Common Operational Picture (COP) and Common Tactical Picture (CTP) Management via a Consistent Networked Information Stream (CNIS)

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Abstract

The US Navy and Marine Corps have been developing technologies for the Common Operational Picture (COP) and Consistent Tactical Picture (CTP). The COP consists of data with long life spans serving war-fighters, who think in terms of minutes, hours, days or months. The CTP is generally envisioned to consist of data with short life spans serving operators and weapons that think in term of seconds or microseconds. Applications and war-fighters are stove-piped to receive the information relevant to their needs, thus, are unable to properly share data in a fashion in which everyone operating throughout the entire battle space can construct a systematic, consistent view of the battle space. The Naval vision is to provide one common, consistent data stream serving every Naval information consumer. Considering the wide breadth and depth of the Naval information community, this will be a challenging task. Therefore, it is extremely important that the Naval research community identifies and addresses the issues inherent to achieving this vision. The objective of the Consistent Networked Information Stream (CNIS) project is to develop a next generation information manager which can provide such a consistent stream of COP/CTP data.

1. Introduction

The objective of the CNIS project is to develop a next generation information manager which can provide war-fighters at every echelon with a consistent stream of information necessary to support a common picture of the tactical environment. The goal is to develop an information manager, which provides this stream of data, with the following requirements:

- Delivery is made in a timely fashion.
- Relevant data sources are checked
- There is a degree of transparency such that users need not be aware of the data source(s) being accessed.
- The user will not receive conflicting information.

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- The information is obtained through a single point of access.

Providing such an information manager will reduce the number of stovepipe information management systems running in parallel in today's Navy. Furthermore, a unified information management system will make better use of precious communications pipes and processing resources and consequently reduce manning requirements.

This paper will begin with a summary of the deficiencies in Naval Information Management systems. Next, the report will describe a set of technologies, which can be utilized in order to rectify the deficiencies. Following the description of the technologies, we will describe the approach taken to integrate these technologies to form an Integrated Information Infrastructure (III). Finally, we will describe the results of our efforts and conclude with a brief summary of upcoming research directions.

2. Deficiencies in Naval Information Management Systems

The general area of "information management" spans many domains (i.e., financial services, defense, etc) and the similarity of the information management problems in each domain is similar. For example, timely and secure delivery of certain information is critical. Information management has become even more critical with the rapid growth of the internet and the contents available through the internet in the form of web pages. Managing all of the information is a daunting task. The study done by NRL and SSC in the area of information management systems has revealed several key deficiencies. These are:

Timely Delivery (Quality of Service - QoS)

The capability to deliver critical information with a small response time is crucial. Often information that is received late is more damaging than not receiving the information at all. Consider an activity that has the job of shooting at a target. If information comes in late, then the firing might be conducted on a target that does not exist any more (but has moved), and a friendly asset may now be occupying that same volume of space, which was previously occupied by the target.

Awareness, access and delivery of information

Information awareness, access and delivery are limited within and across communities. There is very little awareness by an application or user when a data/information source that provides additional information comes on line (particularly across communities). A user or software application may not have a significant ability to find this "new" information. The access and delivery mechanisms should be done in an automated fashion such that it is transparent to the user/application.

Drill Down Capabilities.

The capability to trace the information to its source, and in the process extracting additional information, is important in the information management domain. Historically, systems have had to build their own interfaces to data/information sources. This has meant a considerable duplication of effort within and across services. A means is needed for systems or users to “drill down” into any “external” information source.

Control of Information Sources

Another area that deserves attention involves the ability of having control of the information sources. Commanders/users currently have very limited control of information resources. They are constrained by the application and its hard-coded nature to the information sources. The ability of the commander to become aware of new information and access it with ease is necessary to accomplish the tasks that must be done in Command and Control. What is needed is a graphical interface that allows the user to have a single point of access to the variety of information sources that are available.

Common Protocols and Representations for Exchanging Information

Common protocols and representations for exchanging information are a deficiency in the area of information management. Architectures such as the Defense Information Infrastructure (DII) Common Operating Environment (COE) are being developed to address these problems, but not all systems will be a part of DII COE since some may be research systems, etc. The user community must agree upon these common representations so that seamless communication can occur between systems.

