Challenges of Positive Train Control Interoperability

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Executive Summary
This paper presents the challenges of interoperability with regards to the federally mandated Positive Train Control (PTC) initiative. This paper looks at the challenges associated with interoperability as it relates to the communication system supporting PTC. For purposes of discussion, the challenges presented in this paper can be grouped into three interoperability areas:

- Technology
- Security
- Configuration Management

This paper does not review or discuss the specifics of the Federal mandate or railroad operating rules. For specifics regarding the Federal mandate, it is recommended that an interested party contact the Federal Railroad Administration. For details regarding the impacts of PTC on a railroad’s operating rules, it is recommended that an interested party contact the railroad of interest directly.

Interoperability as defined in association with Positive Train Control can be slotted into the three interoperability areas above. At the core of the interoperability challenge is the need for the system to be:

- Able to meet the design goal of one false enforcement per million train miles
- Able to accommodate multiple communication system architectures
- Able to scale from small operations to Class 1 operations
- Able to interface with existing back office applications
- Able to be interoperable across distributed networks
- Able to support radio interchangeability on board the locomotive
- Able to support varying deployment timelines

This paper references requirements developed by the Interoperable Train Control Committee (ITCC) in order to establish a common point for discussion. The ITCC contains several technical sub-committees that develop common requirements for the supplier community.

Introduction

Ecosystem
The interoperable PTC ecosystem consists of railroads, associations, regulatory organizations and suppliers. The railroads themselves can be classified as Class 1s, Short Lines, and Commuters. The three classifications present unique challenges to interoperability. These challenges include scale, operating requirements, and deployment schedules. The scale of the Class 1 PTC deployments, in conjunction with the amount of required railroad testing, means that PTC communication system deployment will take years.
Short Lines present the other side of the scale challenge. The Short Lines will deploy on a much smaller scale than the Class 1s. PTC technology solutions that are designed to meet the expected traffic load of a Class 1 must also scale down well to meet Short Line business requirements. The PTC communication system architecture was developed for ITC requirements for Class 1 freight railroads.

Commuters have the unique challenges associated with public agencies, expectations of customers and the operational profile of train traffic. Generally, the Commuters are operating in urban areas where system capacity and interoperability requirements are difficult to achieve. This compounds the complexity of the interoperability between Class 1s, Short Line and Commuters.

When tackling PTC deployment, the Class 1s, Short Lines and Commuters all must consider how to support interoperability with new technology deployments as well as interoperability with legacy hardware and software in the back office, on board the locomotive and at the wayside.

**Five Interoperability Components**

Interoperability, in relations with Positive Train Control, has many essential components that can be categorized in the three interoperability areas for the purposes of this paper. There are additional areas of interoperability that are out of scope of this paper such as Governance and Regulatory. The three areas considered in this paper are:

- Technology
- Security
- Configuration Management

The core of the interoperability challenge is the need to support those railroads required to deploy Positive Train Control. As discussed above the Class 1s, Short Lines and Commuters have their own requirements that differ slightly from the other two groups. An interoperable solution must be able to accommodate the list of core system requirements as well as the interoperability requirements associated with specific railroad types.

The ITCC has developed hundreds of technical requirements for the PTC communication system. For the purposes of this paper, the author summarized the vast number of technical requirements into a list of directional requirements. The directional level requirements are for discussion purposes only. At the highest level, the solution must be:

- Able to meet the design goal of high reliability and availability
- Able to accommodate multiple communication system architectures
- Able to scale from small operations to Class 1 operations
- Able to interface with existing back office applications
- Able to be interoperable across distributed networks
- Able to support radio interchangeability on board the locomotive
- Able to support varying deployment timelines
- Able to support multiple layers of security

**Technology**

**Strategy**

The original strategy to designing an interoperable PTC communication solution was based on architectural layers of abstraction to allow different system components to design, develop and evolve at their natural rate. The architectural approach accommodated the varying rate at which requirements were developed for the system components. This approach enabled iterative requirements definition, product development and a field testing
While some architectural abstraction layers have been reduced, or blurred, the approach is still in use today.

