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Exploratory Analysis Programs

*Transit IDEA Program*

# Transit Communications Interface Profiles (TCIP) Traveler Information Pilot

Final Report for
Transit IDEA Project 60

Prepared by:
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*September 2011*

TRANSPORTATION RESEARCH BOARD
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# EXECUTIVE SUMMARY

The purpose of this Transit IDEA project was to develop and test a system that uses Transit Communications Interface Profiles (TCIP) to track transit vehicles and to provide information to transit customers. The use of TCIP will allow these systems to be built and delivered more cost effectively, and will facilitate the interoperation of systems provided by different suppliers.

The Central Florida Regional Transportation Authority (LYNX) staff provided valuable support and assistance for this project. The system was pilot tested at LYNX, which is the transit agency serving the Orlando, Florida area.

Stage I of this project included the site survey and kickoff meeting with LYNX, design changes to accommodate the LYNX environment, and the ordering and initial testing of the equipment. In Stage I we added a Map Display to the scope of the project, allowing dispatcher to see the vehicle tracking in real time.

Stage II included integration testing and installation of the system on the LYNX property. In Stage II we tested the system in a laboratory environment, both at the aE facilities and at LYNX. We addressed some minor integration issues in preparation for the Stage III evaluation.

Stage III included the evaluation of the system and the production of the final report.

In this project, we translated LYNX schedule and GIS data into TCIP schedule files. A central server imports these files and uses the information, along with vehicle location information to generate traveler information.

The TCIP Traveler Information Pilot (TTIP) Project equipped two buses with TCIP-based Vehicle Logic Units (VLU) that report location over a commercial cellular network to a server at the LYNX Central Station. The server combines this information with information from the Mentor Engineering AVL system installed on the LYNX fleet to generate TCIP-formatted AVL information for the entire LYNX fleet. The server uses the location information to produce TCIP formatted traveler information, and a TCIP formatted fleet location feed to a map display. The map display concurrently displays traffic information from an external data provider.

TTIP delivers the traveler information to LYNX customers on a 46" LCD sign at the LYNX Central Station. This sign also displays advertising and other information to customers concurrently with the passenger information.

This project demonstrated the feasibility of using TCIP to provide transit information to transit riders.

The successful prototype demonstration in this project demonstrated the viability of TCIP interfaces to provide operational data within an agency, and to transit customers. The resultant product of this effort provides real time bus location information to riders using industry standard interfaces defined by TCIP. This has wide potential applicability in the transit industry.

Key performance measures for this project related to public acceptance of the Passenger Information Sign, accuracy of the provided information, the ability of the Automatic Vehicle Location System and Transit Traveler Information Systems to support the processing load for a full-size transit fleet, and the readability of the sign. Public acceptance of the sign was very positive. The accuracy of the provided information was determined to primarily be a function of the Automatic Vehicle Location System update rate. Readability of the sign was initially an issue due to glare from the sun; this was resolved by substituting a sign with more luminosity. Although the Automatic Vehicle Location System and the Transit Traveler Information System were hosted on the same server, the post-initialization server processor load never exceeded 10%.

Lessons learned from this project include the need for a frequent data update rate for the Automatic Vehicle Location System and the need to ensure that the signs luminosity is adequate.

Further research opportunities include the use of TCIP for dispatching, incident management, and onboard systems.

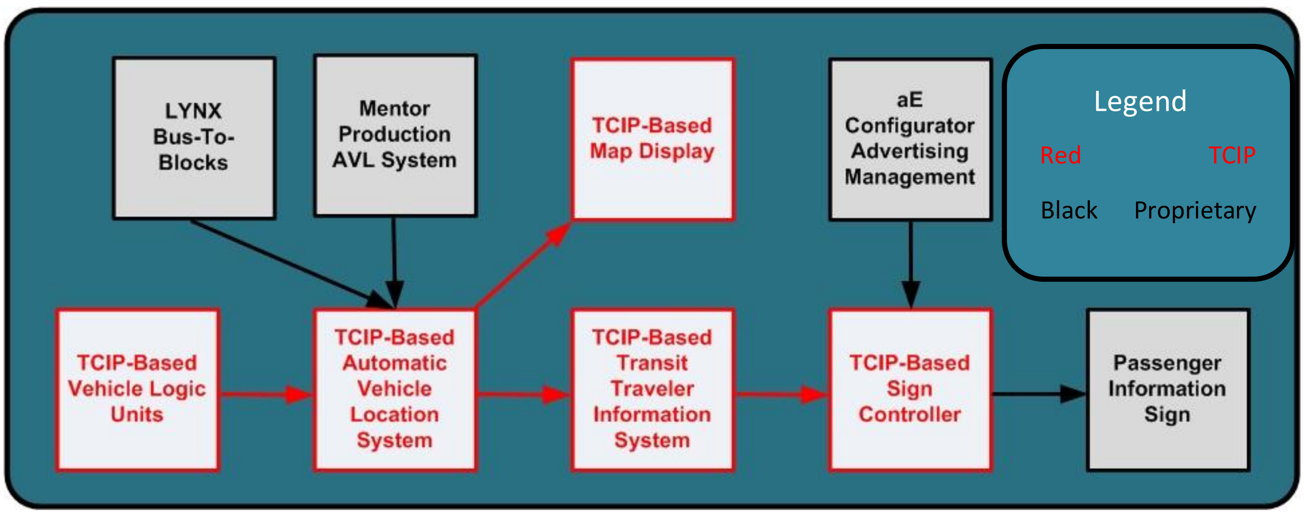



**FIGURE 1 TTIP Top-Level Block Diagram**

## Products

This project demonstrated the use of Transit Communications Interface Profiles (TCIP) standard interfaces operating under realistic transit operating conditions. TCIP interfaces lend themselves to incorporation into a number of products that are useful to the transit industry. In this project, we demonstrated TCIP interfaces with the following prototype products: Vehicle Logic Unit (VLU), Automatic Vehicle Location Server (AVL), Transit Traveler Information Server (TTI), Transit Workstation that provides mapping (TWS), and a Transit Station Control (TSC) product that manages Transit Center Passenger Information Signs.

During the development of the proposal, we planned to implement and demonstrate two time-critical TCIP interfaces: "Publish PTV AVL"-which conveys real-time transit vehicle location from a vehicle to a transit agency server, and "Publish Stoppoint ETA" which conveys real-time service status information from a server to the passenger information signs. During the Design Stage, aE decided to also incorporate additional TCIP interfaces and non-TCIP interfaces.

We added six additional TCIP file transfer interfaces: SchBlockScheduleFile, SchPatternFile, CptStoppointsFile, SchTimepointsFile, SchVehicleAssignmentFile, and SchCalendarFile. Taken together these file transfers provide the ability to export or import the schedule, and the daily vehicle assignments from or to an application. Ayers Electronic Systems, LLC (aE) is using these files in this project for two purposes: to populate the transit vehicle simulator with the planned vehicle movements for the day, and to provide these same planned movements to the Automatic Vehicle Location System for correlation with the real-time data on actual vehicle movements.

We added two additional real-time TCIP interfaces: the "Subscribe Watchdog Timer" dialog and the "Command Set Time" dialog. These interfaces allow the Transit Traveler Information System (TTI) to monitor the availability of the Transit Station Controllers (TSC), and to ensure that the clocks remain in synchronization.

This project also merged an existing Mentor Engineering proprietary data stream with TCIP data. Since the prototype TCIP-enabled Vehicle Logic Units (VLUs) were installed on 2 buses, a source of real-time vehicle information for the fleet was required to service the Transit Traveler Information System (TTI). The prototype Automatic Vehicle Location System (AVL) contains a translation module to convert the feed from the Mentor Engineering Production AVL Server into TCIP CCPTVLocation data frames. The prototype AVL processes these frames as if they originated from a TCIP-enabled source.

The successful prototype demonstration in this project demonstrated the viability of TCIP interfaces to provide operational data within an agency, and to transit customers. The resultant product of this effort provides real time bus location information to riders using industry standard interfaces defined by TCIP. This has wide potential applicability in the transit industry.

## Transit Communication Interface Profiles (TCIP)

APTA released the balloted Transit Communications Interface Profiles (TCIP) Standard in August 2006. This standard provides a means to define and implement interfaces for data exchange among transit business systems. The current released version of TCIP is version 3.0.3. The American Public Transportation Association (APTA) is currently accepting industry comments that will result in refinements to the standard's next version, which is anticipated to be released as version 3.0.4. This project will provide comments to APTA that will make the standard more robust and useful in future releases.

TCIP provides data exchanges for a wide range of transit business needs. These data exchanges are grouped into "Business Areas" reflecting the particular type of data exchange. These Business Areas are:

Scheduling: Transfers of data related to transit schedules, timetables, and assignments of vehicles and operators to scheduled work to be performed.

Common Public Transport: Transfers of data with applicability across many aspects of transit operations including facility, employee, stop point, and vehicle information.

