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Title: Net-Centric Pub/Sub Information Management Design
for Command and Control

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Net-Centric Pub/Sub Information Management Design for Command and Control

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Abstract

Network-centric support for command and control (C2) communications demands interoperability and high performance. The conceptual design and semantics for net-centric C2 have been studied for several years. Recently, reference frameworks have been developed to support C2, each suggesting a net-centric approach. Two of the reference frameworks are considered and the potential for interoperability for the net-centric architectures through experimentation is explored. Issues that affect the interoperability of the information management systems studied impact design decisions that enable network-centricity for C2 frameworks.

Introduction

Software that is developed to be net-centric must interoperate with users (clients) and other systems through defined interfaces. The degree of net-centricity supported by a system is largely defined by the ease with which integration is accomplished. Two systems which were designed with net-centricity as a major goal are described and compared. As a case study, the design issues that affect the implementation of an interface for the MITRE Cursor on Target (CoT) system [Miller 2004] and the Air Force Research Laboratory (AFRL) Advanced Distributed Information Object Space (ADIOS) are considered. ADIOS is an extension of the Joint Battlespace Infosphere (JBI) system [Semy 2004] that is designed to exploit high performance computer architectures and communication systems. The exercise demonstrates a great deal about net-centric design and implementation.

Net-centric systems define standards that can be shared among communicating systems. The standards must be flexible to accommodate inter-system communication in terms of protocols for communication and higher level semantic interpretation of message content. C2 system performance is critical for meeting runtime deadlines for operational systems. Approaches to interoperability that depend on extensive translations are inefficient. Meeting performance goals to support the communication demands of a system also requires a distributed architecture that scales well, to allow additional processors to be added to meet system processing demands.

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Network Centric Systems

The network-centric goals of ADIOS and CoT are consistent with the Defense Information Systems Agency's (DISA) Global Information Grid (GIG) Enterprise Services and Net-Centric Enterprise Services [DISA]. Both CoT [Hobbins 2005] and JBI [JBI Program] support network-centric operations, a Service Oriented Architecture (SOA) [SOA] and the Extended Markup Language (XML) [XML].

The Network Centric Operations Industry Consortium (NCOIC) definitions [NCOIC 2006] for Network-Centric, Network-Centric Operations (NCO), and Network-Centric Warfare (NCW) are shown below.

Network-Centric:

Related to systems and patterns of behavior that are influenced significantly or enabled by current and emergent networks and network technologies. Often these center around IP-based internetworking, but the term is sometimes used to include any type of enabling network.

Network-Centric Operations (NCO):

"An information superiority-enabled concept of operations that generates increased combat power by networking sensors, decision makers, and shooters to achieve shared awareness, increased speed of command, higher tempo of operations, greater lethality, increased survivability and a greater degree of self-synchronization. NCO is the application of the fundamental tenets of Network-Centric Warfare to aspects of national security, especially industry support for the missions of both the Department of Defense (DOD) and the Department of Homeland Security (DHS)".

Network-Centric Warfare (NCW):

NCW is the embodiment of an "Information Age" transformation of the DOD and all the elements that support it. NCW represents a set of war fighting concepts and associated military capabilities that allow warfighters to take full advantage of all available information and bring all available assets to bear in a rapid and flexible manner. NCW is based on the following tenets:

1. A robustly networked force improves information sharing,
2. Information sharing enhances the quality of information and shared situational awareness,
3. Shared situational awareness enables collaboration and self-synchronization, and enhances sustainability and speed of command,
4. These, in turn, dramatically increase mission effectiveness.

C2 Information Management Systems

Net-centric C2 systems can be designed using a two-layer architecture. The AFRL ADIOS and MITRE CoT information management system implements an extensible XML "hierarchy" based on flexible schema definitions. Schemas are cataloged into a lower level routing system for both of the systems.

