Developing standards for new technology signal systems for rail transit applications
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Abstract

Radio communications-based train control (CBTC) systems, also referred to as transmission-based signalling (TBS) systems, permit more effective utilization of rail transit infrastructure by allowing trains to operate safety at much closer headways, by permitting greater flexibility and greater precision in train control, and by providing continuous safe train separation assurance and overspeed protection. One of the challenges facing transit agencies who are considering the introduction of CBTC systems, however, is the lack of industry standards for this emerging technology, and the current inability of trains equipped with CBTC equipment from one supplier to operate on track equipped with CBTC equipment from a second supplier. This paper reports on the status of two separate initiatives being taken in North America to develop standards for CBTC systems for rail transit applications; one based on a voluntary consensus development approach, and the second based on a competitive procurement approach.

1 Background

Conventional signalling and train control systems rely almost exclusively on track circuits to detect the presence of trains. Information on the status of the track ahead is provided to train operators either through wayside signals or trainborne cab signals. Ensuring compliance with the signals is achieved either through strict observance of operating procedures, or through automatic train protection features such as wayside electro-mechanical train stops, or trainborne supervisory equipment linked to the train's braking system.
These conventional systems are effective in providing train protection, but are not particularly efficient in maximizing the utilization of the rail transit infrastructure as a result of a number of fundamental limitations, specifically:

- the location of trains can only be determined to the resolution of the track circuits; if any part of a track circuit is occupied by a train, the whole track circuit must be assumed to be occupied by the train; track circuits can be made shorter, but each additional track circuit requires additional wayside hardware, so there is a practical and economical limit to the number of track circuits that can be provided.
- the information that can be provided to a train is limited to a small number of wayside signal aspects, or a small number of speed codes in a cab signal system.
- for a wayside signal system with automatic train stops, enforcement is only intermittent.

Radio communications-based train control (CBTC) systems, also referred to as transmission-based signalling (TBS) systems, overcome these fundamental limitations of conventional systems and therefore permit more effective utilization of the transit infrastructure, by allowing trains to operate safety at much closer headways, by permitting greater flexibility and greater precision in train control, and by providing continuous safe train separation assurance and overspeed protection (Rumsey [1]). Additional benefits of CBTC technology include improved reliability and reductions in maintenance costs through a significant reduction in trackside equipment.

The basic characteristics of a CBTC system include:

- determination of train location, to a high precision, independent of track circuits; this is typically achieved through the use of wayside transponders (beacons) and trainborne tachometers.
- a continuous train-to-wayside and wayside-to-train RF data communications network to permit the transfer of significantly more control and status information than is possible with conventional systems; while the data radio network may take various forms, in North America there is significant interest in the use of 2.4 GHz spread spectrum data radios for urban transit applications because of their signal propagation characteristics in tunnels, and high level of immunity to interference/jamming.
- wayside and trainborne vital processors to process the train status and control data and provide continuous automatic train protection; automatic train operation and automatic train supervision functions can also be provided, as required by the particular application.
2 The Need for CBTC Standards

To fully exploit the benefits of CBTC technology, there are a number of initiatives being taken in Europe, North America and elsewhere to develop standards for this emerging technology, driven by a need for interoperability between equipment provided by different suppliers and a desire to achieve cost savings through a rationalized procurement process.

The European Rail Traffic Management System (ERTMS) is perhaps the most well know and ambitious initiative on train control system standardization, seeking to harmonize signalling systems on European railways, through the development of a System Requirement Specification (SRS) for a European Train Control System (ETCS). This specification has been derived from operating requirements developed by a number of European countries and is currently being validated/certified at a number of pilot sites. In North America, the U.S. Federal Railway Administration (FRA) is supporting similar efforts for the nation’s railroads through the development of performance and technical standards for Positive Train Control (PTC) systems, to provide the core safety functions of positive train separation, enforcement of speed restrictions, and protection of roadway workers (Molitoris [2]).

For urban rail transit applications, as each transit agency is typically self contained, interoperability between rail transit properties is generally not a requirement. Within a transit agency, interoperability is more a procurement issue to permit competitive bids and to permit wayside and trainborne CBTC equipment to be procured under separate contracts. Comparisons can be made to modern cab-signaling/ATO systems, where wayside and trainborne equipment can either be procured as one package, or alternatively can be procured separately, from separate suppliers, because industry-accepted requirements have been established for wayside-to-trainborne equipment interfaces. Transit agencies are looking for a similar degree of procurement flexibility with CBTC systems, and therefore any proposed CBTC standard must recognize that interoperability is an important functional requirement.