Control Center: Transfers of data between the transit control center and various operational entities within the transit agency.

Onboard Systems: Transfers of information between systems and components onboard a transit vehicle.

Incident Management: Transfers of information related to real-time management of incidents, and historical information regarding incidents.

Spatial Data: Transfers of information describing the spatial relationships among transit entities.

Transit Signal Priority: Transfers of information related to preferential treatment given to transit vehicles by the signal lights governing arterial street networks.

Passenger Information: Transfers of information to assist passengers in using public transit.

Fare Collection: Transfers of information related to the collection and processing of fares. This Business Area has not been balloted.

Prior to this project one TCIP interface had been implemented. TCIP was used in a timetable publication system initially developed under an earlier Transit IDEA Project 39, the "Dynamic Timetable Generator". To date no time-critical TCIP interfaces have been implemented, and TCIP has not been used within an agency to connect operational business systems.

The use of TCIP will reduce the life-cycle cost of ITS projects and projects in the business area discussed above, within the transit industry, and will dramatically simplify the effort to interconnect ITS systems between agencies. aE has developed the industry's largest library of TCIP message encoder/decoder software, and is committed to the ongoing development of TCIP-enabled products. This IDEA project will demonstrate the viability of TCIP interfaces in an agency environment. This is a necessary precursor to full-scale deployment of TCIP interfaces.

# CONCEPT AND INNOVATION

The TCIP Traveler Information Pilot System (TTIP) provides transit customers at the LYNX Central Station with up to date information on the current location of buses. TTIP achieves this by fusing current AVL information with the schedule and bus assignment information. TTIP also displays near-real time vehicle locations on a map, fused with near-real-time traffic information. Finally, TTIP provides advertising capabilities, concurrently with service status information on the traveler information signs. The following paragraphs describe these processes.

## Importing the Schedule

The LYNX provides the schedule to aE in a series of comma separated variable (CSV) files that describe both the temporal and geographical elements of the schedule.  We validate and import these files into a series of tables in our distributed database using the aE Transit Data Collector application.  Some manual adjustments are required to the data before using it in TTIP. These include the assignment of destination names to each pattern, and some manual waypoint location adjustments to ensure that the location name assignment algorithm can use the data. Once we save the schedule into the database, our library of TCIP software converts the schedule to TCIP message files.

LYNX updates the schedule periodically. When this occurs, we must perform a new schedule import and ensure that the TTIP applications continue to function as designed with the new data.

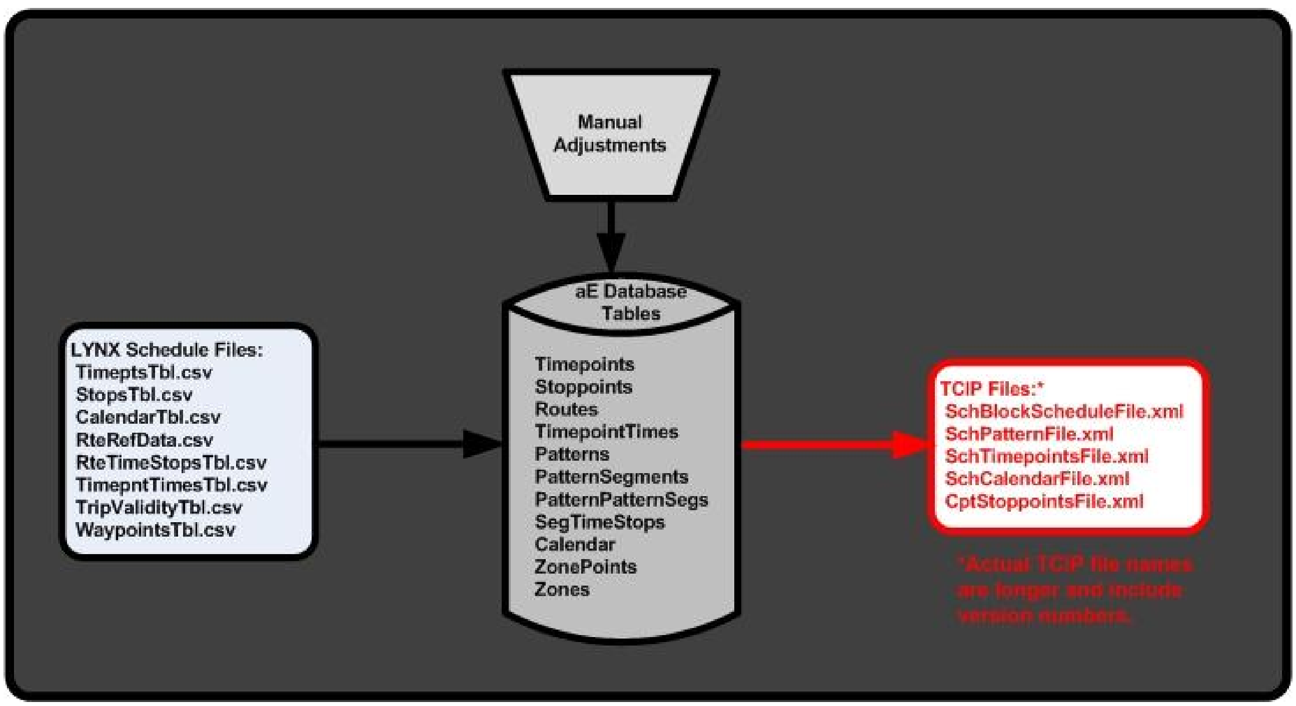



**FIGURE 2 Schedule Import**

## IMPORTING VEHICLE ASSIGNMENTS

Vehicle Assignments specify the relationship between the 'blocks' of work defined for a vehicle in the schedule, and the actual vehicles that have been assigned to perform the work on a daily basis. The vehicle assignments may change throughout the day. LYNX reassigns vehicles when required due to mechanical failures, or on changing operational needs. Consequently, a single vehicle may not actually perform a complete block of work as specified in the schedule. LYNX uses an in-house-developed application to manage these ongoing vehicle assignment changes called "Bus-To-Blocks". Authorized LYNX managers can update the vehicle assignments on a trip-by-trip basis within a block using this application.

The prototype Transit Traveler Information (TTI) application needs to determine which buses will operate on which trips in order to provide the current locations of those buses to the travelers at the LYNX Central Station. After each change to the vehicle assignments, TTI requires an update to the vehicle assignments to continue correctly allocating buses to scheduled trips. In order to accomplish this LYNX has modified Bus-To-Blocks to write out a database file to a shared network folder each time there is a change to the bus assignments. A module within TTI searches the shared folder periodically for a new database file, and upon finding one, copies the file to a local folder, reads the content, translates it to TCIP, saves the resulting TCIP SchVehicleAssignmentsFile.xml, and begins using the new assignment information. On restart, TTI uses the saved TCIP file as its initial set of vehicle assignments.

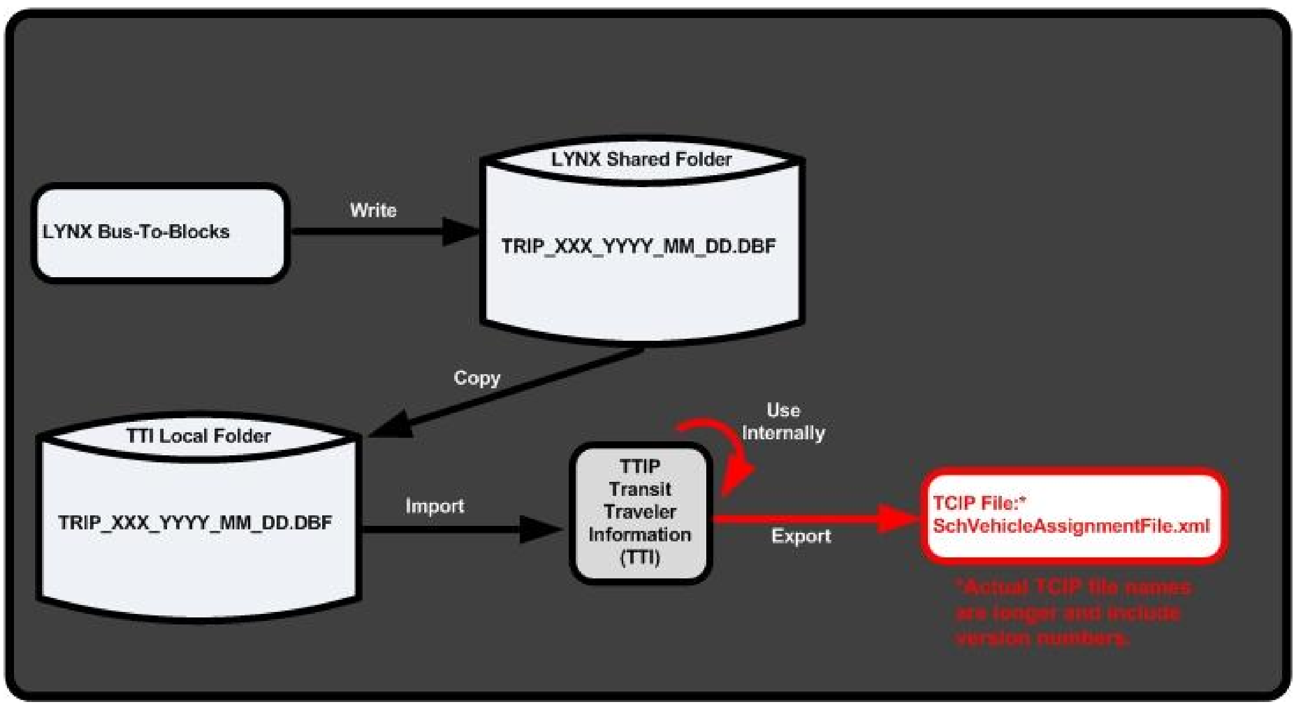



**FIGURE 3 Vehicle Assignment Import**

## IMPORTING BUS LOCATIONS

The prototype AVL application receives bus location information from two sources: The Mentor Engineering AVL System, and the two TCIP-enabled Vehicle Logic Units (VLUs).

