Advanced LRT Train Control

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ABSTRACT:

There has been a surge in activity recently about installing advanced signal systems on Light Rail Transit systems in order to meet the demands of heavy passenger loading and passenger friendly features. This paper investigates the signal advances that makes communications based signaling attractive in this environment as well as how it is applied such as RF data links, wayside message routing, and profile based train control. The unique interaction between the train, highway crossing (both gated and priority control) will be discussed in detail. In addition, several examples will be illustrated where these advanced systems will provide benefits the traveling public. Insight will also be provided into the effects on freight rail operations and how integrated operations can be achieved.

INTRODUCTION

In recent years in the U.S., both freight railroads and transit railways have continued to see increases in traffic while the route mileage of freight carriers has declined as shown in figure 1. The increase in traffic is largely attributed to the passing of the Staggers Act in the 1970’s that deregulated the industry (1). Deregulation has also allowed railroads to abandon or sell less profitable lines while providing transit operators expansion opportunities. All of this has caused an accelerated effect of traffic growth on the lines that still exist (2).
The same conditions have caused a great revival for mass transit. As Figure 2 shows, mass transit ridership has significantly increased over the last decade due largely to the number of new Light Rail Transit (LRT) and Commuter Rail projects that have been built (3). By mid 2008, the gasoline price spike drove ridership to record highs throughout the nation. The recession that followed has lowered transit ridership, however as the economy in the United States and the world recovers, these levels recovered along the same trend.
The demand creating the growth in the freight and transit industry has caused them to either create or increase capacity. This growth provides the need for capital planning for new rail lines, but additional track is not always possible. In these areas, other solutions are used to increase capacity. Many of the capacity constraints can be addressed with upgrading the signal system.

Rail and mass transit systems rely on signal systems of various types to provide safety in their operations. These operations enforce train separation as they operate. The proper design and use of the signaling determine the overall capacity of the system in terms of headway and throughput (the number of trains per hour or the number of passengers per hour per direction).

THE NEED FOR SAFETY AND ENFORCEMENT IN LRT APPLICATIONS

Recent legislation enacted by the United States Congress has mandated the installation of Positive Train Control (PTC) on virtually all Class 1 mainline and Passenger railroads (A Class I railroad is defined as having annual revenues of at least $250M). PTC is a form of train control generally based on the Global Positioning System (GPS) where trains determine their location. Movement authorities are transmitted to trains over data radio networks, and trains ping wayside devices to check the route ahead.

PTC type systems are being developed throughout the world with similar architecture. In Australia; Barney, Haley and Nikandros detailed a simulation methodology to determine SBD of heavy haul freight trains (4). In the U.S., PTC is currently being developed for before the mandated 2015 time limit. The braking algorithm being progressed involves specific inputs such as speed, train weight and alignment. This is called “Adaptive Braking” in that it calculates a different solution based on the data on hand (5). Reports on this development such as those from
Ede, Polivka, Brosseau, Tse, and Reinschmidt detail purely reactive methodology and will determine the overall impact on capacity (6).

LRT train control systems recently deployed have tended to include some sort of enforcement of either wayside signals and/or civil speeds. For example, Dallas, Baltimore, St. Louis, and Northern New Jersey (Hudson Bergen and Newark City LRT) have all installed cab signals for civil and signal enforcement, while Minneapolis and Southern New Jersey have installed Trip Stop systems for mainly signal protection. This enhances the safety of train operation in terms of collision avoidance and operating speeds, but adds significantly to equipment capital and maintenance costs.

**Transit Requirements**

Modern LRT systems require several features that are offered to the riding public that are incorporated in advanced train control and management systems generally associated with heavy rail metros. Some of these features include:

- Collision Avoidance,
- Automatic Routing at junctions,
- Train to Wayside Communications (TWC) devices for station and on board announcements,
- Fixed highway crossing starts for flashing light signals and gate (FLS&G) and preemption, and
- Near side stations with timed approach and reactivation of FLS&G.

These functions are realized in conventional signaling, generally with cab signals and ancillary equipment. However, Communications Based Train Control systems offer these functions with a different concept that can reduce the wayside equipment requirements. Moving
forward, LRT properties generally cannot afford the cost of CBTC systems, but could use key features such as:

- Packaged interfaces to Public Address and Customer Information Systems (PA/CIS),
- Automatic Vehicle Location (AVL) from precise location determination sub systems within CBTC,
- Automatic Train Operation/Driverless Train Operation/Unattended Train Operation (ATO/DTO/UTO), and
- Platform Screen Doors (PSD) interfaces.