This paper focuses on two separate initiatives being taken in North America to develop standards for new technology signal systems for urban rail transit applications; one based on a voluntary consensus development approach, and the second based on a competitive procurement approach.
3 Rail Transit Vehicle Interface Standards

The first approach to CBTC standardization forms part of a research project sponsored by the U.S. Federal Transit Administration (FTA) through the Transportation Cooperative Research Program (TCRP). Working through the Institute of Electrical and Electronic Engineers (IEEE), a Rail Transit Vehicle Interface Standards Committee (RTVISC) was formed in early 1996 with an objective of designing a process for developing voluntary consensus standards for system and subsystem interfaces for light rail, heavy rail and commuter rail vehicles (McGean [3]). To date, nine areas for standardization have been selected by the committee, covering topics which include communication protocols onboard trains, functioning of and interfaces among propulsion, friction brake and trainborne master control, vehicle monitoring and diagnostic systems, passenger information systems, safety verification of processor-based control systems, etc. A number of working groups have been organized to address these topics, and Working Group 2 is specifically addressing standards for CBTC systems.

3.1 Working Group 2 Mandate

The initial mandate of IEEE RTVISC Working Group 2 (WG2) was to establish voluntary consensus standards for the train-to-wayside and wayside-to-train interfaces for CBTC systems. WG2 brought together all of the major suppliers, and potential suppliers, of CBTC equipment in North America to discuss in an open and frank manner the complex issue of developing standards for a new and evolving train control technology. WG2 provided a forum for suppliers to share information concerning their respective CBTC systems, and good progress was achieved in identifying similarities and key differences between the various CBTC systems available or under development. With respect to achieving interface standardization, however, two fundamental difficulties arose; one commercial, the other technical.

From a commercial perspective, suppliers who had already made significant investments in developing CBTC systems, were reluctant to commit to further investments to modify their systems to comply with an IEEE consensus standard without there being some assurance that there was a reasonable opportunity to obtain a return on this investment. Commercially, this issue was further complicated by the NYCT Canarsie Line signal modernization project (see Section 4, below), which was also structured towards developing interface standards to permit
interoperability between CBTC subsystems furnished by different suppliers. Specifically, suppliers were reluctant to commit to additional development investments, so long as they believed they had an opportunity to be selected as the “lead” supplier on the Canarsie project.

From a technical perspective, attempting to establish interface standards, without having first established some degree of standardization on CBTC system performance and functional requirements, and some degree of standardization on basic CBTC system architectures, also proved to be difficult. Specifically, even if suppliers could establish a consensus on certain interfaces between wayside and trainborne CBTC subsystems, there would be no assurance that this interface definition was indeed necessary and sufficient to meet the operational needs of the various transit agencies.

Notwithstanding the commercial and technical difficulties noted above, there was however a general consensus to continue the work of the group, but under a somewhat revised mandate. As of October 1997, WG2 is therefore now focusing its attention less on the specific technical details of the train-to-wayside interfaces, and more on the performance and functional requirements for CBTC systems. Specifically, the current scope and purpose of this working group is to establish a set of performance and functional requirements necessary to achieve an acceptable level of safety, performance, availability and operations for communications-based train control systems. It is anticipated that such a requirements standard will enable transit agencies to streamline their procurement of new technology signal systems, and enable suppliers to better focus their development efforts. The standard is also intended to minimize the amount of new design required for each new application of a CBTC system, and to establish a foundation for further standardization efforts with respect to interoperability interfaces.

The proposed CBTC performance/functional requirements standard addresses operational objectives such as operating modes to be supported, headway capabilities to be achieved, and safety/reliability/availability/maintainability criteria to be satisfied. Automatic Train Protection (ATP) functional requirements are also being defined with respect to train detection, train separation assurance, overspeed protection (including temporary speed restrictions) and interlocking functions, for example. The standard will also address optional Automatic Train Operation (ATO) and Automatic Train Supervision (ATS) functional requirements such as speed regulation (automatic speed control), programmed station stopping, train door control, performance level regulation, automatic vehicle identification and train tracking,
automatic routing and dispatching control, schedule/headway regulation (automatic train regulation), energy management and system performance monitoring. It is planned to complete the standard by the end of 1998.