Synchronization and Scalability of Information Sources:

The last drawback in current information management systems deals with the data itself, specifically, the limited scalability and synchronization of database servers. The scalability problem is one in which there is a tradeoff between the size of the database and the time needed to access that database; the greater the size, the longer it takes to find the data. The synchronization problems arises from the fact that as one database is updated with new information, the new information must be represented in other databases as well. The DII COE has this very same scalability and synchronization issue to deal with.

This last area dealing with scalability and synchronization of information sources will not be a significant area that the CNIS will research. This is a problem that plagues the area of database development; therefore, CNIS will look to other groups or activities to see how they handle this issue.

3. Supporting Technologies

Several key technologies have been identified, which directly impact each of the deficient areas. These technologies, when integrated together, will be the foundation of the CNIS III. The key technologies include

- ReSerVation Protocol (RSVP) [Zhang et al, 1996] for timely delivery
- Lightweight Directory Access Protocol (LDAP) [Howes and Smith, 1997] for timely delivery
- Agent technologies for information awareness, access and delivery
- Agent based drill down capability/technology
- Control of information sources via flexible Java Based GUI

- Common Protocols and representations using XML [Holzner, 1998]

The auxiliary technology includes Decentralized Data Fusion (DDF) [Uhlmann and Julier, 1998]

ReSerVation Protocol (RSVP) for Timely Delivery

A host uses RSVP to request a specific QoS from the network, on behalf of an application data stream. RSVP carries the request through the network, visiting each node (router) the network uses to carry the stream. At each node, RSVP attempts to make a resource reservation for the stream. To make a resource reservation at a node, the RSVP daemon communicates with two local modules – admission control and policy control. Admission control determines whether the node has sufficient available resources to supply the requested QoS while the policy control determines whether the user has administrative permissions to make the request. If both checks pass, then the RSVP daemon sets the packet classifier and packet scheduler to obtain the desired QoS. The former determines the QoS class for each packet and the latter orders packet transmission to achieve the promised QoS for each stream. The primary advantage of RSVP is its scalability because it uses receiver oriented reservation requests that merge as they progress up the multicast tree. Also, RVSP is robust since it does not perform it's own routing, but rather uses the underlying routing protocols. As the routing changes, the RVSP adapts its reservation to the new path. RSVP represents a unique approach to addressing the QoS issue.

LDAP for Timely Delivery

The LDAP technology is an Internet Engineering Task Force (IETF) initiative to build global directories for the internet. Directories are warehouses for information and are very similar to databases but with one key difference. Information is written to directories much less frequently than to databases. If the application wishes to perform frequent updates, then a directory would not be the best choice. The LDAP service allows search capability, filtering based on constraints, etc. This technology will provide the means to store meta-data such as information location, format, etc that can be searched much more rapidly than the actual data and hence will provide a quicker means to access the data itself.

Agent Technologies for Awareness, access and delivery of information

Agent aided information retrieval and decision support has attracted the attention of the agent research community for several years. The concept of large ensembles of semi-autonomous, intelligent agents working together is emerging as an important model for building the next generation of sophisticated software applications. This model is especially appropriate for effectively exploiting the increasing availability of diverse, heterogeneous, and distributed on-line information sources, and as a framework for building large, complex, and robust distributed information processing systems. The development of enabling infrastructure for mobile computing and interoperability among programs residing at distant sites, and new generations of distributed operating systems has made, and will continue to make, the construction of systems based on this model much easier. Several projects (e.g., FIPA_SMART [1] at SPAWAR System Center and

RETSINA [2] at Carnegie Mellon University) have developed infrastructure support, while other projects (e.g., CoABS [3] at DARPA, GPGP [4] and TAEMS [5] at University of Massachusetts) are developing control and coordination strategies for multi-agent environments. A focus of CNIS will be the application of this agent technology to the problem domain of retrieving tactical information to monitor plan execution.

<u>Agent Based Drill Down Capabilities/Technology</u>

The primary technique used to drill down into information is an intelligent aide (possibly an agent or a broker) which recognizes relationships in the queries being processed by a user. After recognizing these patterns the Drill Down aide seeks relevant information both laterally (other sources, same query) and vertically (subservient data / information access tools with related or supporting components but different query rules).