CoT:

The major contribution of CoT to net-centricity is the definition of a core set of attributes required for C2 communication. Thirteen required fields that describe the what, where and when core attributes, can be extended to support subschemas for particular communities of interest (COT). The CoT system places an emphasis on situational awareness. CoT has been successful in field testing. It provided a net-centric solution for interoperability for the U.S. Joint Forces Command (JFCOM) during the Extended Awareness 1 (EA1) experiment, held December 2004 in New Orleans [Lawlor 2005]. During EA1, the JFCOM team enabled forward air controllers to direct and task dissimilar unmanned aerial vehicles (UAVs).

JB1:

The ADIOS is significantly more comprehensive than CoT. ADIOS supports archive and query to manage access to publications that were sent out before a subscription was submitted. It also incorporates "fuselets" into the architecture. Like CoT, ADIOS is a reference architecture that describes functionality and interfaces to facilitate interoperability. Development of the JBI concept that is implemented in ADIOS was encouraged by the U.S. Air Force Scientific Advisory Board (SAB) [SAB 1999] [SAB 2000]. The JBI was used experimentally to support experiments in the field ranging from chemical dispersion analysis [Holzhauer 2001] to Frameworks for high performance computing [Spetka 2005].

The JBI Reference Implementation

One of the most important requirements for net-centricity is that interface standards be available for developers. JBI documentation for developers is freely available. The JBI Common Application Programming Interface (CAPI) is available online at: <http://www.infospherics.org/api/index.html>. It can be downloaded at: http://www.infospherics.org/api/CAPIv1_5/CAPI_Ver_1.5.zip.

The ADIOS Information Object Model [AFRL/IF] implements a standard Managed Information Object (MIO) shown in Figure 1 below. MIO's, submitted by publishers, are "routed" by ADIOS from publishers to subscribers and, optionally, to archival storage in an Information Object Repository (IOR). A process called "brokering" matches MIO metadata with subscriptions to implement MIO routing functions. A "fuselet" capability can respond internally to MIOs that are received by creating and publishing new information objects.

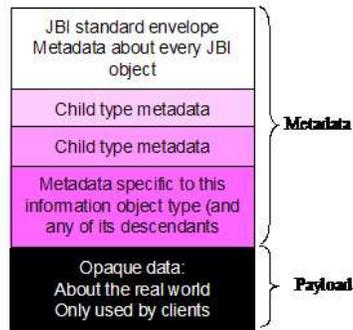


Figure 1 - An ADIOS Managed Information Object

Figure 2 is a diagram that shows an example of some XML metadata that could be used to manage intelligence imagery [Combs 2002]. Each MIO must include a type definition, JBI identifier, publisher, keywords and language. The imagery type specific information includes image type, geographic area, and location.

```

<?xml version="1.0" encoding="UTF-8"?>
<metadata xmlns:xsi="http://www.w3.org/2001/XMLSchemainstance"
xsi:noNamespaceSchemaLocation="Intel_Imagery.xsd">
  <mil.af.rl.jbi.Intel_Imagery/>
  <RequiredMetadata>
    <Type>Imagery</Type>
    <JBIIIdentifier>JBI000023</JBIIIdentifier>
    <publisher>418th</publisher>
    <keywords>Intel</keywords>
    <language>EN</language>
  </RequiredMetadata>
  <ImageDescriptor>
    <ImageType>IR</ImageType>
    <Area>Kabul</Area>
    <LocationCoord>
      <lat>33.34</lat>
      <latord>N</latord>
      <long>69.98</long>
      <longord>E</longord>
    </LocationCoord>
  </ImageDescriptor>
</metadata>

```

Figure 2 - Example of Metadata for Intelligence Imagery

Performance and Scaling: ADIOS

In a net-centric development environment, battlefield system architects can select components that serve their requirements. For targeting information, accuracy and reliability of delivery may be more important than performance. For distribution of large amounts of sensor data, performance and scalability may be more important. These requirements can be addressed by selection of software components or component

configuration.

