The IEEE 1473-L Communications Protocol: Experience In Rail Transit

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ABSTRACT

Even before the IEEE's Rail Transit Vehicle Interface Standards Committee (RTVISC) approved IEEE 1473, railcar manufacturers from Breda in Italy to Kinki-Sharyo in Japan to Bombardier in Canada had been designing the underlying LonWorks® protocol into their rail vehicles. But after its formal adoption in 1999, IEEE 1473-L based networks have begun to proliferate at transit properties in North America and around the world.

The US transit industry's acceptance of IEEE 1473-L as its de facto and de jure protocol for rail transit vehicles is a good indicator of the overall success of the IEEE's RTVIS Committee and its new standards.[1] Today, transit agency staff, suppliers, and consultants from around the world continue to meet regularly and are creating new Working Groups to establish even more standards for rail transit systems[2]. Many will provide additional synergy with these new IEEE 1473 serial train networks.

LonWorks is widely used on rail transit projects throughout the world — both on and off rail vehicles. Recent US applications include NTC Transit's R142 and R143, Amtrak's Acela, NJ Transit's Comets, door monitoring by Vapor; friction brake watchdog monitors and Advanced Automatic Train Control Systems for SF BART; Translite passenger information signs for SF Muni; event recorders by Peerless for Metro North; and propulsion systems from Alstom. Outside the US LonWorks is used on door controls for Sydney Commuter Rail; lighting, heating and air conditioning controls for Deutsche Bundesbahn; and automatic platform door control for monorail stations in Japan and RATP's Meteor line in Paris — to name just a few.[3]

Recently, smaller firms have begun to capitalize on the popularity of LonWorks on rail vehicles by developing new products that increase the throughput of 1473-L by allowing it to be "tunneled" through standard, communications protocols such as T1/E1 and T3/E3. Others have products that tunnel LonWorks through IP (Internet Protocol.) Tunneling establishes a migration path to upgrade the performance of IEEE-1473-L based networks.

Others have developed industrial routers for train applications that permit IEEE 1473-L networks to be overlaid onto existing trainlines currently dedicated to other functions. This is now possible using advanced Power Line Transceiver technology that is now a new ANSI/EIA standard. This new ability to retrofit IEEE 1473-L easily onto existing rail fleets opens new opportunities for many transit properties that otherwise would have had to undergo a major trainline retrofit program to free up existing trainlines.

INTRODUCTION

What do 1,300 buses in Seattle, 6,000 subway cars in New York City and 27 million electric power meters in homes in Italy all have in common? They all have (or soon all will use) LonWorks. So what does this have to do with rail transit cars? Volume and standardization.

High manufacturing volumes are critical both to semiconductor fabricators ("fabs") and the end-users that use these devices. Volume ensures cost-effective parts and long-term availability. Multiple sources of supply are also critical to help establish standardization that further drives down prices. Without high volumes and multiple sources, end users of advanced technology rail transit vehicles may find themselves unable to obtain spares only a few years into the vehicle's design life. Talk to any transit authority and they will agree that open systems, standardization, and the long-term availability of spares are critical issues for any advanced transit technology project.

Consider the world's first 16-bit microprocessor, the Texas Instruments 9900. Many design engineers today may be unaware the TI 9900 even existed (or that it was discontinued soon after it was created). Another firm soon began selling a 16-bit microprocessor it dubbed the 8086. At the time, experts agreed that Intel's 8086 was architecturally inferior. But the 8086 had two features its competitors did not: A clear migration path for its existing 8-bit CPU customers and a full set of development tools that allowed designers to immediately create new 8086-based products. Intel's 80X6 line of CPUs prospered and its compatible successors, the

Pentiums and AMD CPUs, have created an open, competitive market that has benefited many.

In the case of IEEE1473-L, Neuron® integrated circuits are made by both Toshiba in Japan, and by Cypress Semiconductor in the US. Every Neuron has identical LonWorks protocol firmware to insure messages transmitted by one Neuron on a network will be correctly received and acted upon by another. In addition, the LonWorks 7-Layer ISO OSI protocol stack is fully open. The open availability of the LonWorks "Reference Model" also allows the LonWorks protocol to be freely ported any microprocessor[4] further mitigating risks of obsolescence.

