The University of Kansas

Technical Report

Summary of Status: A Unified Architecture for SensorNet with Multiple Owners: Supplement to Advance SensorNet Technologies to Monitor Trusted Corridors

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Abstract

This effort is aimed at monitoring cargo movements along a trusted corridor, e.g., rail facilities, in association with an integrated data-oriented methodology to increase efficiency and security. This goal is being achieved by performing research and deployment of an associated testbed focused on rail transportation issues. This effort is being performed in conjunction with the private sector to enhancing the ability of the to efficiently embed security that provides business value such as safety, faster transport, and reduced theft while supporting law enforcement and national security. This has been demonstrated in a live "short haul" trial and will shortly be demonstrated in a "long haul" trial in a foreign country. (For background and definition of terms see [1]).

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1. Executive Summary

This effort has had numerous thrusts, but is primarily focused on creating the Transportation Security SensorNet Technology (TSSN), information technology that bridges the gap between deployed sensor networks and decision-makers in a multi-modal, multi-organizational transportation environment. In January 2009, we successfully tested the system with a 20 km "short haul" rail-based test. This included the mating of sensor events and data from the Trade Data Exchange (TDE), complex event processing, and timely notification of events with relevant data to decision-makers. For this test the mobile rail network (MRN) was installed in a locomotive; sensors (electronic seals) were attached to several container cars and others placed in the locomotive; the train then traveled for five hours along an approximately 20 km route. KU/ITTC and HP (formerly EDS) personnel traveled with the MRN in the locomotive. The MRN communicated with the virtual operations center (VNOC) located at KU/ITTC in Lawrence, Kansas. The VNOC sent out alarm messages (both SMS and e-mail) to decision makers; in addition to sensor state and location, these messages contained logistics information obtained in real time from the TDE located in Overland Park, Kansas. Extensive message logs were recorded during this test; a visualization tool was developed to graphically study the logged messages and their timing. We have performed extensive analysis, resulting in several reports and publications [1-5], including several peer-reviewed under review and in preparation.

Since the successful short haul test, we have set three goals to be implemented for the next "long haul" test:

- Integrating satellite communications and asynchronous message passing into SOA
- Enhance sensor capability
- Implement security within the SOA

First, integration of satellite communications is straightforward, but the challenge is that most SOA tools assume a continuous (always-on) communications capability and will block waiting for a reply. Consistent with our implementation philosophy, we have found a solution that uses standards-based, open source-supported transport "protocol" that is compatible with SOA. Second, we investigated vendor product that provide enhanced "parent/child" capability and found that the products were too unreliable for use. Third, we have implemented security within portions of the TSSN, most notably between services that uses the publish/subscribe paradigm. We discovered that this is pioneering work, and have made contribution to the open source tools to support this task.

For the "long haul" test, we are partnering with a rail carrier to transport cargo from Mexico to the US. The trial will originate in Mexico, travel through Mexico to the US/Mexico boarder, cross the boarder, and terminate some place in the southeastern US (exact locations TBD). The exact date has not yet been decided, but will be in late July or early August. The objectives of the long haul test are to:

- Collect additional and more detailed system data during the long haul trial
- Demonstrate the new technical features described above
- Collaborate with stakeholders on technology demonstration to further demonstrate security, business value, and facilitate commercialization and impact

2. Introduction

This effort is aimed at monitoring cargo movements along a trusted corridor, e.g., rail facilities, in association with an integrated data-oriented methodology to increase efficiency and security. This goal is being achieved by performing research and deployment of an associated testbed focused on rail transportation issues. This effort is being performed in conjunction with the private sector to enhancing the ability of the to efficiently embed security that provides business value such as safety, faster transport, and reduced theft while supporting law enforcement and national security. This has been demonstrated in a live "short haul" trial and will shortly be demonstrated in a "long haul" trial in a foreign country. (For background and definition of terms see [1]).

3. Status on Technology Proof of Concept and Integration of the SmartPort Trade Data Exchange and Transportation Security SensorNet Technologies

The "short haul" trial that took place in January, 2009 demonstrated a full integration of the Trade Data Exchange (TDE) and the Transportation Security SensorNet Technology (TSSN). This was demonstrated when a sensor on the train indicated that the container door was opened: the TSSN was able to successfully interact with the TDE to extract manifest information which was combined with the sensor event, and the combined information was delivered to the decision-maker in a timely way (less than one minute). The "long haul" test scheduled for late July or early August will demonstrate further integration by implementing security between the TDE and TSSN.

4. Status of the Development of Transportation Security SensorNet (TSSN) Technologies

The development of the TSSN takes an SOA approach, building upon the original ideas of ACE but utilizing current technology and widely accepted open Web Service specifications and publicly available implementations which are suitable for Sensor Networks. Some of the Web Service specifications in use are SOAP, the WS-X specifications, OGC, and UDDIv3. The TSSN is being implemented in three phases. The first phase will be used in the field trials described above.