TCIP-Enabled Vehicle Logic Unit AVL

The project investigators equipped two LYNX buses with TCIP-enabled Vehicle Logic Units (VLU). The VLU's operate on two different hardware platforms, but use the same operating system (Microsoft Windows XP Embedded) and application software (aE's prototype VLU application). The VLUs report bus location to TTIP using AT&T Wireless and the TCIP "Publish PTV AVL" dialog. TTIP uses an encrypted communications link (Virtual Private Network {VPN}) between the TTIP central equipment installed at the LYNX Central Station (LCS) and the cellular modems on the buses. This protects the bus location information, and allows the VLUs on those buses to appear as nodes on the TTIP local area network at the LCS.


**FIGURE 4 VLU Bench Test Setup**

## Mentor Engineering AVL Translation

LYNX has equipped its fleet with a Mentor Engineering AVL System. This system is the main source for real-time bus location information for TTIP. TTIP interfaces to the Mentor at the Mentor Engineering XGate® Middleware (XGate®) Server. The TTIP Prototype Automatic Vehicle Location System (AVL) subscribes to the XGate® Server and receives the real-time location data in a Mentor-defined ASCII-based format.

The XGate® Server can publish to local or remote subscribers. This capability allows us to test the TTIP System's capability to subscribe to Mentor messaging via an Internet connection between the aE labs in Richmond, Virginia and the Mentor Engineering labs in Calgary, Alberta.

The TTIP AVL translates each XGate® location report into a TCIP CCPTVLocation data frame. The TTIP AVL distributes these frames to the TTIP Prototype Traveler Information System (TTI) via an internal queue, and to the TTIP Prototype Transit Workstation using the TCIP "Publish Fleet Location" dialog.

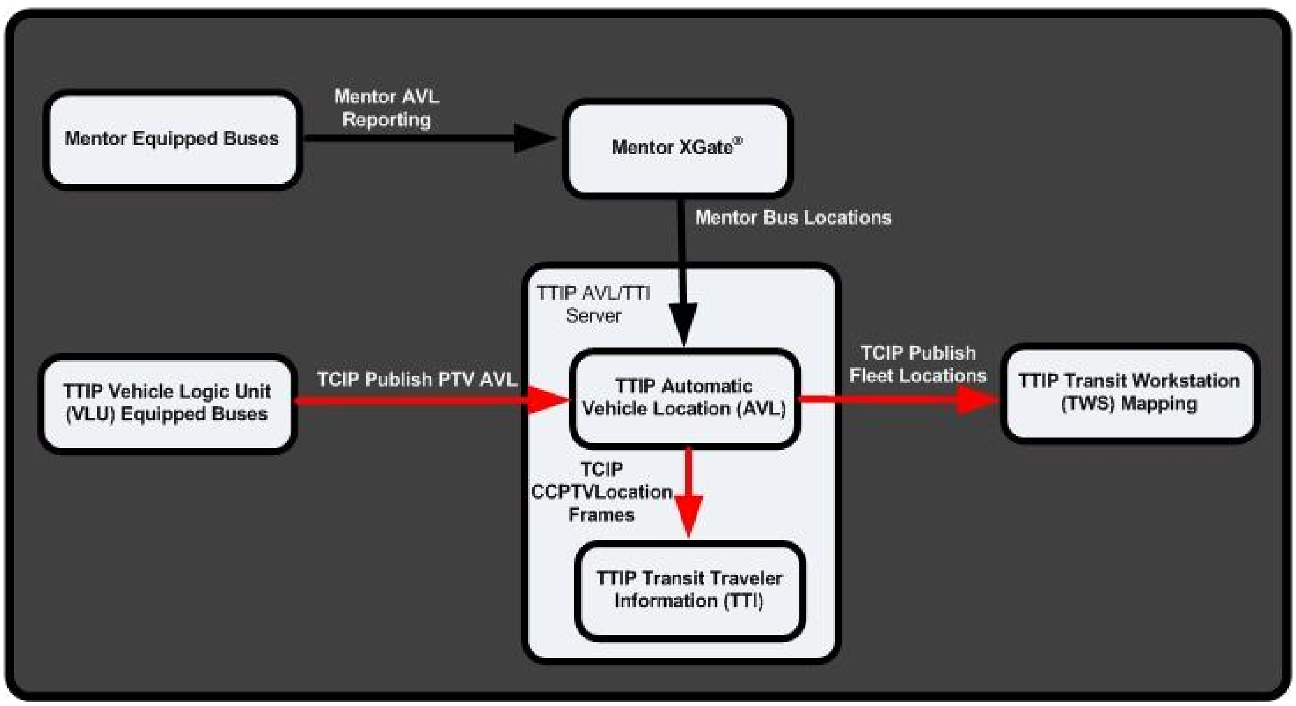



**FIGURE 5 Bus Location Import**

# PROVIDING TRAVELER INFORMATION

TTIP provides traveler information using a Liquid Crystal Display (LCD) sign in the platform area at the LYNX Central Station. This sign is configurable to provide several types of information (e.g., bus status, advertising, time, temperature, crawl text) concurrently.  TTIP will initially provide the current location of the inbound buses, later releases may provide other information such as arrival and departure estimates. The TCIP dialog used for this purpose in TTIP provides for all three of these options.

TTIP fuses data from three sources to provide information from travelers: the schedule, the bus assignments, and the current AVL solution from the buses. TTIP converts all three information sources to TCIP formats before using them to create passenger information solutions.


**FIGURE 6 LYNX Central Station Sign Lab Test**

## PROVIDING DISPATCHER INFORMATION

TTIP provides dispatcher location information from two sources: real-time vehicle location information via the TCIP "Publish Fleet Location" dialog, and traffic information via an Internet traffic feed from Microsoft®. TTIP provides both types of information on a map display. This map display is extensible to add additional information and features as part of ongoing product development efforts. The map application also implements the TCIP Publish Watchdog Timer dialog, which provides a keep-alive capability between the map and the AVL/TTI Server.

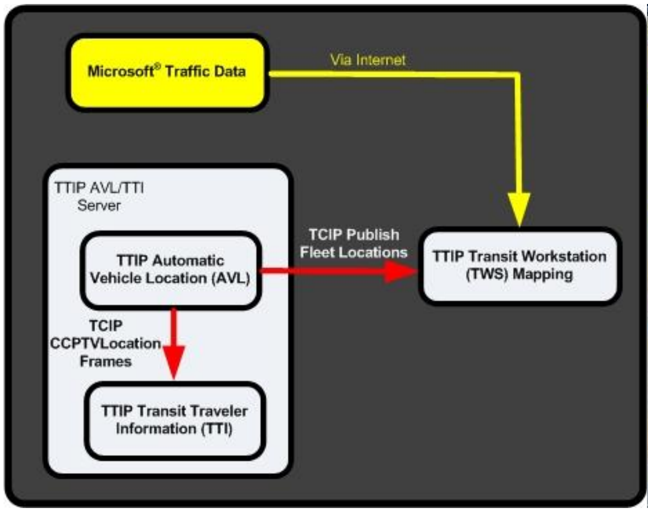



**FIGURE 7 Map Application Block Diagram**

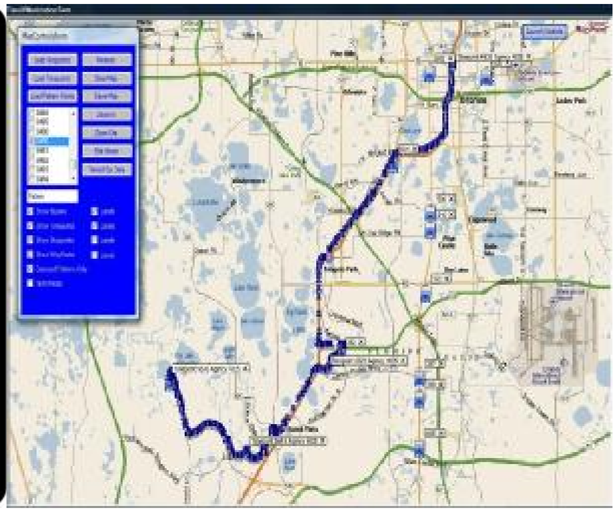


**FIGURE 8 Map Application Screen Shot**

## ADVERTISING

The combination of advertising with traveler information provides an opportunity for agencies to offset some or all of the cost of these systems. aE developed a traveler information sign controller that can simultaneously process both traveler information and advertising on an LCD sign. Advertising may consist of 'print ads' or graphics that display on a portion of the sign for a period of time, text announcements, or video commercials. Support for advertising requires that some of the sign's real estate be reserved for the advertisements. Some sign configurations use all of the available real estate to provide service status information, eliminating the possibility of advertising.

aE developed a Configurator application that manages the sign configuration as well as the storage and display of advertisements for a number of signs simultaneously. Configurator uses proprietary messages to communicate with the signs, over the same network connection that the Traveler Information application uses to provide the service status information. This demonstrates the ability of TCIP to share a network connection with non-TCIP message flows. The Configurator application shares a server computer with aE's data management application.