Since its first appearance in the late 1980's tens of millions of Neurons have been produced by three integrated circuit manufacturers and designed into devices by over 4,000 Original Equipment Manufacturers. Among other things, each Neuron I.C. contains a unique 48-bit serial number identifier and three separate CPU's each roughly equivalent in computing power to a 1960's mainframe computer. Sophisticated firmware in Neurons also makes it possible to remotely download application software ("Layer 7" in the ISO OSI standard 7-layer model) into each Neuron. This provides inherent flexibility both to designers and end-users that previously did not exist at any price.

LONWORKS AND TCN

IEEE 1473 specifies both TCN and LonWorks. But because the TCN protocol specified in IEEE-1473-T is used only on trains, it is unable to benefit from the economy of scale possible with the general purpose LonWorks technology specified in IEEE-1473-L. For this reason IEEE 1473-T has not yet been ported to a single integrated circuit comparable to the LonWorks Neuron.

The heart of IEEE-1473-T, like the heart of IEEE 1473-L, is its protocol stack. However, unlike LonWorks Neurons the IEEE 1473-T protocol stack is typically executed in Read Only Memory on small single board computers. But at present, the reference implementation for the TCN protocol stack remains proprietary. The need for an open reference implementation has been widely understood by many including the RTVIS Committee to be crucial to ensure free and open competition of TCN outside of Europe.

Nevertheless for a number of reasons there remains interest in the development of a gateway between LonWorks and TCN. New Jersey Transit's Comet V is the first project in the Americas to use a TCN to LonWorks Gateway. Alstom is completing the LonWorks portion of these new Comet V cars for NJ Transit by integrating ten different sub-suppliers and subsystems that will all communicate over a common IEEE-1473-L network. These LonWorks vehicle networks will interface with a TCN trainline and Locomotives provided by Bombardier (formerly Adtranz).

Many involved with the NJ Transit Comet project are also involved with IEEE RTVISC Working Group 9[5] that is developing additional standards based upon European Leaflet UIC 556 and the LonMark Interoperability Association.

The LonMark Association is comprised of major technology industry leaders and its primary purpose is to develop open interoperable systems based upon LonWorks. Firms with transit and transportation divisions who have joined the 300+ member LonMark Association include AAR, ABB, Alcatel, Alstom, Bombardier, LT Klauder, New Jersey Transit, New York City Transit, Safetran, Siemens, San Francisco Muni, STV Inc., and Santa Clara Valley Transit Authority.

RELATED RAIL APPLICATIONS OF LONWORKS

In the US freight railroads, AAR's Electronically Controlled Pneumatic (ECP) Brake specifications have been used to control braking on trains over two miles long and three mile long trains are planned (without the need for a trainline repeater). Tests have shown ECP Brakes using LonWorks can reduce the braking distance of a long train on a downgrade by up to 70%. In addition, AAR engineers and vendors carefully specified its LonWorks Network architecture to provide additional spare capacity to allow future health and status monitoring of key rail car subsystems.

Potential future AAR applications include vehicle on-board hot-box detectors (possibly looking at differential axle temperatures or ultrasonic signatures) and monitoring systems for refrigerator and chemical cars to warn of early failures or problems. For these freight applications, AAR has now standardized on Echelon's PLT-22 a PowerLine Transceiver (PLT) that also recently became an open ANSI/EIA standard.

Previously, AAR was designing its ECP Brakes with an earlier part known as the PLT-10 that has since been discontinued. While the PLT-10 worked well, sales volumes were not high enough to keep the fab line open. Combined with the need to comply with new international EMI and RFI requirements no longer compatible with the PLT-10 it was discontinued. But with volumes now in the tens of millions and standardization by ANSI/EIA, the powerline technology in the PLT-22 is likely to remain widely available, stable, and secure.

MTA New York City Transit, the longest subway system in the world, was the first US transit property to fully embrace LonWorks and these new RTVISC standards. But it may be appropriate to review the history of trainline communications to better understand why they are so important to transit properties.

