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14. ABSTRACT

The object of the Tactical SOA project is to develop, assess and understand the application of technologies and protocols to bring the benefits of Service Oriented Architecture (SOA) to tactical environments, and investigate and quantify the network burden and Quality of Service (QoS) requirements for SOA implementation in a variety of tactical environments. Through baselined experimentation, this effort will determine how far to the tactical edge "enterprise-like" SOA can be supported, and as necessary, will implement a reduced SOA capability that works effectively in defense networks that provide low data rates and/or high latency.

15. SUBJECT TERMS
SOA Tactical, Experiment, Info Management, Simulation, Emulation, Bandwidth, Throughput, Latency

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Tactical Service Oriented Architecture (SOA) Protocols and Techniques

28 July 2011

James Milligan, RISD

Air Force Research Laboratory

Outline

- Background
- Tactical SOA Challenge
- Project Objectives
- Approach
- Schedule/Milestones
- Objective Capabilities
- Candidate Technologies
- Potential Metrics
- Technology Capability Sets – Year 1
  - An in-depth look
- Future Capability Sets (Years 2 & 3)
- Conclusion

Background

2009 DSB Report Findings & Recommendations[2]

- In addition to significantly enhanced interoperability, report identified potential benefits of SOA to include:
  - "Improved responsiveness, simplified delivery of mission services, more efficient information sharing, and improved transparency, security, and resilience"
- Recognition that successful SOA implementation is not without challenges, particularly in tactical settings
  - "Current implementations of SOA are effective only if the underlying network provides low latency, low bandwidth-delay variation, and high bandwidth"
- Task force recommends the Government immediately put a SOA-network-performance investigation effort
  - "Determine the network burden of SOA
    Determine how far toward the network edge SOA can be supported
    Develop "lightweight" SOA for the tactical edge
    Develop SOA with an IA architecture"

[2] ***Creating an Assured Joint DoD and Interagency Interoperable Net-centric Enterprise*****, DSB, Mar 2009**
http://www.acq.osd.mil/dsb/reports/ADA498577.pdf

Tactical SOA Challenge

- Pushing a SOA paradigm all the way to the tactical edge is fraught with uncertainty
  - Messaging in enterprise SOA deployments most often use heavy weight formats and protocols
    - TCP/IP, HTTP, XSD/XML, SOAP, BPEL, WS-*, etc.
    - XML and HTTP are fundamental building blocks for many SOA implementations
  - In the tactical environment, both request-response protocols and XML-based data formats may be prohibitively resource intensive to use in terms of latency and overhead
    - Client sends request, request hits server, server-side code receives request, server-side code finishes processing the request, server sends response, client receives response
  - We need to quantify the burden of SOA technologies on tactical networks and systems (wireless, SATCOM, TACCOM) in order to successfully deploy them or find alternatives
    - Data demand rates, delay tolerance (time-outs/dropped sessions), number of roundtrips for service set-up/usage

