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16. Abstract

As part of the activities associated with its research focus areas, TransLink® has supported two field deployments of the products of research conducted as part of project 1752-7, Integrating Train Information for Advanced Transportation Management. Deployments have been completed in both Laredo and Sugar Land. This letter report describes the issues encountered during the implementation, test, and operation phase of each project.

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Report 1752-13
IMPLEMENTATION ISSUES ASSOCIATED WITH TRAIN MONITORING DEPLOYMENTS

By
Leonard G. Ruback, Research Scientist
Texas Transportation Institute

INTRODUCTION

A prototype train monitoring system was developed as part of the Texas Transportation Institute's TransLink project. The system was wholly conceived, designed and tested in College Station under the conditions of a single track rail line and a fairly small corridor. Field implementations outside of College Station were sought to further test the concept, capability and value of monitoring rail activity and producing timely, usable information. Texas Transportation Institute (TTI) and the Texas Department of Transportation (TxDOT) cooperatively installed two train monitoring systems outside of the College Station area. The systems are field deployments of the research conducted as part of TxDOT project 1752-7, Integrating Train Information for Advanced Transportation Management.

A subset of the College Station train monitoring system was utilized for a project in Laredo. The Laredo system uses only a single train detection station and does not have a central processing component. The train detection station equipment manages all radar and preempt data, as well as remotely controlling a highway advisory radio (HAR). The Laredo product is a standalone system that operates in a totally automated fashion.

The complete College Station solution was selected for deployment in Sugar Land as part of the Intelligent Transportation Systems (ITS) Priority Corridor Program. All components including train and preempt detection stations, central processing, and information dissemination components were utilized.

Laredo WARN System

A train monitoring application was identified for the TxDOT Laredo District to provide additional motorist information concerning delays due to railroad blockage on FM 1472 (Mines Road). Prior to project initiation, the Mines Road area used a network of flashing beacon signs advising of delays at the grade crossing. The flashers were controlled by radio and were activated during preemption of the Mines Road traffic signal. To improve upon the in-place system, off right of way train detection was used to give motorists more information about the intersection blockage via highway advisory radio. The new system was proposed to continuously monitor the highway – rail grade crossing for preemption (an indication of lowered crossing warning gates) and to scan for train movement (direction and speed). The flashing beacon signs were to continue operating as before (flash during preemption), with new signing telling motorists to tune to a specified HAR frequency (AM band) for more information. The new equipment at

Mines Road periodically calls the HAR and requests specific messages to be played in unison with conditions at the grade crossing. The messages inform travelers of the train's movement, direction, and the duration of roadway blockage. For example, the message

"Northbound train at Mines Road, FM 1472. Crossing has been blocked for between six and nine minutes"

informs the traveler of train direction and blockage duration at Mines Road. Figure 1 shows the Wireless Advisory Rail Network (WARN) architecture. Installation and testing began in the Summer of 2001, with full operation beginning in the Summer of 2002.