Until recently, it was standard rail transit practice to dedicate one (or more) electric train line wires to control or monitor a single trainline function. For example one pair of trainlines might control all left side doors and another pair the right side. Door status also requires a pair of trainlines to report all left side doors closed and another pair is needed for the right side. Clearly, using this traditional approach, the number of train line wires grows quickly and that makes it impractical to tell exactly which door failed. But doors are just one of many trainlined subsystems and more wires also mean more electric coupler pins, and that means lower reliability.

But rather than simply notifying the train operator after a door has failed it is clearly better to provide an early warning of an impending door failure — i.e., before it actually begins to disrupt service. Such advance warnings can now come to the train operator over a serial trainline. The warning can be triggered either by higher than normal door motor current or when a door takes slightly taking longer than normal to close. Armed with such advance knowledge a running repair vehicle maintainer can be dispatched to perform a temporary door adjustment well before the potential problem degenerates into a service-disrupting failure. Of course, doors are just one example of scores of real time remote diagnostics that can provide advance warnings to train operators and control centers once serial trainline backbones have been deployed.

Real time early warning diagnostic systems are godsend to transit operators to help them improve on-time performance. Los Angeles County's Pasadena Gold Line is a recent procurement that now specifies a IEEE 1473-L network and which requires train operator notification when either excessive door motor currents or slow door close times limits are exceeded.

ACHIEVING INTEROPERABILITY

IEEE-1473 defines a number of permitted configurations. However, because LonWorks is a general-purpose communications protocol it does not inherently have nor does it define detailed levels of compatibility for rail cars. Therefore, it is up to the user or the LonMark Interoperability Association's Transportation Task Group to help ensure compatibility between car systems of different manufacturers. NYCT is a case in point. NYCT specified both LonWorks and LonMark compatible trains. This provides a common reference for subsystem suppliers to help insure interoperability between cars and components.

NYCT specified LonWorks because it wanted an open protocol with product maturity and universal worldwide acceptance. Bombardier, the car builder for NYCT's R142, also had many years of experience designing rail cars based on LonWorks. However, a subsequent R142A car order went to Kawasaki and NYCT wanted to insure that Bombardier's R142 and Kawasaki's R142A consists work together seamlessly with its new LonWorks-based serial trainlines. This requirement has since been successfully demonstrated. See Figure 1.

Straight physical and electrical connections and compatibility is achieved through the use of identical Wabtec electric couplers. These new couplers also use fewer pins and are therefore expected to have higher reliability than previous NYCT couplers. Fundamental communications between car consists is achieved through the use of identical E1 communications channels provided by Telephonics.

Consistent with the IEEE 1473-L standard, NYCT specified the 78 Kbps free topology network transceiver for LonWorks. To help meet rigid specification requirements for automatic car and node initialization, Bombardier used an embedded network management device. When a LonWorks-based subsystem is replaced in a Bombardier car, the network automatically recognizes the new part and seamlessly reconfigures it into the network. This capability has also been provided in other newer systems such Santa Clara Valley Transit's new Kinki-Shario's LRV. This capability is especially appreciated by maintenance departments because no special tools or skills are required when networked subsystems are replaced — because the embedded network manager automatically discovers and folds them into the network. See Figure 2.

THE RAILROAD AHEAD

The IEEE's new Rail Transit Vehicle Interface Standards are revolutionizing vehicle trainline control. Newly emerging wireless standards such as IEEE 802.11b and now IEEE 802.11a for bi-directional train-to-wayside communications are currently being designed into new systems. See Figure 3.

The synergy of a open IEEE 1473 LonWorks control network communicating over an open IEEE 802.11 wireless protocol back to a standard office IEEE 802.3 TCP/IP over Ethernet network offers significant benefits both to transit operators and their maintenance departments.