3.2 Working Group 2 Membership

As a voluntary consensus standard development process, membership of WG2 is open to any users (transit agencies), equipment suppliers, and any other parties interested in CBTC standardization. The current make up of the working group includes representatives from all North American transit agencies who are actively implementing, planning or considering CBTC systems, representatives from all the major transit signalling suppliers, representatives of various government agencies, and other interested parties. The working group is chaired by Dr. Alan F. Rumsey (alan_rumsey@parsons.com) and information on the groups activities, as well as other RTVISC working groups, can be found on the web at www.tsd.org.

Achieving a consensus performance/functional requirements standard for CBTC requires a strong and consistent involvement of the transit agencies. With the encouragement of the Federal Transit Administration (FTA), therefore, an ad-hoc CBTC Peer Group has been established which is open to representatives of all North American transit agencies with an interest in CBTC technology. The objective of the CBTC Peer Group meetings is to provide a forum for transit agencies to share past experiences, and discuss future plans, with respect to implementation of CBTC systems. The Peer Group meetings also provide a means for transit agencies to explore common operational needs, and operational differences, which may influence CBTC standardization initiatives. The group is committed to actively support the efforts of the IEEE Working Group 2 in developing a CBTC performance/functional requirements standard, and to promote the use of such a standard in future CBTC procurements.

4 NYCT Signal Modernization Program

The second approach to CBTC standardization is an ambitious project being undertaken by New York City Transit (NYCT) to develop interoperability interface specifications for CBTC systems, to permit competitive procurement of interoperable wayside and trainborne
systems on future NYCT re-signalling projects and new car procurement contracts (Mooney [4]).

NYCT runs one of the largest and most complex subway systems in the world with over 700 miles of track, 468 stations, and a fleet of over 6,000 subway cars. The existing signal system, based on fixed block/wayside signal/automatic train stop technology, with no cab signalling or ATO, consists of more than 11,000 track circuits and wayside signals, and over 9,500 automatic train stop devices.

As part of its ongoing modernization program, NYCT plans to modernize its signal system from fixed block/wayside signals to CBTC technology. Given the size of the NYCT subway system, the transition to CBTC technology must be implemented in stages over a number of years. The implementation strategy is further complicated by the fact that NYCT track is a complex rail network of highly interoperable lines. This interoperability permits a high degree of operational flexibility and system-wide fault tolerance and NYCT desires to retain this flexibility where feasible as it transitions to CBTC technology. As a consequence, CBTC-equipped trains which normally run on one line, must also be capable of operating over other CBTC-equipped lines modernized both prior to and subsequent to equipping of the cars. Also, to minimize the number of existing revenue cars that will have to be retrofit with CBTC equipment, the signal modernization program is being closely coordinated with the future procurement of new transit cars with an intent that trainborne CBTC equipment is procured as part of the car procurement with equipment installed by the carbuilder prior to delivery.

These operational requirements and implementation strategies lead to the following specific CBTC interoperability requirements:

- trainborne CBTC equipment supplied by one supplier must be capable of operating with wayside CBTC equipment supplied by a second supplier.
- wayside CBTC equipment supplied by one supplier must be capable of interfacing with wayside CBTC equipment supplied by a second supplier at the border between two lines or two line segments resignalled at different times.
- within a train made up from a number of independent basic operating units, trainborne CBTC equipment from multiple suppliers must be capable of operating together.

Because of its size, the NYCT subway system represents more than half of the market in North America for train control systems and related components and it is therefore inevitable that New York’s decision to convert to a new technology, communications-based train control system
will facilitate new industry standards for this technology in North America.

4.1 Canarsie Line Pilot Project

The Canarsie Line Signal Modernization project is NYCT’s Pilot Project for communications-based train control. The Canarsie Line was selected as the first CBTC line as it is one of only two lines in the NYCT subway system that is essentially self-contained with a dedicated right-of-way. The original signal equipment on this line was installed in 1926.

A unique aspect of the Canarsie Line pilot project is the procurement process that is being used to select the new signal system. As a first step (Phase I), NYCT is shortlisting three suppliers to demonstrate their systems on a designated test track. From these tests, and other relevant information, the signal system best suited for NYCT’s requirements will be selected for installation on the Canarsie Line (Phase II) and will become NYCT’s standard for CBTC technology. As part of this installation contract, this “lead” supplier must also provide detailed interoperability interface specifications for this “standard” system so that the other two “follower” suppliers can develop compatible systems and demonstrate the interoperability of their systems with the “lead” supplier’s system (Phase III).

