Network Aware Tactical Collaborative Environments[1,2]

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Abstract

The implications of using mobile wireless communications are significant for emerging peer-to-peer (P2P) collaborative environments. From a networking perspective, the use of wireless technologies to support collaboration may impact bandwidth and spectrum utilization. This paper explores these network effects and describes an agent-based solution for providing feedback to system users regarding wireless P2P network behavior on the performance of collaboration support applications. We refer to this operational feedback as "network awareness." The underlying premise is that providing feedback on the status of the network will enable users to self-organize their behavior to maintain quality of data sharing. Results achieved during experiments conducted at the Naval Postgraduate School demonstrate significant effects of network behavior on application sharing performance and integration with client-server applications. A solution for improving network aware P2P collaboration, identified during the experiment, is discussed.

1. Introduction

Communication within a collaborative network environment includes many different modalities, including e-mail, chat, voice-over-IP and peer-to-peer (P2P). P2P, or wireless networking refers to technology that enables two or more computers to communicate using standard network protocols. Wireless networks provide unique capabilities related to mobility and cost savings. Wireless networking enables users to physically move while using the appliance, such as a hand-held PC or data collection device. This ability to collaborate via mobile wireless communications provides a valuable feature since many jobs require workers to be mobile, e.g., healthcare workers, police officers, inventory workers, emergency care specialists, and military personnel. A wireless network allows multiple users to access a database or application software via wireless links and mobile wireless appliances. An example of cost savings is the ability to install wireless networks in difficult-to-wire areas.

Each of these forms of collaborative communication has a different way of interacting with the network environment [1]. While most communication processes interact in a hierarchical fashion, P2P communications occur within a different framework. In a P2P architecture, computers that have traditionally been used solely as clients communicate directly among themselves and can act as both client and a server, assuming whatever role is most efficient for the network.

Three experiments were conducted by researchers at the Naval Postgraduate School (NPS), Monterey, CA, to test the effectiveness of providing network awareness in wireless tactical collaborative P2P communications. The results of all three experiments are described in this paper. The first experiment was conducted to provide initial data to evaluate the potential impact of using collaborative P2P technology in an urban warfare environment. The second experiment was conducted to evaluate the effects of sharing network awareness and providing a common operational picture on conducting tactical level humanitarian operations. The third experiment was conducted to test sensor-UAV-decision maker collaboration to support target surveillance and acquisition.

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2. Experiment I: Managing a Peer-to-Peer Collaborative Environment for Reconnaissance and Surveillance Team Missions

The first experiment was conducted at NPS in March 2002 and involved a hostage search and rescue scenario within the confines of the NPS campus quad. The mission for the Reconnaissance and Surveillance Team (RST) was to develop sufficient situational awareness (SA) among the group of geographically distributed participants such that the rescue phase of the mission could be planned through use of a P2P collaborative networking environment. In general, SA refers to the person's moment-by-moment ability to monitor and understand the state of the complex system and its environment. [2] When emergencies arise, the completeness and accuracy of the decision-maker's SA are critical to the ability to make decisions, revise plans, and manage the system. [2] Specific decision making tasks included under SA comprise the ability to: (1) maintain an accurate perception of the surrounding environment; (2) identify problems and/or potential problems; (3) recognize a need for action; (4) note deviations in the mission; and (5) maintain awareness of tasks performed. [3]

Study participants included the RST unit members who were searching the campus for hostages, members of the local command post, RST members located at the remote headquarters (HQ), in Norfolk, VA, and the en route scene-of-action commander. The scenario involved six collaborating pairs, who formed the RST unit, armed with only their laptops, Pocket personal computers (PCs), wireless local area network (LAN) cards, Groove P2P collaborative tools and a set of GPS interface agents. The RST unit was asked to collaborate with both the en route scene-of-action commander and HQ in Norfolk, to enable these geographically distributed team members to track the developing situation. The goal for the RST unit was to develop their situational awareness — and share it with the rest of the participants — such that it was sufficient for the non-collocated team members to plan and execute an emergency response mission. Figure 1 depicts the display that was used by the RST unit to view the unfolding situation as it developed.

This SA view was shared between all participants in the collaborative environment. The location of RST unit pairs (indicated on the display as TM1, TM2, etc.) is shown along with symbols to indicate objects that have been located (e.g., a bomb, indicated by the black circle in the lower right-hand corner). Using collaboration tools, this view was shared by HQ and the individual collaborating pairs in order to provide an awareness of the other pairs' positions as well as their views of the targets (i.e., the location of objects such as bombs, hostages, etc.). Performance of the applications provided in this collaborative environment was expected to be rather sensitive to the state of the wireless network. Thus, a Network Operations Center (NOC) was established to assist the RST teams in managing their application resources.

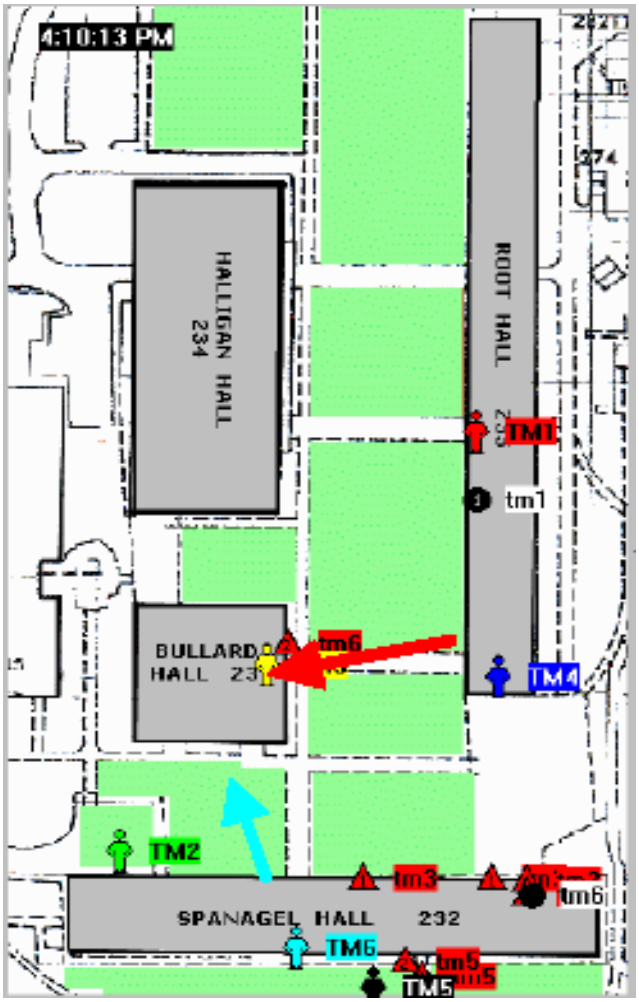

Figure 1. The RST situational awareness view display.

2.1 Network Operations Center

The NOC was responsible for performing the following primary functions:

- Set up the experimental P2P wireless collaborative network
- Manage the network during the experiment
- Provide the situational awareness view to the local command post and remote headquarters
- Assist the operational team members
- Maintain communications during the experiment
- Collect the experimental data.

Additionally, the research role of the NOC included performing the following functions:

- Explore the feasibility of providing bandwidth management for P2P clients
- Collect data on the scalability and mobility of a collaborative network
- Integrate P2P and client-server communications
- Investigate the feasibility of achieving P2P collaborative network self-organizing behavior.

