

## Cisco Positive Train Control: Enhancing End-to-End Rail Safety



### What You Will Learn

Positive Train Control (PTC), one of many new safety measures mandated by the U.S. Federal Government, is designed to help prevent train-to-train collisions, derailments, and other human-caused accidents. The Rail Safety Improvement Act of 2008 mandates that seven Class I railroads as well as several other freight, commuter and short line railroads install PTC on roughly 70,000 miles of track used to transport hazardous materials and passengers by December 31, 2015.

This brief highlights the costs and business benefits of PTC for railroads as well as overall safety implications. High level architecture diagrams are included to show how Cisco networking solutions fit into the PTC infrastructure.

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## What is Positive Train Control?

Positive Train Control (PTC) is one of many new safety measures mandated by the United States Federal government when President George W. Bush signed the *Rail Safety Improvement Act* in October of 2008. PTC is an end-to-end rail safety system designed to help prevent the following incidents:

- Train-to-train collisions
- Derailments caused by excessive speed
- Train incursions into established work zone limits
- Movement of a train through a track switch left in the wrong position

An effective PTC system is able to determine the location and speed of trains and is designed to augment the safety measures already taken by the engineer to control the train. However, if warnings to slow down or stop the train are ignored or cannot be performed by the engineer, PTC will automatically apply the brakes to achieve the desired speed or state of the train.

Seven Class I railroads in the U.S. as well as several other regional commuter and short line railroads are required to install PTC. PTC systems must be deployed on approximately 70,000 miles of track and on more than 20,000 locomotives that provide passenger transportation or transport hazardous materials, by December 31, 2015.

## Costs and Benefits of Positive Train Control

The Federal Railroad Administration (FRA) estimates that full PTC implementation will cost more than \$10 billion, with annual maintenance costs of about \$850 million. In 2012, the FRA submitted a Report to Congress<sup>1</sup>, which stated that the U.S. railroad industry had already invested over \$1.5 billion into PTC implementation.

The primary benefit of Positive Train Control, and the driver behind the Federal mandate to implement it, is to improve rail safety. Beyond rail safety improvement, investment in PTC will likely pay for itself over the long term through several potential business benefits.

## Rail Safety

While PTC will not prevent all rail accidents, it is designed to prevent a number of human-caused accidents. PTC had been discussed for several years, but it was a major train collision between a Metrolink commuter train and a Union Pacific freight train in September 2008 that prompted the quick passage of the *Rail Safety Improvement Act* in October of 2008. That collision killed 25 people and injured another 135. Damages totaled over \$7 million.

An NTSB investigation concluded that the cause of the collision was the failure of the Metrolink commuter train engineer to notice a red signal in order to stop the train accordingly<sup>2</sup>. Further, the NTSB report stated that *“Contributing to the accident was the lack of a Positive Train Control system that would have stopped the Metrolink train short of the red signal and thus prevented the collision.”*

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<sup>1</sup> Federal Railroad Administration Report to Congress, Positive Train Control Implementation, Issues and Impacts, August 2012

<sup>2</sup> Railroad Accident Report NTSB/RAR -10/01

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The PTC system would have allowed the engineer up to 15 seconds to respond appropriately to the red signal, and stop the train, before the brakes would have been automatically applied by the system.

### Business Benefits

The same digital data link and network used to meet PTC safety mandates can also be used to transmit information to train crews, track completed work, or send real-time diagnostic locomotive information.

The Federal Railroad Association (FRA) funded an analysis of the costs and benefits of deploying a Positive Train Control system<sup>3</sup>, and estimated that annual ongoing benefits upon completion are expected to be between \$2.2 billion and \$3.8 billion.