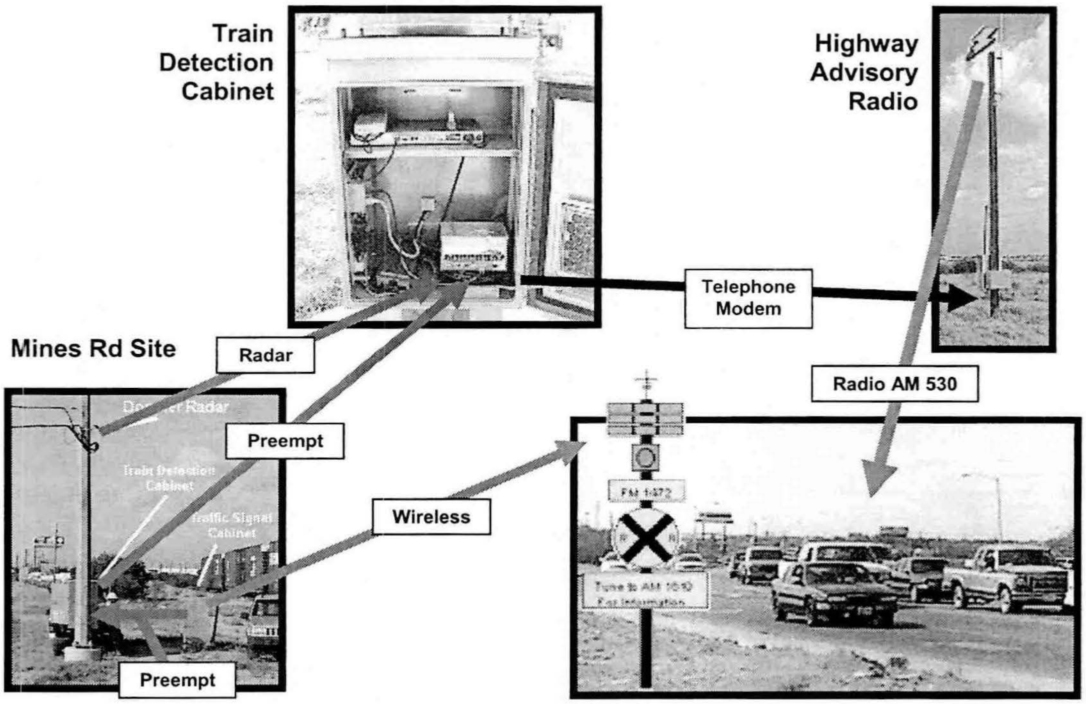

Figure 1. Wireless Advisory Rail Network Architecture.

The HAR identified for use in the project was being used for occasional roadway construction advisories. Early designs required that the HAR play railroad messages then revert back to construction advisories or simply blank when no trains were present. The stipulation required that the Mines Road equipment did not lock out access by TxDOT. To accomplish the requirement, the Mines Road equipment did not continually communicate with the HAR. The HAR was called when the train detection equipment needed to place a message. The impact of the design was a longer time for new messages to arrive on the air. Considerable time (40 seconds) is lost in the process of dialing, authentication, and message selection. Additionally, the HAR only changes play messages at the end of a program. As the program grows longer, more time is lost migrating to the new message content.

District staff preferred to operate the HAR in calendar mode for delivering traffic advisories. Calendar mode allows programmability in message play start times and dates as well as message lists (groups of messages) to be played at different times and dates. Testing of this operation mode in conjunction with the live interruptions introduced by the WARN system showed to be problematic. It was not feasible to support real-time messaging with scheduled content. In response, the HAR was fully dedicated to the Mines Road WARN effort, while another accompanying HAR was dedicated to construction advisories.

Early testing with a traditional dialup modem showed that the modem could lock up with the only recovery being a full power cycle reboot. It was deemed too risky to rely on the modem being fully operational for long periods of time. The solution was to add in a relay that would cycle the power on the modem prior to every command set requiring a call out. The solution was a very good remedy to the lockup problem but added to the time required to post a new message.

Examination of the HAR product manual and subsequent phone conversations with the vendor revealed that even though there was a communications port (DB9 for RS232), the port was inoperative. The vendor stated the port was added for future enhancements. Currently the only way to interact with the HAR is via telephone dual tone multi-frequency (DTMF) tones. DTMF are the dial tones commonly heard when using a touch tone phone. The vendor offered an automation software package, but it, too, used DTMF tones for control. The only responses available from the HAR were prerecorded text messages that guide a telephone user through the various menus. Unfortunately the audio text is unusable to a computer. Without a command / response dialog, the control computer is not be able to query the HAR for status and, thus, would not be able to verify that the proper commands were received.

The control computer is required to interface with the HAR using DTMF tones. The tones are generated using a traditional dialup modem and issuing specific commands to keep the modem in dial mode. The modem is also used to transfer data out of the control computer and as a link to remotely configure the control computer. The system software was written in a manner to manage both dial mode and data mode to effectively achieve both goals. The software in the control computer was designed to periodically call the HAR to resynchronize it. If the HAR misses a command, it continues with the last message. There had to be a method to correct for mistaken messages or corrupt messages. The periodic calling happens during periods of no train activity. The lack of a true command / response adds unnecessary uncertainty into the control process.

