Location and Communications Services for Maintenance of Way Vehicles (HyRail)

641 River Oaks Parkway, San Jose, CA 95134

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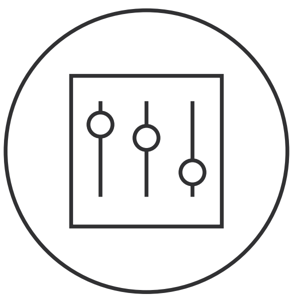
Executive Summary

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.

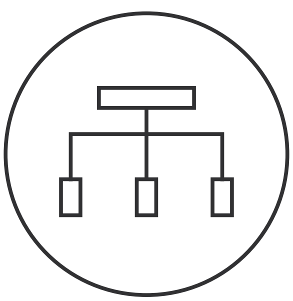
The LILEE Systems HyRail solution is built on three core components:



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

Maintenance of Way (MOW) vehicles are designed to operate on regular highways and roads as well as rails. Such vehicles are normally used for railroad right-of-way maintenance during engineering possessions of the line. They can be driven on roads to near the site and then convert to rail vehicles for the final journey to the worksite. This avoids the complex maneuvers that would be associated with a road vehicle accessing the worksite if the worksite is not near a road. They are generally designed to be insulated, thus they do not activate track (signaling) circuits although some rail operators, normally those operating remote lines without boom gates etc. prefer them to be non-insulated so that they are detectable by train safety systems.

They are often converted road vehicles (but may also be purpose-built), keeping their normal wheels with rubber tires, but fitted with additional flanged steel wheels for running on rails. The rail wheels can be raised and lowered as needed. MOW vehicles are typically called hi-rail, from highway and rail, or variations such as high-rail, HiRail, HyRail, etc.

Figure 1: Connected Transportation Passenger Experience Ecosystem

HyRail Limits Compliance System (HLCS)

Because HyRail vehicles share the tracks with freight and passenger trains, a key system for maintaining the safety of their operators is the HyRail Limits Compliance System (HLCS). This system provides safety overlays for HyRail vehicles by adding a layer of security to the operation of HyRail vehicles on active railroad tracks.

HLCS uses global positioning satellites (GPS) to determine the location of HyRail vehicles and transmits that position to the railway operator's back office, where it is compared to the authority given to the vehicle operator. As the HyRail vehicle approaches or exceeds its authority limits, the back office will send alerts/alarms to a visual display on the on-board system, as well as to the train dispatcher via the train dispatch computer system. The system also works in a peer-to-peer mode to provide proximity alerts as HyRail vehicles approach other HyRail vehicles that are on or near the same railroad tracks.

To support this, a HyRail vehicle needs:

- A GPS receiver to locate the vehicle. A high-precision GPS receiver (3 feet accuracy or better) typically provides enough resolution to know if a vehicle is on the tracks or inside/outside the safety fence (if present). If the vehicle is equipped with regular GPS, then rail sensors are required to indicate whether the vehicle is on the track
- A cellular network connection to communicate with the back office
- A visual display that serves as the input/output interface for the Hy-Rail operator