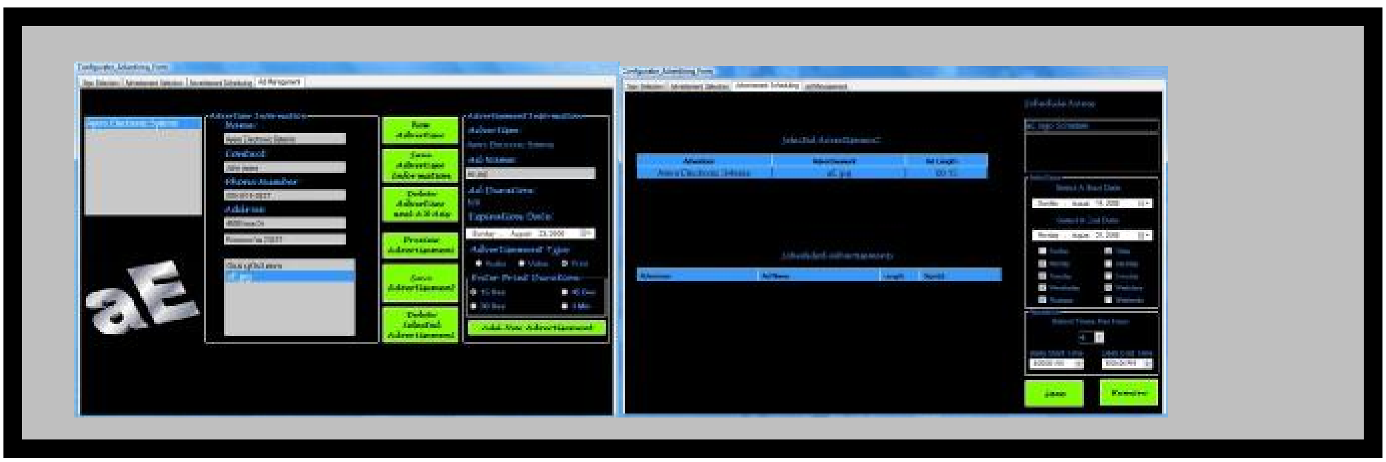


**FIGURE 9 Configurator Advertising Management Screens**

# INVESTIGATION

The inception of this project goes back to discussions with LYNX that began in 2008. These discussions concerned TCIP and its possible role at LYNX. LYNX has a number of ongoing efforts to enhance and further develop its Information Technology and Intelligent Transportation Systems. The continued evolution of these systems within LYNX will result in the development of a number of new interfaces between information systems. Several of these interfaces have the potential to be implemented using TCIP.

Concurrently, aE was prototyping a new command and control system platform targeted to public transit and security applications. This platform provides a number of software services that facilitate the development of distributed systems. These services include communications, subsystem health monitoring, user logon, privilege management, and distributed data sharing. The platform also includes integrated support for TCIP messaging and file transfers.

Prior to the initiation of this project, aE began developing a number of prototype transit applications on the new platform. These include TCIP schedule file generation application ("Rough Cut"), a transit schedule and GIS data collection application ("Transit Data Collector"), transit fleet simulator, a vehicle logic unit ("VLU") capable of TCIP-based AVL reporting, an AVL Server ("AVL"), a passenger information server ("Transit Traveler Information") and passenger information sign controllers ("Transit Station Control"). aE demonstrated versions of these applications at the 2008 APTA Expo in San Diego, at the 2008 ITS World Congress in New York, and at the 2009 Community Transit Expo in Rhode Island.

There is a close tie between the ongoing product development efforts and the efforts tied specifically to the LYNX TTIP project.

# STAGE I INVESTIGATION

The tasks in Stage I of this project were: Equipment (Task 1) and Application Engineering (Task 2). The following subsections describe the progress in each of these areas.

## Task 1Equipment

The TTIP project as originally proposed required the following equipment:

- Vehicle Logic Unit (VLU)
- Vehicle Junction Box (JBox)
- Vehicle Cabling/Brackets
- Traveler Information and Automatic Vehicle Location Server (TTI/AVL Server)
- Router
- Transit Station Control (TSC) Computer
- Passenger Information Sign (Sign)
- Sign and Server Cabling and Brackets

- Central Equipment Uninterrupted Power Supply

Vehicle Logic Unit (VLU): The VLU is the onboard bus computer for the TTIP project. The primary purpose for these units is to host the software that runs onboard to report TCIP locations to the central TTI/AVL Server. We originally envisioned the VLU to include the GPS receiver, a cellular modem, and discrete I/O capabilities to allow us to monitor door and ignition status. The original VLU hardware incorporated all of these features; however, this unit normally ships with a LINUX operating system, while our units run on Windows XP®. The operating system change led to some integration issues with the discrete IO and so we decided to design an external USB device into the JBox to provide this feature. Later we ran into additional integration problems with the internal cell modem, and decided to use an external device for this purpose as well. Unfortunately, by this time, the JBox extrusions were on hand and assembly was underway. There was insufficient space inside each JBox to add the cell modem. We decided to mount the cell modems on the sides of the JBoxes.

We also decided to test a second brand of VLU hardware. This brand also runs on Windows XP, but does not include an internal modem, GPS or discrete IO. The second VLU runs the same aE platform and application software as the original VLU.

JBox: The JBox is a hollow aluminum extrusion with aluminum end caps. Its purpose is to house the external components and power supply for the onboard equipment. These external components include the discrete IO conditioning board, the power supply (including shutoff relays), the external discrete IO to USB interface, and in the case of the second VLU, the GPS receiver. As noted above, the JBox also provides a mounting point for the cellular modem.

Vehicle Cabling and Brackets: We designed cables for the vehicle installation based on the survey performed in task 2. These cables are on hand and ready to use in Stage 2. We have also developed additional lab cables to allow us to test the equipment in the laboratory environment. The VLUS and JBoxes mount onto a mounting plate that in turn mounts onto a particleboard shelf in an electronics enclosure on the bus. These mounting plates are on hand and ready for use in Stage II. We have also purchased and tested the tri-band antennas for the GPS receivers, and the cellular modems.

Router: We originally envisioned an inexpensive four-port Ethernet/Wireless router to be used for this project. A Virtual Private Network (VPN) Server and an Ethernet switch have replaced this router. This was necessary to set up the communications between the VLUs and the TTI/AVL Server via the cellular carrier. The VPN Server, hosted on a Dell Dimension XPS T800r, is on hand and ready to install in Stage II.

Traveler Information and Automatic Vehicle Location Server (TTI/AVL Server): We originally ordered two Dell Power Edge®1900 small business servers with Windows Server Small Business 2003® for use as the TTI/AVL Servers (one for the lab and one for installation at LYNX). These servers have two quad core processors. Initial testing of these servers was promising; however, we later determined that we needed to move our server applications to a 64-bit environment. The cost of upgrading these servers to a 64-bit operating system was prohibitive. Instead, we purchased HP Pavilion p6130y PC computers to use as the servers. We now plan to use these alternative computers for both the TTI/AVL Server and the Configurator/Data Server in TTIP.

Transit Station Control Computer. This computer is a Dell Studio Hybrid. The computer was ready for installation in Stage II.

Passenger Information Sign: We wanted a large NEMA-4 LCD sign that would be vandal resistant and audio capable. We worked with CCS-Inc. to modify one of their standard products to meet our needs. Originally, this enclosure contained a 42" diagonal screen, but we later upgraded it to 46". The resulting sign was ready for installation at LYNX in Stage II.