Experimenting with the HAR uncovered other issues. The HAR expects an orderly, by command, disconnect sequence. If the phone line is dropped during communication or simply dropping the line to end the call, the HAR blocks out incoming calls for a period of minutes. All communications with the HAR must end by issuing the proper disconnect commands to ensure that the HAR will be available for the next incoming call. Resetting the HAR has far reaching implications. The reset function erases all stored messages, thus requiring considerable effort to restore the HAR to full operation. This recovery option should be used only as a last resort.

The message audio quality of the recorded messages seemed to slightly degrade over time. Several of the messages seemed to get a short bit of noise ("pops" or "clicks") added to the front or tail of individual messages. The duration of the noise was short, probably a fraction of a second. Unfortunately, when the message is heard over and over again the noise becomes quite noticeable. The same noise effect has been seen in electronic recording technology using charge coupled devices (CCD) to store live sound. Given the degradation over time, message quality needs to be monitored periodically as some messages may have to be rerecorded to reestablish expected quality.

The range of an HAR's Amplitude Modulated (AM) signal is commonly listed as approximately 3 miles. Unfortunately, the AM radio in most automobiles is not as high quality as other entertainment accessories. The result is the sensitivity of the radio and fidelity of the audio varies greatly among vehicles. This is an important issue for projects utilizing the AM band. The HAR is not collocated at the Mines Road grade crossing; rather, it is approximately 2 miles north of the grade crossing. The received audio in vehicles in the near vicinity of the grade crossing is degraded in a varying degree by background white noise. The further south along IH35 the vehicle is, the stronger the intrusion of the white noise.

Early deployment called for all Mines Road equipment to be installed in a pole cabinet located adjacent to the railroad grade crossing (west side) at Mines Road. The radar, control computer, and the modem were collocated in the cabinet. The telephone communication line was pulled in the cabinet from a nearby telco field box. Due to upcoming construction in the area, project leadership decided to move the equipment to a new pole located across the railroad from the original line (east of the railroad tracks). Standard operating practice does not allow for power and communication lines to run in the same conduit. The solution was to break the original package of equipment into two locations, the new pole cabinet and a new cabinet near the telco field box. Figure 2 shows the new arrangement.

Given the longer distance between the control computer and the modem, a different wireline communication technique was required. The solution was to migrate from a RS232 link to an RS422 link. The RS422 link is specifically designed for longer distance runs and is a common replacement for RS232. The use of RS422 requires RS232 to RS422 communication converters at both ends of the underground link (both the control computer and the dialup modem support only RS232). The pole cabinet houses the control computer and the RS422 converter to connect with the telco box. The telco box now contains the modem, the modem power reset relay, and the RS422 communication converter.