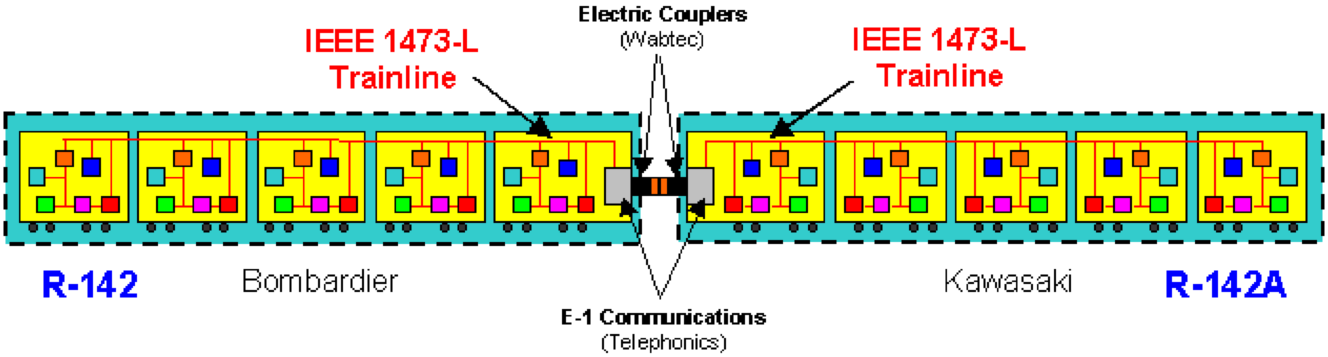

Figure 1. NYC Transit's IEEE 1473-L Train Bus.

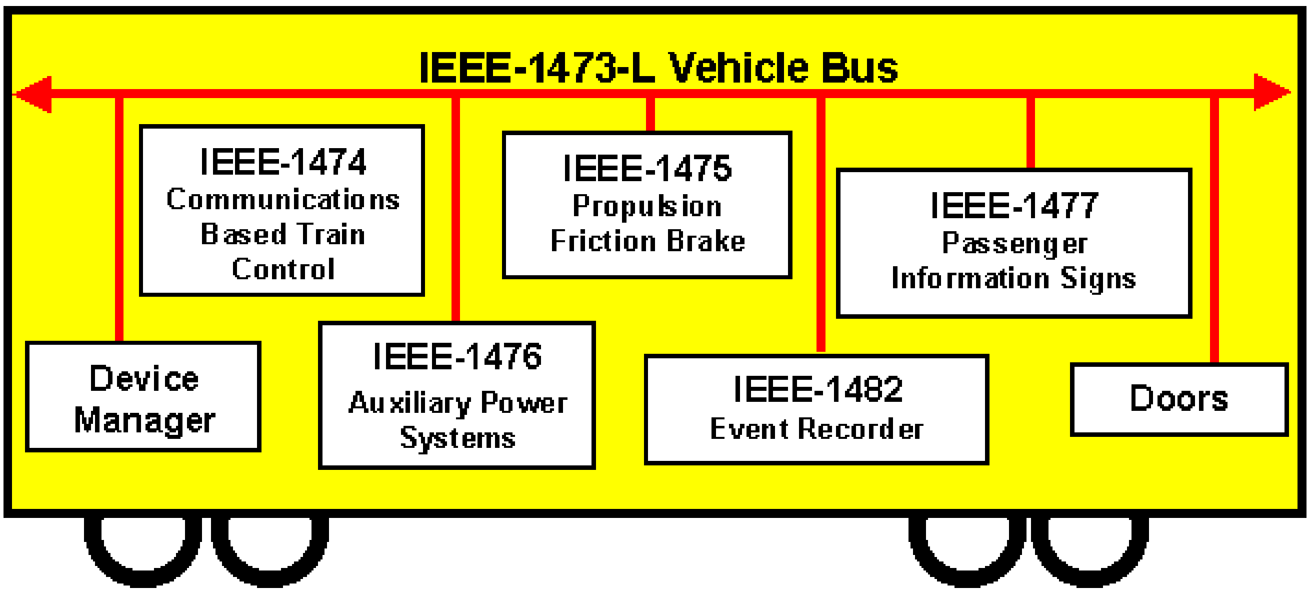

Figure 2. IEEE 1473-L Vehicle Bus.