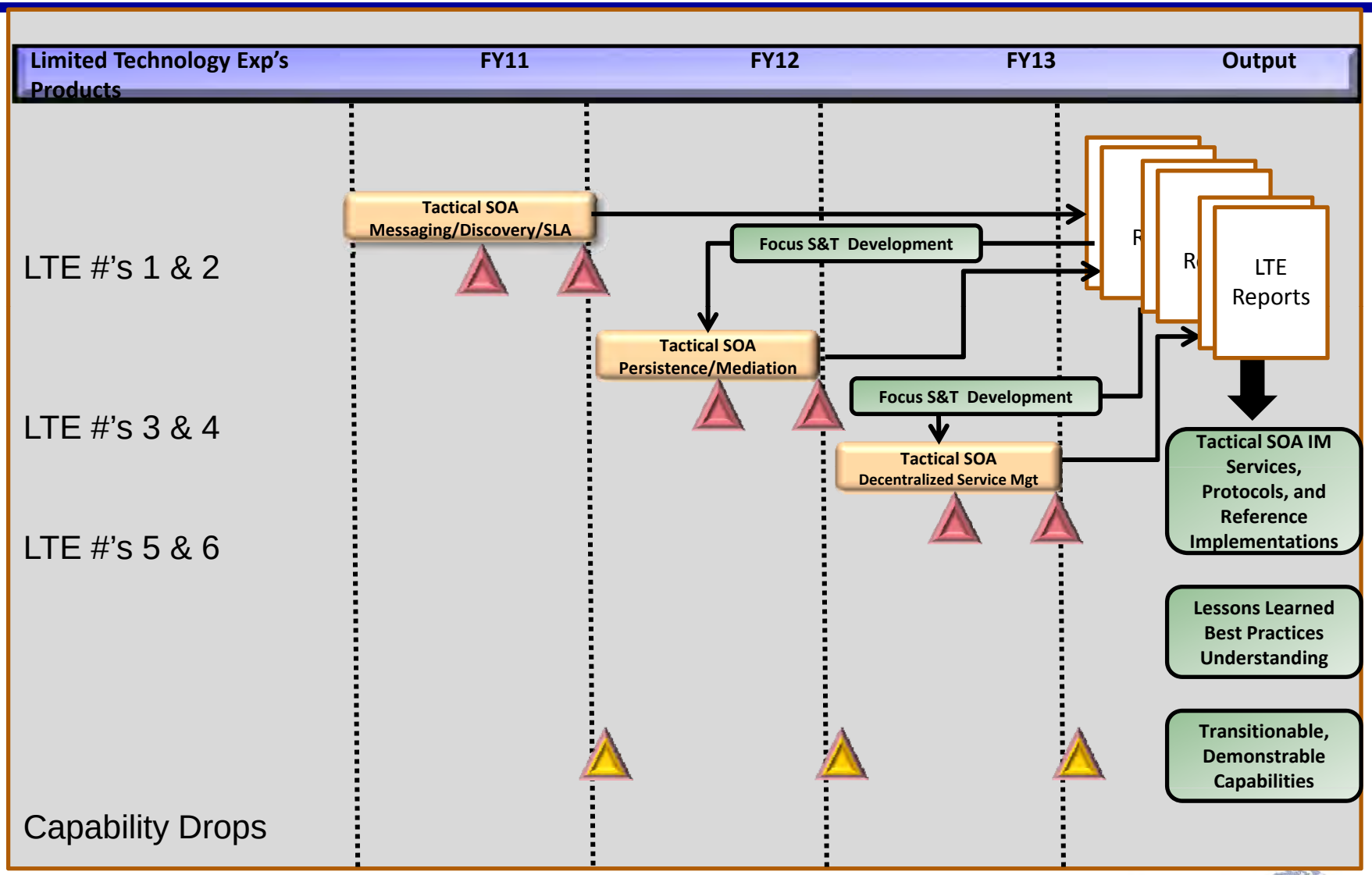
Project Objectives

- Bring the benefits of SOA to tactical environments
  - Increased Interoperability:
    - Modularity, encapsulation, loose coupling, standards compliance
  - Reduced integration and maintenance costs
  - Greater reuse of assets across business processes
  - Increased agility to respond to changing requirements
    - Discoverability, composability, configurable service orchestrations
- Investigate and quantify the network burden and QoS requirements for SOA implementations in a variety of tactical environments
  - Determine how far we can push enterprise-level SOA technologies to the tactical edge
  - Experiment with alternatives where these technologies prove to be insufficient
- Incrementally implement a reduced SOA capability that works effectively in defense networks that provide low data rates and/or high latency

Approach

- Employ an iterative tactical SOA development and experimentation process
- Develop tactical network models and testbed environments
- Conduct a series of Limited Technology Experiments (LTEs) – 1 to 2 / year
  - Each LTE focusing on a manageable set of related SOA capabilities and tactical constraints
- Develop, tailor and assess the techniques, technologies, and protocols that are best suited for the deployment of tactical SOA stacks

Schedule/Milestones



Tactical SOA Capabilities

Objective Capabilities [1]	**"Short Name"**
1) Assured delivery of end-to-end service performance guarantees	1) Service Level Agreements/Quality of Service (SLAs/QoS)
2) Effective mediation between SOA federations	2) Mediation
3) Effective messaging paradigms for mobile platform service interaction	3) Effective Messaging
4) Service, content, and resource discovery	4) Service/Info Discovery
5) Adaptive, network-aware services and orchestrations	5) Decentralized Service Management
6) Persistence and retrieval of data, metadata, and state information	6) Persistence and Access

[1] ***Critical S&T Issues for Addressing Tactical SOA*****, Tactical SOA Workshop Report, 26 Aug 2009**
-- NRL, ONR, SAF/XCT, NUWC, OSD/NII, MITRE, OSD/ATL, DISA, RAND, MIT Lincoln Lab, AFRL, Industry

Candidate Technologies

Capabilities	Candidate Technologies
1) SLAs/QoS	• QoS Enabled Dissemination (QED) • KAoS policies/guards
2) Mediation	• Lightweight ESB • Gateways (Secure Tactical-to-Enterprise)
3) Effective Messaging	• Various publish/subscribe technologies • Binary Arithmetic Coding (BAC) • NORM, pNORM, ECN • XMPP
4) Service/Info Discovery	• Services 7
5) Decentralized Service Management	• Quagga/Zebra routing • MANET – proactive/reactive/hybrid
6) Persistence and Access	• Web Caching • Federated Subscription • Federated Query

Some Potential Metrics for Experimentation

- Resource utilization
- Scalability
- Overhead
- Latency
- Packet loss rate
- Throughput
- Availability
- Reliability

Year 1 Capabilities

Set 1 – Jun 2011

- "As-is" network model and emulation testbed based on a Close Air Support (CAS) scenario