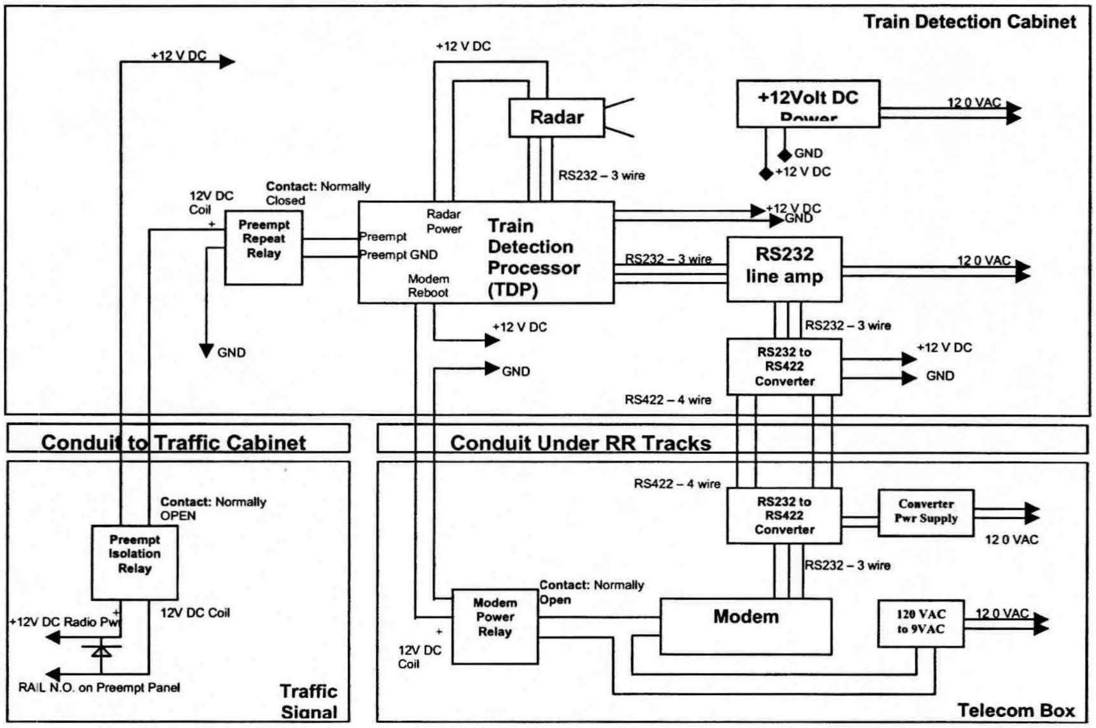

Figure 2. Mines Road WARN System final wiring diagram.

Testing revealed that the RS422 communication converter uses power from the RS232 host port to power its own RS232 circuits. It was found that this extra power drain was causing the voltage levels on the host RS232 port to drop to undetermined levels (as mandated by the RS232 standard). The problem was seen on both the control computer and the modem RS232 ports. The root cause of the issue is the widespread use of charge pump RS232 integrated circuits that take 5 volts dc and transform into +10v and -10v for use by the RS232 circuitry. The extra power draw is too much for these circuits and the pumped voltage fails to remain steady. The solution was to build a small RS232 amplifier to remove the loading of the RS422 communication converter circuitry.

The Laredo Mines Road system has been operating as designed for more than a year. The only failed component was the dialup modem, and it was diagnosed and replaced by TxDOT Laredo staff. Within the last few months, an error condition has been identified. Occasionally, the control computer calls the HAR, but an error occurs in the HAR's understanding of the commands and/or information. A troubleshooting trip is scheduled for early in September to address the problem.

Sugar Land Railroad Monitoring System

The Sugar Land Rail Monitoring System covers the 6.4 mile US 90A rail-highway corridor between Kirkwood and Grand Parkway in Sugar Land, Texas. The adjacent Union Pacific rail line is one of the oldest in the state and hosts, on average, more than 30 trains per day from several railroad companies. The rail monitoring project was developed by the TxDOT Houston District and the Texas Transportation Institute as part of the ITS Priority Corridor Program. The system monitors for the presence, speed, direction, and length of the trains using the TransLink® Rail Monitoring System. The Sugar Land deployment also monitors the grade crossing for closures via traffic signal preemption. Real-time train status and downstream crossing blockage and clearance times are calculated and displayed on a graphic map of the corridor. The corridor status map is available at two Sugar Land fire stations and emergency services dispatch via an Internet kiosk permanently set to the rail monitor webpage. Installation of the train detection stations began in September 2001 with full system testing being completed in early 2002. The system was pronounced fully operational with all field sites and kiosks online in April 2002. The rail monitor webpage is used daily by Sugar Land emergency services to assist in their dispatching efforts. Recently, the rail monitor was made available to the Internet public at large, hosted by the Houston TranStar website (http://traffic.tamu.edu/rail).

One of the unique aspects of the rail monitoring project was the use of public wireless services to move *raw* train data to the central processing location. The link essentially replaced a traditional wireline or fiber solution. The raw data are message-based. The size of the messages is approximately 100 bytes per message. The messages vary in frequency from once every 20 seconds (for heartbeat messages) to one message per second during a train event (including preemption). Message latency is very low (a fraction of a second) and, therefore, not an issue even for the raw data feed.