Sign and Server Cables and Brackets. We originally planned to suspend the sign from the canopy structure at the LYNX Central Station as part of this project. During the site survey, we discussed this with the LYNX facilities representatives, and determined that this plan was infeasible. We have designed and ordered a pedestal mount. The pedestal mount will be on hand in time for installation in Stage II. The central server equipment will be stored on a set of shelves in a LYNX communications closet at the LYNX Central Station. These shelves are on hand and ready for use in Stage II. The cabling for the installation at the LYNX Central Station is standard Cat-5 cable, and 120V power connections. These cables were ready for use in Stage II.

Central Equipment Uninterrupted Power Supply: This unit is an APC Backup UPS XS1500. The unit is on hand and ready for installation in Stage II.

As the project has progressed, we have added two additional features: Advertising Management, and Mapping. The addition of these features required the addition of additional hardware and software. These additional items are on hand and ready for installation in Stage II.

## Task 2 Application Engineering

We visited LYNX for a Kickoff Meeting and Site Survey in May 2009. During this visit, we were able to survey the bus for the VLU installation, and the Central Station locations for the sign, and the central computers.

Bus Survey. During the bus survey, we determined the mounting location to be used for our equipment, including the VLU, JBox and antenna. We worked with the LYNX vehicle maintenance to determine the routing for the wiring and the electrical connection points to the bus for the discrete IO. This allowed us to design and order the cables for use in Stage II.

Central Station Survey. We met with the facilities department and determined locations for the central equipment, and the sign. The original plan to suspend the sign turned out to be infeasible, leading to a design change to a pedestal mount. The Facilities Department worked out a cable route for the Cat-5 cable from the communications closet to the sign's intended location. The Facilities Department also worked out a source of power to the sign.

# STAGEII INVESTIGATION

In Stage II, we integrated and tested the equipment in the lab environment to ensure proper operation of the system prior to delivery and installation at LYNX. After lab integration, we disassembled the equipment and moved it to LYNX for reassembly and installation, with the sign installed out of sight in the third floor IT Server Room.

## Task 3 Lab Integration

We performed the Lab Integration activities at the aE offices in Richmond, Virginia. Beginning prior to the project contact award, we began operating the TTIP software on dedicated computers in our labs on a 24X7 basis. As new applications and features were developed, we incrementally added these items to the test environment. Prior to the receipt of LYNX schedule and bus assignment data, we ran the software on a simulated circulator route in the Richmond area.

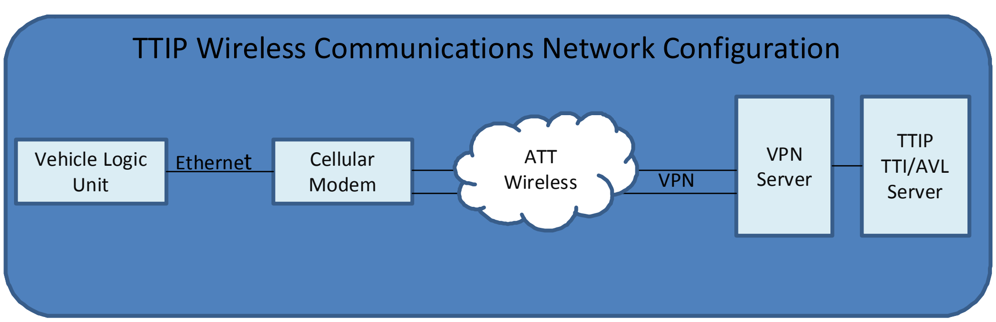
Upon receipt of the LYNX schedule and bus assignment data, we imported the data into our database, and then exported the data as TCIP data files. We then transferred these TCIP files for use by our applications. This process was repeated several times over a period of weeks, as we uncovered and corrected some software defects, and made some minor adjustments to the GIS data associated with the schedule.

By the end of the Lab Integration task, we had run TTIP (with simulated bus movements) on LYNX data for approximately 8 weeks. This 24X7 testing ran concurrently with the specific tests described below.

### Task 3.1 Communications Test

We established basic TCP/IP and UDP/IP communications among the TTIP applications prior to the IDEA contract award. The key communications challenge for this test was to verify that we could operate the VLU to AVL Server communications over the cellular communications link. The primary communications over this link are the TCIP Publish PTV AVL dialog. Critical Link, LLC of Syracuse took the lead in the integration of this link.

We tried a few configurations with one carrier without success, prior to switching to AT&T wireless as our cellular carrier. In the final configuration, we use an AT&T wireless connection. The Vehicle Logic Units communicate with a Multi-Tech GPRS Cellular modem. The Cell modem terminates one end of a Virtual Private Network (VPN) through AT&T Wireless to the Internet and to a VPN Router provided by Critical Link. The VPN Router terminates the other end of the link, and routes the traffic between the VPN and the Local Area Network serving the TTIP computers.



The final configuration works reliably, however the setup and configuration is more complex than would be desirable for a production system. Additionally, this configuration has some limitations on address assignments, which present some scaling issues for a large bus fleet.

We tested this configuration in the lab environment, but connected across the wireless network and the Internet in a similar configuration to the planned LYNX installation. Due to some facility issues, we limited the duration of the final laboratory end-to-end test to about 24 hours of total 'air time'.

Task 3.2 Compatibility Software Test

The purpose of this task was to verify that the aE Services software platform operates correctly on the VLU, TTIP Server, and Transit Station Control Computer. The aE Services software package is a group of software capabilities that we use as a platform upon which to build our applications. Figure 10 depicts aE's layered approach to application design. Initially we expected to use Windows XP Embedded for the VLU, Windows Small Business Server 2003 for the AVL/TTI Server and Windows Vista for Transit Station Control. We successfully tested the services on all three of these platforms, as well as Windows XP Pro. The only operating system compatibility issue we encountered was that the XP Compatibility Mode feature in Windows Vista needed to be disabled.

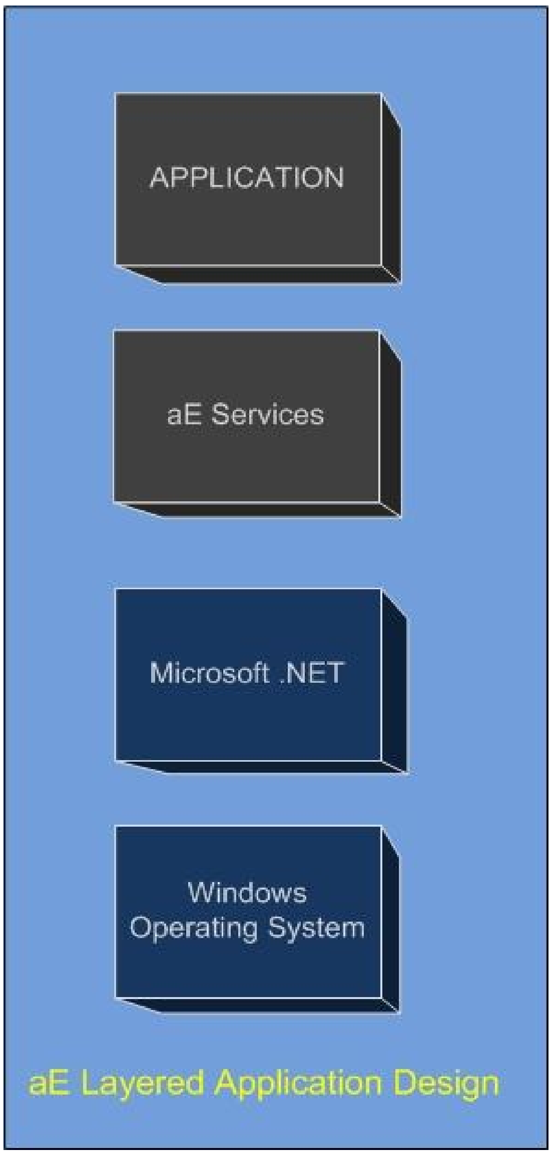



**FIGURE 10 Layered Application Design**

As our testing continued, we determined that we needed to move the server and simulation applications to a 64-bit environment. We transitioned these applications to a 64-bit version of Windows Vista. At this point, we learned that Microsoft's JET Engine middleware (used to connect applications to Microsoft Office) is not compatible with any 64-bit version of Windows. This led to us converting all application data storage to a combination of flat files, and Microsoft SQL Server databases.

We also determined that our build of Windows XP Embedded was not compatible with all device drivers required to operate our VLUs. This led us to convert the VLU operating systems to Windows XP Professional.

Task 3.3 Application Software

As we developed the AVL, TTI, TSC, TWS, and Configurator applications, we ran the various versions in our lab environment. This environment includes a TCIP-based bus movement simulator that exercises the software as if it were in a production environment. This lab test process continues, beyond the initial delivery of the TTIP hardware to LYNX.

During the application software testing, we detected and corrected a number of software defects. We also migrated from a local circulating route test data set to a LYNX schedule-based dataset.

