



Enabling Mobile Applications in the Transportation Industry

Firetide's AutoMesh™ Technology in Action



State of the Transportation Market

Transportation is critical to economic development worldwide. For decades, advances in transportation have played a major role in fostering economic growth. As today's transportation industry continues to evolve, several market changes are in play:

- Population is increasing across the globe.
- Train and bus ridership is up – estimates are that approximately 50 percent of the world lives in cities, with projections that this will increase to two-thirds in the near future.
- Continued growth of international trade is straining global supply chains.
- World events require increasing surveillance to ensure the safety of passengers, personnel, vehicles, and infrastructure.
- As the rapidly-growing population of senior citizens ages, more and more seniors will not be driving cars.
- The new generation of young people is showing less interest in owning and driving an automobile.
- Rising fuel costs and the emphasis on green initiatives challenge providers to develop more affordable and eco-friendly alternatives.

In response, public and private transportation providers are evolving operations and systems to remain financially secure and competitive. This places great pressure on providers to maximize revenues, reduce costs, increase security, and improve the overall passenger experience. Advanced, intelligent technology plays a key role in shaping next-generation transportation systems that can keep pace with changing conditions while achieving critical financial and operational objectives. The challenges are significant as providers strive to:

- Increase surveillance to protect passengers, personnel, and assets
- Achieve high-speed video off-loading and real-time access to data analytics
- Improve the efficiency and convenience of customer service systems
- Maximize asset and infrastructure availability for revenue generation
- Improve operational efficiencies to reduce costs
- Enable traveler access to digital signage, schedule changes, end-to-end connectivity, and personalized offers
- Support green initiatives to improve efficiency and reduce environmental impact

The same intelligent technology needed to support the above objectives also needs to efficiently and seamlessly transition between static and mobile network operations. In a static environment, typical applications can encompass the transmission of schedules from dispatch to a bus depot and video streaming from a train station to a surveillance center. In mobile scenarios, linear mobility applications can include enabling emergency response vehicles to have on-the-move access to critical location information and giving passengers uninterrupted, streaming connectivity while seated on a high-speed train.

Because mobility is the biggest challenge transportation operators face today, the technology supporting transportation systems has to function flawlessly while on-the-move. Sensors, cameras, and transportation equipment are increasingly mobile and often operate in remote and harsh environments where traditional wired networks or public access is limited or not cost-effective. As people and assets demand more mobility, applications such as real-time video surveillance, video off-load, data analytics, digital signage, and always-on connectivity are simply beyond the capabilities of wired and Wi-Fi networks. In addition, added focus on surveillance and monitoring means that high-definition video is now as critical on the network as voice and data.

A “mobile” node can attach to available static nodes on a single radio which is optimized to transfer data while moving at high speeds. The mobile node maintains close contact with a controller appliance to send and receive data across multiple meshes.

As a result, wireless infrastructure has emerged as the preferred solution and the de facto standard for mobile vehicles, rail, and public transit. Further, network professionals are seeking wireless solutions that deliver *intelligent* mobile technology to help them make more informed decisions and drive better results.

Applying Essential Network Parameters to Mobility

Network operators have come to realize that, although highly reliable, fiber and other wired infrastructures have shortcomings that impede the performance transportation agencies require. Fiber and other coax networks lack scalability and are expensive to deploy and maintain. While Wi-Fi performs adequately for short-distance connectivity with reasonable bandwidth requirements, the technology is not sufficient to support linear mobility and typically runs into serious communication shortfalls.