Positive Train Control offers a potential solution to LRT operations; however PTC from the Class 1 railroad perspective (using the I-ETMS approach described further on in the paper) is still largely a development project. This means that adding features that would allow full integration into the LRT environment will likely not take place until after the mandated deployment date of December 31, 2015.

PTC Types

For PTC, there are four approaches as defined by the FRA (7). The first is a Non-vital overlay. A Non-Vital Overlay PTC system is designed to enforce features of an existing method of operation and must be shown to reliably execute the functions set forth in CFR 49 236.1005 with at least an 80 percent reduction of the risk associated with accidents. The system enforces an underlying system such as conventional wayside signals. Sensors are configured in such a way as to determine what aspects signals display, or what position switches are in.

The second is a Vital Overlay. A Vital Overlay PTC system is similar to a Non-Vital Overlay in that it must reliably execute the functions set forth in CFR 49 236.1005, and have
sufficient documentation to demonstrate fulfillment of the safety assurance principles required by the FRA. A Vital Overlay system is essentially the same as a Non-Vital Overlay system that realizes with vital processes. This represents the safety critical nature of conventional train control and greatly enhances safety.

The third PTC type is Stand-alone. A Stand alone PTC system is a replacement for an existing signal or train control system, or otherwise changes to the existing method of operations. The system must reliably execute the functions required by CFR 236.1005 and be demonstrated it does so to FRA’s satisfaction. A Vital Stand Alone system has no underlying system and directly controls the enforcement of civil speeds, train separation, etc. without any other input. This is similar to CBTC systems that operate on moving or virtual block arrangement.

The last type is a Mixed PTC system. A Mixed PTC system combines Stand-Alone, Vital, or Non-Vital characteristics while possessing appropriate structuring of the safety case and analysis.

**Commercial Offerings**

There are three commercial approaches that are being progressed within the industry at present for PTC:

1. ITCS, A proprietary system in service on Amtrak lines in Michigan (Vital Overlay),
2. ACSES, An open system used on the Northeast Corridor developed by Amtrak (Vital Overlay), and
3. I-ETMS, A proprietary system being developed by the Class 1 freight railroads (Vital Overlay)

It should be noted that all of these systems are considered Vital Overlay type PTC. Of these offerings, both I-ETMS and ITCS provide features and development that can greatly
benefit LRT operations. Although ITCS has been used outside of North America as a Vital Stand-Alone application, I-ETMS has not

Once PTC is in an established market (albeit forced by legislation of the Rail Safety Act of 2008), there may be options to acquire a standalone train control system with full moving block that does not require conventional signal equipment. As in CBTC, the basic concepts of communications based signaling offer several advantages over track circuit based systems.

Below is a comparison of key features of both CBTC and PTC that can help understand where these systems are in the market and how they can be applied to LRT operations.

**CBTC vs. PTC**

Both CBTC and PTC can fill niches associated with transit line capacity and available infrastructure. Since these systems are similar in architecture, but very different on application, a comparison of the two systems is warranted. Table 2, below starts this comparison and highlights some of the basic features of both.

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*Table 1, Key Attributes of PTC and CBTC*

CBTC has been developed for use in transit systems for over 30 years. As such, it is a mature but proprietary system. I-ETMS PTC on the other hand will be an open source architecture some time after the initial 2015 deployment. In fact, the ITCS system is currently being modified to adapt to I-ETMS protocols and data streams for the Caltrain Communications Based Overlay Signal System (CBOSS) PTC project.
Although there will be licensed products for interoperable I-ETMS (i.e. the MeteorComm radio and Network Message Servers, and WABTEC Back Office Servers and Train Management Computers), the total value of proprietary material and components for the Metrolink PTC Project does not represent a significant percentage of the total Vendor/Integrator contract as shown below in Figure 3.

![Pie Chart](image)

**Figure 3, the not so Proprietary Nature of I-ETMS PTC**

By contrast, CBTC systems are virtually all non-interoperable; a key feature of PTC systems (they must be interoperable by law). In addition, CBTC systems are all proprietary once acquired.