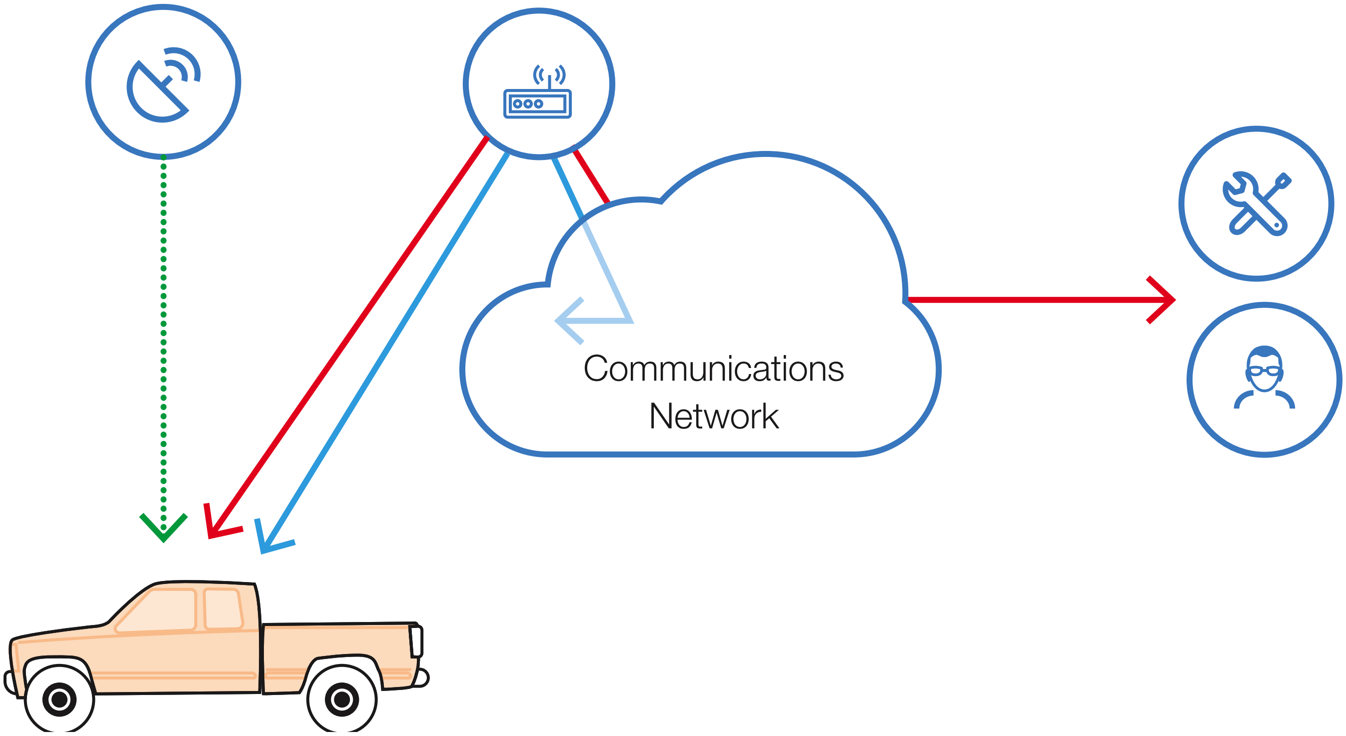
The HLCS system takes a reading from the GPS receiver and forms a position report for the back office. This report includes the truck number, track selections, rail status, and additional information. It is cross-referenced to the train dispatch system to ensure that the vehicle operator had a valid authority to be on the track, and was within the limits of its authority. This allows the back office to activate any necessary alarms or alerts.

LILEE Solution Overview

Solution Architecture

LILEE Systems' operational principle and solution architecture to support location and communications services for HyRail vehicles is depicted in Figure 2. A vehicle equipped with an on-board unit (OBU) with high-precision GPS transmits its precise location to the dispatch and back office using the cellular interfaces that are also installed in the OBU. The cellular interfaces can be used to provide network access for the HyRail crew and other crewmembers if a Wi-Fi access point is equipped.

Figure 2: LILEE Systems Location and Communications Services for Maintenance of Way Vehicles (HyRail)



Solution Components

The LILEE Systems solutions portfolio consists of three components as depicted in Figure 3. The Communications Controller can manage multiple Communications Servers that can be located on locomotives or wayside, and provides integrated network management for centralized provisioning, monitoring, and management. The on-board Communications Servers can house up to 10 wireless network interfaces (3G, LTE, Wi-Fi, GPS) and/or appliances, like Ethernet switches and application engines, and serve as the network access point and central communications hub for all services that require access to the network.