2.2 Collaboration Network Configuration

A wireless network consisting of Cisco and Apple access points (Base Stations) was connected to the NPS LAN and was segmented from the main LAN by placing the base stations on a separate subnet. Personal Pocket PCs and laptop computers, with wireless access cards, were configured to connect to the LAN through these access points. The remote headquarters had connectivity to this network through a secure pipe via the Internet. The P2P wireless collaborative network was comprised of the following building blocks:

- Six mobile terminals each comprised of a Pocket PC (iPAQ) with a GPS receiver and a mobile wireless laptop connected to the local area wireless network
- 15 access points distributed over the NPS campus to provide local area coverage and routing functionality
- Four network monitoring workstations
- Two situational awareness web servers: one at the local NOC, the other at the remote headquarters, in Norfolk, VA.

2.3 Capturing Network Topology

The first step was to create and capture the topology of the environment. OPNET is a commercial, network management software tool that provides the capability to create topologies manually or automatically [4]. Prior to the experiment, project members created the topology manually because many of the devices were not configured with appropriate MIBs (Management Information Bases). Based on analysis of simulation performance data conducted prior to the experiment, results indicated allocation of additional assets was warranted. Several components, including a second dedicated server, were added to the network. This pre-experimental analysis also determined that hypertext transmission protocol (http) traffic would transmit through the P2P network without any serious delays. Moreover, the analysis also demonstrated the network could handle an increased load without affecting service provided.

OPNET's Application Characterization Environment (ACE) application was used to capture packet data necessary to analyze application specific loads. Files and associated packet traffic were traced and documented to create an accurate model of network data exchange. These data were used to populate both the application layer and network layer views in the network model. Spectrum Network Management Software enabled the NOC manager to "drill down" into the network and provide detailed views of the network at user-defined levels [4]. The experiment was dynamic and exercised the functionality of both a traditional and a wireless hybrid network from a network management perspective. Spectrum Network Management Software facilitated effective event tracking and system monitoring. There were sufficient user-defined parameters and alarms that allowed the NOC to shift assets to avoid impeding packet traffic during the scenario.

2.4 Collaborative Network Performance Monitoring

Several factors were specifically chosen to be monitored during the P2P experiment, including:

- Bandwidth utilization
- Current response time and percent packet loss
- Average response time and percent packet loss

The bandwidth monitor feature of SolarWinds Network Management System provided a variety of display options. The primary limitation of this software was that each terminal needed to be simple network protocol management (SNMP) compliant. In the experiment, none of the hand-held Pocket PCs, and only four of the six laptop terminals, had functional MIBs. Bandwidth capability had to be monitored on the servers. Capturing packets was initiated at the beginning of the experiment. System errors that occurred during the experiment required re-initialization of the capture process. The result was that only the last segment of the experiment was recorded and compiled for analysis. What became evident in this analysis is that network degradation could often be attributed to specific application use. Microsoft Net Meeting, the Situational Awareness Agent, and GPS Agent data transmissions to the HQ server degraded the network to some degree, but in most cases degradation was consistent across teams and between one wireless access point to another.

3. Observations and Results

Performance measurement was not consistent across all devices. This is attributed to the varying locations of the individual teams relative to the wireless access points or to individual laptop application configurations, in terms of processes running in the background on each node. One recommendation to improve application packet

transfer would be to include the use of coordinated "turnkey" configurations on each node of the network. Specifically, this would involve adjusting the system configurations so there are minimal applications running in the background on the wireless nodes.

3.1 Bandwidth

Bandwidth availability did not appear to be an issue during this experiment. Bandwidth utilization for each of the terminals averaged around one percent of capacity and peaked at two percent. Figure 2 depicts the amount of bandwidth received and transmitted, and indicates that the average bandwidth received was around 100 Kbps, and transmissions averaged around 10 Kbps. While this experiment was not bandwidth intensive, the percent packet loss averaged around 35.2, as depicted in Figure 3. This indicates that the network was not configured for applications that require dedicated bandwidth.

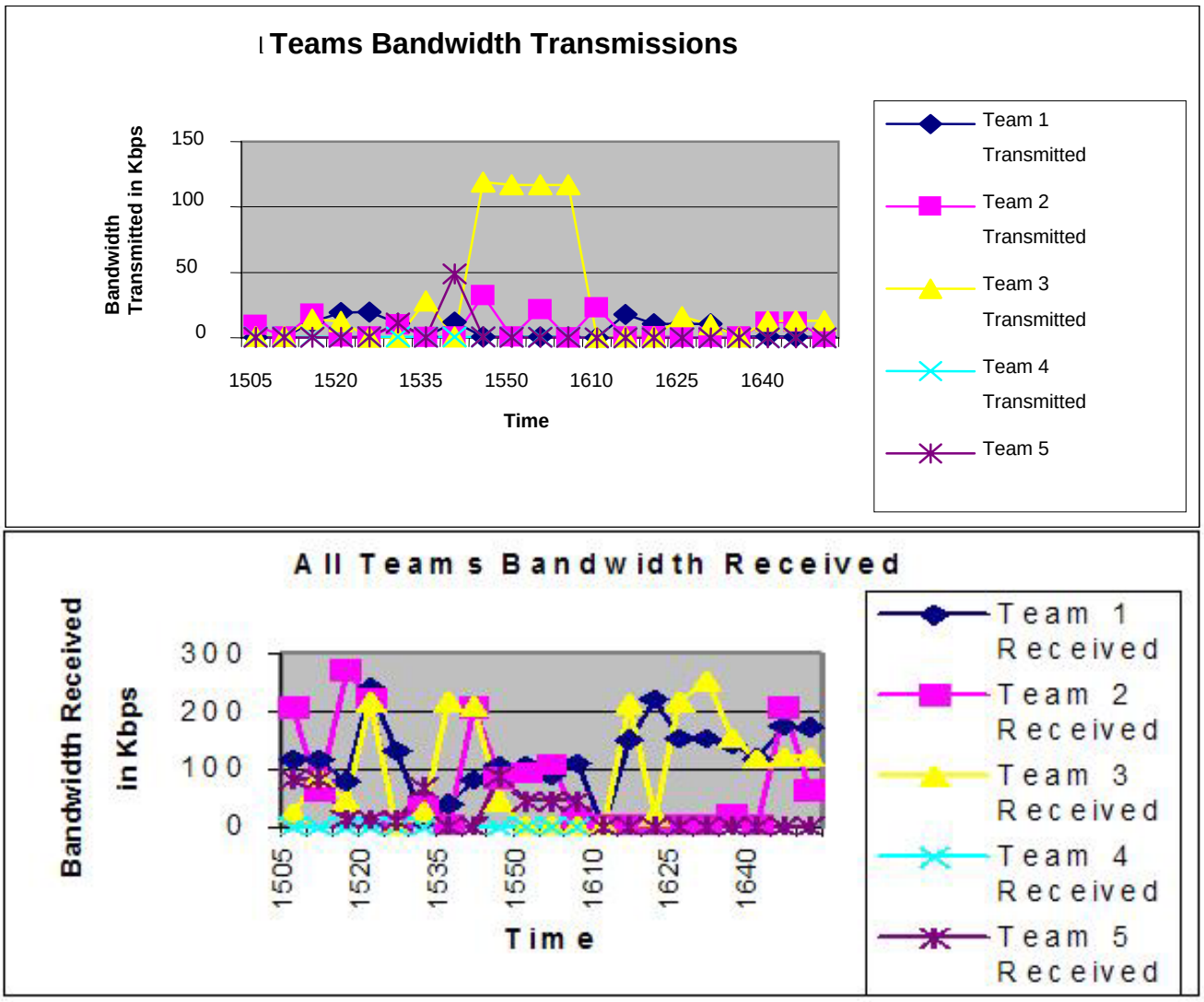

Figure 2. Bandwidth received and transmitted between collaborating teams.