Due to the high speeds and constant transitions in location, these traditional networking solutions do not provide transportation operators the performance characteristics required. Conversely, wireless mesh networks provide transportation operators the mobility needed to augment their existing wired infrastructures and are characterized by either or both of the following requirements:

- High performance and reliability at high speed
- Seamless roaming across multiple meshes

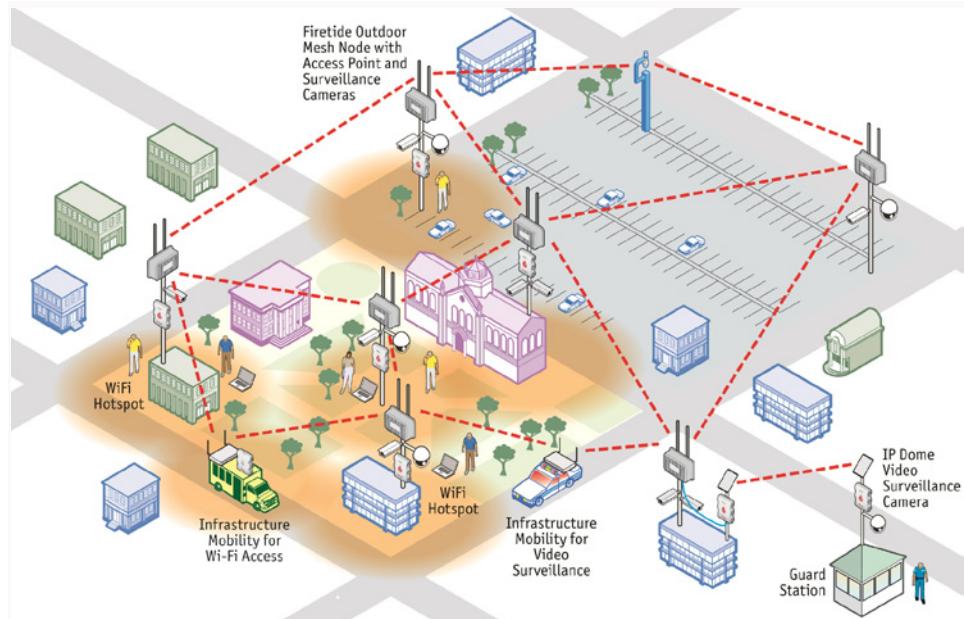
These requirements should be applied each time there is a question about whether or not an application calls for static mesh or mobile mesh. A static mesh consists of stationary mesh nodes which are anchored to a fixed location and establish links with other static nodes to form the mesh.

A “mobile” node can attach to available static nodes on a single radio which is optimized to transfer data while moving at high speeds. The mobile node maintains close contact with a controller appliance to send and receive data across multiple meshes. It can associate with the static nodes in these meshes to communicate with clients connected to any part of the static meshes. In many cases, the mobile client can communicate with a client on the wired side to which the mobile mesh has a connection. In this way, the mobile node can seamlessly travel across multiple meshes without a break in data, control, or management. This is extremely critical to the extensibility and scalability of a linear-mobility solution.

When evaluating wireless solutions, there are several pre-requisites for successful deployment: performance, reliability, resiliency, scalability, extensibility, manageability, and security. Rather than focusing on a single network attribute such as performance, these attributes need to be considered together.

Attribute	Considerations
Performance	Speed, long distances, re-associations between mobile and static radios, applications, latency tolerance, traffic patterns, encryption, RF interference, access to special channels (ITS, DFS, 4.9, etc.)
Reliability	Link availability, link redundancy, self-healing capabilities
Resiliency	How network performs in harsh environments such as crowded bus depots and train stations, bridges, tunnels; with interference, shock, and vibration on moving vehicles or trains; wide range of power inputs, strong electromagnetic interference (EMI) fields due to overhead catenaries, etc.
Scalability	Grow end-to-end throughput, bandwidth, speed, and coverage area without replacing hardware, load balancing
Extensibility	Add nodes to an installed network, deliver mobility at key points, and extend mobile wireless capabilities from a city's metro transport to its light rail system
Manageability	Maintain end-to-end control of the network with a management solution that can deliver statistics, alarms, faults, configuration, and provisioning
Security	End-to-end protection for confidential data, voice and video

Scalability, manageability, performance, extensibility, and security have become critical networking attributes that serve as the foundation on which high-performance networks are judged. Wireless mesh networks are no different. For city networks, including transportation networks, it is crucial that these individual and collective attributes are equally robust.