Cellular Digital Packet Data (CDPD), which is wireless mobile IP (Internet) sold by the major telecom providers, was selected as the communications media for moving the raw train data to the central processing location. CDPD is typically available in metropolitan and surrounding areas and is priced to compete with a dedicated phone line for narrowband service (traditional dialup). An analysis determined that CDPD coverage encompassed the project area, and initial testing showed that the CDPD radio equipment was able to stay online continuously and deliver the message-based data reliably and timely. However, during the initial operation of the system, several sites exhibited signal degradation only during train presence. More intense testing of each site showed that the CDPD signal strength was close to the edge for reliable reception. The presence of the train and/or the increase in message frequency was enough to degrade the signal below the threshold and thus drop the connection. Once a connection was dropped, the radios had to go through a time-consuming reauthentication process. By the time the modem reregistered and became fully operational, much of the train event data was lost. To increase the signal strength at each site and keep the modem continually registered, the original omnidirectional antenna was replaced with a yagi antenna. Replacing the antennas resulted in a gain of approximately 6dBd (four times more signal than the simple dipole). The new antenna solved the signal strength problem at all sites except at Industrial, where the problem was greatly reduced but not eliminated.

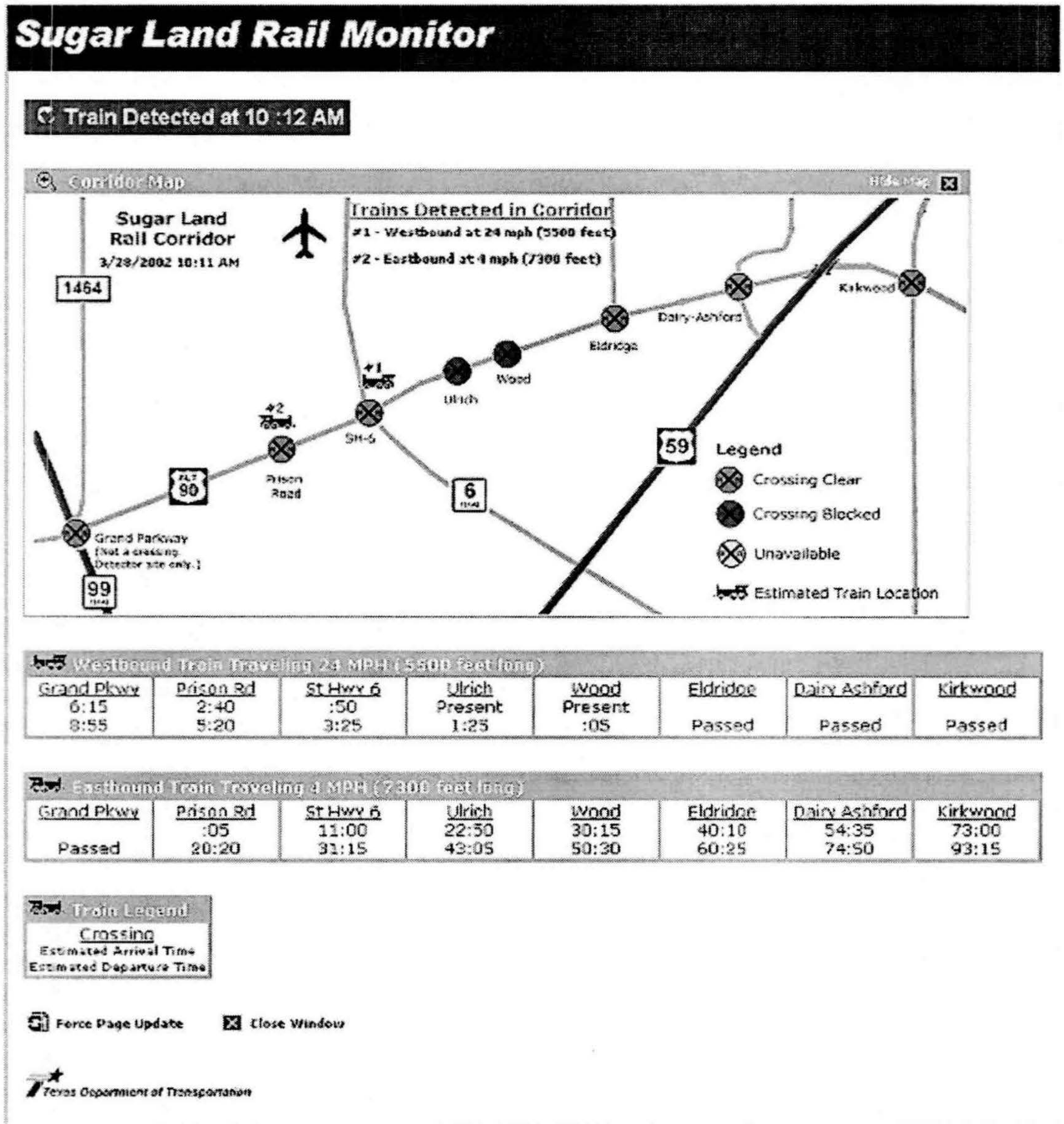

Figure 3. Sugar Land Rail Monitor Kiosk Webpage

Another issue with the CDPD service was maintaining valid registration. The provider occasionally dropped users off the network, and the subscriber radio was unable to reregister on the network. The result was a service outage until the provider refreshed or adjusted his equipment to allow the subscriber unit (our CDPD radio) back online. While the number of times this occurred was not high (approximately six times during the year evaluation), it remains an issue for continuous, real-time service. Some of the outages were due to malfunctions in the provider's equipment. Network router malfunctions and cell site problems occurred on several occasions, producing outages that ranged from several minutes to several days.

Providers have begun announcing that CDPD service will be phased out by the end of 2005, with a migration to newer technologies. The newer services are all digital (CDPD was a part of the older analog cellular system). Products and services are slowly emerging to replace the CDPD market, and the bandwidth is expected to triple CDPD's capability.