With this approach, after the successful completion of the Canarsie project, NYCT will have 3 qualified suppliers of trainborne CBTC equipment and 3 qualified suppliers of wayside CBTC equipment. For future car procurements, trainborne CBTC equipment will typically be included in the carbuilder’s scope of supply (using pre-qualified CBTC suppliers). CBTC wayside equipment will be procured on a line segment-by-line segment basis under the Signal Modernization program, and interoperability will be assured through the interface specifications developed during the Canarsie Line pilot project.

4.2 Project Schedule and Current Status

A Request For Proposals (RFP) for the Canarsie project was issued in October, 1997 and Technical Proposals were received from the following six Proposers in February 1998: Adtranz, Alcatel, GEC Alsthom Transport/General Railway Signal, Harmon Industries, Safetran and Union Switch & Signal/MATRA Transport International. Management Proposals were also received from these six Proposers in March.
NYCT evaluation of the Proposals is currently in progress and in parallel with the proposal evaluations, NYCT is also conducting formal Software Capability Evaluations at the suppliers’ software development facilities. Suppliers who are unable to demonstrate an appropriate level of software development maturity, will not be considered for potential shortlisting for Phase I.

NYCT’s objective is to shortlist to three suppliers and award the three Phase I Demonstration Test Program contracts (US$1.1 million each) by September 1998 with installation of equipment on NYCT’s test track and test vehicles before the end of the year. All three suppliers selected for Phase I will demonstrate their CBTC systems in the same test area, and will complete the demonstration tests essentially in parallel. The test area will be approximately 2.0 miles long. NYCT will provide dedicated test trains for the Demonstration Test Program; two 2-car trains for each supplier. The demonstration tests will commence early in 1999 and will run for approximately 6 months. The primary objectives of the demonstration test program are to demonstrate/evaluate the suppliers’ proposed RF data communications system, to demonstrate/evaluate the suppliers’ proposed train position/speed measurement system, and to demonstrate/evaluate the suppliers’ proposed approach to implementing automatic train protection functions. Suppliers will also be given an opportunity to demonstrate other capabilities of their proposed system.

The “lead” supplier will be selected, and Phase II contract for re-signalling the Canarsie Line will be awarded, late in 1999. Evaluation criteria for the selection include: the technical proposal (as supported by results of Phase I Demonstration Tests), supplier qualifications/capabilities, price, and other pertinent factors.

Two Phase III contracts, for US$3 million each, to demonstrate interoperability with the “lead” supplier’s system (and validate the interoperability interface specifications) will be awarded to the two remaining suppliers (“followers”) also in late 1999.

Phase II and Phase III contracts will be completed in early 2004.

5 Conclusions

There is a general industry recognition that in order to fully realize the operational and economic benefits of communications-based train control systems, there is a need to develop standards for this evolving technology. This paper has focused on two separate initiatives currently being taken in North America to develop standards for new technology
signal systems for urban rail transit applications; one based on a voluntary consensus development approach, and the second based on a competitive procurement approach.

The voluntary consensus development approach, as an element of the IEEE Rail Transit Vehicle Interface Standards Committee, has highlighted that important progress can be made towards standardization when users (transit agencies), equipment suppliers and other interested parties work in partnership in a co-operative fashion towards a common objective. The process has also highlighted that for the voluntary consensus approach to be successful, all parties must perceive benefits being realized through adoption of the standard. In this regard, standards development must recognize not only the operational requirements of the users, but also the cost benefit considerations.

The NYCT Canarsie Line signal modernization project has adopted a competitive procurement approach to first select the “best” CBTC system to meet NYCT’s long term operational needs, and then require the supplier of this NYCT “standard” system to provide interoperability interface specifications for this system, and to work co-operatively with other suppliers to validate the specifications.

These two separate initiatives, while differing in approach, are in fact complementary, since both approaches are focused on the same ultimate objective. As a consequence, there is considerable synergy between the NYCT Canarsie project team and IEEE WG2 to ensure that the evolving standards for new technology signal systems will have industry-wide benefits to funding agencies, suppliers, transit agencies, and their passengers.

6 References