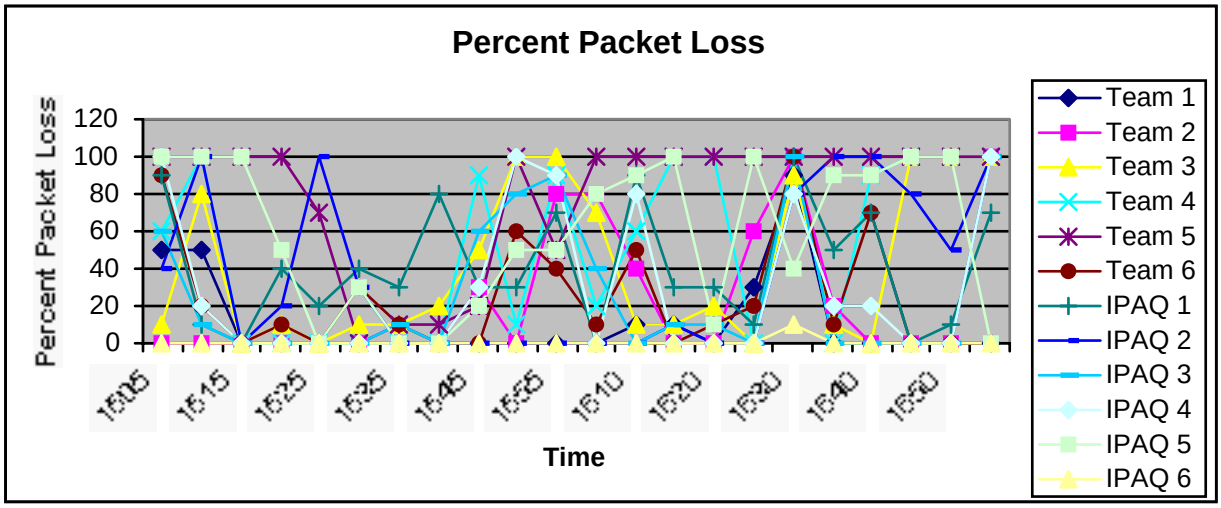

Figure 3. Percent of packet loss occurring over time.

3.2 Network Performance Awareness

A mobile node should be able to monitor its own signal strength and bandwidth utilization. This monitoring of signal strength was a critical form of operational feedback. We refer to this monitoring of signal strength as network performance awareness, which was provided to the teams by the NOC. Teams adjusted their physical location or changed the applications being used on their devices, as a result of receiving this critical information. This experiment demonstrated that P2P and client-server integration is feasible, but it is sensitive to roaming between the access point coverage areas.

3.3 Application Sharing

Application sharing was particularly sensitive to roaming, as applications would drop when a team crossed a boundary of access point coverage. Substantial packet loss occurred until the application was restarted in the new area. Error checking, system synchronization, and restoration features are necessary to ensure that team members maintain an accurate and current awareness of network performance.

3.4 Self-Organizing Behavior

Self-organizing behavior was demonstrated when RST members switched communication modes due to signal loss or interference. Yet, the strongest—and unexpected—effect of self-organizing network behavior emerged at the local command post site when the NOC manager was able to effectively monitor network performance and fault data. The NOC manager synchronized this data with the voice and data sharing calls, and in turn, adjusted assets or operations before packets and connectivity between peers was lost. Essentially, new channels of communication between team members were facilitated in real time by the NOC monitoring team observer.

4. Conclusions: Experiment I

Experiment I demonstrated the critical role of developing and providing network awareness in P2P collaborative applications operations when conducted by mobile expeditionary units. It also demonstrated the feasibility of providing network performance feedback to the operators involved in reconnaissance and surveillance missions concurrent with their collaborative transactions. Monitoring the network environment enabled the NOC manager to prioritize network performance variables in accordance with their effect on the overall collaborative application behavior.

4.1 Bandwidth Use

The most critical network performance indicator appeared to be the percent of packet loss. Every team was “all over the board” regarding packet loss. Teams dropped approximately 35.2 percent of the data packets, yet even with re-transmission of the affected data packets, the twelve wireless units still consumed less than one percent of the bandwidth available. While bandwidth was not an issue in this small experiment, it is important to keep in mind that much of the bandwidth utilization resulted from the re-transmission of data packets lost through application drop-off.

4.2 Network Operations Manager

Enabling network awareness in wireless P2P collaborative environments is feasible, but it requires an additional robust software infrastructure that is capable of providing instantaneous feedback on the most critical network performance control variables directly to the level of the P2P client interface. In the experiments described in this paper, an ad-hoc NOC observer and network operations crew played this critical role. The observer and the NOC crew managed to manually facilitate the RST units' management of their Pocket PC and laptop collaborative tools by refining the network monitoring data that was provided automatically by the network management agents.

We used the second experiment to explore how to share and integrate this critical observer function — which was discovered in experiment I — with the mobile unit multiagent situational awareness environment. Experiment II focused on deploying and managing a tactical collaborative network that was assembled to support a humanitarian operations site.

5. Experiment II: Managing a P2P Collaborative Environment for Tactical Humanitarian Operations

In experiment II we replicated this mechanism for providing network awareness and incorporated it in the multiagent architecture. This feature enabled users of Groove [6] P2P collaborative applications to automatically re-establish communications if dropped from a mobile network. We used the DARPA Network-Centric Habitat concept [7] to structure the collaborative environment for a tactical level Complex Humanitarian Emergency (CHE) site.

5.1 Habitat of Network and Software Agents

For a number of years, DoD has recognized the key role technology can play in the effort to improve communication between International Organizations (IO), Non-Governmental Organizations (NGO), and the military in humanitarian and peace operations [8]. After Complex Humanitarian Emergencies (CHEs) such as those in Northern Iraq, Somalia, and Haiti, the National Defense University's Institute for National Strategic Studies Directorate for Advanced Concepts, Technologies, and Information Strategies attempted to capitalize on the lessons learned. As a result, several subsequent technological research efforts relevant to the military were developed [9].

The DARPA habitat resides within the global information grid and uses an information exchange infrastructure to facilitate the intelligent tailoring and dissemination of knowledge. Simply networking components together does not create a habitat. Components must be able to share resources (information, services, etc.) in a way that optimizes their ability to carry out their assigned tasks effectively within the constraints imposed by security or policy. A habitat is dynamically created to support a specific operational mission. It interfaces with other habitats as well as all other "legacy" systems, assets, organizations, or individuals (i.e., those that are equipped with a compatible interface or "wrapper").

5.2 Architecture for the Tactical Humanitarian Relief Operations Habitat

A Tactical Humanitarian Relief Operations habitat was developed for use within a P2P collaborative tool called "Groove." [6] A Groove Workspace is a virtual space for small group interaction. In a Groove Workspace users make immediate and direct connections to perform a wide variety of activities – from working on a project, to brainstorming, planning an event, discussing issues, sharing documents, and coordinating. This is all accomplished using the P2P networking technique. The essence of P2P is establishing a direct connection between people. There are tools in the Groove Workspace that facilitate the sharing of content (files, images, maps), conversations on that content (discussions, instant messages, live voice, text-based chat), and working together on shared activities (real-time co-editing and co-viewing of documents, co-browsing, group project management and tracking, and meetings management). By bringing these tools together in a single construct, the Groove Workspace streamlines work and communication so teams can speed up their decision-making time.

5.2.1 Enhanced Awareness. A collaborative work-space provides the potential capability for enhanced awareness of other members who are working in the Groove Workspace and this enhanced awareness promotes serendipitous, as well as planned, collaboration. Each shared work-space shows the online status of all members, so that when two or more members 'find' themselves in the same shared space at the same time, they are able to quickly take advantage of the situation and work together in real time. Similarly, a single user can glance at a single view of all shared spaces to see if there are any 'active' members. The ability to know who is currently and actively working on certain projects is a new and powerful catalyst for enhanced productivity.

