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Project Summary Report 0-4768-S
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Project 0-4768: Investigation of Ethernet Technologies as a Transport Mechanism for ITS Field Data

Authors: Leonard Ruback, Edward Brackin, and David Rickerson

PROJECT SUMMARY REPORT

Ethernet for ITS Field Data Communications

There are many justifications for using Ethernet in traffic and intelligent transportation systems (ITS) applications. Ethernet enjoys widespread acceptance, is nonproprietary, and supports the universally popular transmission control protocol/Internet protocol (TCP/IP) suite of protocols. These Internet protocols support point-to-point and point-to-multipoint links as well as numerous utilities, such as telnet and simple network management protocol (SNMP), which can be used to remotely configure equipment. From the user's point of view, the most obvious benefits are that Ethernet is based on an open standard, which translates to interoperability by design while providing very affordable bandwidth.

Ethernet has become common in large and small office networking because of its ability to deliver exceptional performance, scalability, and reliability for the dollar investment. In the last few years, Ethernet-based products have begun to be promoted for use in industrial and harsh environments.

As the Texas Department of Transportation's (TxDOT) Advanced Transportation Management Systems (ATMS) expand across the state, it is important to deploy the most beneficial technologies available to accomplish the goals of the present and to provide capability for the future. Past project work by the Statewide ITS Systems Integrator has identified Ethernet (field hubs to satellite) as the technology of choice for transport of ITS command and control data.

What We Did...

A research team from the Texas Transportation Institute (TTI) conducted a one-year project to examine the issues surrounding the use of Ethernet as a center-to-field communications technology. The researchers investigated how TxDOT currently deploys communications in the field and the types of ITS field equipment that must be supported. With this information, an Ethernet-based solution was proposed and evaluated in a laboratory environment.

Current ITS Communications Model

Current TxDOT ITS field hubs typically use a combination of state-owned fiber-optic and leased telephone service for communications from the traffic management center (TMC) to the field. In urban deployments, fiber creates a daisy-chained link among field hubs housing T1 multiplexers operating at a standard rate of 1.544 megabits per second as shown in Figure 1. Channel cards in the T1 chassis provide RS-232 lines to individual field devices such as a local control unit (LCU),

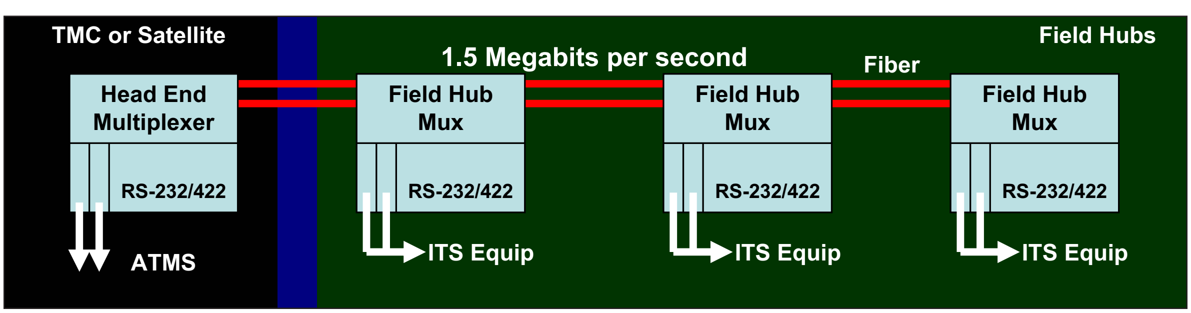

Figure 1. Traditional T1 Field Hub and Satellite Architecture.

a dynamic message sign, or a camera controller. A representative installation is shown in Figure 2.

Although TxDOT-owned fiber is the most attractive infrastructure choice for center-to-field communications, many areas do not have fiber resources. In these areas, integrated services digital network (ISDN) telephone lines and regular public switch telephone network (PSTN) lines, also known as "plain old telephone system" or POTS, are used to provide connectivity. A field hub design that will accept any of these communication services for the center-to-field link would allow TxDOT to move toward a standardized field cabinet design and operation yet still provide flexibility.