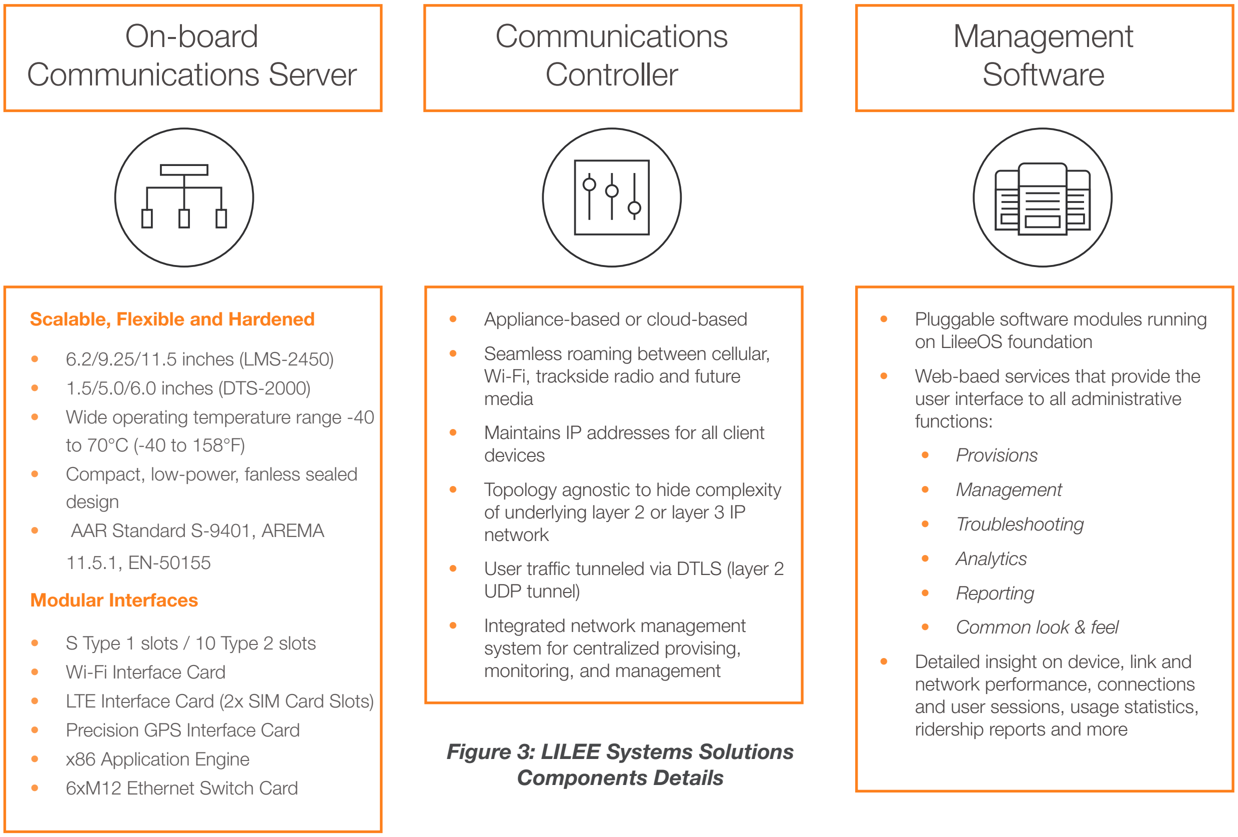


Figure 3: LILEE Systems Solutions Components Details

The Management Software Suite provides the user interface to all administrative functions, so you can provision, configure, manage, and monitor all devices in the network. It supports a suite of troubleshooting and diagnostic tools and also provides a comprehensive reporting tool that accumulates all network statistics that are collected by the Communications Controllers. It then renders those statistics 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.

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.

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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.