This is expected to be seen in the following potential business benefits:

- Line capacity enhancement
- Improved service reliability
- Faster over-the-road running times
- More efficient use of cars and locomotives (made possible by real-time location information)
- Reduction in locomotive failures (due to availability of real-time diagnostics)
- Larger windows for track maintenance (made possible by real-time location information)
- Fuel savings

*Source: Transportation Research Forum*

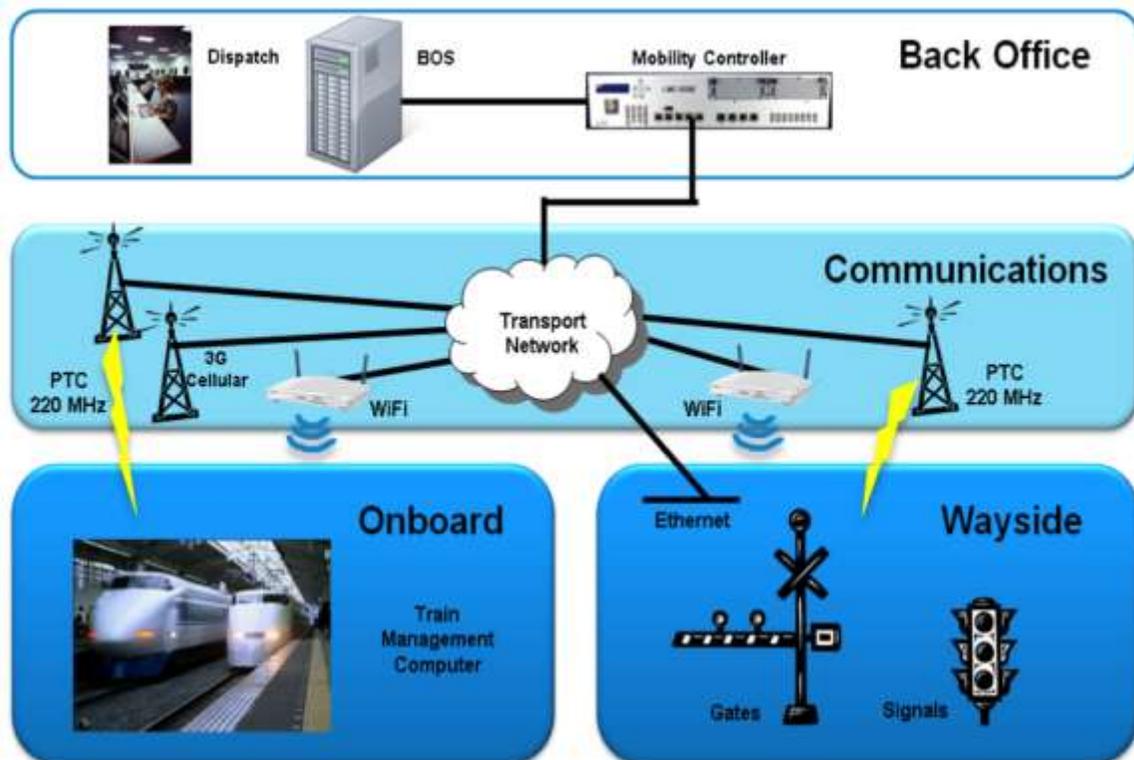
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<sup>3</sup> Positive Train Control (PTC): Calculating Benefits and Costs of New Railroad Control Technology – ZETA-TECH as part of FRA contract DTRF-53-01-D-0021

## End-to-End PTC Components

An end-to-end PTC solution, as shown in figure 1, is comprised of four main architectural components that include: the back office, onboard, wayside, and bi-directional communication transport.

**Figure 1.** The high-level architecture of an end-to-end PTC solution



### Back Office

The back office houses the Back Office Server (BOS), which stores, processes, and acts on information it receives from the on-board locomotive computer, wayside messaging server, and maintenance personnel. Its database maintains information on trains, tracks, work zones, and speed restrictions. Based on this data, the BOS will issue movement authorities and notifications to the locomotives.