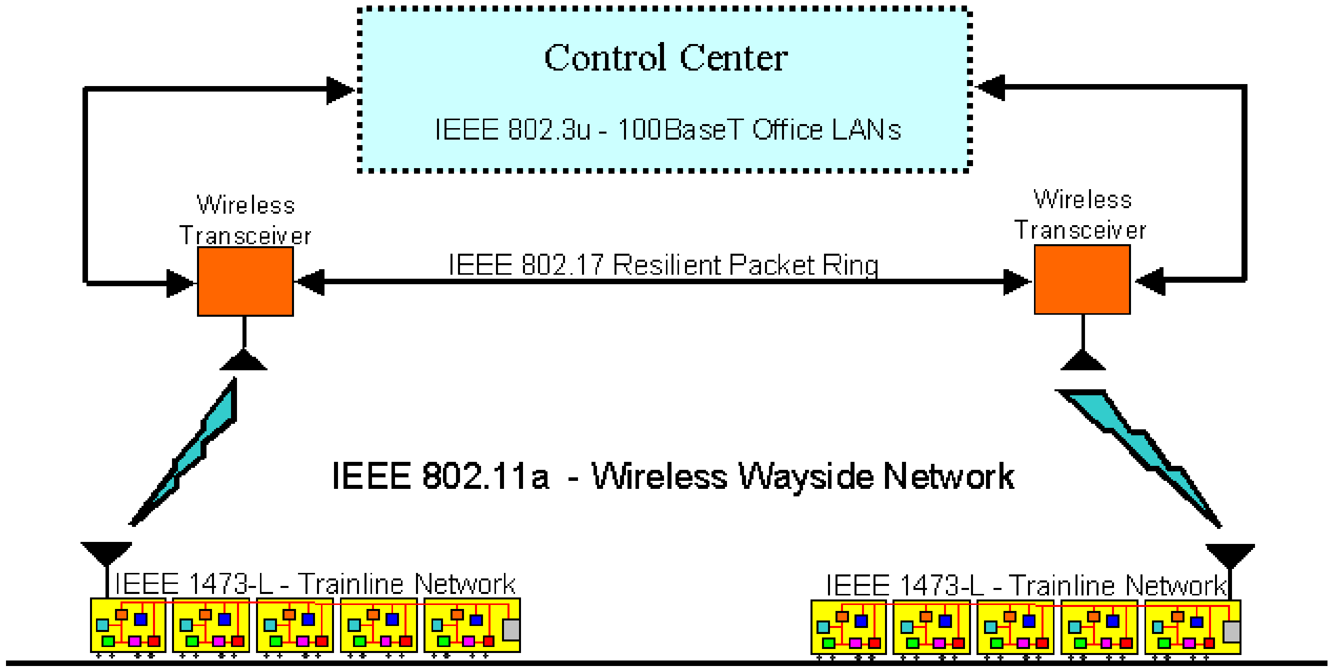

Figure 3. Open Interoperable Networking Using IEEE Standards.

To learn more about this technology, a new George Washington University course, CWEG 118 "Advanced Communications Based Train Control,"[6] is being expanded to assist software and hardware designers in better understanding these new technologies. However, most of these new rail standards are emerging from the IEEE's Rail Transit Vehicle Interface Standards Committee and cooperating groups such as the LonMark Interoperability Association's Transportation Task Group. We welcome your participation and look forward to your continued help and support.

ENDNOTES

1. See "Setting the Standards," Railway Age, June 2000. This article can be read on-line at: http://www.railwayage.com/jun00/setting_standards.html
2. IEEE RTVISC meetings are open. For committee and working group meeting dates, minutes and related information see: http://www.tsd.org/rsc.
3. A constantly updated list and "Frequently Asked Questions" page for IEEE can be found at: http://www.tsd.org/ieee1473
4. You may download the LonWorks Reference Implementation at: http://www.echelon.com/Products/Core/protocol/Default.htm
5. More information on RTVISC WG9 can be found at www.tsd.org/wg9
6. See: http://www.gwu.edu/~cpd/ceip/courses/courses/cweg118.html