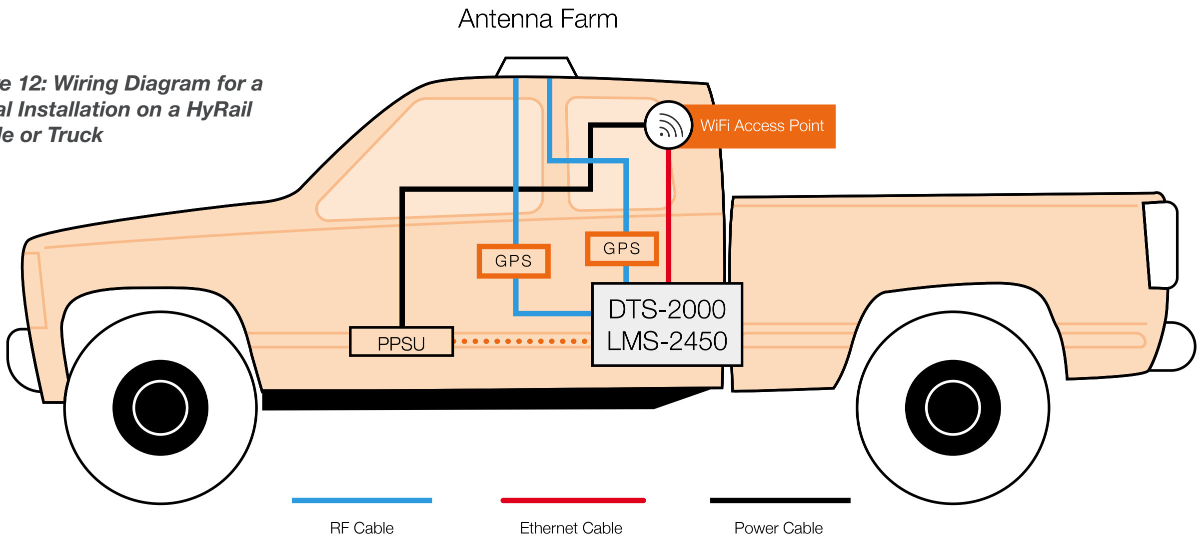


Antennas should be connected directly to the network interface cards in the on-board systems avoiding excess wiring and intermediate connectors to reduce signal loss. The antenna farm should be selected to maximize efficiency of the desired network configuration and can contain antennas for LTE access, GPS, WiFi (for in-station/terminal network) and/or trackside radio.

The dotted lines in the diagrams identify auxiliary equipment connected to the LMS-2450 on-board unit via the 6-port Ethernet switch module. Examples include ticketing and pass validation systems, Information displays and security cameras, which can be powered by the switch module's PoE+ ports. As mentioned earlier, these auxiliary systems are an integral part of the business case, and with the ability to become the central communications hub in the train carriage, bus or other vehicle, the LMS-2450 can consolidate all networking requirements and optimize capex and opex. For train applications, LMS-2450 can also accommodate the inter-car communications systems, which can consists of cat 6 GE or wireless interconnects.

The third application worth mentioning is deployment on HyRail vehicles as part of HLCS (HyRail Compliance Limit System), which adds an additional layer of safety to the operation of HyRail vehicles on active mainline tracks. It does so by using Global Positioning Satellites (GPS) to monitor the locations of "on-rail" HyRail vehicles and comparing locations against respective track authorization limits issued to the vehicle.

Figure 12: Wiring Diagram for a Typical Installation on a HyRail Vehicle or Truck



This application can typically be supported by the 2-slot DTS-2000. Since it requires high-precision GPS, which occupies one slot, the second slot can be used to provide Internet access to the HyRail crew and potentially other crew members if a WiFi access point is equipped as well. If less accurate GPS is acceptable, a combined LTE+GPS module can be used, doubling the LTE capacity. If more network capacity is desired or there is a need to connect additional equipment, the LMS-2450 should be used and additional antennas need to be mounted.

The configuration depicted in Figure 12 also serves as the basis for emergency vehicles such as police cars, ambulances and fire trucks.

LILEE Partners Program

Working with leading integrators, value-added resellers and service providers, LILEE SYSTEMS provides the communications platform to enable always connected broadband services to our customers and end users.

Partners looking to deploy applications and services that enable the connected traveler prefer the flexibility of the LILEE platform. Whether extending first responder services through the connected city, corporate services for worker productivity, fleet services or passenger Wi-Fi and infotainment, partners choose LILEE Systems for the proven track record of delivering broadband services.

With the growing market opportunity to provide connected services to the transportation industry, LILEE Systems is interested in working with partners providing applications, services and solutions around:

- Passenger infotainment/content delivery
- Video safety/surveillance
- Fleet Management
- Mobile ticketing/commerce
- Digital signage/advertising
- GPS location and route services

LILEE Company Overview

LILEE SYSTEMS was founded in 2009 by industry leaders with extensive backgrounds in wireless communications, network routing and switching, and software defined radio (SDR). Headquartered in San Jose, we opened a subsidiary office in Taipei, Taiwan in 2010 to establish an engineering center and work more efficiently with our manufacturer in production, testing, and rollouts of various PTC projects.

Founded with the main purpose of providing communication networks to the railroad industry, we shipped our first products in 4Q 2011 into the freight railroad market, seizing the opportunity that emerged with the Congress-mandated deployment of Positive Train Control (PTC) which required wired and wireless networking solutions that were previously nonexistent in the railroad industry.

We recently expanded into the broader transportation market with a solutions portfolio that includes passenger connectivity and other broadband solutions such as safety, security, maintenance and management. Additional markets include First Responders, Homeland Security, Military, and Machine-to-Machine (M2M) communications in the broader Internet of Things (IoT) market.

Our mission is to create "Connectivity in Motion" by merging multiple wireless connections into a predictable, stable and manageable network. All our hardware and software is manufactured in-house, and our hardware is ruggedized, future-proof and modular. LILEE is the market leader in the connected transportation space, with well-established partner and alliance programs. Our hardware, software and services enable customers to provide applications and services in the growing software defined transportation market.

Since our founding in 2009, LILEE Systems has grown from a staff of less than 10 core engineers and administrative staff to over 110 people. Our team is recognized as leaders in the wireless industry, with core strengths and cross-disciplined backgrounds obtained from careers at Cisco, Juniper, Extreme Networks, AMD, Apple Inc., Aruba Networks, Motorola, Citrix, Fujitsu Network Communications, Safetran Systems Inc., Invensys Rail, and GE Transportation. We are actively participating in the standard bodies in defining next generation wireless architectures and have been Voting Members of both 802.11 WLAN and 802.16 WiMAX for several years. Our executives have many years of engineering, project management and go-to-market experience in the networking industry and in wireless design and development, holding several patents for Software Defined Radio.

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