5.2.2 Web-based applications. Using Groove as the habitat's construct program, the Tactical Humanitarian Relief Operations habitat includes two web-based applications called the Relief Operation Coordination Center (ROCC) and Virtual Civil Military Operation Center (VCMOC). The ROCC and VCMOC are technological tools that use central hypertext markup language (HTML) and active server pages (ASP) to interface with a database to insert, edit, view, delete and manipulate information to enhance multi-participant communications and data sharing. It is expected that these applications will improve the overall dissemination of vital information and mitigate breakdowns in communication.

The ROCC and VCMOC are designed to promote and support better information transparency and exchange to reduce operational security risks and avoid duplication of efforts. Both applications provide the capability to track information on the activities of various organizations, plans, and the resources that are available and keep this information up to date. The ROCC and VCMOC can provide the location for field assessments and associated databases to assist planners, pre-deployment actors, people who will implement, and post-crisis analysts. Moreover, as web-based applications, they are mobile and accessible via internet connectivity. The main reason that the ROCC and VCMOC are embedded in Groove is to enhance the ability of geographically distributed users to plan, organize, and collaborate for problem solving.

5.3 Agent-Based Architecture for Experiment II

A web agent-based application referred to as the Complex Humanitarian Emergency (CHE) Situational Awareness Tool (SAT), or CHESAT, was created at NPS to investigate ways to promote shared SA in the field environment. The purpose of the CHESAT is to provide CHE participants with a situation awareness capability to support their ability to maintain shared SA regarding each other's location and to have common knowledge of events in their area of operations. The CHESAT includes several software agents that perform a number of functions. (These agents are described in the following sections.) All of the agents reside on the CHESAT web server.

The CHESAT exists in two different spaces at the same time. The web server (client-server) is the first space that we will discuss. The client-server software architecture was chosen as one of the spaces for the CHESAT because it is a versatile, message-based and modular infrastructure that is intended to improve usability, flexibility, interoperability, and scalability in information technology networks. A client is defined as a requester of services and a server is defined as the provider of services. A single machine can be both a client and a server depending on the software configuration. An advantage of making this tool a web-based application is that clients do not have to download any software. We get the best of both worlds by taking advantage of the benefits offered by a client-server architecture while not requiring clients to download the CHESAT as an application. As long as the CHE participant can access the network where the CHESAT server resides, they will have access to the CHESAT.

5.3.1 Control of Agent-Based Systems Grid. The Control of Agent-Based Systems (CoABS) grid is the second space where the CHESAT resides. CoABS is a DARPA program to develop and demonstrate techniques to safely control, coordinate, and manage large systems of autonomous software agents. The CoABS Grid is middleware that integrates heterogeneous agent-based systems, object-based applications, and legacy systems. It includes a method-based application programming interface to register agents, advertise their capabilities, discover agents based on their capabilities, and send messages between agents. The grid is only one part of the overall CoABS program; the grid is the "plumbing" that connects the components of legacy systems to solve real world problems. Therefore, one can also think of the grid as an infrastructure layer that has all of the agents and services running on it.

5.3.2 SA Management Agent. The SA Management Agent provides the visual interface display for all CHE participants through their web browser. This agent is intended to support the shared SA of all CHESAT users. The SA Management Agent uses input from the web flash technology server and the Tracking Agent to display the location of CHE participants and significant events. Users have the ability to gain access to a wealth of information through the display provided by the SA Management Agent. For example, one can view the capabilities of other users (e.g. identify what communications capabilities other users have), post an alert for other users to view, or view events posted by other users. This awareness allows a user to make informed decisions on how to assist in a particular event and provides the necessary information to coordinate assistance.

5.3.3 Tracking Agent. The Tracking Agent provides position-location information to the SA Management Agent for display in the browser. Data collected by the Tracking Agent comes from one of two input sources. One source uses manual inputs from the user who clicks and drags a user icon to a location on the display. The icon is then dynamically displayed to everyone accessing the CHESAT. A second input source is from a GPS receiver. This is accomplished by enabling a software

agent that takes the GPS receiver input and transmits it to the SA Management Agent in the CHESAT, which subsequently moves the user icon to the correct location on the display. This second method is much more accurate and requires no user input to adjust position information. However, this method of input is obviously hindered when a CHE participant is obstructed from GPS detection (e.g. inside a building) or does not have a GPS receiver. In this situation, the user can easily switch to manual inputs by clicking the appropriate button on the CHESAT display.

5.3.4 CoABS Grid Agent. The CoABS Grid Agent is the third agent in the CHESAT. This agent performs the liaison role between the CHESAT and the CoABS grid. The CoABS Grid Agent constructs bridges to different systems, due to its ability to wrap legacy systems and interfaces to other components (or agents) and legacy systems. This allows the CHESAT to use data from any database that is part of the grid. This approach was taken to overcome the interoperability challenges inherent in many stove-piped legacy systems.

5.3.5 Text Messaging Agent. The Text Messaging Agent allows users to communicate simple text messages to other users participating in the CHESAT. Typing a message in the appropriate screen and then clicking and dragging the messaging icon over the desired recipient enables the functionality of this agent. The recipient of the message is notified with an audio message and a visual pop-up message.

5.3.6 Agent Database. The Agent Database contains the repository for all the events that occur in the CHESAT tool. For example, when a CHE participant wants to use the CHESAT they will have to log-in to the tool via their web browser. This log-in event, along with all the actions of the CHE participant in the CHESAT, are captured and stored in a database by the Agent Database.

6. Experimental Scenarios

The first experimental scenario was executed on an ad-hoc wireless local area network (WLAN) that was established at Marine Corps Base Hawaii (MCBH). The goal for this scenario was to demonstrate the ability of a CHE participant to effectively conduct humanitarian relief efforts within the Tactical Humanitarian Relief Operations Habitat. The scenario involved three CHE participants in the habitat who represented the following organizations: military civil affairs, NGOs and IOs. Two of the CHE participants had a laptop computer and one had a Pocket PC configured to function on an ad-hoc WLAN. Additionally, the PDA user had a GPS receiver.

6.1 Developing Shared SA Through Peer-to-Peer Collaborative Applications

The CHE participants worked in a remote area of MCBH which contained a few buildings and basic services such as running water, restrooms, electricity, and two telephones. This was done to simulate a typically sparse CHE working environment. However, it was noted that some CHE environments, during the early phase of execution, lack most of the basic services listed in the previous sentence. The only reach-back capability that the CHE participants had were cellular phones and the two telephone lines that could be used to make long distance calls and establish internet connectivity at rates varying between 28Kbps and 45Kbps.

6.1.1 Assumptions Made Prior to Scenario Start. Prior to the start of the scenario, some basic assumptions were made. First, the NGO and IO representatives had already conducted the required coordination for approval to join the Tactical Humanitarian Relief Operations Habitat. This would be accomplished via telephone calls and emails based on the information provided in the log-in page of the VCMOC. Previous CHE after action reports have pointed out the importance of preplanning when it comes to NGOs and IOs who want to provide assistance during a CHE. When these organizations arrive in country without having participated in any planning conferences for the CHE, there is normally a great discrepancy between the level of logistics required to coordinate and resources available to meet the critical needs at a particular time with the proper resources. The VCMOC registration process was designed specifically to deal with this issue.

The second assumption was that all members of the habitat would have received the software and training needed to be productive members of the habitat. The components of the habitat were designed for non-technical computer users. Two to three hours of training would have to be conducted to give a new member of the habitat a good understanding of the functionality that is resident within the CHESAT, ROCC, VCMOC and Groove. The only software license that would have to be given to new habitat users is Groove. The CHESAT GPS poster was developed at NPS and does not require a license to distribute to habitat members who desire to use GPS receivers for positional reporting.