**PTC MODIFICATIONS NEEDED FOR TRANSIT OPERATONS**

Applying PTC to LRT operations in this instance is similar to freight railroad terms “dark territory”. Using PTC as a Vital Stand Alone application allows for the full benefit of the technology. Some PTC schemes have been applied in this manner, but it is outside of the current I-ETMS development currently underway. In addition, LRT systems are not always interested in continuous broken rail detection. This stems from several facts that include:

1) Track is often embedded into city streets and bound by concrete minimizing broken rail risk,

2) Speeds are often lower, and
3) The system exhibits light axle loads.

In addition, there are several pieces of conventional signaling that can be addressed safely, but without the extensive hardware installations required to support these functions. The following is brief discussing on some of these attributes of PTC type signaling in a Vital Stand-Alone application on LRT systems:

1) Interlockings – The classic definition of “…between opposing home signals…” that utilize track circuits for train detection could change dramatically. Functions such as detector, time, approach, route, and traffic locking can be accomplished with position information transmitted from the train. Therefore, we no longer need to define these limits with signal masts.

2) Automatic signals – These are no longer required based on in cab enforcement by PTC. In fact, most cab signal systems are now Go-No Go type without automatic wayside signaling.

3) Crossing approaches and pre-emption – Activation of crossings can now be done without the need for remote wayside devices at fixed points along the right of way.

4) Priority activation for crossing bar signals – This is a similar application to the highway crossing starts mentioned above. In this case, even the bar signals can be eliminated and the information can be displayed in the cab of the LRV.

5) Near Side Station – Enforced stops improve system safety while allowing for dynamic response to train operation with many types of LRVs without field equipment.

6) Stop Bar/Signal overrun alarms – These can be logged for alertness monitoring.
7) General business functions – Several sub systems can be used to aid operations and passenger experience such as revenue counting in real time, Gap train placement and insertion, intermediate turn backs without complex traffic circuit changes (at virtually anywhere in the system), and enhanced emergency response scenarios.

WHY PTC FOR LIGHT RAIL?

Advance signal solutions for LRT systems discussed here offer many advantages in terms of operations, safety, and capacity. Key factors in choosing PTC for LRT train control have been discussed in this paper, but other considerations include:

1) There will be a very large installed base of equipment that provides a stable market,

2) Transit agencies will be able to take advantage of future development for both hardware and software as the PTC products mature,

3) Since PTC will be common throughout the U.S., utilizing the same PTC system may offer opportunities to eliminate Temporal Separation on joint use facilities. This would greatly benefit both the freight and transit operations,

4) Crossing starts, preemption and priority control of highway crossings can be based on prediction from the known parameters on the train as opposed to fixed locations. This can greatly enhance operations and interfaces to highway vehicular traffic.

5) The inherent position determination system can be used to replace Automatic Vehicle Location (AVL) systems and Train to Wayside Communications (TWC) loops currently in service. This can reduce the
equipment and power consumption on LRVs and provide precise train announcements on board and at stations, and

6) Without the need for broken rail protection, track circuits will not be necessary. Significant cost savings can result from reduced field equipment, but also from the elimination of traction power bonding associated with track circuits and special track work.

Figure 4, A PTC Demonstration of an LRT Street Running System

The Market is already adapting these technologies for other applications in nontraditional modes, such as PTC as a collision avoidance system for the Houston Metro LRT. In the figure above, one PTC system was demonstration tested on the Red Line which consists of 100% embedded track within the city. The MBTA is already considering PTC for the Green Line LRT line as well. This does not suggest that CBTC will not be applied to LRT systems. In fact, where near Metro capacity numbers are required or where GPS navigation is not possible, CBTC remains an excellent option. Recent Requests for Proposals tendered by the City of Ottawa, Ontario require CBTC to support 22,500 passengers per hour per direction (9). SEPTA in
Philadelphia is exploring the installation of CBTC on the Media-Sharon Hill (10). Finally in Toronto, the TTC is currently engineering CBTC of the LRT expansion program.

What does the future hold for PTC? Although there will be a self sustaining market for PTC related equipment and development, PTC as an overlay will not provide the full benefit of the technologies capabilities but adaptable to transit needs. Transit applications offer an expanded, sustainable market for the future.

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LISTING OF ALL TABLE TITLES AND FIGURE CAPTIONS

Figure 1, U.S. Mainline Freight Railroad Traffic Growth vs. Route Miles.

Figure 2, U.S. Mass Transit Ridership Growth.