<u>Control of Information Sources via Flexible Java Based GUI</u>

Providing an intuitive and easy to user interface which allows the user to interface with the myriad of data/information sources and direct it to the application/user needing the information is critical. If the user cannot easily interact through a user-friendly interface, it has the potential to render all, or some, of the underlying information infrastructure useless. Since there is such a vast amount of information available, it is critical to provide access and control through a single interface, thus reducing the number of systems the operator must go through in extracting the necessary data.

<u>Common Protocols and Representations for Exchanging Information using XML</u>

The eXtensible Markup Language (XML) will be utilized for the common representation of information. XML is different from HTML in that it allows an unlimited number of "tags" to be associated with the information. In other words, an unlimited number of "tags" can be used as meta-data. This provides for a richer expression of the information contained in a web page as compared to HTML, without the overhead of using SGML. It also has the advantage that search agents can wander through the web (XML pages) in search of information using the rich set of meta-data contained in a web page.

<u>Decentralized Data Fusion (DDF)</u>

Fusion of information is an area of information management that we have not yet mentioned. This is a vast area of research and deserves a great deal of attention. There is groundbreaking work being done on an ONR sponsored 6.2 project titled "Decentralized Data Fusion" which utilizes a new technology called Covariance Intersection (CI). This program seeks to rectify some of the deficiencies found in the use of the Kalman filter for fusing two or more pieces of information together when their correlation is not exactly known. For example, if two pieces of information are correlated (i.e., one influences the other), then circulating these two pieces of information in a network creates redundancy. The CI approach is able to fuse two pieces together irrespective of their correlation. CNIS will leverage work performed in the DDF project for information fusion.

An important component of the CNIS information manager will be a security manager. This has not been an issue so far, as the primary emphasis has been to showcase a prototype system using unclassified data. However, security mechanisms will be designed into the architecture to accommodate the implementation in the latter years.

4. Approach

Figure 1 represents a high level view of the CNIS III. The information sources (e.g., databases, message streams and static files) are contained to the left in the figure and the users/applications, such as the

- Intelligent Information Exploitation and Retrieval (IIER) [6]
- Real time Execution and Decision Support (REDS) [7]
- 3-Dimensional Interactive Collaborative Environment (3DICE) [8]
- Battlefield Augmented Reality System (BARS) [9]

are shown to the right in the figure. This paper will not discuss the content of these databases, but it is worth noting the types of data sources that the III must interact with. The III is the mediator, the focal point, through which information is accessed, extracted and delivered to the applications. The services component will supply technologies that CNIS is not developing but are being developed elsewhere (e.g., industry, ONR, academia, etc). The auxiliary technologies will be contained in the service component of the III.

