Service Oriented Architecture
for Monitoring Cargo in Motion
Along Trusted Corridors

Martin Kuehnhausen

Department of Electrical Engineering & Computer Science
Master's Thesis Defense
July 1, 2009

Committee
Dr. Victor S. Frost (Chair)
Dr. Joseph B. Evans
Dr. Gary J. Minden
Acknowledgment

• Defense Committee
  • Dr. Victor S. Frost
  • Dr. Joseph B. Evans
  • Dr. Gary J. Minden

• SensorNet Team
  • Leon Searl, Ed Komp, Dan DePardo, Daniel Deavours
  • Daniel Fokum, Matt Zeets, Angela Oguna, Jim Stevens, George Cox
Outline

• Introduction
• Statement of Problem
• Service Oriented Architecture
• Design & Architecture of TSSN
• Service implementations
• Implementation Results
• Conclusion
• Future Work
Introduction

• Transportation Security SensorNet project
  • Service Oriented Architecture
  • Open Geospatial Consortium
  • Sensor Networks

• Main goals
  • Remote sensor management
  • Alarm notification
  • Use of open standards, tools and software
  • Combination of SOA, OGC and sensor networks
Statement of Problem

“How can a Service Oriented Architecture, open standards and specifications be used to overcome the problems of proprietary systems that are currently in place and provide a reusable framework that can be implemented across the entire transportation industry?”
Service Oriented Architecture

• Concept:
  • Information processing and sharing across various applications using so-called *web services*
  • Components are *web services*
  • *Clients* utilize *web services* through clearly defined open web standards interfaces

• Standard protocols for communication
• Independent of technologies, platforms, programming languages
• Interfaces follow web service standards
Service Overview
Benefits for TSSN

• Related to the transportation industry:
  • Automation
  • Efficient communication
• Efficient development through modularity
• More reuse of the system
• Simplified maintenance
• Incremental adoption
• Graceful evolution
Web Service Specifications

- **SOAP**
  - Flexible message format
- **WS-Addressing**
  - Message propagation
  - Routing
- **WS-Eventing**
  - Event subscriptions and publications
- **WS-Security**
  - Encryption
  - Signatures

SOAP message format:
- Envelope
- Header
- Body
- Fault
Web Service Specifications

• UDDI
  • Universal Description, Discovery and Integration
  • Service Discovery
  • Scalability

• WSDL 2.0
  • Web Service Description Language
  • Elements, operations, interface and binding definitions

WSDL 2.0 overview
Design & Architecture

• **Transportation Security SensorNet**
  • Based on Service Oriented Architecture
  • Utilize web services and Open Geospatial Consortium specifications
  • Combine web services with sensor network technology

• **Provide:**
  • Service Oriented Architecture for cargo monitoring
  • Remote sensor management
  • Event processing
  • Alarm notifications
Design & Architecture

- Distributed service clouds
  - Trade Data Exchange
  - Virtual Network Operation Center
  - Mobile Rail Network

![Service clouds diagram]
Apache Axis2

• Basis for TSSN
  • Provides basis for web services and clients
  • Supports variety of transports (HTTP, HTTPS, JMS, etc.)
  • Allows several data bindings (Axis Data Binding (ADB), XMLBeans, JibX, etc.)
  • Modular approach to web service specifications

Axis2 module architecture from [16]
A KTEC Center of Excellence

Service composition

- WSDL
- Service XML Schema
- External XML Schemas

WSDL2Java

Service Java Classes
- Schema Elements
- Service Skeleton
- External Service Stub A
- External Service Stub B

Data A
Data B
External library A
External library B

Service Implementation

Service
Automatic Code Generation

• Axis2 provides tools for:
  • XML schema compilations -> data bindings
  • Java service classes generation from WSDL
• Use of Apache Ant as a build system
• Improvements to standard implementation
  • Schema compilation of OGC schema elements
  • Ping module
  • Logging module
  • Subscriptions/Publications mechanism
  • Build process
Components

• Services
  • Long term storage (MySQL database & Hibernate)
  • Event processing (Esper)
  • Sensor management (Hi-G-Tek (HGT))
  • Location tracking (GPS)
  • Stateless vs. stateful web services

• Clients
  • Standalone & embedded in a service
  • User interfaces (Apache CLI & Command Center GUI)