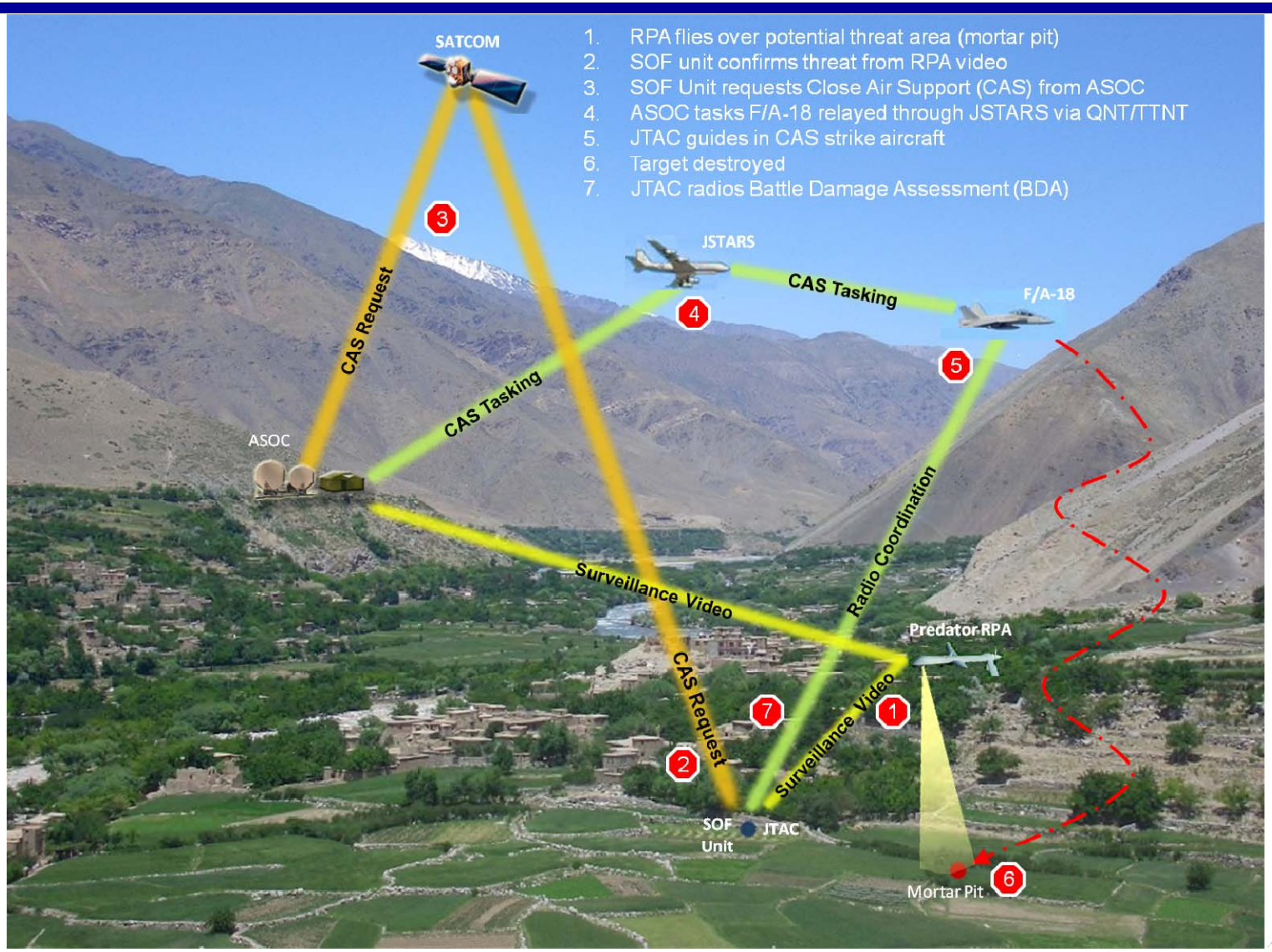
Set 2 – Aug 2011

- Deploy conventional (ESB, SOAP) enterprise SOA tech
- Measure SOA tech performance and establish baseline
  - "Pristine" vs. contested network

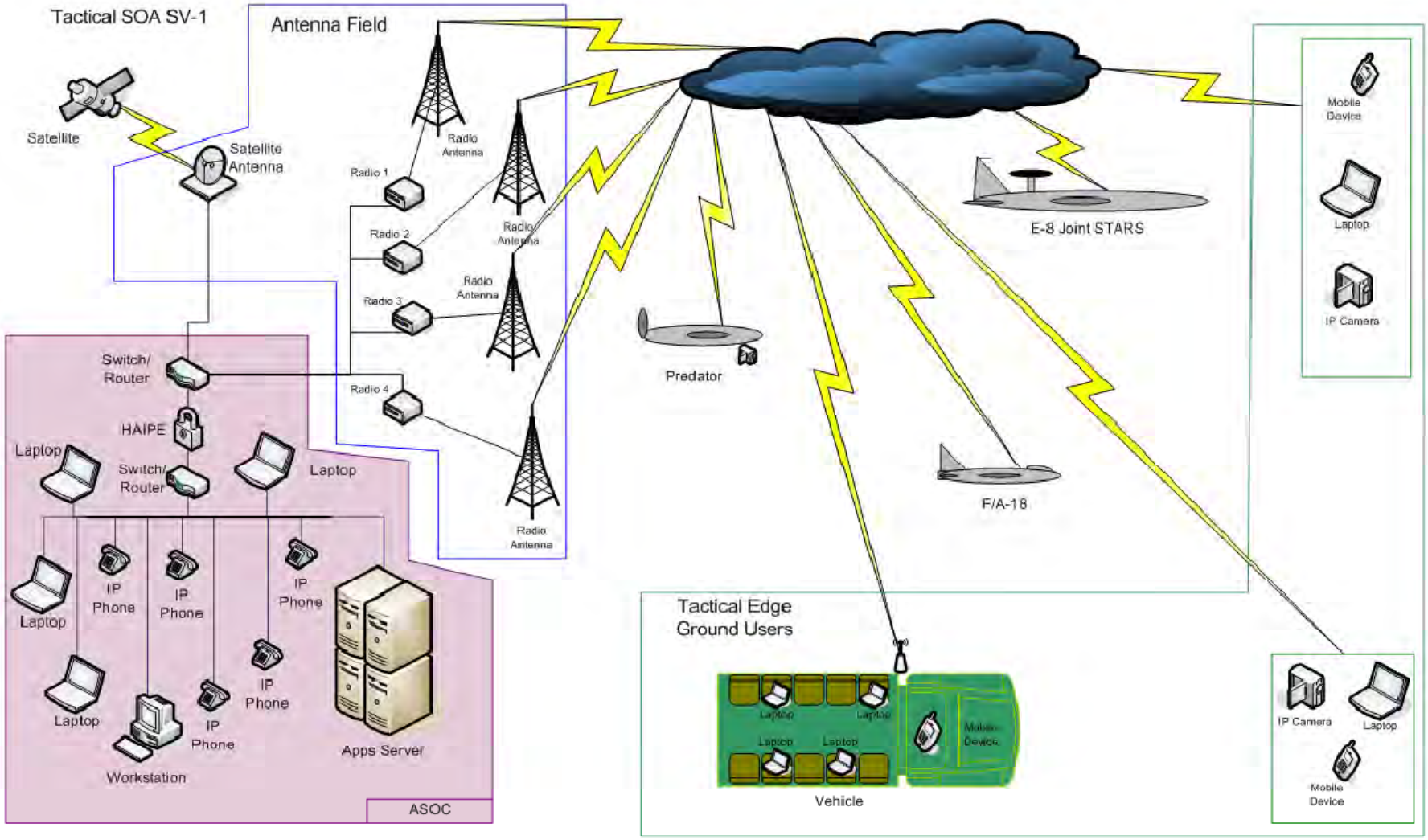
Set 3 – Sep 2011

- Compare the following to baseline performance and capabilities
  - SLAs/QoS
    - Web Service Based Message Prioritization (QED)
  - Effective Messaging
    - Marti (pub/sub)
    - DDS (OpenSplice)
  - Service Discovery
    - Services 7

Operational View
Close Air Support (CAS)