6.1.2 Executed Tasks. Most of the tasks executed were based on the premise that the habitat was a virtual environment in which members of the habitat could collaborate and coordinate with each other without the direct control of a centralized authority. Members of the habitat were able to use all the functionality of the CHESAT, Groove, ROCC, and the VCMOC. Face-to-face meetings at the civil-military operations center (CMOC) (physical operation center) were held primarily

for final coordination of issues that were discussed in the VCMOC. As requirements were posted in the VCMOC, members of the habitat had the freedom to either fulfill or not fulfill the requirement.

Habitat members were favorably impressed with the combined capabilities of the technology tools provided in the habitat. The ability to share files, conduct Microsoft PowerPoint briefs, and use voice over IP while browsing internet web pages with the use of Groove was perceived to be a force multiplier. The CHESAT ability to depict the location of habitat members based on a manual or GPS input offers a tremendous advantage in terms of aiding the situation awareness of participants. Figure 4 provides a screen shot of a program that uses CoABS wrappers and software agents to take positional information and post it to the ROCC viewer web display. Color coded people icons represent actual CHE participants. Displaying this type of position location information served to enhance the shared situational awareness of habitat members.

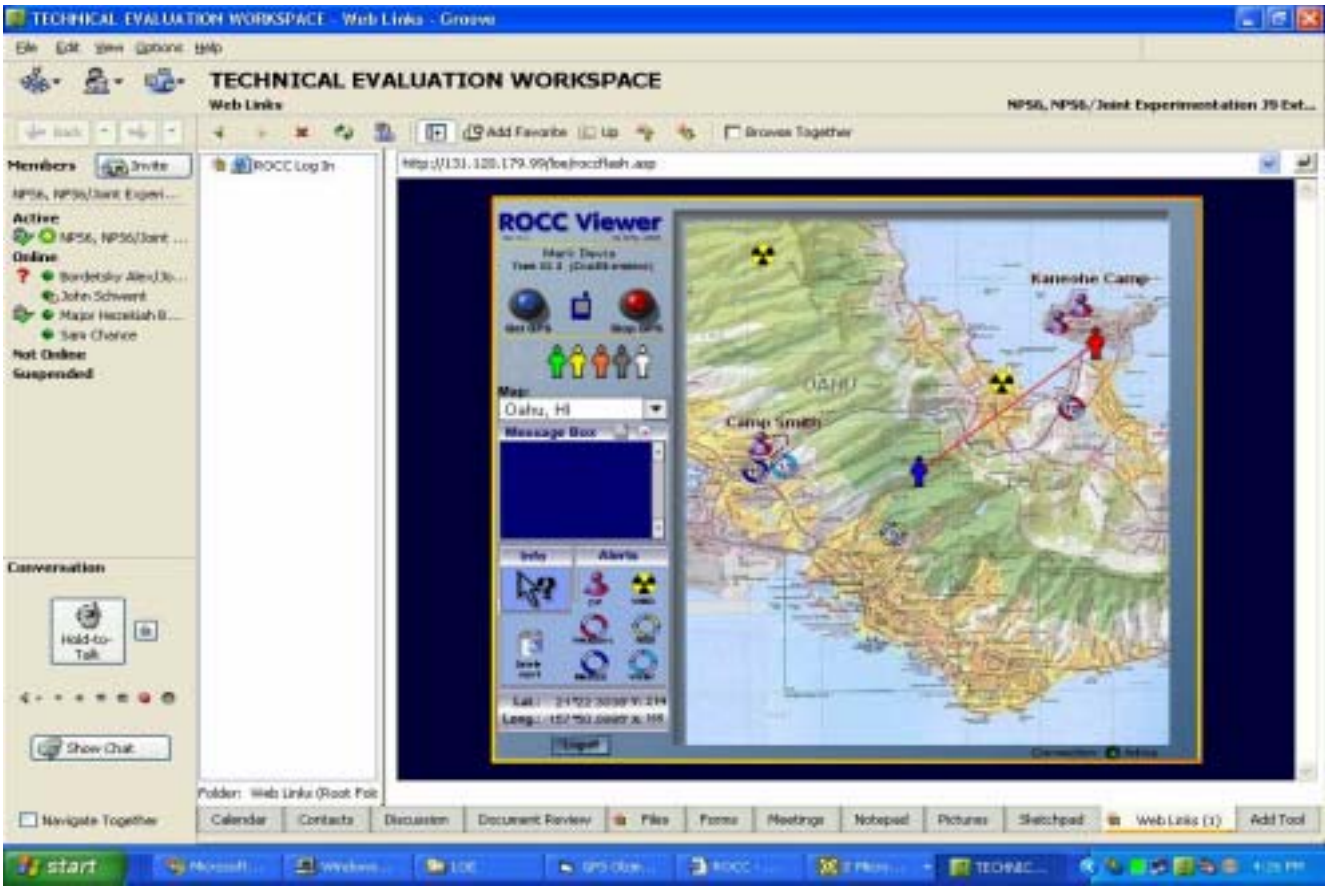

Figure 4. CHE Unit P2P Collaborative Environment.

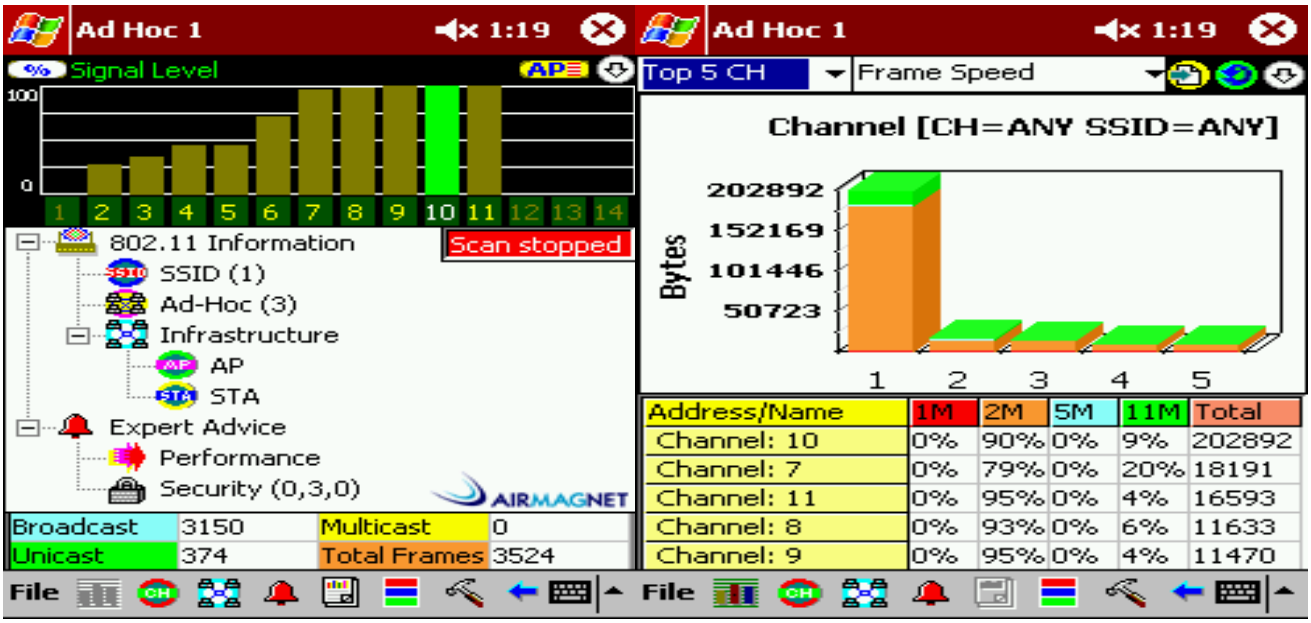

Figure 5. CHE Unit Member Pocket PC View of Network Performance Observer Feedback.