### Onboard

The onboard computer located on the locomotive receives the movement authorities from the BOS and notifies the engineer of changes in the speed limit or other safety concerns. The engineer uses this data, along with information from wayside devices regarding trackside signaling, and takes appropriate action. If the engineer does not slow or stop the train within 15 seconds, the onboard computer automatically applies the brakes. In the event that the onboard system loses connectivity and cannot receive this mission-critical information, the train must be stopped prior to entering the next block.

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## Wayside

The wayside system encompasses the signaling equipment on and around the track. This includes lamps, switches, gates and track circuits, among other things. These devices can connect to a wayside-messaging server through the use of a Wayside Interface Unit (WIU). This allows the messaging server to send information about the trackside equipment to the BOS for processing, and to broadcast the information over a radio interface so that locomotives can receive the information directly and act on it accordingly.

## Communication

Communication between the back office, locomotive, and wayside devices relies on a redundant and resilient bi-directional communications network. The PTC solution offers up to four different interface types that can be used for communication, including Ethernet, Wi-Fi, 220 MHz PTC Radio, and 3G/4G Cellular.

The wayside equipment may communicate with the BOS over any one of the four interface types. In order to provide mobility, the onboard equipment uses either the 220 MHz radio or 3G/4G cellular interface. In the case of the locomotive, the device must be capable of roaming horizontally from base station to base station. In either case, the device must also be capable of roaming vertically between communications technologies. For example, 3G cellular may be used as a backup to 220 MHz radio or a train may switch to Wi-Fi while at the train station or in the yard.

The industry has standardized on 220 MHz radio frequency due to its long range (20–30 miles). This distance decreases the number of base stations deployed along the tracks. Because rails are frequently shared across multiple railroad companies, standardizing on a common PTC radio frequency also allows railroads to interoperate with each other, which streamlines operations and reduces costs.

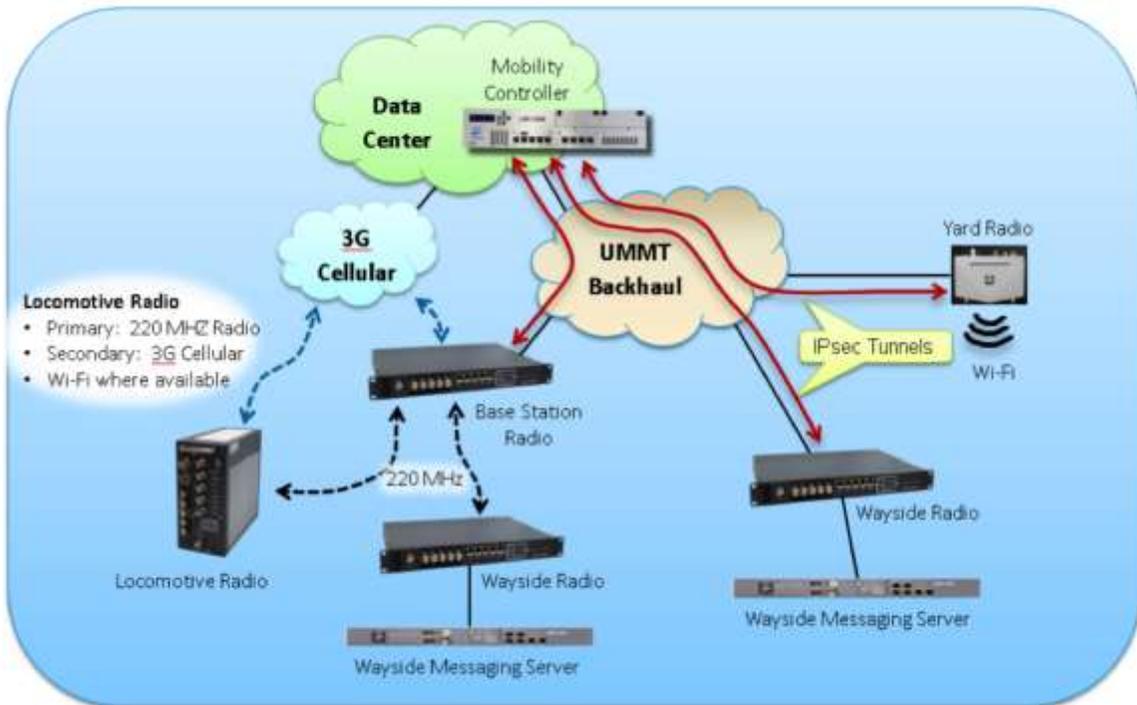
The transport network, consisting of the access, aggregation, and core networks, also provides a resilient communications path between the field devices and the BOS. This includes ruggedized Ethernet switching at the edge, and a multipath backhaul with sub-second re-convergence.