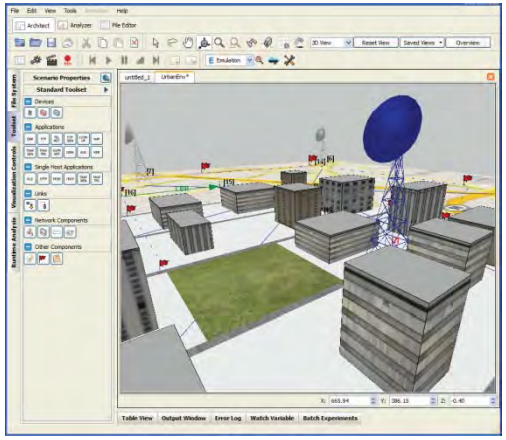
System View



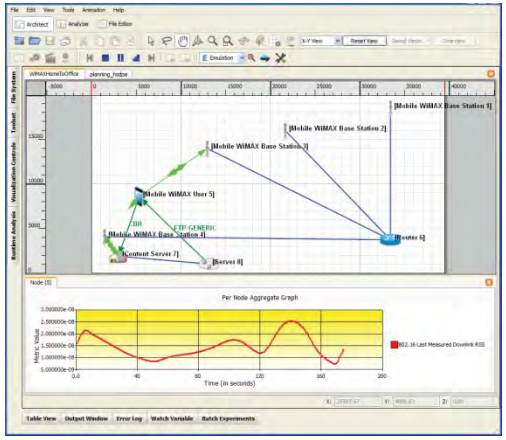
EXata/Cyber

- Using to build tactical testbed for experiments
- EXata is a network emulator specifically designed for wireless networks
  - Provides a virtual network so accurate that it cannot be discerned from the real thing
  - Same high fidelity at 50 or 5000 nodes
  - Connects to live networks and external devices
  - Detailed models with parameters such as signal power levels, data rates, routing protocols, antenna weighting, link scheduling…
  - Can run multiple real applications on a single computer and assign each to run on a different emulated node
  - Provides powerful analysis and debugging tools
- EXata/Cyber includes features to create and modify cyber attacks and counter measures

Design Mode

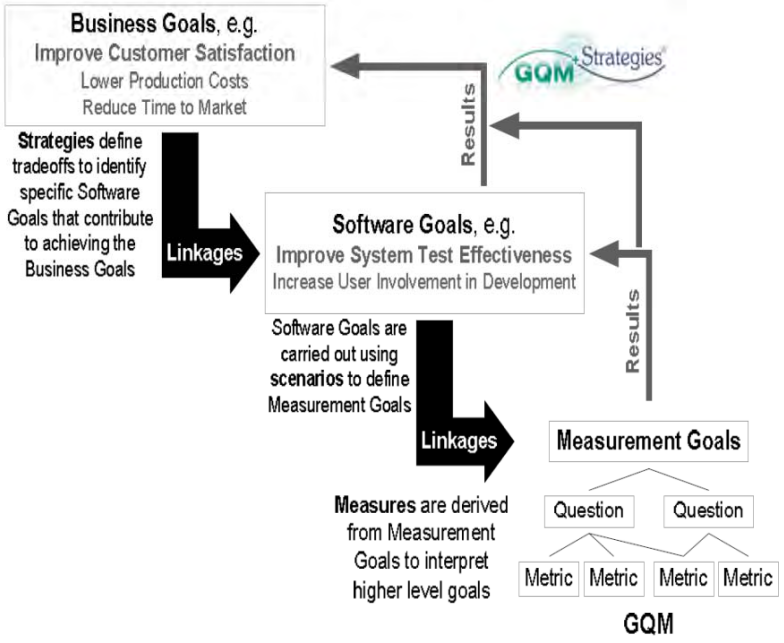


Visualization Mode



Experimentation Method

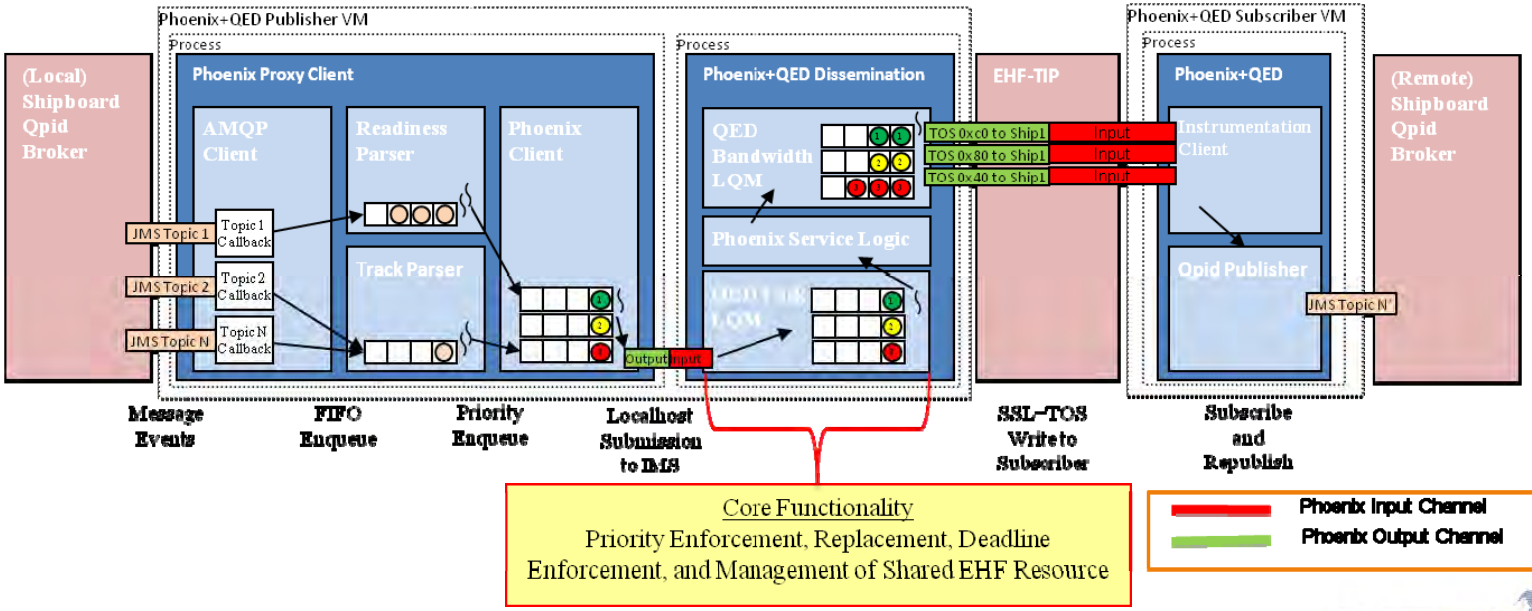
- A variant of GQM+Strategies method is being applied
  - GQM+Strategies is based on the Goal Question Metric (GQM) approach to defining software metrics
    - GQM is in widespread use throughout the software industry
    - GQM+Strategies adds alignment of business goals and strategies to GQM's software-specific measurement goals, questions and metrics
  - Variant to suit limited technology experimentation
    - Hypotheses = Business Goals
    - Technical Objectives = Software/Measurement Goals