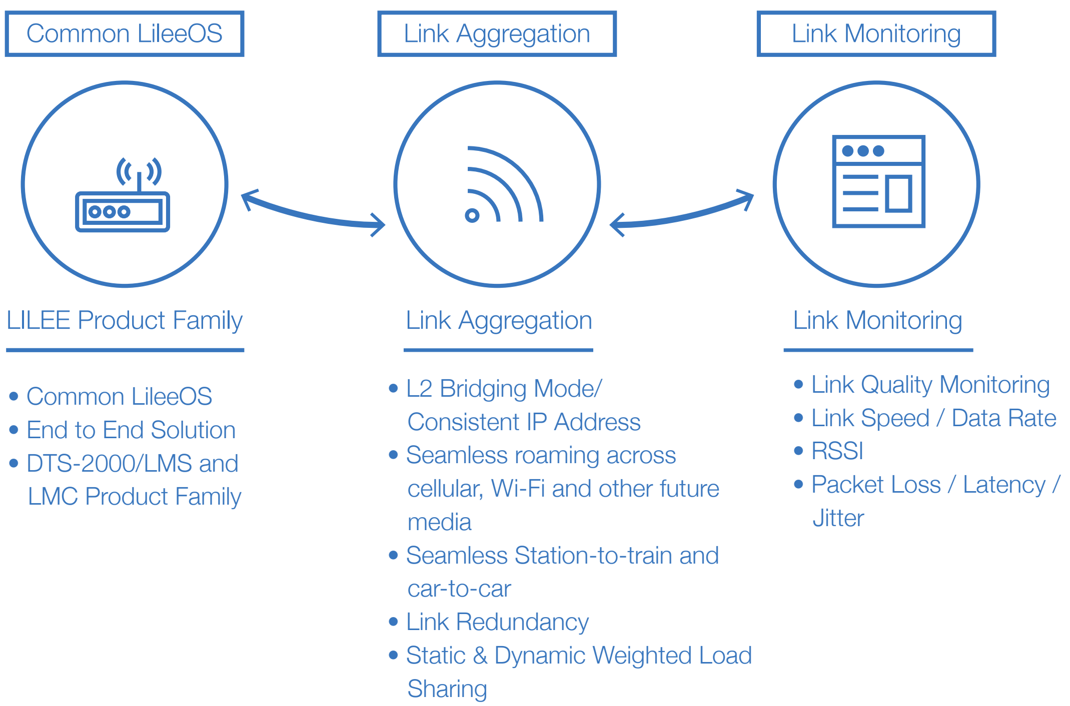


Figure 4: LILEE SYSTEMS Link Aggregation and Monitoring

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 2: Link Aggregation and Load Balancing Functionality

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, TransAir 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 the LMS-2450 or DTS-2000 chassis. For trial purposes, window antennas or antennas mounted inside directly behind the windows can be used, although performance may be impacted if the windows are treated for privacy or sun screening as these treatments typically contain metallic substances. The LMS and DTS systems can be preconfigured before deployment, and remotely updated when new features are available.

The following diagram shows a wiring diagram for a typical installation on a HyRail vehicle or truck. The solid lines represent the minimum wiring that needs to be done to connect power, a Wi-Fi access point, and the antennas. A protected power supply isolates the communications 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.