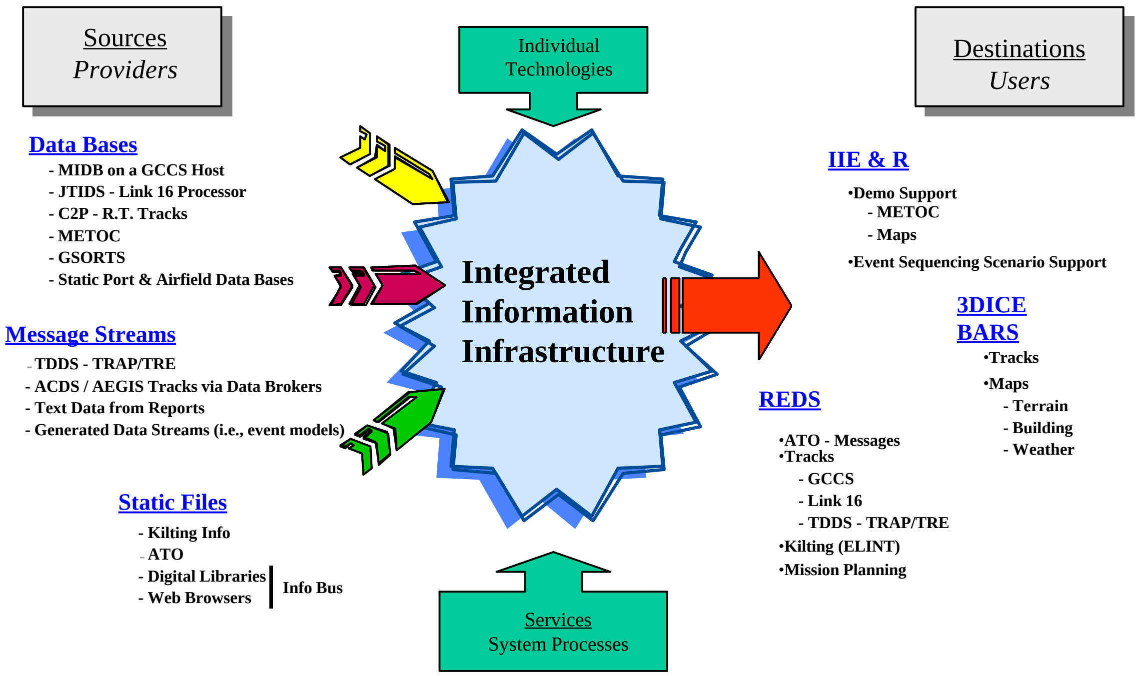

Figure 1: A high level view of the CNIS III and interfaces to Data and Users

If we decompose the III in Figure 1, we would arrive at Figure 2. Using this figure, one can map the supporting technologies previously mentioned to the individual components of the III.   For example, the agents for information awareness, access and delivery are contained in the ovals indicating agent activities. The RSVP mechanism is contained in QoS Manager. The LDAP can be mapped to the information registry component.

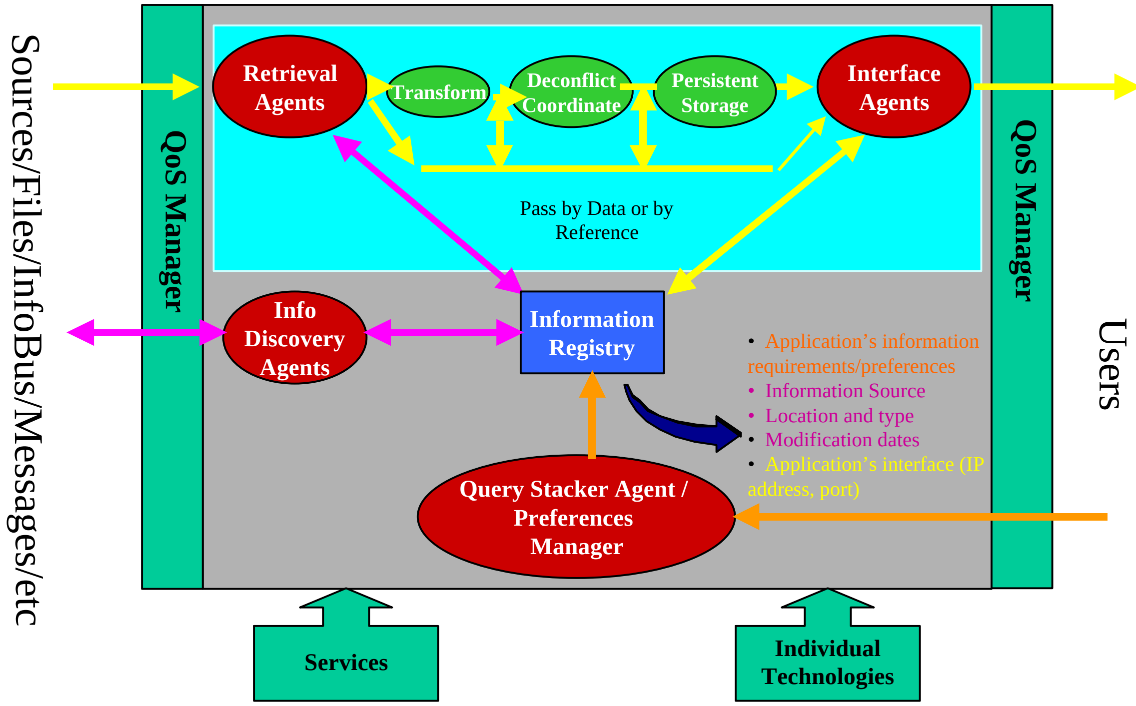

Figure 2: Details of the CNIS III

The CNIS III user interface will allow the user to enter the necessary parameters associated with the request such as the application's interface and information requirements, which includes the IP address of the application, port that it's listening from on a TCP/IP connection, etc. If a user requires the data vice an application, then these parameters are not necessary.