Researchers conducted an informal survey to determine what devices were typically networked at the roadside and to quantify communications needs in terms of interface, bandwidth, and latency (delay) sensitivity. The survey revealed that all roadside ITS equipment uses low bandwidth, serial RS-232 or RS-422 interfaces. TxDOT's inductive loop management system is communication delay sensitive and requires special attention to timing issues. The system employs a master unit known as a system control unit (SCU) which continuously exchanges information with numerous local control units in the field. Delay time between the SCU issuing a request and an LCU responding must remain low (fraction of a second) to enable proper operation.

Ethernet Solution

A common internal cabinet architecture was adopted that utilized a hardened 100 megabit per second Ethernet switch and a multi-channel terminal server. The switch and terminal server combination provides all the functionality of the T1 solution and delivers capacity for future needs. The Ethernet switch provides multiple broadband connection points within the cabinet, and the terminal server provides low bandwidth RS-232 and RS-422 links to the ITS field equipment. Communication system architectures were created which would support an Ethernet field hub linked to a satellite or TMC via three different infrastructure options: fiber, ISDN, and pubic network (Internet). The fiber option is a replacement for current T1 systems while the other two are directed toward regions where TxDOT has no communication infrastructure in place.

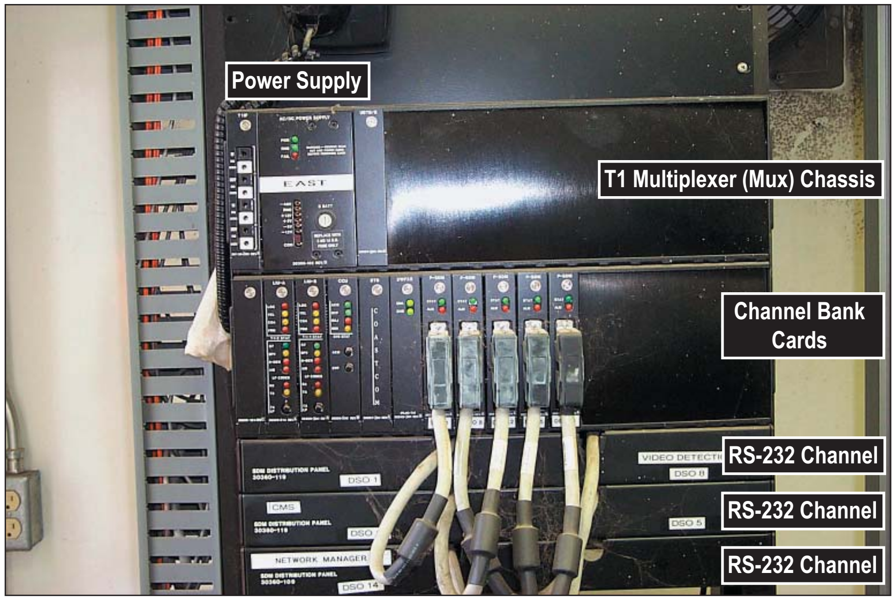

Figure 2. T1 Multiplexer and Channel Cards in a Typical Field Hub Installation.

Evaluation Network

Vendors of hardened Ethernet equipment were contacted and asked to participate in this project by providing demonstration equipment to build a small fiber-based network in a laboratory environment. A four-node evaluation network was constructed in TTI's TransLink® Laboratory and oriented in a traditional ring design. The ring design provides redundancy and increases the reliability of the network.

Additional links were included to create an experimental network utilizing each of the defined communication architectures. An ISDN leased-line link to a field remote site was included as well as two field remote links employing the Internet. The field remotes provided access to operate ITS field devices for integration. One remote site was located in Austin at the IH-35 sensor testbed and the second in College Station at the Highway 6 sensor testbed. Additional traffic sensors were located in the TransLink® Laboratory.