• Modules
  • Ping, Logging
  • Web service specifications (Addressing, Savan, Rampart)
Service message overview
Mobile Rail Network

- Located on train
- Responsibilities
  - Sensor management
  - Sensor monitoring
  - Propagation of sensor events

Mobile Rail Network message overview
MRN Sensor Node

- Abstraction layer to dealing with HGT, GPS and other sensors

- Provides
  - Sensor monitoring
  - Sensor control
  - Location retrieval
  - OGC specifications
    - GetCapabilities and GetObservation (SOS)
MRN Alarm Processor

- Processes events that it receives from Sensor Node
- Provides
  - Initial event processing
  - Monitoring state control
    - Security vs. information
  - Alarm notifications
Virtual Network Operation Center

- Located at KU
- Management facility of TSSN
- Responsibilities
  - Sensor management
  - Complex event processing
  - Interfacing with trade information
  - Alarm notifications

Virtual Network Operation Center message overview
VNOCC Sensor Management

- Remote sensor management via message relay
- Provides
  - Sensor control
  - Monitoring control
  - Location retrieval
VNOC Alarm Processor

- Processes events that it receives from MRNs
- Provides
  - Complex event processing using Esper
  - Correlation of trade information with events
  - Alarm notifications
VNOC Alarm Reporting

- Sends alarm notifications using email and/or SMS
- Provides
  - Alarm to contact mappings management
  - Alarm history
  - Alarm notifications
Trade Data Exchange

• Located in Overland Park, KS
• Interface to transport systems
• Responsibilities
  • Providing trade data and other information
TDE Trade Data Exchange

- Supplies Alarm Processor with trade information
- Provides
  - Alarm storage
  - Shipment information
Implementation Results

• Several tools used during trials and analysis

• Logging module
  • Capture message flows

• Log parser
  • Reconstructs messages
  • Provides listing and analysis functionality

SOAP message (left) to Log parser classes (right) comparison
Visual SensorNet
Message Relationships

• Transmit-Receive Pair
  • Combination of outgoing and incoming messages with the same message id
  • Allows computation of
    - Transmit times

• Message Couple
  • Combination of outgoing request and outgoing response
  • Allows computation of
    - Round trip times
    - Processing times
Trial results

• Road tests with trucks
  • MRN deployed on a truck
  • Sensor read range about 400 meters
  • Temporary GSM and GPS loss
  • All messages (sensor management and alarms) successfully sent and received

• Short Haul Rail Trial
  • MRN deployed on a locomotive
  • Train traveled approximately 35 kilometers from a rail intermodal facility to a rail yard
  • Similar GSM and GPS issues
Short Haul Rail Trial

• Message counts
  • 546 alerts at the MRN
  • 131 alarms at the VNOC
  • 63 Shipment information inquiries at the TDE
  • 30 location retrievals

• Message sizes
  • Control messages such as getLocation, startMonitoring, etc. on average 690 bytes
  • Alarms from the MRN around 1420 bytes
Request Performance

- Sensor Management to Sensor Node or Alarm Processor
  - Fastest: 0.9 seconds
  - Slowest: 11 seconds
  - Average: 4.4 seconds

- Bottleneck: network
  - Processing on average only 0.6 seconds
  - 85% spent on message transmission

Network transmission and processing performance from [31]

Request performance from [31]
Alarm Notification Performance

• Time going through entire TSSN
  • Fastest: 1.9 seconds
  • Slowest: 4.9 seconds
  • Average: 2.1 seconds

• Problem
  • Clock drift on the MRN

• Solution
  • Approximation using request transmit times

System alarm notification performance from [31]
Conclusion

• Implementation works
  • Trials successful
  • Performance evaluated

• Transportation Security SensorNet
  • Sensor management and alarm notification infrastructure
  • Built using open standards and specifications
  • Integration with OGC standards

• Demonstrates combination of SOA, OGC and sensor networks
Future Work

• Clock synchronization
  • NTP over GPS integrated into Sensor Node

• Service discovery
  • Basic framework in place, bug fixing needed

• Multiple service clouds
  • Most of the services already support this

• Security
  • Policy based security for subscriptions in development

• Asynchronous communication
  • JMS transport implemented for clients and services
  • Deployment using ActiveMQ currently being tested
Thank you for coming today.

Any questions?