6.2 Integrating Network Awareness: Distributed Observer Model

The second scenario was executed on the ad-hoc WLAN that was used by members of the Tactical Humanitarian Relief Habitat. The purpose of this scenario was to demonstrate the ability of the habitat network manager to effectively administer the network.

6.2.1 Transmission Speeds. Transmission speeds for sending data varied between 2-11Mbps depending on the distance and obstructions (buildings, vehicles, etc.) between the nodes. The average travel time for when a text or voice message was sent and was received using Groove was 4 seconds. In comparison, the average travel time between when a text or voice message was sent and received using the CHESAT was 2 seconds. When sharing files in Groove, the average time for a 25K file that was posted in a Groove workspace to be synchronized in the workspace of the other members of the habitat was 90 seconds.

6.2.2 Air Magnet Tool. Air Magnet Pocket PC views of the P2P collaborative network management space were used to provide automated observer feedback to the CHE unit (Figure 5). While habitat members were performing the collaborative application tasks, Air Magnet was used to monitor network performance. Over the course of the monitoring period of approximately two hours, Air Magnet collected data in a real-time manner. Using a data collection model called Pocket Screen Capture, we were able to capture screen shots of the discovery, performance, and security events. The greatest indicator of network flow was found in analysis of network transmission rates. In order to communicate this vital network performance awareness information to the CHE unit members in a timely manner, we had to split the roles of managing the habitat software environment and designated one person for handling the network management feedback.

7. Experiment III: Bringing Network Awareness to A Shared Situational Awareness Interface

In order to automate the network behavior observer (facilitator) function, that was discovered during the first experiment and applied as a part of the CHE unit shared situational awareness environment in the second experiment, we needed to integrate the Simple Network Management Protocol (SNMP) agents, which control the networking elements, with the collaborative tools. This task constituted the goal for the next step of our research. We implemented an observer/facilitator model using the DARPA Control of Agent–Based System (CoABS) middleware platform.

In experiment III, during a subsequent series of tactical networking experiments, sponsored by US Special Operations Command, the focus shifted to collaboration that occurs between self-organizing peer-to-peer sensor-

UAV-small unit operators, which is essential to accomplish their cooperative work. Participants included in these experiments are depicted in Figure 6. Control of multiple sensors and UAVs required elaborate instantaneous feedback on P2P network performance. An example of the types of data that were monitored by the facilitator of the collaborative network in the NOC is shown in Figure 7. Within a 3-5 second allotted time delay, for providing shared awareness integration, operators on the ground needed to know which sensors to use (or to enable) for continuing surveillance subject to airborne-based wireless long-haul mesh network behavior. Each node, whether it was a ground sensor, UAV, or human operator, needed to know it's own networking status as well as the performance level of the neighboring nodes. This was accomplished by bringing the SNMP agents into the CoABS grid using the previously identified network observer model. Figure 8 illustrates the architecture that was used to test the agent-based network awareness model. Figure 9 depicts the agent-based network awareness model implementation in conjunction with wearable nodes, enabling self-healing to the tactical sensor network.

8. Conclusions

Experiment participants found the integration of feedback on network awareness in the Tactical Humanitarian Relief Operations Habitat to be an extremely useful approach for solving the traditional problem of bringing CHE participants together in a dynamic, self-organizing environment. This habitat implementation enabled CHE participants to work effectively to provide aid to those in need. Despite not having internet reach-back connectivity, the habitat members who were in charge of camp management functions were able to perform their jobs as camp managers. Other role players were able to self organize and collaborate with each other on a WLAN without access points even when the wide area satellite link went down. This was all made possible through use of P2P applications such as Groove, the CHESAT, and by providing timely feedback on network performance via the Pocket PC-based distributed observer.

These results validate the proposed CHESAT multiagent model for integrating network awareness in a CHE collaborative environment. They confirm the critical need for allocating the human observer role to one or more CHE unit members. Such a person would be capable of rapidly interpreting network performance and providing feedback to the shared situational awareness view in an austere environment. The CHESAT multiagent model also provides the foundation for exploring new situational awareness models that include instantaneous network performance feedback.

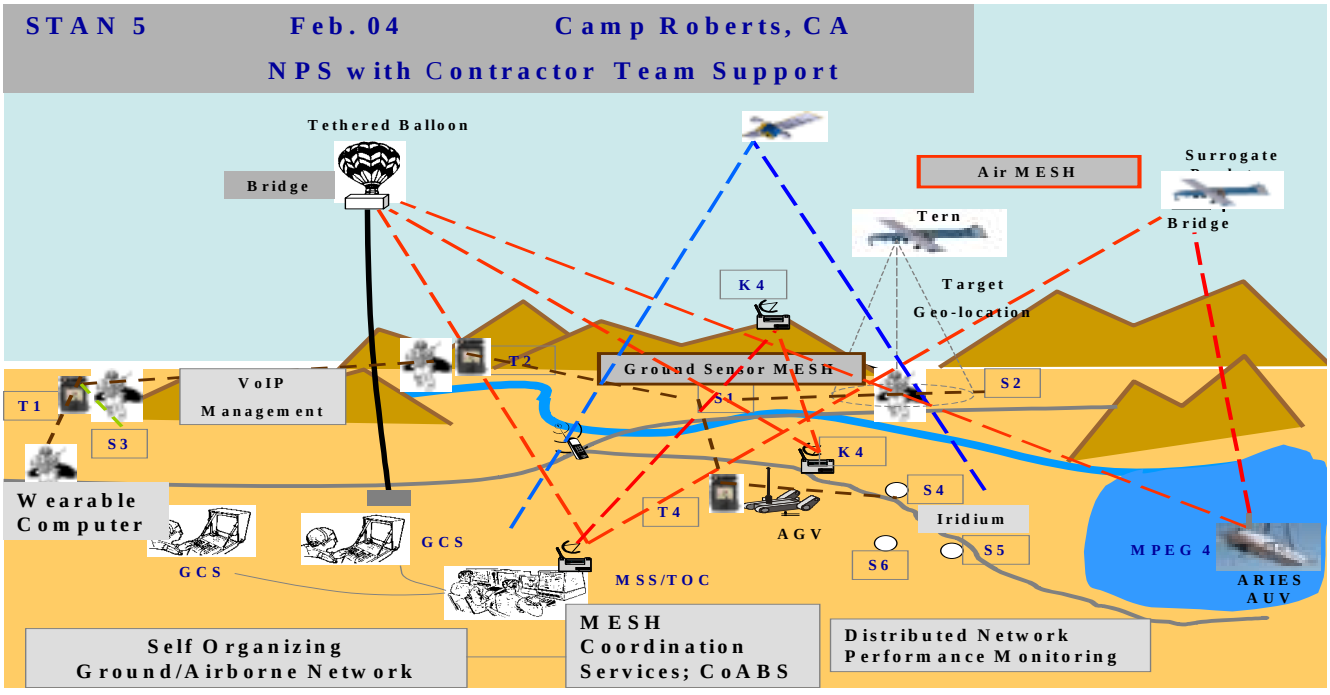

Figure 6. UAV-sensor-decision maker collaborative mesh networking experiment.