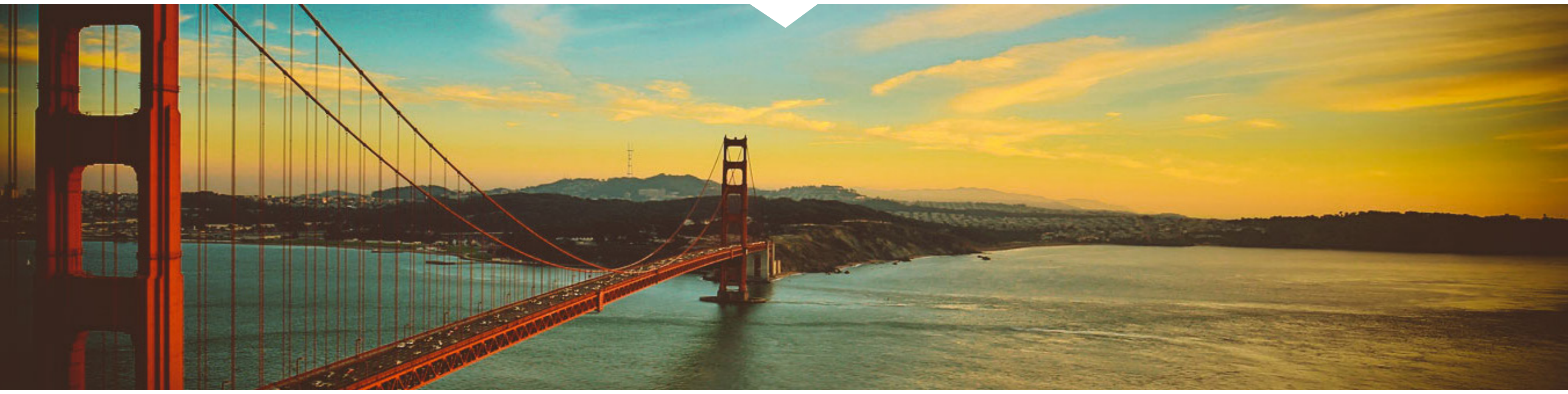
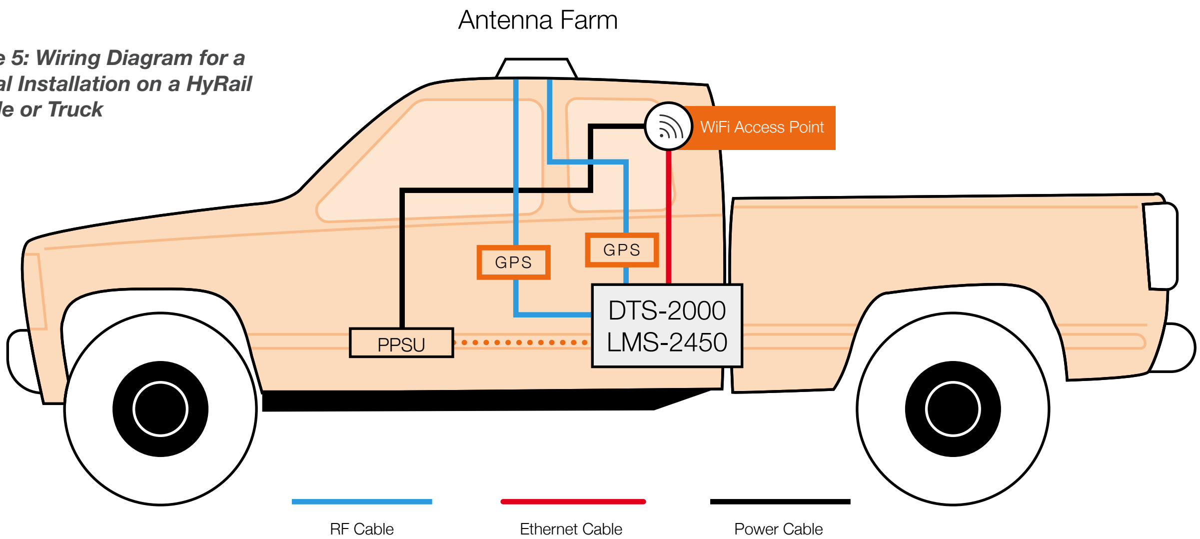


Figure 5: Wiring Diagram for a Typical Installation on a HyRail Vehicle or Truck



The HyRail 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 Wi-Fi access point is equipped.

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 (with additional antennas).

This configuration also serves as a communication platform for emergency vehicles such as police cars, ambulances and fire trucks, emergency/disaster response such as utility bucket trucks providing emergency restoration services during utility outages.

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.