## The Cisco PTC Solution

To enable railroads within the United States to increase rail safety and meet the requirements of the Federal mandate, Cisco® has partnered with Lilee Systems to provide a state-of-the-art Positive Train Control solution. Combining the expertise of Lilee Systems' software-defined PTC radio components with Cisco's network and transport expertise, railroads can count on a solid and scalable solution.

The PTC radio components supplied by Lilee Systems include the base station, wayside, yard, and locomotive radios, as well as the mobility controller. The mobility controller provides central management of all the PTC components and also manages mobility. Base station, yard, and wayside radios communicate securely via an IPsec tunnel to the mobility controller. PTC, as shown on figure 2, relies on a redundant and resilient backhaul network with cellular backup.

**Figure 2.** A logical PTC radio network layout



The Lilee Systems software-defined radios (SDR) provide a high level of flexibility within the PTC network as they can be configured through software to have one or more virtual interfaces. These interfaces can be of the following types:

- 220 MHz TDM (Time Division Multiplex) radio
- 2.4 GHz/5 GHz Wi-Fi a/b/g/n
- 3G cellular UMTS
- Ethernet

The radios are also equipped with a GPS receiver for time synchronization and location information.

## Onboard Radio

A train management computer (TMC) is the onboard computer that communicates with the back office server. It uses the onboard locomotive radio as its gateway to reach the data center hosting the BOS. The locomotive radio typically connects to a base station radio over a 220 MHz radio frequency. The base station then securely tunnels traffic it receives from the locomotive radio back to the mobility controller. In the event that communications to a base station are not available over the radio interface, the locomotive radio may be configured to use the 3G cellular interface as a backup.



When a train enters a train station or train yard, where Wi-Fi is available, the locomotive radio can connect to an available Lilee Systems Wi-Fi access point, known as a Yard Radio. Connecting to an available Wi-Fi network offloads some traffic from the 220 MHz radio and offers a high-bandwidth connection for management scenarios including train schedule downloads, onboard software maintenance (configurations, upgrades, etc.), or even mission-critical PTC communications if the railroad prefers to use Wi-Fi for this purpose when available.

## Base Station Radio

Base station radios can be placed 20 to 30 miles apart from each other along the track, with each operating at a unique frequency within the 218-222 MHz range. Through its Ethernet interface, the radio will communicate across the backhaul network securely with the mobility controller hosted in a remote operating center (ROC). In the event that the base station loses its wired connection to the backhaul network, it can be configured to use a 3G cellular connection as a backup.



The base station also has a Wi-Fi interface that can be configured as an access point or a Wi-Fi client. This offers high-speed Wi-Fi connectivity to maintenance personnel in the immediate area of the base station.

## Wayside Radio

The wayside radio is used in wayside (trackside) stations to provide PTC network connectivity to wayside signaling equipment. If fixed wire-line access to the backhaul network is available, the wayside radio may connect to the BOS in the same manner as a base station radio, and use its 3G cellular interface as a backup. If direct connection to the backhaul network is not possible, then the wayside radio may connect to the closest base station over 220 MHz PTC radio for communications. The wayside radio will also broadcast wayside signaling messages so that locomotive radios can receive and act on them directly.