The Query Stacker Agent and/or Preferences Manager will collect this information and prioritize the queries. This information will be placed in the information registry. The information discovery agents will use the preferences stored in the information registry to locate the information from the various information sources and place the location back into the information registry. It is the job of the retrieval agents to query the information registry to find the location of the information and go out and retrieve the information. The retrieval agents will interact with the Quality of Service (QoS) manager to retrieve the information in a timely manner.   From this point one or all of three things will occur – Transformation, deconfliction and coordination, and persistent storage.   The transformation mechanism will allow the data to be reformatted to an internal data structure (object oriented). The de-confliction and coordination process will allow the redundant information to be eliminated in addition to coordinating similar pieces of information together. The persistent storage mechanism will allow transient data that was obtained to be stored internally. Finally, the interface agents will query the information registry to locate the application that needs the information and deliver it utilizing the QoS manager once again.

5. Results

This first year of the CNIS project has concentrated on the development of several of the core pieces of the III. These core pieces include the Query GUI, which allows a user to enter a query, the LDAP information registry, as well as basic agent software for information access and delivery.

5.1 The Query GUI

The Query GUI allows a user to develop a query using selection boxes, which can be AND'ed or OR'ed to form an expression. This GUI has been written in Java using the Swing API. For example the user can make the following query via the GUI:

(BE# = s1234 AND CATEGORY = THREAT) OR (BE# = ef435 OR THREAT = HOSTILE)

The selection boxes allow one to select the attribute (e.g., BE#), and then either type in values for that attribute or select the value from a pick list. The GUI allows multiple levels of nesting of the query, so that complex queries can be formed. Once formed, the query is passed to the information registry (controlled by a registry agent) for modification and decomposition.

5.2 The Information Registry

The organization of the information within the CNIS registry is similar to the organization of the information as described in the Naval C4ISR operational architecture document. The Clinger-Cohen Act of 1996 and the Information management reform act of 1993 require DoD organizations to measure the performance of existing systems and planned information systems. In response, the Assistant Secretary of Defense for Command, Control, Communications and Intelligence (ASD C3I) jointly developed the C4ISR architecture framework, which directs the use of the operational, systems and technical architecture as the means for developing, maintaining and evolving C4ISR systems. The Naval C4ISR Operational Architecture is one view of the total approach. It must be used in conjunction with the System and Technical architecture. An automated tool called the Naval Architecture Database (NAD) supports these architectures. Within the NAD, a concept called Hierarchical Data Dictionary (HDD) is defined. The HDD describes a methodology for organizing information. The figure below is a partial view of the information registry implemented via LDAP and based on the HDD. The numbers in parentheses in this figure represent the index to the actual entries in the HDD.