As part of the system deployment plan, preempts at critical intersections were to be monitored as a positive indication of the grade crossing gates being down. A unified plan among all parties involved was needed for the design of the preempt sense system. The traffic signal preempt would be monitored in the traffic signal cabinet and measured in the train detection cabinet. The two cabinets (traffic signal and train detection) are a significant distance apart, therefore electrical isolation between the two cabinets was needed. The isolation will protect the traffic signal equipment from any possible power surges brought in by the line linking the traffic cabinet and the train detection cabinet. After discussions with TxDOT Houston District staff, the decision was made to sense the preempt using a relay in parallel with the normal train preempt relay in the traffic signal cabinet. The preempt sense relay would have the same 110VAC coil, and its operation and/or availability would in no way compromise the actions of the traffic signal controller. The contacts of the preempt sense relay open or close a copper wire path originating in the train detection cabinet. In essence, the loop provides a "call" on a microcontroller that is easily measured. An additional relay is used in the train detection cabinet to provide extra isolation and to deliver a good logic ground to the microcontroller. The extra relay also gives the ability to "induce" a preempt by simply pulling the relay out of its socket in the train detection cabinet.

All of the train detection stations were built separate from traffic signal cabinets. The train equipment was installed, in most cases, across the street from the traffic signal cabinet, thus, the AC line power and a pair of communication wires (for sensing preempt) were run overhead between the traffic cabinet and the train cabinet. The overhead wires and longer runs made the train cabinet system susceptible to power surges from lightning. The prototype systems in College Station and the installation in Laredo have not experienced problems due to power surges. Equipment in Sugar Land experienced several failures due directly to power surges in the AC lines and communication lines.

It became evident that all the paths into the train detection cabinet needed to be "hardened" to eliminate, or at least greatly reduce, the amount of damage caused by the outdoor environment. Filtered surge protection was applied to the AC line and the twin line for the preempt detection. A lightning suppressor was also installed in line with the CDPD antenna. No equipment damage has been sustained after the cabinets were hardened.