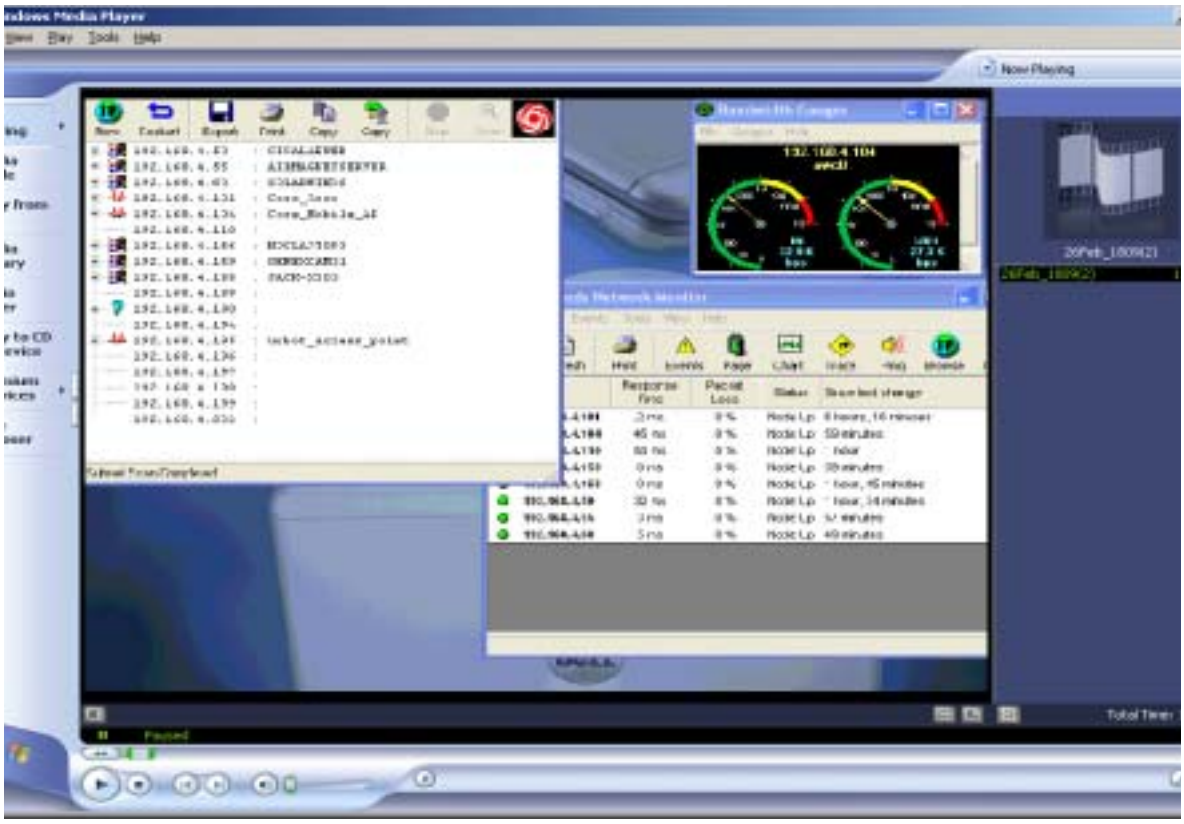

Figure 7. Typical observer (facilitator) view of collaborative network behavior at the Tactical Operations Center/ Network Operations Center facility.

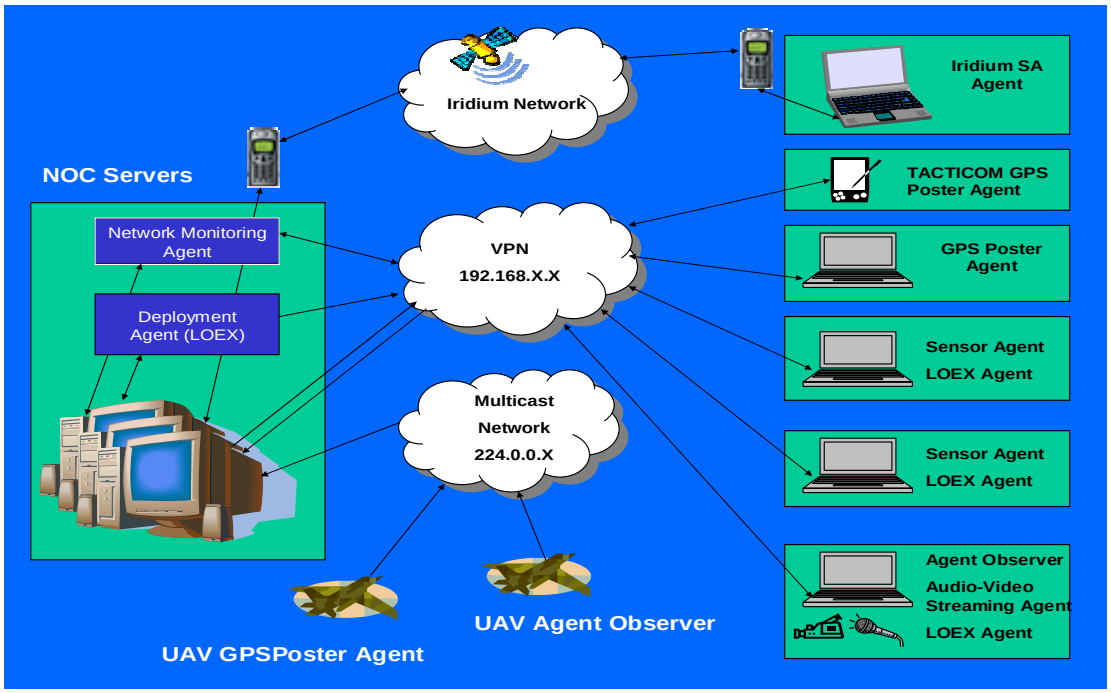

Figure 8. Agent-Based solution for network awareness feedback: CoABS approach.