The ADIOS high performance implementation of the JBI architecture was developed to support high performance requirements for C2 systems. It is particularly well suited for use by applications that require publication and dissemination of large data sets. Examples include data associated with airborne sensors and real-time communications systems that incorporate video data. ADIOS implements modern parallel programming techniques on high performance cluster computers to achieve significant speedups for many functions.

Brokering can, in general, be arbitrarily complex. Thus, brokering publications can be a significant bottleneck for high performance pub/sub systems. Brokers can be used interchangeably, to perform brokering functions when publications arrive in the system, because each broker implements the CAPI interface described above. This is, of course, a trivial example of net-centricity, which proves that CAPI implementations can be used interchangeably.

Network-Centric Systems - Using the JBI to support CoT

Our goal is to understand net-centricity, for pub/sub-based information management systems, by experimenting with using either CoT routing to support the AFRL ADIOS routing or using the AFRL ADIOS routing to support CoT. The first design, reported here, used the underlying AFRL distributed high performance routing system to support CoT.

The ADIOS high performance computing (HPC) Routing system uses high performance computers for scalable guaranteed throughput for supplied bandwidth. ADIOS can be configured with variable numbers of brokers that interface with publishers and disseminators that interface with subscribers. ADIOS implements the JBI reference implementation CAPI interface to assure interoperability with any implementation of the JBI architecture.

CoT has been successful implementing interoperability by building plugins to existing applications to enhance data sharing. An interoperable CoT/JBI (see Figure 3 below) was designed to study net-centricity in the context of pub/sub systems. The diagram shows the architecture. Implementing the integrated system will provide further understanding of net-centricity and lead to proposed standards.

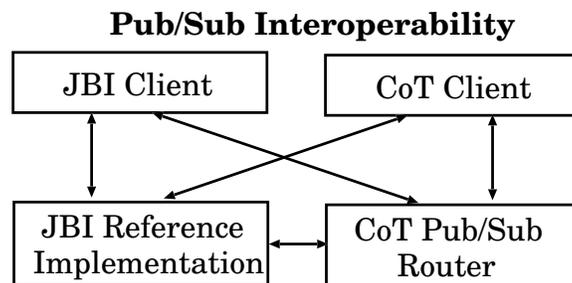


Figure 3 - Integrated ADIOS/CoT Architecture

Related Work

The Operator Network using Y-filter for XML Dissemination (ONYX) system, developed at University of California, Berkeley [Diao 2004], implements an Internet-scale XML dissemination service. Although the scalability issues are similar to the issues addressed by ADIOS, the system introduces additional semantic techniques to generalize XML matching operations. ONYX uses a distributed architecture to support scalability where ADIOS uses both distributed processing and parallel processing to enhance brokering performance and increase scalability.

The S-ToPSS (Semantic Toronto Publish/Subscribe System) [Petrovic 2003] introduces a higher-level semantic model for the pub/sub model. Instead of limiting users to low-level XML that requires shared lexicons, the system used synonyms, ontologies and semantic information techniques to exchange information based on meaning. The idea is consistent with a net-centric model at a higher level where similar applications may interoperate with S-ToPSS. Additionally, higher-level functions may map into an XML layer, allowing interoperability with ADIOS.

Conclusions

A net-centric C2 system based on the JBI and CoT implementations is being implemented. Interoperability allows designers to select the components that are most appropriate for an application. CoT client publishers and subscribers can use ADIOS to replace the CoT message router for applications where performance is important. Similarly, ADIOS can use the CoT message router when parallel computers are not available to support ADIOS scaling for performance or when simplicity of configuration is a paramount consideration. Of course, if archive and query support are mission critical requirements, the JBI or ADIOS pub/sub components must be used.

Experiments have been performed to confirm the viability of a CoT/ADIOS integration. The need for improved interface design to increase interoperability for pub/sub systems has been demonstrated. The difficulties faced in enabling interoperability for the two pub/sub systems discussed in this paper are helping to develop an improved interface design that may become a net-centric standard. Net-centric standards can enable enterprise, theatre and global interoperability if services publish interfaces so that developers can select the components that best satisfy the requirements.

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