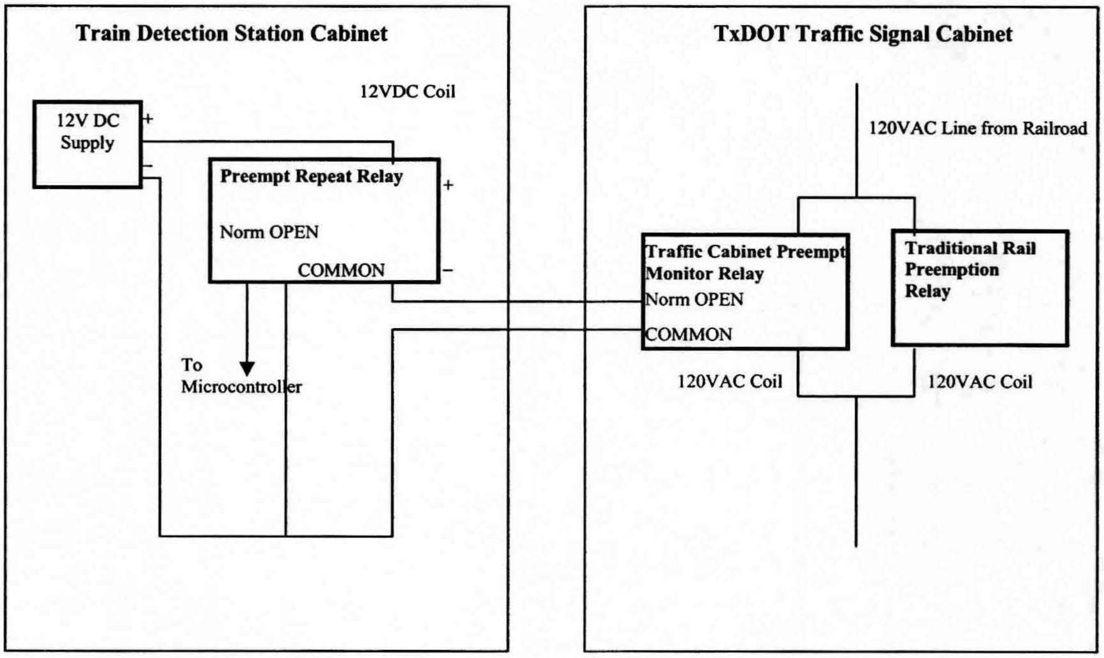

Figure 4. Sugar Land Train Detection Station Preempt Sensing Design.

The train traffic through Sugar Land is high, on the order of 30 trains per day. The original central processing software for the train monitor was designed to acquire and track a single train. It was agreed that the central processing software would require an upgrade to identify and track multiple trains. An analysis ensued to define a method that would perform well while requiring a minimum of software rewrite/creation. The College Station prototype system utilized a method that linked train information to the site that was reporting it. Each site would know its immediate neighbor and essentially hand off a train from site to site. This system worked well for a single train, which was the underlying assumption for the prototype in College Station, but was unable to manage multiple trains moving in the same or conflicting directions. The software upgrade introduced a method of managing multiple trains. All incoming data would be immediately associated or linked with a train. If no train was found corresponding to the data, a new train was created. As a train passed a corridor endpoint or a train failed to reach the next sensor station in a reasonable amount of time, the specific train gets removed from the train list. The new software required several months of design, coding and test time. The code was tested in College Station and was migrated to Sugar Land for full scale trial. The performance and stability has shown to be good. The upgrade has proven to be a valuable addition to the Sugar Land and College Station package.

CONCLUSION

Each of the field implementations cited continue in daily service. The Laredo District is considering another, more significant deployment of the technology in the downtown area. The envisioned system would implement the full suite of components of the train monitor with the goal of providing automation to a dynamic message sign (DMS) along IH35, automation of another highway advisory radio station and control of more flashing beacon signs in the downtown area. In addition, train information could be relayed and shown on a website in conjunction with the new traffic management center.

The Sugar Land system also continues operation. Although no expansion of the coverage area is foreseen in the near future, a new communication system is likely on the horizon. All current communication is based on CDPD, and the service is slated to be deactivated in the future. Continued interest from the City of Sugar Land may open up new avenues for communication (use of City of Sugar Land resources for field site to central communication) as well as new applications. Sugar Land has indicated a desire to use train information to better operate traffic signals along the US90A corridor.