The Firetide HotPort® wireless mesh network allows indoor and outdoor video surveillance without costly backbone cabling between walls and buildings.

Firetide Mesh Solutions: Meeting Mobility Demands in Transportation

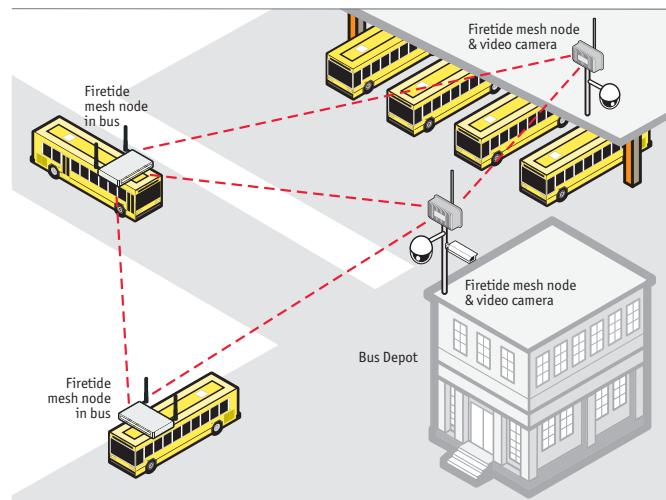
Firetide is the force behind next-generation mesh technology and the new paradigm in mobile wireless solutions for mission-critical networking applications. As the only wireless mesh technology built from the ground up with mobility and video in mind, Firetide is the acknowledged leader in delivering the capabilities and benefits of mesh networking for today's fast-moving trains, subways, buses and public safety vehicles. Operating at sustained speeds of up to 100 mph, its patented mesh technologies provide the only solutions proven capable of supporting high-definition video streams and seamless roaming across extended distances. To deliver end-to-end security, the solutions utilize the highest available 256-bit AES encryption.

Powering all Firetide products is Firetide's patented AutoMesh protocol, a new technology that delivers true fiber-like reliability and performance as well as scalability, RF environmental awareness, and powerful multi-service and Quality-of-Service capabilities. Firetide's mesh networks form instantaneously and automatically, healing themselves when a link is interrupted or broken to ensure that communications are immediate and constant. Compatible with any existing equipment, network, or software, a Firetide mesh network can handle voice, data, and video seamlessly. Firetide's unparalleled mobility makes it the networking technology of choice for today's transportation industry.

The Impetus to Advance Wireless Mesh Networks (WMNs)

Wireless mesh technology has proven to be highly reliable for private broadband networks across many markets, including industrial, public safety, oil and gas, and community. Simultaneously, the implementation of wireless mesh networks for transportation is growing in global acceptance. More and more WMNs have been deployed over the past decade as associated costs of extending and supporting a wired infrastructure over the long haul are no longer acceptable or financially feasible.

Delivering seamless mobility to support real-time data, voice and video is a mission-critical requirement in transportation. With mobility stakes and the associated safety, legal, and economic risks to bear, network decision-makers are seeking technology partners who understand that their accountability goes further than ensuring their systems are operationally functional. These systems must be intelligently optimized to increase revenue and follow-on services.



Gigabytes of data in less than a minute with Firetide's fleet offload option.

Optimizations to Mesh for Mobility

Today, an increasing number of transportation organizations worldwide are benefiting from the self forming, self-healing nature of wireless mesh networks. In part, this growth has been a result of WMN maturation as vendor innovation has overcome the myriad of environmental and logistical challenges that can negatively impact network reliability and performance. Vendors with deep expertise and extensive hands-on experience in designing and implementing large infrastructure projects have been able to successfully overcome these challenges.