Phase 1 – Simple service messages based on OGC specifications (used in trials).
Phase 2 – Use full OGC specification interface messages.
Phase 3 – Use lessons learned from Phases 1 and 2 to make improvements.
Phase 4 – Satellite communications in conjunction with GSM and software support for asynchronous communications
Phase 5 – Security framework and implementation throughout the TSSN

Phases 1–3 have been completed, and lessons learned have been documented in [3] and [4]. Phase 4 has recently been completed and is documented in [4] and described more in Section 6. Phase 5 has partially been completed and has resulted in contributions to open source tools to support security. One of the major lessons learned is that the available open tool support is lacking the functionality for a fully generalized approach to implementing security within the SOA. We have instead focused on implementing a fully-functional security model within the constraints of the contemporary tool support. Details will be documented in future reports.

5. Status of System Architecture, Modeling, and Optimization

This task is focused on developing models of the TSSN to identify trade-offs and enable system optimization. (An extended abstract of the model was presented in [5]. An updated description is under development.) The short-haul rail trial has provided the basis to determine the performance of the TSSN system with respect to detecting events on intermodal containers in a rail environment. Analysis of the data from the short-haul trial has provided realistic parameters, including message sizes, probabilities of notifying decision makers within a given interval, and network times from the train to a virtual network operations center, that will be used with the developed models to determine trade-offs and study system optimization. A full description of the short-haul trial and results of the post-processing is in [3].

The final step is to combine the developed models with the realistic parameters to conduct the trade-offs and system optimization. Specifically, the visibility of cargo shipments on a train will be determined as a function of sensors placement, onboard network and backhaul communication system; the system trade-offs and optimizations will be performed with respect to cargo visibility.

6. Status of Communications System Evaluation

Research is continuing on radio technologies for TSSN. As part of evaluating the current active container seal technology operating in the 916 MHz band, it was discovered that the communication range for the devices selected for this research was more limited than expected. We provided a custom bi-directional RF amplifier to their system, which boosted the communication range to over 400 meters, which was used for the “short haul” test.

We have investigated the use of a vendor-provided “parent-child” capability of the active seals. This capability would provide a second “parent” tag covertly located on the container, which would monitor the “child” seal. If the seal was broken or lost while the container was not in range of the mobile rail network, the parent would keep a status event, including the time of the event, which could later be recovered. After extensive testing, we determined that the vendor-provided capability was not sufficiently robust for inclusion on the “long haul” trial, and that the vendor-proposed fixes would not be available with sufficient lead time for the trial.

The mobile rail network communicates to the network operations center through either a GSM modem, or when there is no GSM coverage, a satellite modem. The satellite modem has been integrated into the mobile rail network. The substantial challenge has been the reliable exchange of messages over an unreliable link because the majority of SOA open tools assume a continuous (always-on) communications channel. The implementation uses using a Java Message Service (JMS) and the Apache ActiveMQ implementation at the protocol layer. This new capability will be exercised in the “long haul” test. The developed system is an example of a delay tolerant network (DTN) and demonstrates that Java Message Service (JMS) and the Apache ActiveMQ implementation addresses DTN issues.

7. Status RFID Technology Evaluation and Development

The combination of the new (patent-pending) ITTC/KU on-metal RFID tag technology and the Mojix [6] system was deployed and tested in a warehouse environment. While this initial testing focused on the suitability of the system on an MES (manufacturing and execution system, i.e., an assembly line) and for scanning entering and exiting a dock door, the results of this testing lead to conclusions concerning applicability of the technology in an intermodal environment. Additional experiments have been conducted; the results of those experiments as well as the suitability for intermodal environments are described in [7].

8. Associated Efforts

KC SmartPort has continued to coordinate meetings for the groups involved in TSSN, CTIP and EFM, as well as additional activities. These meeting are creating a common, open environment with low entry barriers to enable broader access by stakeholders while contributing a venue to commercialization. Recently, KCS SmartPort has initiated a small activity to expand the capabilities of the TSSN, specifically to enhance the capability to track the transfer of containers across organizational boundaries.

9. Project Timeline

The "short haul" field trial was completed in January of 2009. A "long haul" field trial is currently being scheduled and is anticipated to take place in late July or early August of 2009. The long haul trial will start in Mexico, cross the US – Mexico boarder, and terminate somewhere in the southern USA. The efforts associated with the summer modeling, communications, and RFID are planned to be completed by the end of Fall 2009 and interim reports describing these activities are currently available. Activities associated with SmartPort, EFM, and CTIP will continue until June 2010. The current date of completion for the effort is June 15, 2010.

10. References

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