In this task we also performed lab integration of the Mentor AVL data feed with our real-time TCIP translation software. We started by developing our own emulator, based on the Mentor data feed specification, and integrating our software with that emulator. Mentor provided us some sample test data from their AVL application, and we uncovered some data fields that we had not interpreted correctly. This led to some adjustments to the emulator and to our software to adapt to our revised understanding of the feed specification. Next Mentor provided us with an over the Internet path to an AVL Server in their laboratory. This led us to discover some needed changes in our TCP connection to Mentor. After these corrections, we were able to receive and translate the Mentor feed reliably.

Since we plan to install the passenger information sign at the LYNX Central Station (LCS), and provide information related to Link 4 (LCS to Kissimmee), and Link 50 (LCS to Magic Kingdom), the focus of the laboratory testing was on these two routes. We did however simulate and test with other routes on a limited basis.

One application software feature remained incomplete at the time we decided to start Task 4. This is the implementation of traffic data on the map display. Integration testing of the traffic data continued in parallel with Task 4.

## Task 4 Relocate System to LYNX

### Task 4.1 Disassemble & Ship

In this task, we disassembled the equipment, packaged it for shipment, and took it to LYNX for onsite installation. We performed the disassembly during the week of September 14, and arrived at LYNX with the equipment on September 21, 2009.

### Task 4.2 Inspect & Reassemble

During the week of September 21, 2009 we inspected reassembled the equipment at LYNX. At this time, we delivered all of the equipment, except for the sign pedestal. We delivered the pedestal for the sign to the LYNX Central Station on October 5th. The later pedestal delivery does not affect the project's overall schedule. The shipment to LYNX resulted in no shipping damage.

### Task 4.3 Equipment Checkout

During the week of September 21, 2009, we reassembled the central TTIP equipment in the LYNX Central Station 3rd floor server room. LYNX-IT provided us with the necessary network connections to access the Internet, the Mentor AVL Server, and the LYNX Bus-To-Blocks application. We also installed the onboard equipment on buses 814 and 815.

During the installation, we learned of a software upgrade to the Bus-To-Blocks application. This led both aE and LYNX to make application software updates following the first day of installation. These updates implemented a change in the vehicle assignments file format. We tested the updated applications the following day, and both sides of the amended interface worked as intended.

After correcting a grounding fault during the initial installation on bus 814, the VLU installations on both buses appeared to operate as intended. On the following day, however we detected that the TCIP AVL reports from bus 814 showed the bus location lagging the Mentor-reported locations by several minutes. We later traced this to a queuing problem in the aE VLU software. We updated and replaced the VLU software in the early morning hours of October 4, and the latency problem has not recurred.

On October 6th, 2009we detected two new problems. We noted that one bus on Link 50 (LCS to Magic Kingdom) was providing an incorrect indication on the sign. The sign was showing the bus as delayed, when the AVL reported location of the bus was correct based on the schedule. Upon further investigation, we discovered that the aE AVL software had not correctly detected the completion of the previous trip. We made a series of changes to the aE TTI software during October and November 2009, rewriting the portion of this software used to detect and transition trip assignments, resolving this problem.

The second problem we noted was that the sign displayed advertisements with incorrect spacing in time between those ads. This problem was subtle, as the casual observer has no obvious cue that the spacing is wrong. We traced this problem to a calculation error in the script executor. We updated the script executor, and this problem was resolved.

We also noted that over a period of weeks, the aE VLUs occasionally fail to restart upon a bus restart. This may be a symptom of more than one problem. We initiated a change to the initialization software in our application, and installed this software in late October 2009. We also set up an experiment in our lab to attempt to recreate this problem. We were unable to recreate this problem in the lab; however, since installing the replacement initialization software, the problem has not recurred in the field. We continue to monitor the equipment for any recurrence of this problem.

We received a request from LYNX in October 2009 to make two changes to the appearance of the sign. The first request was to increase the size of the clock display on the sign. The second request was to make the delay indication for a bus more distinct from the other information related to the bus status. We updated the TTI and TSC software in late November to implement these changes.

In November, we developed a prototype extension to the project to allow cell phones to access real-time traveler information from TTIP. We demonstrated this prototype to LYNX in early December; however, this capability is not yet mature enough to release to the public.


**FIGURE 11 Prototype TTIP Cell Phone Application**

In November 2009, with the assistance from LYNX, we implemented a remote desktop capability on the machines installed at LYNX. This allows us to look at the current condition of the applications, and to remotely install software updates.

In December, we received a request from LYNX to investigate the possibility of displaying the current bus locations on the routes in schematic form. This capability was included in the design for the TSC, but stubbed out as an item for future development. As of the end of Stage 2 we are investigating what changes will be required to the AVL/TTI server and to the TSC software to bring this capability online.

On December 18th, 2009we moved the TWS mapping application and an instance of the station sign on a 22-inch monitor into the LYNX Central Station dispatch area. The dispatchers will be monitoring the system to verify that it operates as expected, and will report any anomalies via the LYNX Help Desk. This action transitions the project into Stage III (Evaluation).

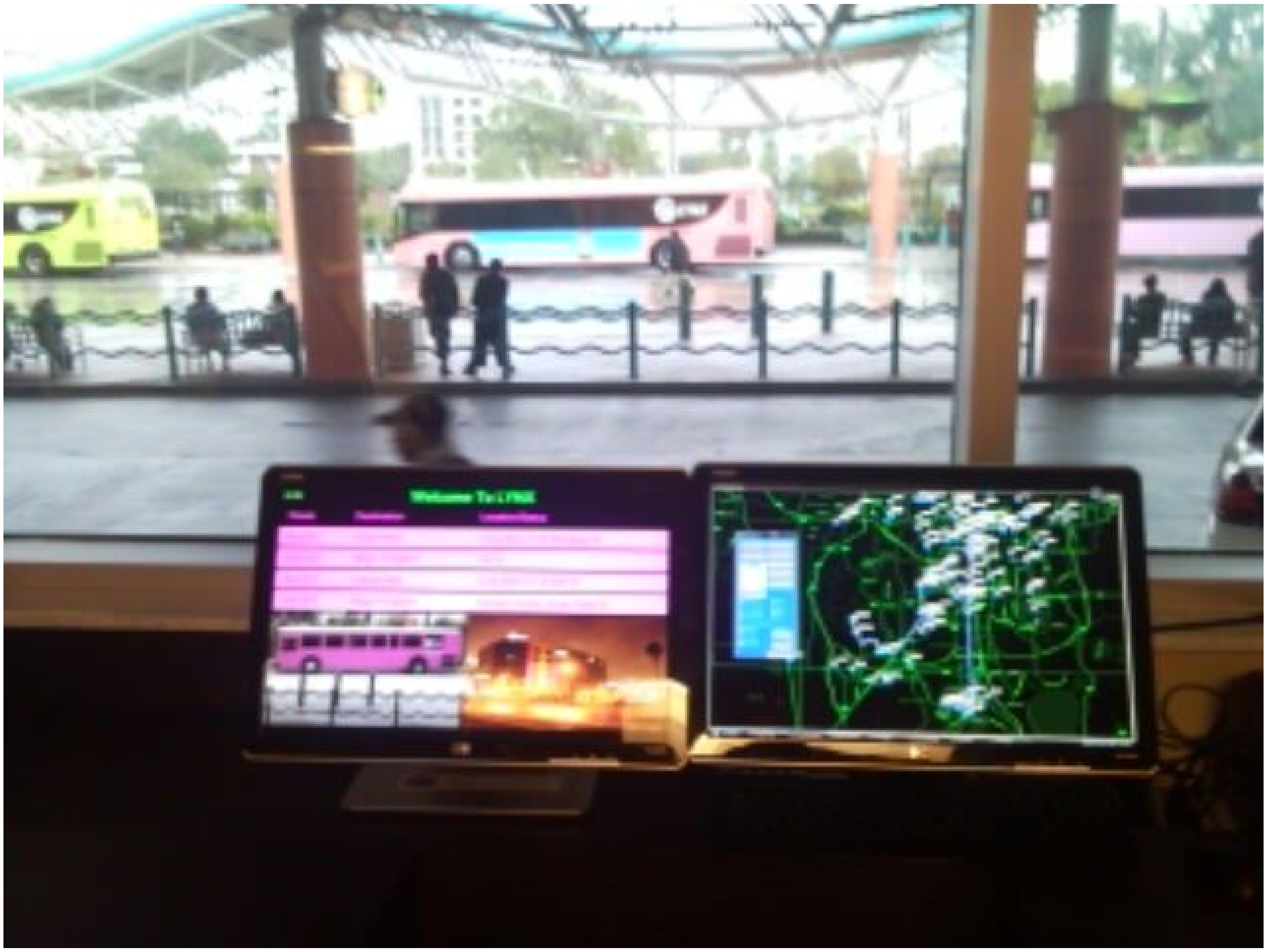


**Figure 12 TTIP Evaluation in LYNX Central Station Dispatch Area**

Task 5 Mentor AVL Integration

LYNX provided aE with a network connection to the Mentor AVL server within a few hours of our equipment delivery at LYNX. We immediately connected the TTIP server to the Mentor server to verify this interface. As soon we established the connection, the TTIP server began receiving Mentor AVL messages, and correctly converting those to TCIP.