One only has to look at the environments in which high and low speed rail, subways, bus systems, and public safety emergency vehicles must operate to recognize the diversity and challenges of each of their respective environments. Rail systems traverse endless miles of flat and curvy terrain and are under constant pressure to improve safety and enhance the passenger experience. As a result, rail administrators need to know that the WMN can be fully optimized to support demanding linear-mobility applications.

Subway and metro systems reside in underground worlds which are not conducive for wireless transmissions and where the confines of the wired world prevent extended wireless mobile communications. The impact of urban sprawl and resulting traffic congestion are driving network requirements for real-time traffic control measures. Additionally, studies have shown that allowing public safety and emergency responders access to critical, time-sensitive data, voice, and video while en route to their destinations helps improve safety and, in many cases, save lives.

It is no easy task to overcome these obstacles. Consequently, successful deployment and operation of a mobility solution requires that the system can be configured for the specific applications, environment, and infrastructure. Optimization of the wireless mesh for transportation is manifested in the following:

- Application Specific Configuration: Mobility can span a wide range of applications and each application introduces unique challenges. Mobility vendors must recognize and resolve these challenges at an engineering level and provide customers with a means to custom-tweak the system for their projects while accommodating future growth and scalability.
- Radio Level Optimizations: The heart of the mobility solution lies in the efficiency and performance of radio switchovers in the mobile environment. Routing protocol and efficient channel assignment play key roles in reducing potential interference and minimizing network congestion. Vendors also need to understand the RF challenges that lie within mobility to optimize radio switchover time, thereby improving overall system performance and reliability.
- RF Challenges: Perhaps the biggest challenges to the success of a mobility network are the RF and wireless domain constraints which lay the ground rules of system capability. Today's network requirements are dense in nature which adds another level of complexity when it comes to scalability and extensibility. Vendors have to develop multi-layered solutions which can overcome these challenges while remaining flexible to the evolving needs of each new project.
- Project Design and Deployment Considerations: A mature mobility solution will lend itself to deployment in a fashion that enables system integrators and installers to clearly identify the demarcations between product and project in their system design. The logistics of deployment need to be facilitated by the solution to achieve a deterministic, reliable, and repeatable installation model.

Firetide solutions are engineered with flexible configuration and optimization capabilities that accommodate the various mobility requirements prevalent in transportation operations.

AutoMesh Technology Powers Mobility in Transportation

Firetide's AutoMesh technology gives network operators the confidence to deploy wireless networks in tough RF environments with the reliable performance once thought to be achievable only with fiber. Five characteristics define the Automesh platform and distinguish it from other competitive vendors:

- Layer 2 Wireless Distributed Ethernet paradigm
- Redundant, self-healing mesh topology
- Seamless infrastructure roaming with zero packet loss
- Multi-hop optimization
- End-to-end security and management

In order for applications such as video off-load and streaming of bandwidth-intensive video to perform optimally, it is important to understand the mobile profile of your operating environment as network effectiveness will be impacted by the mobility profile. Node behavior will vary and perform differently based on whether the transit environment is linear, non-linear, or considered a hot zone.

On today's fast-moving trains, buses, and public safety vehicles, the ability to successfully transmit high-definition video and support seamless roaming across extended distances is paramount.

Wireless Distributed Ethernet: Hybrid Model Unique to Industry

Behind Firetide's Distributed Ethernet paradigm is a unique strategy that streamlines network deployment and operations while ensuring seamless functionality of all IP applications. An interesting hybrid, Firetide mesh plays off the strengths of both Layer 2 and Layer 3 switches by appearing as a Layer 2 switch to the outside world while improving the performance on the given routing protocol. By utilizing the Layer 2 Distributed Wireless Architecture, each port can assume wireless capability independently and ultimately can create a virtual Ethernet switch. Additional benefits are derived since the same routing protocol, access, and policies apply to indoor deployments as well as outdoor deployments.