What We Found…

As Figure 3 shows, the Ethernet replacement architecture for the current T1 solution is similar in physical layout to the original T1 architecture. A hardened Ethernet switch replaces the T1 multiplexer, and a terminal server replaces the T1 channel bank cards. All the Ethernet equipment meets or exceeds the National Electrical Manufacturing Association (NEMA) environmental standards and can be deployed in a much smaller, less costly enclosure such as a type P signal cabinet. Figure 4 shows an installation of an Ethernet replacement for an old T1 multiplexer solution.

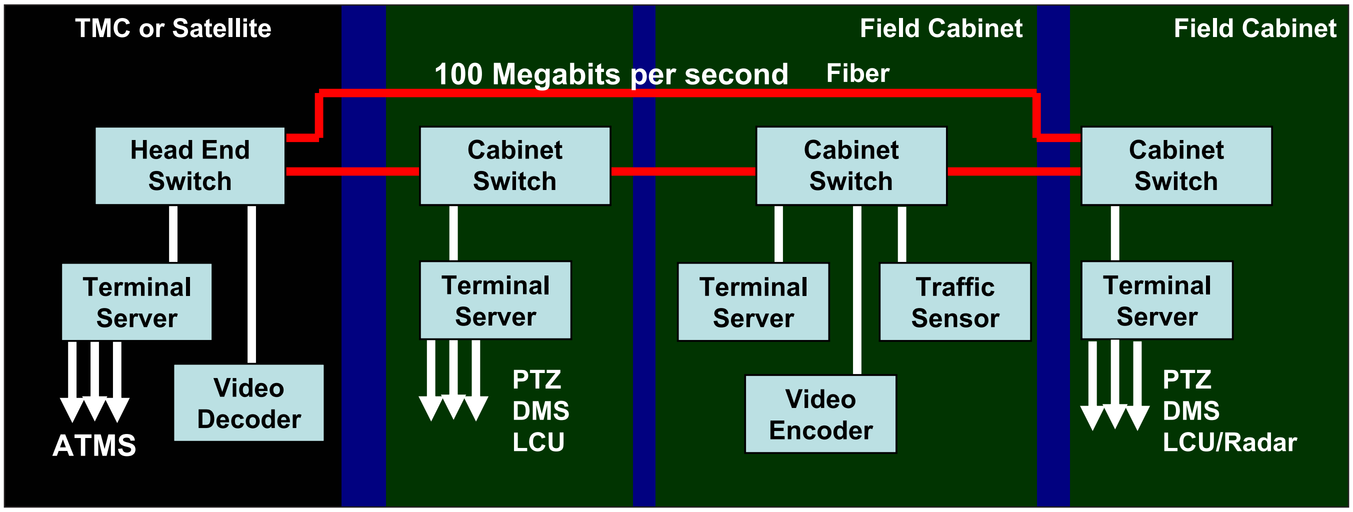

Figure 3. Ethernet Replacing T1.

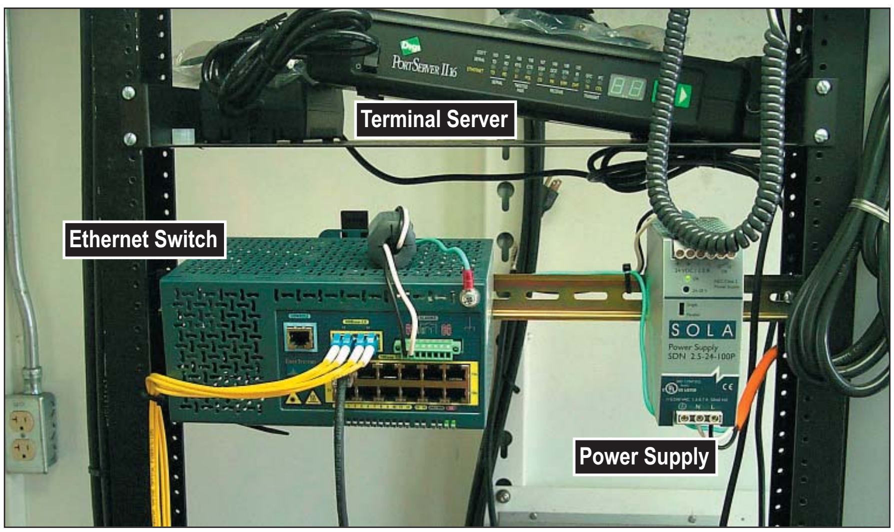

Figure 4. Ethernet Solution in Old T1 Rack Space.