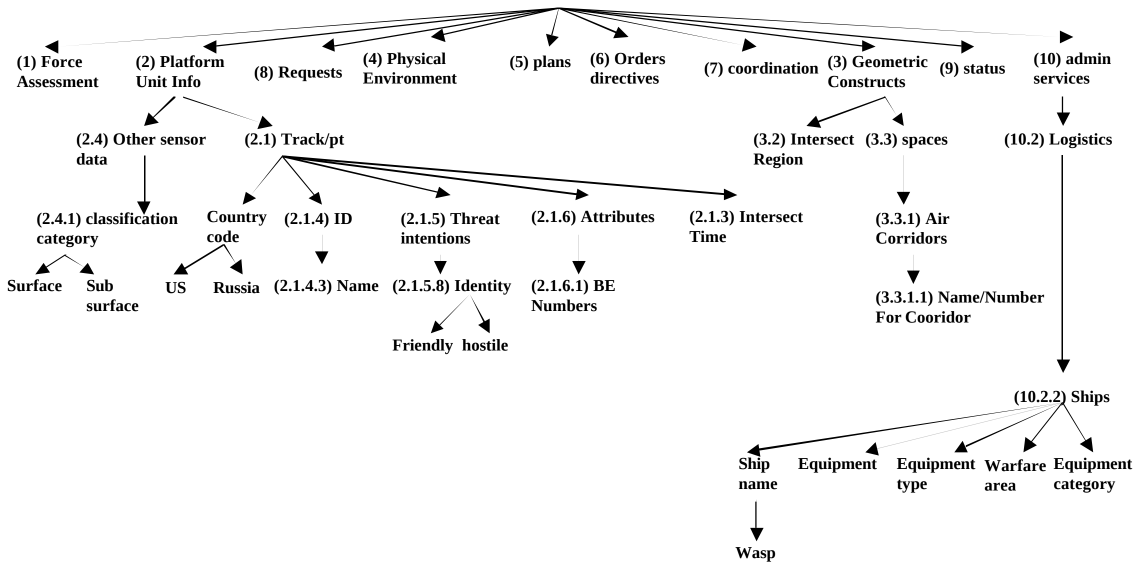

Figure 3: Partial view of Information Registry

Each leaf node contains an entry which specifies the database in which that attribute can be found. Once the query has been formed, it is passed to the registry agent, which compares each attribute against the information registry to obtain information regarding the database(s) which contain that attribute. For example, the first attribute encountered in the query expression is BE# = s1234. A check will be made with the registry to locate which database(s) has attributes labeled BE#. This is done for each attribute/value pair, hence the initial query has been modified with this additional information. After each attribute/value pair has been checked in this manner, the query can be decomposed as follows. Assume the modified query is as follows:

(BE# = s1234 AND CATEGORY = SURFACE) OR (BE# = ef435 OR THREAT = HOSTILE)
(MIDB/TDBM AND TDBM) OR (MIDB/TDBM OR TDBM)

This modified query can be decomposed into two queries, one for the MIDB database and the other for the TDBM database.

<u>MIDB Query:</u>

(BE# = s1234) OR (BE# = ef435)

<u>TDBM Query:</u>

(BE# = s1234 AND CATEGORY = SURFACE) OR (BE# = ef435 OR THREAT = HOSTILE)

5.3 Retrieval and Delivery Agents

The agent software, which CNIS employs, is based on the Foundation for Intelligent Physical Agents (FIPA) Stationary and Mobile Agent Resource Toolkit (SMART). FIPA is an international non-profit association of companies, which agree to share efforts to produce specifications of generic agent technologies. All software agents written developed for CNIS are based on FIPA SMART.

The decomposed query is passed to the Retrieval Agent Manager, which is responsible for sending a FIPA SMART Agent Communication Language (ACL) message to the appropriate agent responsible, in our case, for the MIDB and TDBM database. The agents will then extract the information from the appropriate database and send an ACL message back to the retrieval agent manager, along with the corresponding data. Redundancies in the data will be eliminated (i.e., deconfliction agent to be developed in later years), and associations will be made. These associations allow the data to be "grouped" according to similar "keys", or attributes, in the data. The data is then formatted, and passed to LEIF [10] for display. This entire process can be seen from the "flow" diagram in figure 4 below (discovery agent development to be done in later years). It should be noted that a scenario driver is reading in a scenario, and based on that scenario, is updating the TDBM and ACDS databases.