Redundancy and Load Balancing Paves the Path for Flexible Networks

For network operators, redundancy is more than a security blanket or a fall-back plan. It provides the assurance that a network won't fail or lose connectivity due to a loss of a single endpoint, since individual nodes will always have an alternate path. In a true redundant mesh topology, every node has a connection with every other node in the network, creating a direct correlation to the network's reliability. The inherent self-healing and load-balancing capabilities across the mesh further ensure failsafe operations.

Wireless mesh networks supporting mobility and high-bandwidth applications are particularly sensitized to load-balancing capabilities. Load imbalances result in inadequate bandwidth supply, packet loss, and buffer overflow. Unlike comparable wireless mesh technologies which perform load balancing via packets, Firetide performs load balancing functions based on "flows," using two load-balancing concepts – a flow and a path. A flow is a communication between a source and a destination MAC (media access control). A path is a mesh route for a flow between a source and destination. Firetide's intelligent Mesh Routing Protocol (FMRP) can perform load-balancing activities automatically and optimize traffic flow mesh-wide.

Packet-based load balancing poses a risk of reordering data at the receiver whereas, Firetide's FMRP balances flows across available paths. This approach is highly effective in situations where clients are being added behind a mesh node and the primary path starts to get saturated. In such situations, the protocol can automatically route the new flow over secondary and tertiary paths. Firetide's load-balancing strength has been tested and proven effective with hundreds of customers who push large amounts of video across their nodes.

Closely tied to the network's self-healing attribute is its resiliency. Given the indoor and outdoor environments that mass transit encounters, network performance can be hampered by a number of factors such as physical obstructions caused by trees, buildings, and even people congestion. Wireless networks that require line-of-sight conditions have even greater difficulty navigating such obstacles and can contribute to a decline in reliability and performance. From the ruggedized hardware to FMRP, Firetide's networking devices are built and designed to withstand the adverse conditions of outdoor broadband networks.

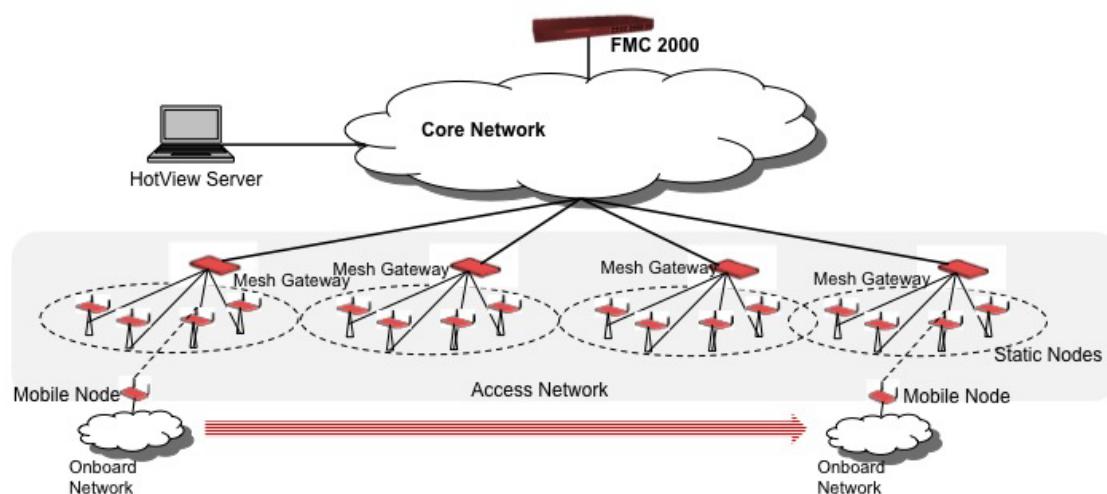
In summary, load balancing and redundancy coupled with high reliability provides network operators great flexibility to build-out or extend their networks and easily deploy nodes out-of-the-box with short notice.