Goal	Purpose Issue Object (process) Viewpoint	Improve the timeliness of change request processing from the project manager's viewpoint
Question		What is the current change request processing speed?
Metrics		Average cycle time Standard deviation % cases outside of the upper limit
Question		Is the performance of the process improving?
Metrics		$\frac{\text{Current average cycle time}}{\text{Baseline average cycle time}} * 100$ Subjective rating of manager's satisfaction

Test Articles for Experimentation
Year 1 – SLAs/QoS

- QoS Enabled Dissemination (QED) Information Management Services (IMS)
  - Delivers information in order of priority based on enterprise policy specifications
  - Plug-in to AFRL's Phoenix publish/subscribe and query information management services
  - QED is currently being modified to provide web service message prioritization in addition to topic-based message prioritization
  - Evaluation occurring as part of a Multi-Service Limited Technology Experiment (LTE) with participation from AFRL, ESC, ONR, and Army RDECOM



SLAs/QoS

Hypothesis: The ability to deliver information in the order specified by prioritization policies will increase mission assurance through delivery of the most critical information first.

Objectives:

Purpose	Assess	Assess
Issue	the ability of QED to properly deliver information over tactical networks	the impact that QED has on the delivery speed and utilization of network resources
Object	in the order of priority specified	for high priority messages
Viewpoint	by enterprise policies	over constrained tactical networks

Questions:	**Metrics:**
Can information prioritization policies be utilized by services to increase the quality and throughput of information delivery over disadvantaged links? a. Does QED ever deliver messages of lower priority before higher priority ones? b. Do policy aware information dissemination services increase the speed of delivery for a set of high priority messages? c. What are the savings in terms of network utilization for the delivery of a set of high priority messages?	• Order of delivery/priority • Time to deliver a set of high priority messages • Bandwidth utilization over time to deliver the set

Candidate Technology: Quality Enabled Dissemination (QED) based IMS services

Test Articles for Experimentation
Year 1 – Effective Messaging

- Publish/Subscribe Technologies
  - Data Distribution Service for Real-time Systems (DDS)
    - A pub/sub middleware specification created in response to the need to standardize a data-centric publish-subscribe programming model for distributed systems
    - OpenSplice Community Edition is one open source implementation of OMG's DDS specification we're looking at
  - Marti
    - AFRL developed Information Management Services (IMS) currently being exercised specifically for tactical operations involving mobile users and platforms exchanging Cursor on Target (CoT) messages
  - Phoenix base implementation (Fawkes)
    - AFRL developed service-oriented IMS for all-purpose, configurable message dissemination services for information exchange between a variety of producers and consumers

Effective Messaging

Hypothesis: Publish, subscribe and query Information Management Services (IMS) can be utilized to increase shared Situational Awareness (SA) across tactical operations

Objective:

Purpose	Compare
Issue	the performance and reliability of IMS
Object	to baselined conventional SOA performance
Viewpoint	under a variety of tactical network conditions

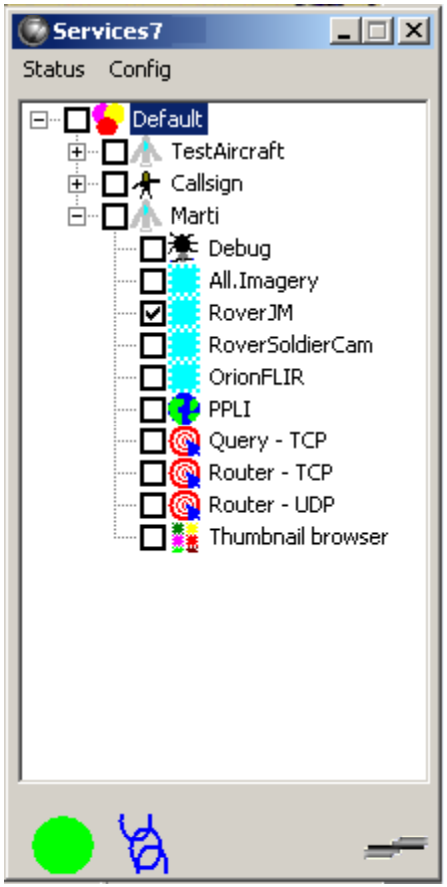
Questions:	**Metrics:**
What is the performance and reliability of IMS services in tactical network environments, and under what conditions do they become ineffective? a. Are requests for information (subscriptions/queries) satisfied by IMS services? b. How quickly is information delivered from the time of a request? c. What services fail or cause performance impacts and under what conditions?	• # of dropped messages • Latency • Instrumented component interaction timestamps

Candidate Technologies: DDS, Marti, Fawkes

Test Articles for Experimentation

Year 1 – Service Discovery

- Services 7
  - A lightweight interface for service and information advertisement; specifically designed for Cursor-on-Target (CoT) message types
  - Periodic broadcast of multicast messages notifying tactical network users of available information
  - Provides a list of services available on each node of the network, and the information they provide
  - Enables the means for third party applications to access the information



Service Discovery

Hypothesis: Services 7 will allow users and applications to discover information across the tactical network that may be beneficial to satisfying mission objectives.