Very shortly after establishing the connection, we discovered that the TTIP server was generating a large volume of bad message alarms for the Mentor connection. Upon further investigation, we learned of a Mentor server upgrade to a later version. The new version generates a new type of AVL message (in addition to the AVL message used by TTIP). We implemented a minor software revision to filter out the new messages. With this fix in place, we have had no reliability problems with the Mentor AVL feed.

## STAGEIII INVESTIGATION

On January 26, 2010, we installed the passenger information sign in the public area at the LYNX Central Station. The installation went smoothly and the sign worked as designed as soon as all of the connections were made.

**Figure 13 Passenger Information Sign Installation at LYNX Central Station**

While the sign was being installed, we immediately began receiving queries and favorable comments from the public. LYNX customers were happy to see that LYNX was working to provide real-time information, and that LYNX was involved in leading edge research in transit.

Unfortunately, shortly after installation we observed that the glare from the sun was reflecting off of the buildings behind the LYNX Central Station, under the canopy and off of the surface of the sign. This glare is more apparent in the photographs of the sign than it was on site; however it was severe enough that we immediately began looking for a mitigation approach. We investigated the use of a film covering for the display area; we considered replacing the Lexan cover over the display area, as well as other techniques. Unfortunately, none of these approaches appeared to be adequate to resolve the glare problem.

Eventually, we looked at replacing the sign itself with a unit containing a brighter display. The original sign had a display luminescence of approximately 300 Nits (Candelas/Square Meter). We found a replacement sign with a display luminescence of 1500 Nits. This replacement sign was installed at LYNX on July 14, 2010 after several months of testing in Richmond. The new sign is clearly legible under all conditions as installed. There are still some reflections that appear on the face of the sign when photographed during the day in bright sunlight, but these images are much less noticeable when the sign is viewed in person. We also note that the vandal-resistant features of the replacement sign are not as robust as the original sign. Consequently we anticipate further refinements in the sign packaging will be necessary.

**Figure 14 Newly Installed Sign Showing Glare Problem**

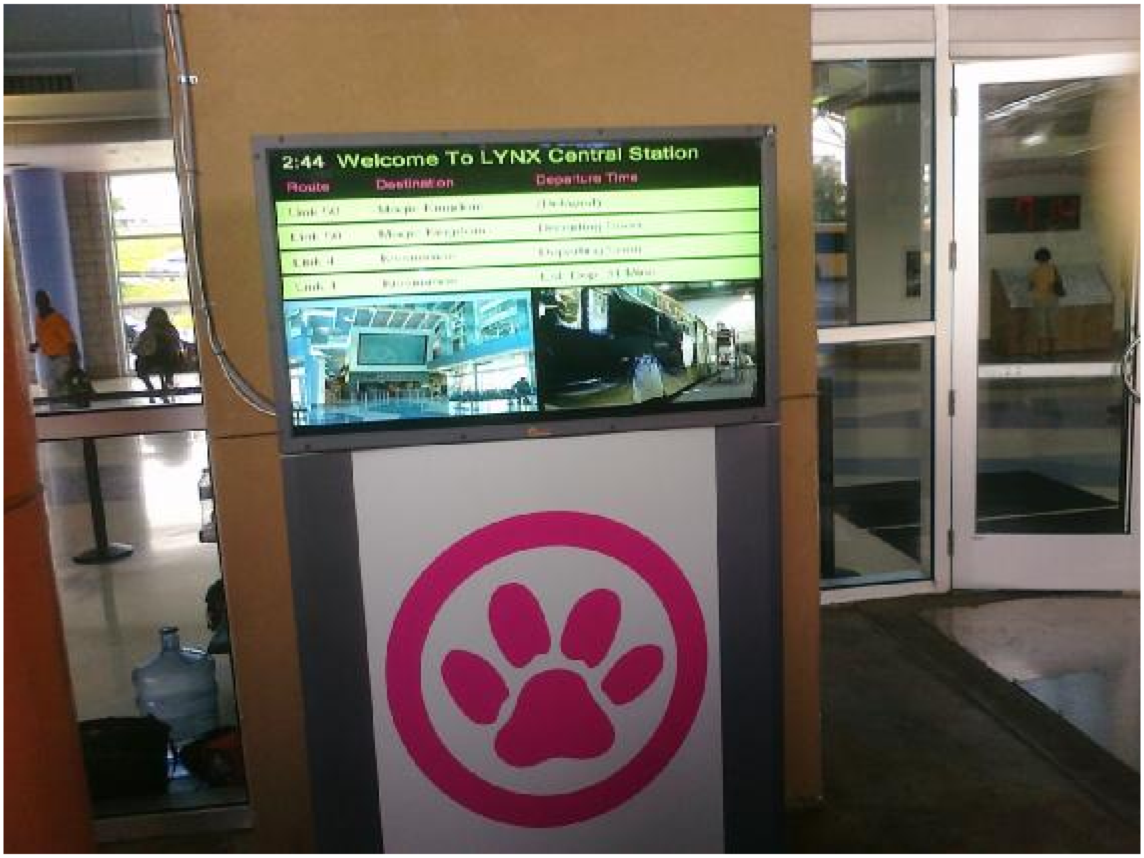



**Figure 15 Replacement Sign With Improved Luminescence**

In addition to the resolution of the glare problem, we spent some effort attempting to determine the utility of the information on the sign to the customers. With LYNX's help we implemented an email address to obtain feedback from the public. We put information on the sign requesting people to email feedback, but this approach was ultimately not effective. Lacking email responses, we spent time in proximity to the sign and asked waiting passengers what they thought about the sign. We also solicited feedback from LYNX staff.

This feedback led us to implement a graphical version of the service status information. We implemented this in the panel of the display that is used for the slide show. We also determined that the type of data that is useful to riders is dependent on the type of stop at which they are waiting. This information led us to implement multiple modes of operation for our signs, including Current Location Mode (original mode that specifies the names of the locations of the approaching buses), Estimated Departure Mode (specifies the expected departure times of buses from the stop), Stops Away Mode (specifies the number of stops from the approaching bus's location to the stop containing the sign), Distance Away Mode (specifies the distance {along the route} from the approaching bus to the stop containing the sign), and finally Estimated Arrival Mode (specifies when the bus is expected to arrive).

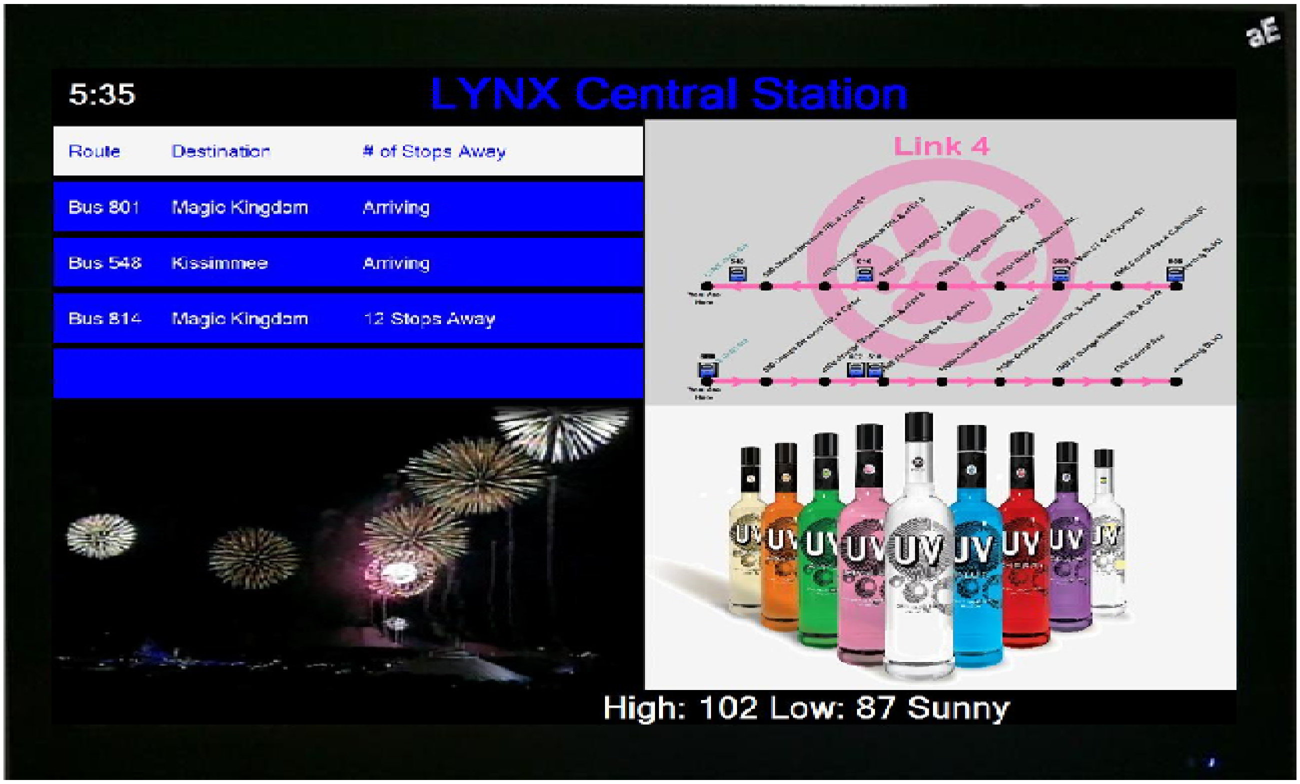



**Figure 16 Laboratory Sign Illustrating Simultaneous Stops Away Mode, Schematic Map, Video and Print Advertisements. Note: Vodka advertisement is for illustration, and was not used on LYNX property.**

During this stage we also looked at the accuracy of the data. We found that it was rare to have an incorrect result, but there were a few occasions where old data was retained too long, or a bus would be temporarily dropped from the display. We found some issues that appeared to be the root cause of these problems, and resolved them individually.