Seamless Roaming, Metrics That Will Impress

True mobile networks are characterized by their ability to perform at high speed and enable seamless roaming across multiple meshes. Firetide prides itself on providing seamless roaming across mobile mesh nodes with zero packet loss at 100 Mbps. These capabilities enable the delivery of real-time video and high-quality voice on moving vehicles, creating a new breed of wireless mobile networks for transportation and public safety applications.

Packet loss plays the biggest role in effecting node-roaming efficiency. How networks approach and manage packet loss is typically a strong indicator of how networks will manage node-roaming periods. While many factors can contribute to packet loss, the primary ones include transmission errors, corrupted packets, RF noise and interference, and excessive data rates. Networks must also maintain enough aggregate throughput to efficiently deliver packetized video streams, or video performance can incur unacceptable latency and jitter.

On today's fast-moving trains, buses, and public safety vehicles, the ability to successfully transmit high-definition video and support seamless roaming across extended distances is paramount. Operating at sustained speeds of up to 100 mph, Firetide's mobile mesh technologies provide the only proven solutions capable of supporting high-definition video streams and seamless roaming across extended distances. Flow-based routing helps to balance traffic across the mesh, optimize aggregate throughput, and increase network performance. Established between source and destination MACs, flows are balanced on link-specific traffic loads and class-of-service priorities.



The Firetide Mobility Controller manages multiple mesh networks comprised of static and mobile nodes.

Multi-Hop Optimization with Intelligent Routing Protocol

Multi-hop optimization reduces contention in mesh topologies by providing numerous redundant paths. Intelligent FMRP is able to preemptively reroute traffic around any node that encounters interference, throughput overload, or other obstacles that may cause its failure. The packet-forwarding protocol can account for various last-minute changes in the RF and network topography and then determine the best path forward.

Firetide's depth of expertise in routing protocols is unparalleled in the mesh industry and has made a significant contribution in the optimization of multi-hop mesh networks. The routing protocols not only support connecting between mesh nodes, but they simultaneously seek to optimize the links in order to identify available, high throughput paths. High consideration is also placed on the quality of the link path rather than the shortest route due to concerns for packet loss. Multiple radios greatly increase the potential for enhanced channel selection as well.

Advanced End-to-End Security Protects Mesh-Wide Communications

Security is vital and one of the key considerations when evaluating WMN platforms. The potentially large number of over-the-air communication links presents one of the major challenges in securing the network. To ensure transmission confidentiality and privacy, Firetide's technology provides reliable and secure, end-to-end transmission of data, voice, and video traffic and management information.

At the heart of Firetide's security capabilities is 256-bit Advanced Encryption Standard (AES). Firetide utilizes the highest available, 256-bit key size AES encryption coupled with end-to-end packet transmission. Because Firetide mesh eliminates the need to open-up packets into Layer 3 between hops, the potential for sniffing data packets over a hop is eliminated, and transmissions are faster and more secure. Many comparable mesh solutions decrypt data packets at every hop which creates a point of vulnerability and slows down the process.

To communicate between mesh nodes, Firetide uses proprietary protocols which are not susceptible to other Wi-Fi-enabled devices. As a result, any device such as a laptop, smartphone, or tablet – other than a Firetide mesh node – cannot connect or communicate directly to the mesh network. Additionally, Firetide provides digitally-signed firmware files to stop any unauthorized firmware installation on nodes and VLAN-based access control lists to provide access control for all packets that are routed into or out of a VLAN.

Firetide also employs a MAC-based access control list and an option to block the ports completely on a need-basis. Although no unauthorized device can access the mesh network directly, this "High Security" feature can be enabled to detect any rogue node that is attempting to access the mesh network. In addition, the Firetide network management system communicates and shares network configuration information only with nodes having authorized Firetide-issued certificates. This blocks any rogue node that is attempting to spoof as a mesh node and join the network.