The bandwidth of the Ethernet-over-fiber solution is more than 60 times greater than the T1 solution, providing capacity for communications-intensive applications such as video. A cost estimate for TxDOT's current T1 system for a field hub is $16,000 to $19,000. An Ethernet replacement is estimated to cost $5000 to $7000.

Although the SCU/LCU multi-drop architecture has significant command-response timing requirements, the LCU's can be integrated using a packet switch network. The response delay time in the SCU's message control table must be increased from the default value to at least 200 milliseconds plus network delay to accommodate the packetization delay through the terminal servers. The network delay is very small for a private fiber network but can grow to approximately 100 milliseconds for ISDN links. The terminal servers must be set to use user datagram protocol (UDP) to emulate a multi-drop environment.

The evaluation network provided by vendors was successfully operated in the TransLink® Lab for a month. The network supported a full complement of LCUs, camera pan-tilt-zoom control, live video, and a host of live traffic sensors from the field sites. Network reliability was tested by removing fiber paths to simulate a severed fiber trunk. The network successfully rebounded by activating redundant links to overcome the broken link. In general, the network proved to be robust as well as easy to configure and manage.

The Researchers Recommend...

The research conducted showed that Ethernet technology is definitely an option for ITS communications. Based on Ethernet's costs and capabilities, the solution is very attractive. Projects that are deploying new communications or replacing older systems should strongly consider Ethernet technology.

Longer-term testing should be conducted to better evaluate the more subtle aspects of an Ethernet system. This research evaluated only the technological feasibility, not long-term performance and survivability in a representative environment.

Wireless technology, and in particular wireless Ethernet, is a rapidly emerging area in the industry. The use of wireless options to extend TxDOT's communication infrastructure should be investigated.

For More Details...

The research is documented in Report 0-4768-1, *Feasibility of Ethernet for Center to Field Network for ITS Field Data Communications.*

Research Supervisor: Leonard Ruback, TTI, l-ruback@ttimail.tamu.edu, (979) 862-4343

Key Researchers: David Rickerson, TTI, d-rickerson@ttimail.tamu.edu, (979) 862-4590
Edward Brackin, TTI, e-brackin@ttimail.tamu.edu, (979) 845-9894

TxDOT Project Director: Charlie Brindell, cbrinde@dot.state.tx.us, (512) 506-5114

To obtain copies of reports, contact Nancy Pippin, Texas Transportation Institute, TTI Communications, at (979) 458-0481 or n-pippin@ttimail.tamu.edu. See our online catalog at http://tti.tamu.edu.

TxDOT Implementation Status—February 2005

The objective of this research project was to explore the benefits of an intelligent transportation system (ITS) field cabinet communication design using local area network concepts and Ethernet technologies. Two products were required for this project: 1) technology demonstration for TxDOT staff, and 2) technical report addressing the cabinet architecture choice and the concept of operation of an Ethernet cabinet. The technologies developed in this project will be employed as a wireless-based and fiber-based Ethernet network in the Laredo District on the TxDOT Camino Colombia Toll Road as well as the existing Laredo metropolitan area ITS network. Through field implementation, the developed architecture will enable the development of TxDOT standards and specifications for low-cost, low-maintenance, high-capacity ITS communications network options primarily for ITS deployments in smaller districts, but will also be applicable for deployments in larger districts. In addition, it is expected to provide insight into options for monitoring and managing small toll-based road segments throughout the state.

For more information, contact Mr. Wade Odell, P.E., RTI Research Engineer, at (512) 465-7403 or email wodell@dot.state.tx.us.

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Texas Transportation Institute/TTI Communications
The Texas A&M University System
3135 TAMU
College Station, TX 77843-3135