Objective:

Purpose	Measure
Issue	the overhead performance impact
Object	of the Services 7 capability
Viewpoint	in a tactical network

Questions:	**Metrics:**
What is the load of Services 7 message traffic on the tactical network? a. How often and what type/size of messages are broadcast? b. At what rate does this message traffic increase as a function of the number of available services and information sources increases?	• Message frequency & size • Bandwidth utilization

Candidate Technologies: DDS, Marti, Fawkes

Year 2 Capabilities

Set 4 – Jun 2012

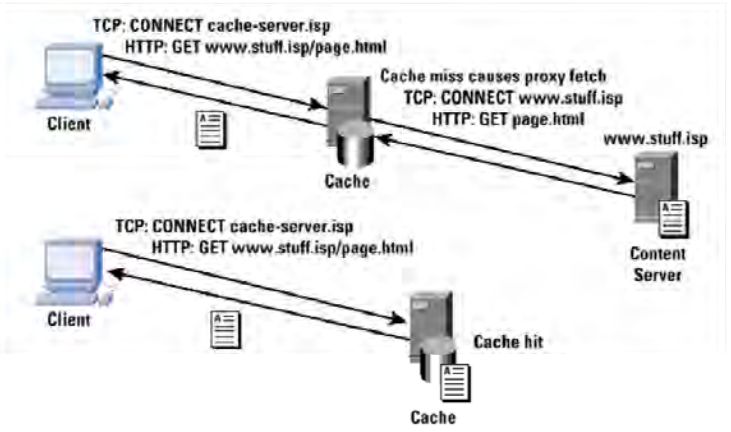
- Persistence and Access
  - Web Caching
  - Federated Subscription
  - Federated Query
- Effective Messaging
  - Binary Arithmetic Coding (BAC)
  - Joint Video Compression and Encryption (JVCE)

Set 5 – Oct 2012

- Decentralized Svc Mgt
  - MANET technologies
  - Quagga/Zebra routing
- Effective Messaging
  - NORM
  - NORM+ECN
  - Fawkes NORM Channel

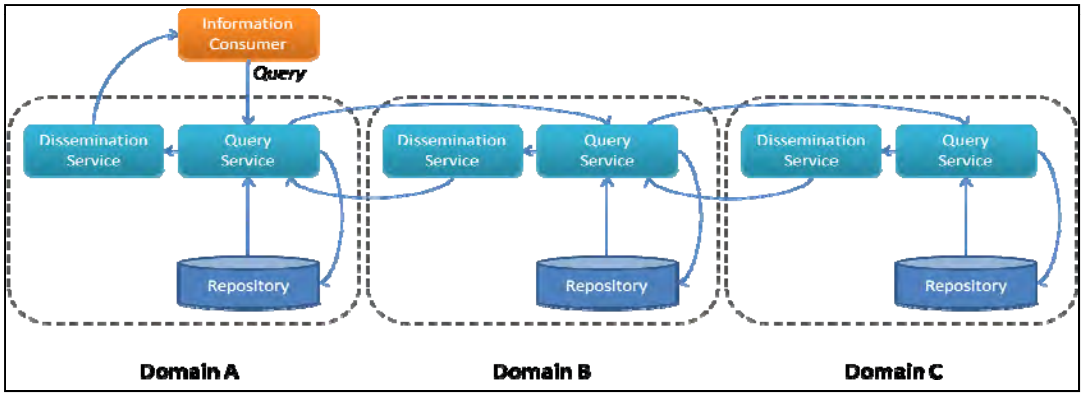
Test Articles for Experimentation
Set 4 – Persistence and Access

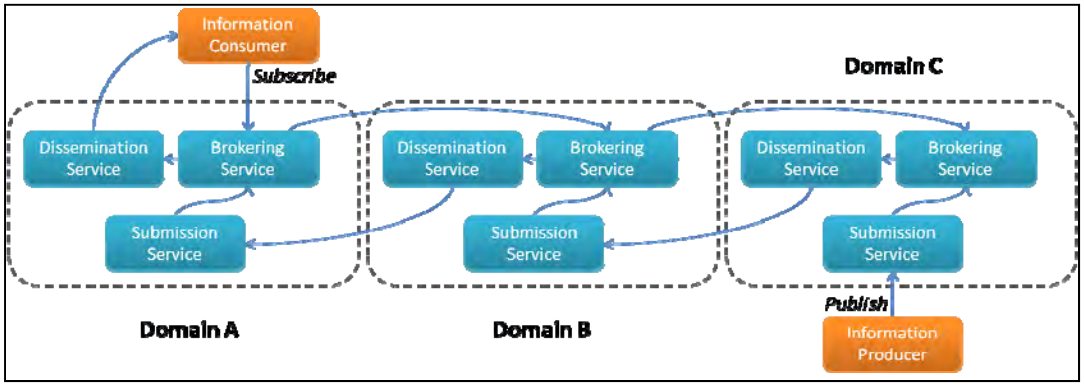
- Web Caching
  - Provides mechanisms for the temporary storage of information to reduce bandwidth usage, server load, and perceived latency
  - Copies of information passing through it are stored for rapid response to subsequent requests
  - A network or context-aware forward cache only caches heavily accessed items on the side of the information consumer
  - A reverse cache sits in front of one or more information sources, accelerating satisfaction of requests for information
  - Representative open source offerings
    - Squid
    - Apache Traffic Server