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### Wayside Messaging Server

A wayside messaging server connects to a wayside radio in order to send PTC messaging about the wayside signaling back to the BOS. Wayside signaling may include lamps, track circuits, grade level gates and track switches, among other things. These wayside devices connect to the wayside messaging server through a wayside interface unit (WIU). The WIU creates a digital message consumed by the messaging server. The messaging server hosts an x86 application engine that processes the messages from the WIU and sends them to the BOS and broadcasts them to the locomotive, both via the wayside radio. If the messaging server loses its connection to the wayside radio, it may be configured to use a 3G cellular interface as a backup to get the messaging to the BOS.

### Mobility Controller

The mobility controller is hosted in a remote operating center (ROC). It provides communication between the trackside network, including locomotive and wayside radios, and the back office server. Communications between the mobility controller and any base station and wayside radios with which it communicates with are secured through the use of IPsec tunneling.

Remote management, including configuration and monitoring, of remote devices is performed by the mobility controller. This means that while configuration changes to a wayside, locomotive, or base station radio can be performed locally at the device, the changes can also be made at the mobility controller and pushed down to the device.

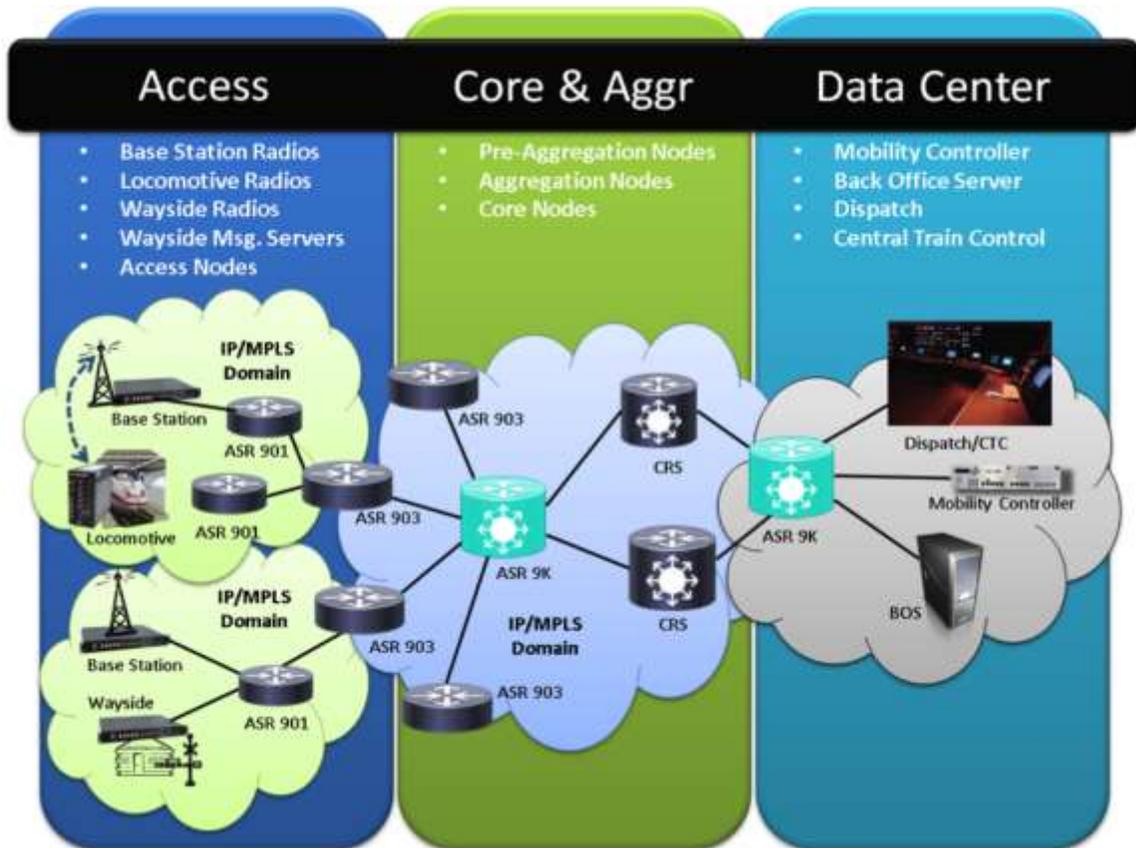
### Cisco Unified MPLS for Mobile Transport (UMMT) Backhaul

Another critical consideration is to backhaul the remote PTC radio traffic to the back office server and transport mission-critical movement authorities from the back office server to the locomotives. While some railroads may already have a backhaul transport network to some degree, it is assumed that one does not exist.