Figure 3, the not so Proprietary Nature of I-ETMS PTC

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Table 1, Key Attributes of PTC and CBTC (8)
BIOGRAPHICAL SKETCH

David F. Thurston

David Thurston is Vice President for Rail Systems for Parsons, a position he has held for the past 4 years. David joined Parsons after 20 years with SYSTRA, where he served in a similar role. He received his BS in Electrical and Computer Engineering from Clemson University in 1977, a MS in Electrical and Computer Engineering from George Mason University in 1989, and his PhD in Engineering from Temple University in 2012. He is a registered Professional Engineer in 8 States. David is also a Fellow in the Institution of Railway Signal Engineers and serves as the North American Section Chair. He is currently Sub Committee Chair for Maintenance and Testing on AREMA Committee 24 for Positive Train Control, and a member of Committee 2 (Track Measurement Systems) and 38 (Information, Defect Detection & Energy Systems).
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AREMA Conference and Exposition, Chicago, IL

September 18, 2012
Freight traffic trends continue to increase, while the available track continues to shrink.
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Transit Growth is fueled by increased demand as well as new starts.
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The demand causes systems to either create or increase capacity.

Additional track is not always the cost effective answer.

Capacity constraints can be addressed with upgrades to the signal system.
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With increased traffic and the need to operate more trains, train control with enforcement is becoming more popular on LRT lines.
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For example, Los Angeles, Dallas, Baltimore, St. Louis, and Northern New Jersey (Hudson Bergen and Newark City LRT) have all installed cab signals for civil speed and signal enforcement, while Minneapolis and Southern New Jersey have installed Trip Stop systems for mainly signal protection.
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This enhances the safety of train operation in terms of collision avoidance and operating speeds, but adds significantly to equipment capital and maintenance costs for items such as:

1) Track Circuits
2) TWC loops
3) Traction Power Bonding
4) Trip Stops
5) Wayside housings....
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Modern LRT systems require several features that are offered to the riding public that are incorporated in advanced train control and management systems generally associated with heavy rail metros. Some of these features include:

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These functions are realized in conventional signaling, generally with cab signals and ancillary equipment. However, Communications Based Signaling systems offer these functions with a different concept that can reduce the wayside equipment requirements.
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Moving forward, LRT properties generally cannot afford the cost of CBTC systems, but could use key features such as:

1) Packaged interfaces to Public Address and Customer Information Systems,
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3) Platform Screen Doors.
CBTC has been developed for use in transit systems for over 30 years. As such, it is a mature but proprietary system.

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Although there will be licensed products for interoperable I-ETMS (i.e. the MeteorComm radio and Network Message Servers/WABTEC Back Office Servers and Train Management Computers), the total percentage of the proprietary portion of the V/I contract for Metrolink is not significant.
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PTC Modifications needed for Transit Operations will generally require a Vital Stand Alone application. This will allow the full benefit of the technology. Some PTC schemes have been applied in this manner, but it is outside of the current I-ETMS development.
Advanced LRT Train Control

In addition, LRT systems are not always interested in continuous broken rail detection. This stems from several facts that include:

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In addition, there are several pieces of conventional signaling that can be addressed safely, but without the extensive hardware installations required to support these functions.

1) Interlockings – “…between opposing home signals”

2) Automatic signals

3) Crossing approaches and pre-emption
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Functions, continued:

4) Priority activation for crossing bar signals
5) Near Side Station – Enforced platform stops
6) Stop Bar/Signal overrun alarms
7) General business
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WHY PTC FOR LIGHT RAIL?

1) Large installed base of equipment,
2) Able to take advantage of future development,
3) Eliminate Temporal Separation,
4) Prediction for Crossings, preemption and priority,
5) The inherent position determination for AVL,
6) Elimination of Train to Wayside loops,
7) Eliminate track circuits.
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The Market is already adapting these technologies for other applications in nontraditional modes, such as The MBTA is already considering PTC for the Green Line LRT.
PTC has also been recommended as a collision avoidance system for the Houston Metro LRT. PTC was demonstration on the Red Line (100% embedded track).
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This does not suggest that CBTC will not be applied to LRT systems. In fact, where capacity is required or GPS navigation is not possible, it remains an excellent but more expensive option. Recent RFPs from Ottawa (22,500 pphpd), SEPTA (Media-Sharon Hill trolley), and Toronto (LRT expansion) all are CBTC Projects.
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What does the future hold for LRT PTC? Although there will be a self sustaining market for PTC related equipment and development, PTC as an overlay will not provide the full benefits of the technology. Transit applications, however offer an expanded, sustainable market for the future.
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Thank You

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