Test Articles for Experimentation
Set 4 – Persistence and Access

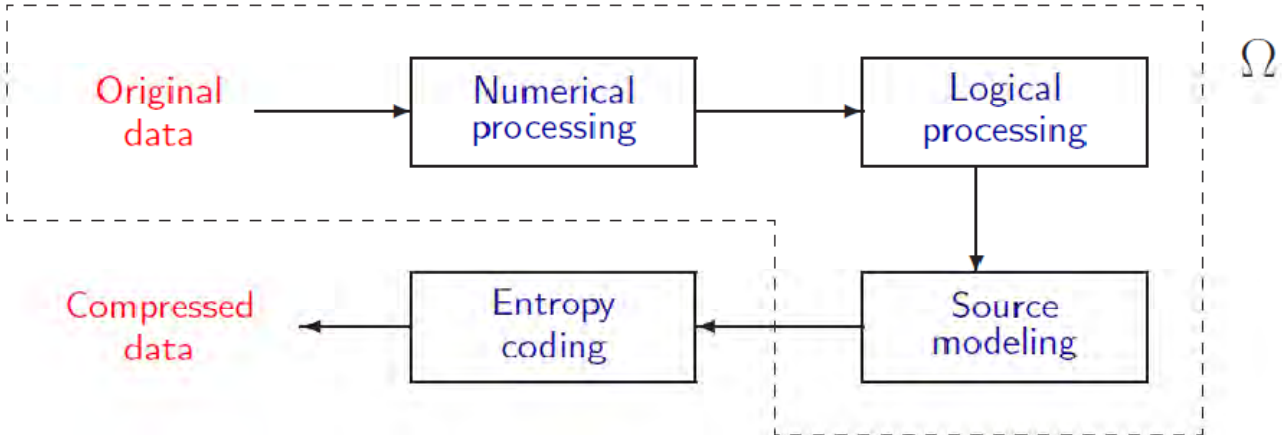
- Federated Query & Subscription
  - Enterprise resource management services that enable the tactical edge user to query or subscribe for information across multiple domains, but from a single access point
  - Reduces the number of requests necessary and the bandwidth utilized to forward retrieved information from different domains





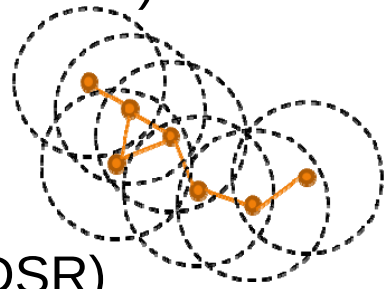
Test Articles for Experimentation
Set 4 – Effective Messaging

- Binary Arithmetic Coding (BAC) for Joint Video Compression and Encryption (JVCE)
  - A form of entropy coding for lossless data compression by replacing each fixed-length input symbol by a corresponding variable-length prefix-free output codeword
  - The length of each codeword is approximately proportional to the negative logarithm of the probability, so the most common symbols use the shortest codes



Test Articles for Experimentation
Set 5 – Decentralized Service Mgt

- Mobile Ad-hoc Network (MANET) technologies
  - Proactive (table-driven) routing protocols (OSPF, OLSR)
    - Attempt to continuously evaluate all of the routes within a network
    - When a packet needs to be forwarded, a route is known and can be used immediately



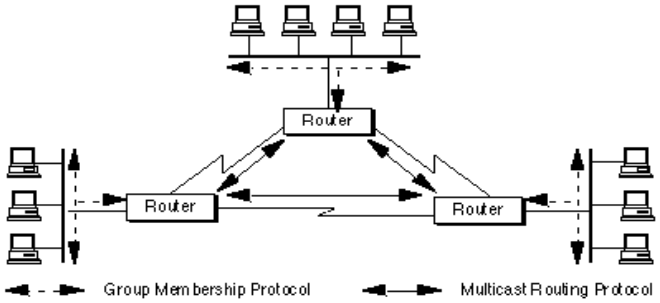
  - Reactive (on-demand) routing protocols (AODV, DSR)
    - Invoke a route determination procedure “on-demand” only
    - If a route is needed then some sort of a global-search procedure is employed
    - Classical flood-search algorithms are simple reactive protocols
  - Hybrid routing protocol solutions (ZRP, WARP)
    - Proactive-protocols are not optimal for either MANETs that have rapidly changing topologies
    - Purely reactive protocols are often inappropriate for several common MANET topologies such as cluster-based networks and relatively static networks, and also introduce additional latency (and possibly source-routing overhead) for real-time traffic

Test Articles for Experimentation
Set 5 – Decentralized Service Mgt

- Quagga/Zebra
  - Quagga is a routing software suite, fork of GNU Zebra, providing implementations of Open Shortest Path First - OSPF (v2 & v3), Routing Information Protocol - RIP (v1, v2 & RIPng), Border Gateway Protocol - BGP (v4) and Intermediate system-to-intermediate system - IS-IS for Unix platforms
  - Traditional routing software is made as a one process program which provides all of the routing protocol functionalities
  - Quagga takes a different approach – it is made from a collection of several daemons that work together to build the routing table
  - There may be several protocol-specific routing daemons and zebra the kernel routing manager
  - Supports common unicast protocols and offers multicast support
  - For network topologies that change frequently, support for dynamic routing protocols can be taken advantage of

Test Articles for Experimentation
Set 5 – Effective Messaging

- Negative ACKnowledgement (NACK) Oriented Reliable Multicast (NORM)
  - Provides reliable transport of data from one or more senders to a group of receivers over an IP multicast network
  - NORM receivers generate NACK messages to request repair of detected data transmission losses
  - Receivers generally detect losses by tracking the sequence of transmission from a sender; sequencing information is embedded in the transmitted data packet



- Explicit Congestion Notification (ECN)
  - Allows end-to-end notification of network congestion without dropping packets
  - Traditionally, TCP/IP networks signal congestion by dropping packets
  - An ECN-aware router may set a mark in the IP header instead of dropping a packet in order to signal impending congestion
  - The receiver of the packet echoes the congestion indication to the sender, which can react as though a packet was dropped
- NORM + ECN
  - Combining ECN with NORM may protect systems from the effects of multicast receivers that seek to acquire more than a fair share of network capacity, thus minimizing the effects of misbehaving receivers and protecting other important traffic flows in the network