The Cisco Unified MPLS Mobile Transport (UMMT) network design will accommodate the backhaul needs of PTC deployments of any size or scale. While the design breaks down the network into access, pre-aggregation, aggregation, and core segments, some segments can be combined depending on the size and scope of the network.

The network design example in figure 3 represents a smaller network where the core, aggregation, and pre-aggregation networks are combined into a single network domain. The access network is where the base station and wayside radios would access the network via Ethernet.

**Figure 3.** UMMT spans the access, aggregation, and core network to connect PTC to the data center



The example in figure 3 assumes a flat Label Distribution Protocol (LDP) and Label Switched Path (LSP) across the core and aggregation networks. Together, these two networks form one IGP and LDP domain. The MPLS mobile access network is based on MPLS access rings with ASR 901 access routers, and integrated with labeled BGP LSPs. This network can scale up to thousands of access routers and hundreds of pre-aggregation network nodes.

In cases where a larger backhaul transport is needed, the core and aggregation networks can be separated into independent IGP/LDP domains. Inter-domain MPLS connectivity would continue to be based on hierarchical labeled BGP LSPs. A network design such as this would allow for tens of thousands of access nodes and thousands of pre-aggregation nodes. The Cisco Unified MPLS Mobile Transport network design as shown in table 1 will accommodate the backhaul needs of PTC deployments of any size or scale

Several unified MPLS architecture models have been tested, validated, and documented as part of the UMMT Cisco Validated Design. Further, many UMMT production deployments mean it is a mature and tested design that railroads can confidently deploy.

**Table 1.** Components validated as part of the UMMT design and platforms used in UMMT backhaul network

Role	Platform	Software Release
Access Router	ASR 901 	15.2(2)SNG
Pre-Aggregation Node	ASR 903 	15.2(2)S1
Pre-Aggregation Node	ME 3600-24CX 	15.2(2)S1
Aggregation Node	ASR 9000 	4.2.1
Core Node	CRS 	4.2.1
Network Management System	CiscoPrime IP NGN	1.1

### Remote Ruggedized Switching

The base station and wayside station use ruggedized switches that can withstand large ambient temperature ranges (-40C to 75C), and support flexible configurations. The Cisco Industrial Ethernet (IE) 2000 and 3000 series switches are layer 2 and layer 3 capable, respectively. They both offer easy deployment, security, and resiliency in a din-rail form factor.



IE 2000



IE 3000

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## Summary

The Cisco PTC solution provides a full end-to-end solution that provides the required networking infrastructure needed to comply with the Federal mandate for Positive Train Control across the railroad. The PTC solution is designed to augment safety precautions already undertaken by the locomotive engineer, in order to help prevent human-caused train incidents. In addition, the potential business benefits of PTC provide a compelling Return on Investment for railroads within a few years of completion, which can also drive longer term benefits and new business models.

The Lilee Systems software-defined PTC radios offer a fully redundant and resilient solution at the trackside and on the locomotive, while Cisco's remote switching and Unified MPLS Mobile Transport offer redundancy and resiliency throughout the backhaul network. The network can scale to meet the needs of current rail deployments, while accommodating future capacity growth and new applications.

## For More Information

For more information on Positive Train Control and Cisco's Connected Rail solutions, visit <http://www.cisco.com/go/transportation>

For additional information and PTC resources you can also visit the sites below.

[Association of American Railroads](#)

[Federal Railroad Administration](#)



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