Customer Profile

Seoul Metropolitan Rapid Transit Corporation

- Four underground subway lines
- 2,037,00 daily ridership
- 201 subway trains at 148 stations

Integrator

- Korea Telecom
- Global Telecom (subcontractor)

Solution

- Firetide Wireless Infrastructure Mesh Solution
- 1,000 Firetide mesh nodes
- 350 cameras in stations
- 300 cameras in trains

Results

- Streaming video to and from moving trains
- High-speed handover
- Overcome challenging subway conditions
- Firetide Case Study: Seoul Korea Subway System



Train on the Seoul Metropolitan Subway system.

Firetide Case Study: Seoul Korea Subway System

High-performance, real-time streaming video to and from 50 mph moving trains in a challenging subway environment.

Objective

After 198 people perished in the Daegu, Korea subway fire in 2003, Seoul Metropolitan Rapid Transit Corporation (SMRT) decided to deploy a real-time wireless video surveillance system in four subway lines to help protect subway riders and transit workers against potential fires, accidents, thefts, and other harmful incidents.

Requirements

SMRT wanted a system that would provide train operators with a video of the station being entered. In that way, a driver could decide not to enter the station if there were accidents or other problems such as a person on the track. Technical requirements of the system included:

- Ability to stream video to and from trains moving at 50 mph
- Ability to transmit video to and from subway cars
- Seamless handoff and roaming along the fixed wireless infrastructure
- Video surveillance from inside passenger trains to a monitoring center
- Streaming video on passenger-train monitors for public announcements and commercial advertisements
- Overcome harsh subway conditions: reflective metal surfaces, noise and vibrations, and high-voltage electric power

Solution

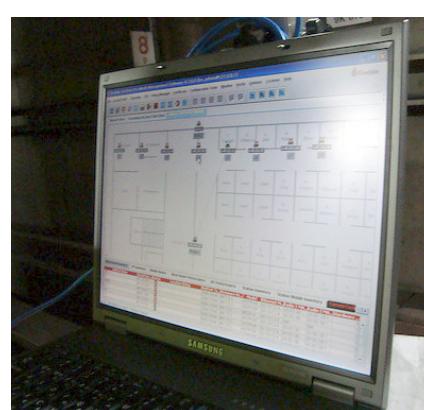
After competitive testing, Firetide was the only supplier to successfully complete the high-speed handover. The Firetide Wireless Mesh Infrastructure was deployed with a total of 1,000 Firetide mesh nodes, 350 cameras in the stations, and 300 cameras in the trains.

Results

The wireless infrastructure delivers 20 Mbps of capacity, enabling real-time streaming video to and from trains moving at 50 mph. The system operates reliably in the highly challenged subway environment.

"Firetide was selected because no other vendor's wireless mesh equipment could provide the high-speed performance required to deliver streaming video from the station to moving rail cars and operate in one of the harshest of environments for RF networks."

— Jung Yeong-Hyun, Project Manager of Global Telecom



SMRT decided to deploy a real-time wireless video surveillance system in subway lines to help protect subway riders and transit workers.

Summary

Globalization, urbanization, and population growth have changed the landscape for today's transportation providers. To remain financially viable and competitive, these providers are looking for ways to maximize revenues, reduce costs, increase security, and improve the overall passenger experience. Intelligent, advanced wireless mesh technology can help today's transportation providers operate more efficiently, improve the overall customer experience, and protect people and assets.

However, not all wireless mesh networks are equal. From inception, Firetide's next-generation Automesh technology was built with mobility and video in mind, allowing network operators to reliably and securely support mission-critical applications in a wide variety of challenging mobile environments. With more than 10,000 customers in 40 countries, Firetide has successfully deployed mesh networks in government, public safety, transportation, industrial automation, and service provider organizations. The Company's technical support team, in collaboration with a global community of qualified solution providers, has the experience and expertise to help transportation agencies optimally configure, deploy, operate, and manage mesh networks based on each agency's individual requirements.

White Paper

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