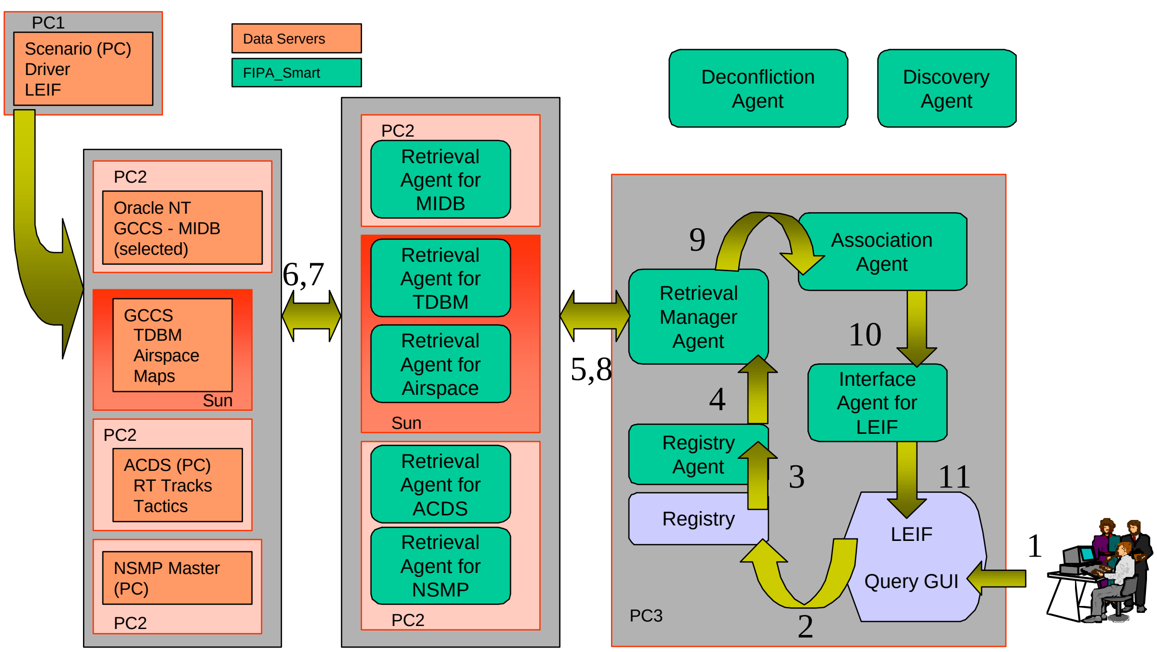

Figure 4: Infrastructure Configuration

Each FIPA SMART agent, database and display can be run in a distributed fashion. The III is currently configured to run between three sites, namely NRL, SSC, and Metron, Inc. Multiple configurations have been tested. For example, in one configuration, NRL has taken the role of the query GUI and LEIF, SSC has taken on the role of hosting the MIDB and NSMP databases as well as the database agents, and Metron has taken on the role of hosting the ACDS and Airspace databases as well as the Retrieval Agent Manager. Each site is capable of interchanging the software so that any configuration can be supported.

The overall performance of the CNIS III will be determined by how well it can provide the user or application with information in a timely manner, it's quality and it's adaptability to non-homogenous data/information sources. The performance will also be judged on how well it handles secure information transactions and as well as on it's usability. Comparisons will be made to similar systems (with regard to the above mentioned performance characteristics) which have to deal with the same problem – information management.

6. Future Work

With the completion of the core information infrastructure, the near term focus of the research and subsequent development will be in three main areas. These areas include the expansion of the FIPA SMART agents, automated information discovery and Quality of Service issues.

The development efforts up to this point have focused on building a core set of retrieval agents and retrieval manager agent and an interface agent capable of sending the results to LEIF. Future work includes expanding the capability of the information retrieval agents and retrieval agent manager to handle interfaces to other information sources. These sources include meteorological databases, message streams and static files. Additionally, an agent process capable of prioritizing the request must be built. This agent, based on some set of criteria, will prioritize and queue the requests, so that, for example, urgent request can be handled before other requests.

A second area that will be addressed is the automated discovery of information. The III has assumed a pre-built information registry. This was done as a matter of convenience and other project constraints. In the most general case, information discovery agents would be used to populate the registry from scratch, or update the registry, as new information is located. An issue that should be considered is the interaction of the discovery agents with the registry. For example, the agents may have to interact with multiple, distributed registries. There may be a master registry, which contains pointers to other distributed registries. Alternatively, there may be several "peer" registries, with each peer holding the exact same pointers to the distributed registries. The interaction between the discovery agents and the registry can become quite involved, requiring complex logic to be built into the discovery agents.

A third area, which will be investigated, is the capability to extract the information from the data sources and deliver it to the end user within a specified response time. This will require the development of a Quality of Service (QoS) Manager. The initial research direction is towards the use of the Resource Reservation Protocol (RSVP) for the development of the QoS Manager.

The long term goals are to develop and integrate agent-based drill down aids, XML as a basis for information representation and fusion technology using DDF.

7. References

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[2] Web Address: http://www.cs.cmu.edu/~softagents/retsina/retsina.html

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[4] Web Address: http://icmas.cs.umass.edu/research/taems/gpgp-detail.html

[5] Web Address: http://dis.cs.umass.edu/research/taems.html

[6] Contact Mr. Paul Quinn at ONR for more information

[7] Contact Mr. Paul Quinn at ONR for more information

[8] Contact Mr. Paul Quinn at ONR for more information

[9] Contact Mr. Paul Quinn at ONR for more information

[10] Web Address: http://www.dtai.com