Year 3 Capabilities

Set 6 – Jun 2013

- Effective Messaging
  - XMPP
- SLAs/QoS
  - KAoS Policies/Guards
- Mediation
  - Secure Tactical-to-Enterprise Gateway

Set 7 – Sep 2013

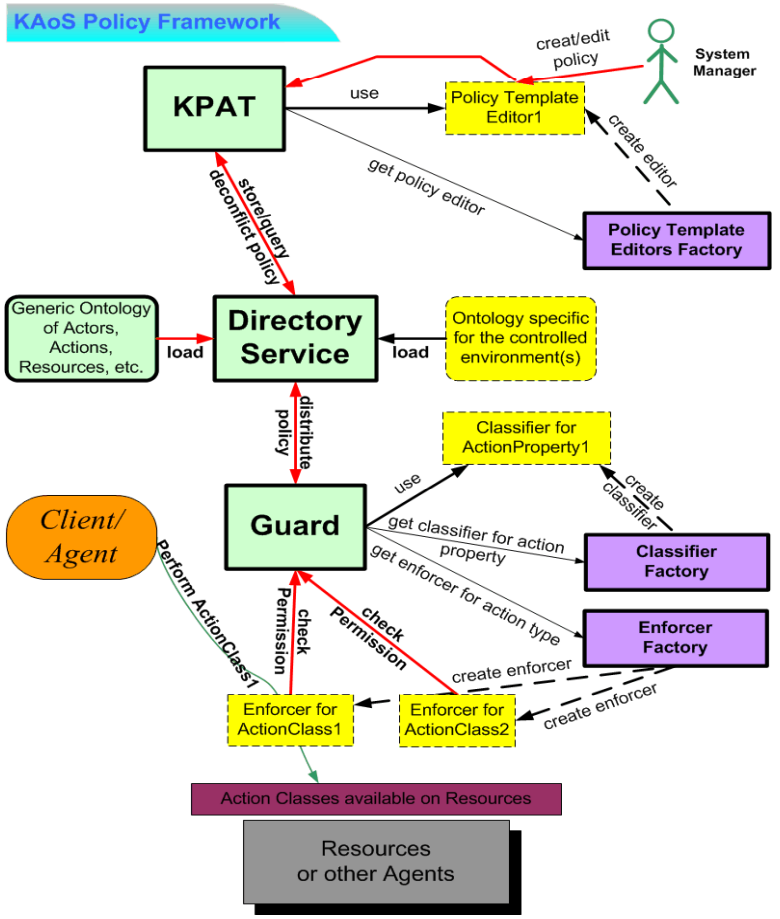
- Service/Info Discovery + Decentralized Svc Mgt + SLA/QoS + Effective Messaging + Mediation + Persistence
- Best-of-breed Tactical SOA Stack Integration & Alternatives

Test Articles for Experimentation
Set 6 – Effective Messaging

- Extensible Messaging and Presence Protocol (XMPP)
  - An open-standard communications protocol for message-oriented middleware based on XML
  - Used for a wide range of applications including instant messaging, presence, multi-party chat, voice and video calls, collaboration, lightweight middleware, content syndication, and generalized routing of XML data
  - XMPP is not that well suited for the transmission of any significant amount of binary data (e.g., file transfers)
  - The XMPP Standards Foundation states that "any list of XMPP servers, clients or libraries will, due to the dynamic and evolving nature of the XMPP market, be out of date almost as soon as it's published", so we haven't chosen anything specific yet to experiment with

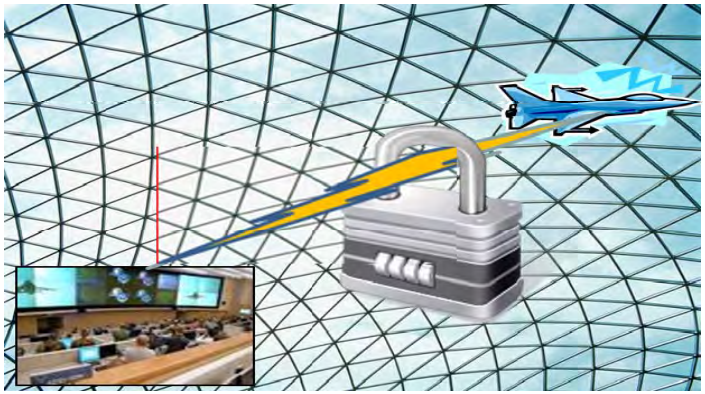
Test Articles for Experimentation
Set 6 – SLAs/QoS

- KAoS Policies/Guards
  - Developed by IHMC
  - Provides an extensible framework for policy specification and enforcement; compatible with semantic web and SOA standards (OWL, WSDL, XML, RDF, etc.)
  - Provides policy dissemination and decision making infrastructure that is distributed, highly efficient and transparently pluggable
  - May be used for SLA specification and the implementation of mechanisms that take remedial actions in response to underperforming services



Test Articles for Experimentation
Set 6 – Mediation

- Secure Tactical to Enterprise Gateway (STEG)
  - STEG is a two-year FY12 new start project
  - Will develop a system to manage the boundary between the operations center networks and IP-based tactical networks
    - Robust
    - Prioritized
    - Compatible with current mission planning tools
  - Addresses two key aspects of “management”
    - *Security*: essential because IP-routability exposes tactical system vulnerability to enterprise threats and vice versa
    - *Mediation*: to address protocol, security, and resource mismatches between the operation center and the tactical assets



Conclusion

- In summary, the objective of this project is to:
  - Develop, assess and understand the application of technologies and protocols to bring the benefits of SOA to tactical environments
  - Investigate and quantify the network burden and Quality of Service (QoS) requirements for SOA implementations in a variety of tactical environments
  - Determine how far to the tactical edge “enterprise-like” SOA can be supported
  - As necessary, implement a reduced SOA capability that works effectively in defense networks that provide low data rates and/or high latency
- We’ve still got a long road ahead of us