**Interoperability**
The strategy of architectural layers enabled the parallel development of an interoperable wireless component, a messaging component and a system management framework.

The interoperable wireless component is based on an over-the-air protocol developed by Meteorcomm. The protocol was designed specifically to meet the performance requirements as defined by the Interoperable Train Control Committee (ITCC) based on estimated railroad loading. The protocol accommodates both scheduled and ad hoc messages. The wayside to locomotive communication link has aggressive reliability requirements that result in a protocol with both fixed and dynamic portions. The fixed slot portion of the protocol ensures the locomotive receives the wayside status messages. The over-the-air protocol must also support ad hoc messages associated with changing conditions, subscription requests and status updates.

The interoperable, over-the-air protocol is frequency independent. The railroad industry purchased 220 MHz spectrum for PTC. The 220 MHz spectrum is intended to serve as the primary interoperable wireless link for PTC. An essential part of the over-the-air protocol being interoperable is based on the design using a ‘common channel’ approach. The common channel is core to the over-the-air protocol and its ability to handle planned and ad hoc traffic. The premise is that any locomotive can hear and communicate with any fixed 220 MHz PTC communication system infrastructure.

Interoperability requires that all interoperable PTC communication systems use the same common channel. Access to the common channel is achieved through PTC220 LLC.

The ITCC’s communication system includes support for other transports such as digital cell, satellite and interoperable WiFi. Each of these transports is not considered directly interoperable. These transports connect directly to a single railroad back office. Interoperability is achieved between these types of transport through the messaging system defined by ITCC.

Messaging is considered core to the PTC communication system and interoperability. Messaging serves as the glue that ties the ITCC communication system together. As noted above, the messaging layer allows railroads to leverage existing IP transports in addition to the 220 MHz transport. From the application perspective, applications are not aware of the pathway its messages are using to reach the remote device.

Beyond abstracting the wireless transports from the back office applications, messaging has several major functions that it supports. It is responsible for the routing and delivery of messages between offices and remotes. Remotes include wayside equipment as well as equipment on board the locomotive. This requires that the message layer supports transport selection, mobility, protocol transformation and high availability. In addition, the Messaging layer supports peer-to-peer broadcasts for things such as wayside interface unit (WIU) status updates.

The ITCC requirements in principal describe interoperability as the ability for a locomotive to connect to any base station and, therefore, back office and to communicate with any PTC equipped wayside. The description also defines a distributed network of back offices that are interconnected. The architecture allows individual railroads to establish their own back office or share with other railroads. In addition, the ITCC requirements enable a railroad to deploy remotes under another railroad’s PTC infrastructure and have them connect to their own back office.

To provide an interoperable method for remote monitoring and management of assets, the ITCC requirements define a systems management framework. The systems management framework requirements provide for:

- A security infrastructure for distributing sensitive data
• Large file distribution
• Asset-kit distribution and loading over-the-air
• Unsolicited notifications and status
• Configuration management
• Session management and access control
• Command execution and diagnostics

Meteorcomm’s approach created three distinctive, development work streams: radio products; messaging; and systems management based on ITC requirements. Each work stream contained key interoperability functionality. Meteorcomm’s strategy included working closely with the ITC and its subcommittees to deliver functionality incrementally ahead of ITC member testing. As a result, Meteorcomm has published five major, integrated software releases. The integrated releases include releases of each of its radio, messaging and systems management products.

**Interchangeability**

The PTC communication system includes a unique requirement of ‘interchangeability’ onboard locomotives. The interchangeability requirement extends beyond interoperability requirements. For the PTC communication system, not only are radios from different suppliers required to communicate with each other, they are required to be interchangeable. The intent is that if a locomotive radio fails, another manufacturer’s radio can replace it without any modifications to the locomotive equipment. PTC radio manufacturers are required to produce locomotive radios with the same form, fit, and function. As part of the solution for interoperability, ITC radio requirements include a removable memory card in each radio type. The intent is for the removable memory to hold the radio’s personality. The removable memory containing the radio’s personality enables technicians the ability to interchange radios by swapping memory cards.