# CONCLUSIONS

## Stage 1 Conclusions

Our Stage I conclusions are as follows:

The original plan to mount the sign suspended from the LYNX Central Station structure was modified. We substituted a pedestal for the overhead mount for TTIP.  We plan to offer a larger number of installation options for the final product, possibly including several types of pedestal designs.

The original sign included a 42" LCD screen. We substituted a 46" screen for better readability. Varieties of screen sizes are desirable for a final product line.

We needed to add an automatic shut-off feature to the onboard equipment to prevent it from depleting the bus batteries. This feature needs to be standard in the final product.

## Stage 2 Conclusions

Our Stage 2 conclusions are as follows:

We encountered no integration issues that we in any way attributable to TCIP.

We did initially encounter some integration issues with legacy systems; however, these were relatively minor considering that we are integrating new software and new hardware into a mature operating environment.

We have seen no recurrence of the intermittent VLU failure to restart problem, however as a precaution we plan to continue monitoring for any sign of this problem during Stage III.

For a long-term production installation, policies and procedures will need to be in place to ensure that configuration changes to systems and datasets that drive TTIP are coordinated and tested with TTIP prior to implementation.

## Stage 3 Conclusions

Our Stage 3 conclusions are as follows:

The ambient light conditions must be carefully considered during sign selection and placement. A covered location does not ensure that the luminescence of the sign will be adequate.

The Mentor AVL system uses interim short AVL reports to supplement the full AVL reports. Originally we used only the full reports; however we later determined that this occasionally impacted the quality of the passenger information provided. AVL update rate is a key determinant of the quality of passenger information provided. This is not a factor using the TCIP AVL system, which has the ability to support higher update rates.

The power control mechanism used on the test VLUs installed at LYNX, did not reliably restart the VLUs at the beginning of a new day. This algorithm needs adjustments and further testing before production use.

The process of obtaining the new schedule data for each new schedule release needs to start early to account for data issues that may arise during the import and conversion of the agency schedule data to TCIP. Additionally, we found that we needed to add new features to the data import software to deal with various unexpected conditions in the schedule data.

The successful prototype demonstration in this project demonstrated the viability of TCIP interfaces to provide operational data within an agency, and to transit customers. The resultant product of this effort provides real time bus location information to riders using industry standard interfaces defined by TCIP. This has wide potential applicability in the transit industry.

The utility of service status information to riders varies based on the type of stop. The table below shows our conclusions about the usefulness of the information by stop type:

| Passenger Information Utility By Stop Type | | | | | |
|---|---|---|---|---|---|
| Stop Type | Information Type | | | | |
| | Estimated Arrival | Estimated Departure | Stops Away | Distance Away | Location Name |
| Central Station | | √ | | | |
| Enroute Hub | | √ | √ | √ | √ |
| Enroute Stop | √ | | √ | √ | √ |
| End of Spoke Stop | √ | √ | √ | √ | |

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| Key Subcontractor<br>Outdoor Sign Enclosure and Pedestal<br>Vehicle Logic Unit | CCS-Inc<br>105 Industrial Drive<br>Christiansburg, VA 24073 |
| Key Subcontractor<br>Cabling & Connectors | EMSCO Inc.<br>11093 Air Park Road<br>Ashland, VA 23005 |
| Key Subcontractor<br>AVL System Interface | Mentor Engineering Inc.<br>10, 2175-29th Street NE<br>Calgary, AB, Canada T1Y 7H8 |
| Key Subcontractor<br>Vehicle Logic Unit | Parvus Corporation<br>3222 South Washington Street<br>Salt Lake City, UT 84115 |

GLOSSARY

| Term/Acronym | Definition |
|---|---|
| American Public Transportation Association | Serves and leads its diverse membership through advocacy, innovation, and information sharing to strengthen and expand public transportation. |
| APTA | American Public Transportation Association |
| Category 5 Cable | A twisted pair high signal integrity cable type often referred to as Cat5. Most cables are unshielded relying on the twisted pair design for noise rejection, although some are shielded. |
| Comma Separated Variables | A computer file format in which records are stored as lines of text, and fields (variables) within records are separated by commas |
| Configurator | An application that provides sign and advertising management for the TTIP Project |
| CSV | Comma Separated Variables |
| Global Positioning System | A constellation of earth orbiting satellites transmitting timing and ephemeris data that allow compatible receivers to calculate their geographical location, altitude, and time |
| GPS | Global Positioning System |
| GPS Receiver | A receiver capable of receiving and decoding signals from GPS satellites |
| IDEA | Innovation Deserving Exploratory Analysis |
| Intelligent Transportation Systems | A worldwide initiative to use advanced technologies, and computer-based technologies specifically to enhance the safety and efficiency of transportation systems |
| IO | Input-Output |
| ITS | Intelligent Transportation Systems |
| JBox | An enclosure used on the bus to house electrical equipment and wiring external to the VLU. |
| LCD | Liquid Crystal Display |

| **Term/Acronym** | **Definition** |
|---|---|
| LCS | LYNX Central Station |
| LYNX | Central Florida Regional Transportation Authority, in charge of coordinating public transportation for Orange, Osceola and Seminole Counties in Florida |
| National Electrical Manufacturers Association | Provides a forum for the standardization of electrical equipment, enabling consumers to select from a range of safe, effective, and compatible electrical products. |
| NEMA | National Electrical Manufacturers Association |
| NEMA 250 | A standard entitled "Enclosures for Electrical Equipment (1000V maximum)" |
| NEMA-4 | An enclosure rating within the NEMA 250 standard |
| SAE | Society of Automotive Engineers |
| Society of Automotive Engineers | A non-profit educational and scientific organization dedicated to advancing mobility technology to better serve humanity. SAE members, develop technical information on all forms of self-propelled vehicles including automobiles, trucks and buses, off-highway equipment, aircraft, aerospace vehicles, marine, rail, and transit systems. SAE disseminates this information through its meetings, books, technical papers, magazines, standards, reports, professional development programs, and electronic databases. |
| TCIP | Transit Communications Interface Profiles |
| Transit Communications Interface Profiles | TCIP is an interface standard for transit Intelligent Transportation Systems (ITS). Its primary purpose is to define standardized mechanisms for the exchange of information in the form of data among transit business systems, subsystems, components and devices. TCIP allows transit ITS to be developed, deployed, and evolved more cost-effectively than systems based on proprietary interfaces. |
| TSC | Transit Station Control |
| Transit Station Control | A set of computer hardware and/or software installed at a transit center, or stop point to provide monitoring and control of traveler information and/or security systems installed at |

| **Term/Acronym** | **Definition** |
|---|---|
| | that location. |
| Transit Traveler Information/Automatic Vehicle Location Server | A set of hardware and software the provides the vehicle tracking and traveler information processing components for the TTIP Project |
| TRB | Transportation Research Board |
| TTI/AVL Server | Transit Traveler Information/Automatic Vehicle Location Server |
| TTIP Project | TCIP Traveler Information Pilot Project |
| TWS | Transit Work Station |
| Vehicle Logic Unit | A set of computer hardware and/or software installed on a bus to provide monitoring, communications, and/or control functions. |
| Virtual Private Network | A computer network in which some of the links between nodes are carried by open connections or virtual circuits in some larger networks (such as the Internet), as opposed to running across a single private network. The Link Layer protocols of the virtual network are said to be 'tunneled through' the transport network. A common application is to secure communications through the public Internet. |
| VLU | Vehicle Logic Unit |
| VPN | Virtual Private Network |

# FIGURE TABLE

| Figure Number | Figure Description |
|---|---|
| Figure 1 | TTIP Top-Level Block Diagram |
| Figure 2 | Schedule Import |
| Figure 3 | Vehicle Assignment Import |

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