**Security**

**ITC Communication System**
The ITC Communication System contains multiple security mechanisms. Security functions are implemented within ITC systems management requirements. The ITC systems management requirements are designed to securely pass information about status, events, alerts and configuration for the different ITC Assets over the ITC Communication platform. Systems management provides a secure method for railroad Back Office applications (BO) to configure and manage each ITC Asset remotely. Systems management also supports the transfer and loading of software, security, data and configuration kits, remote execution of commands and it fulfills the ITC Railroad interoperability requirements.

**Configuration Management**

Configuration management will become increasingly important to interoperability as railroads move through deployment into operational status. Given the large number of devices that are deploying nationwide over a period of multiple years, maintaining interoperability once achieved will require establishment of a strong interoperability governance process. The importance of configuration management is expected to increase rapidly. The railroad industry will be required to establish a framework to ensure that interoperability achieved during initial deployments is not broken at some point in the future due to lack of coordination on upgrading critical components.

**Closing**

As noted by many railroad executives, PTC is the largest technology initiative undertaken by the railroad industry. The safety overlay of PTC requires unprecedented reliability and availability requirements for field deployed technology. In addition, PTC requires railroads coordinate deployment to ensure success of the PTC system. At the core of PTC is the wireless communication system. The PTC communication system will grow, change, and evolve over the next decade. It will serve as a model for future technology deployments.
Understanding the Complexity of Implementing PTC Communications Technology

Communications System Overview
Meteorcomm’s Role in PTC Communications

- Design the System and Ensure Interoperability
  - Wayside, Locomotive & Base Station Radio
  - Messaging System
  - Systems Management System
  - Integration Testing
- Support Radio Manufacturers: CalAmp and Meteorcomm

ITC Communication System Overview

- ITCC – Interoperable Train Control Communications system
  - ITCM – Messaging System
  - ITCR – 220 MHz Radio Network
  - ITCSM – Systems Management System (SMS)

ITCSM Platform Overview

- ITCSM – ITC Systems Management System
  - Framework (Gateway, Protocol, and reference Agent) providing an interoperable method for remote monitoring and management of assets

Major ITCSM Functions

- Security Infrastructure for distributing sensitive data
- File transfer
- Asset-kit distribution and load over-the-air (Security, Configuration, Firmware/Software)
- Unsolicited notifications and status
- Full configuration management (Asset + ITCSM)
- File distribution
- Session management & access control
- Notification enrichment & propagation
- Command execution & diagnostics

ITCM Platform Overview

- ITCM – Interoperable Train Control Messaging system
  - Custom messaging solution that allows applications to exchange messages regardless of their physical location or type of connectivity (available transports)

Transports

- Within ITCC, the wireless transports are made up of
  - Narrow-band networks (low data throughput and high coverage such as 220 MHz)
  - Broad-band networks (high data throughput and low coverage such as 802.11)
- Broad-band networks are primarily targeted for initial bulk data downloads
- The narrow-band network is intended to be geographically ubiquitous and is primarily used in continuous communications (e.g. wayside status, position reports)
- The narrow-band network can serve as a secondary network for initial bulk data download
- The communications system provides data communications between Office segments over an MPLS network

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Major ITCM Functions

- Routing and delivery of messages between office and remote
- Routing and delivery of messages between offices
- Support for peer to peer broadcasts
- Transport selection
- Support for mobility
- Protocol Transformation
- Multi-Transport Support (220 MHz and wireless IP)
- Fragmentation
- Multi-Layer High Availability Design
- Support for Class D & AMQP application transports

ITCM Components

ITCR Platform Overview

- ITCR – Interoperable Train Control Radio network
- Highly efficient low bandwidth radio network customized to support PTC communications with the intention of being the only guaranteed nationwide network

Communication Patterns

Major ITCR Functions

- Routing and delivery of messages between office and remote
- Support for peer to peer broadcasts (e.g. WIUStatus)
- Support for mobility
- Support for FEC and Diversity Receive (on Loco & Base)
- Support for easy swapping through the use of a removable Configuration Information Module (CIM)

Thank you