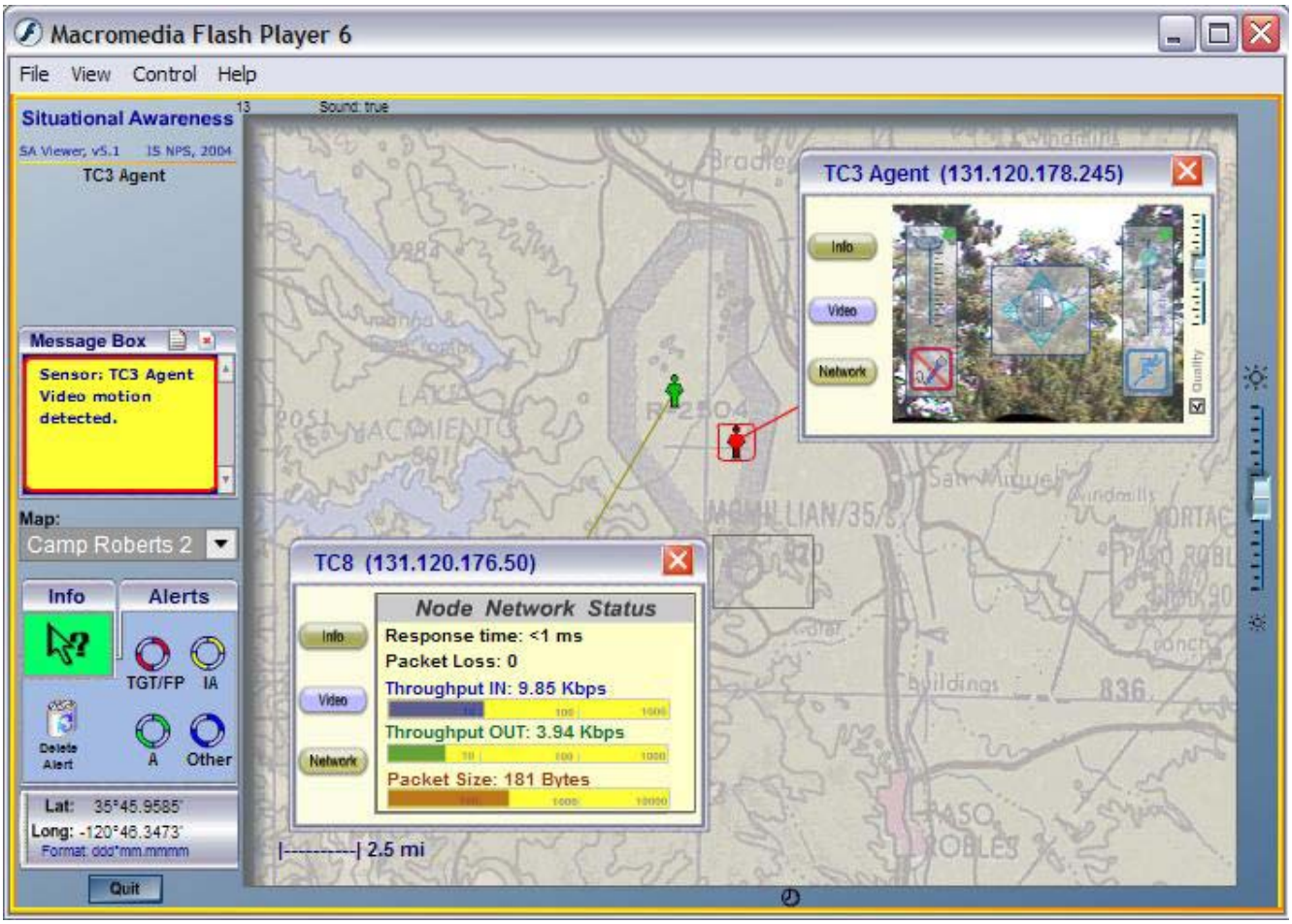

Figure 9: Network aware tactical sensor-DM grid: SNMP agents report to shared situational awareness interface via CoABS grid.

In order to automate the network behavior observer function that was discovered during the first experiment we integrated the SNMP agents, which control the networking elements, with the situational awareness collaboration support agents using the CoABS. The subsequent tactical sensor-decision maker peer-to-peer collaboration experiments demonstrated the feasibility of the developed network awareness model. Our next step for this research is to explore the constraints and policies for self-organizing sensor-decision maker collaboration that apply in a network aware tactical grid environment.

8. References

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[9] Ford, T, Hogan, J., and Perry, M., Communication During Complex Humanitarian Emergencies: Using Technology to Bridge the Gap. Naval Postgraduate School, Master's Thesis. September 2002.

Network-Aware Wireless Peer-to-Peer Collaborative Environments

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Sue Hutchins
Bill Kemple
Eugene Bourakov

Naval Postgraduate School

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- Paul Keel, MIT
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- CWII Chris Manuel, US Army SOF, NPS
- NPS GIGA Lab Student Team

Research Goals

- *Explore the solutions for an emerging concept of network aware tactical sensor-decision maker P2P collaborative environments. GIG/FORCEnet correspondence:*

  -adaptive multipath collaborative environments,

  -GIG tactical extension
- *Explore the models for network awareness enabling P2P grid nodes to self-organize their collaborative behavior and maintain quality of data sharing.*
- *Explore the multiagent solutions enabling node networking role and status sharing*
- *Explore the human-centric solutions for network awareness facilitation: network of operation centers*

Approach

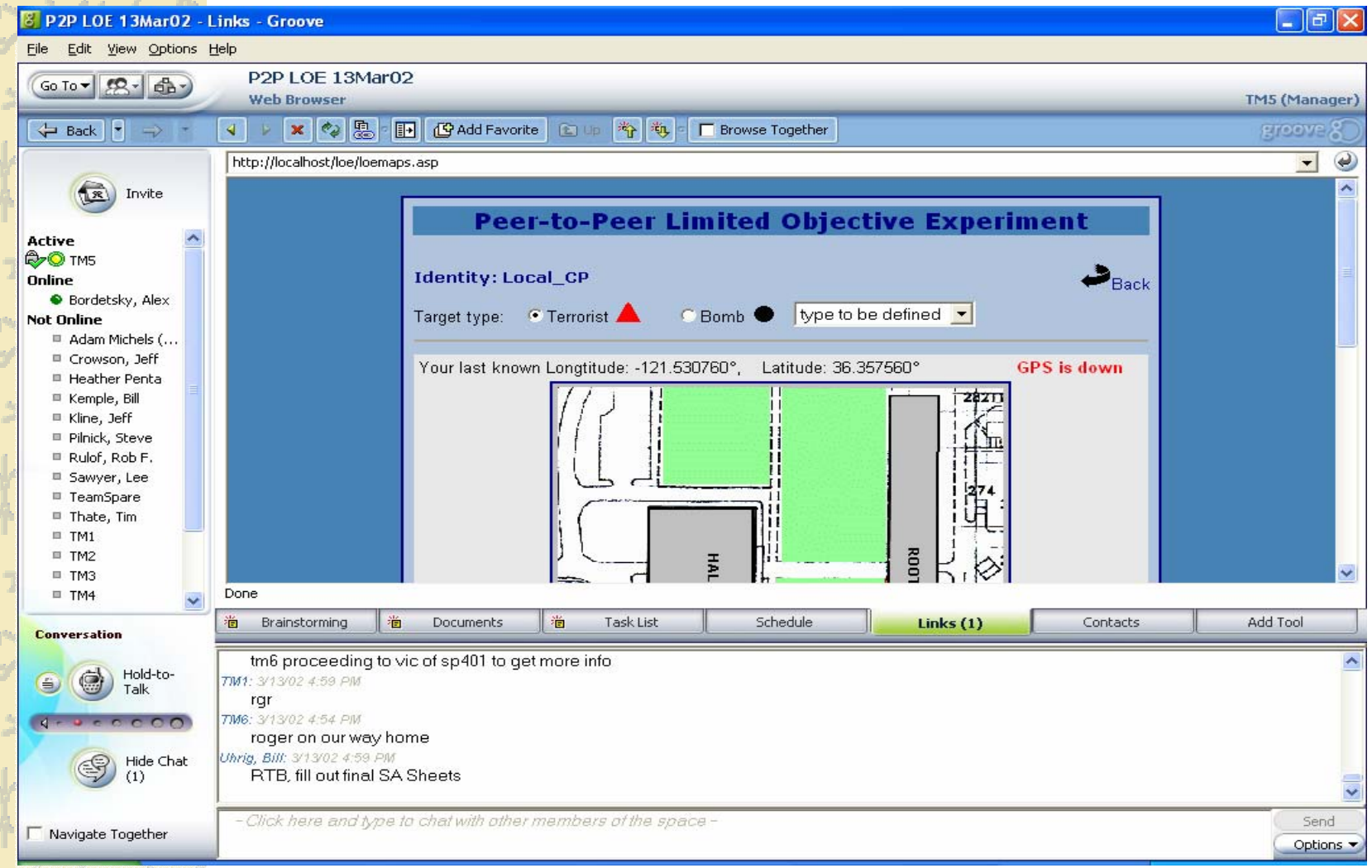
- Three limited objective experiments conducted at the Naval Postgraduate School (NPS), Monterey, CA, Camp Smith, Hawaii, and Camp Roberts, CA
- The first experiment was focused on providing initial data to evaluate the potential impact of using collaborative P2P technology in an urban warfare environment.
- The second experiment was conducted to evaluate the effects of sharing network awareness and common operational picture on the tactical level humanitarian operations.
- The third experiment, STAN-6, was conducted at Camp Roberts, CA, to evaluate tactical sensor-decision maker collaboration and self-organizing capability in the environment of unmanned (UAV, UGV, and AUV) networks
- We used DARPA CoABS agent services approach to evaluate the awareness sharing effects in P2P collaborative environment.

JFCOM Experiment on Peer-to-Peer Surveillance and Reconnaissance Collaborative Command and Control Environments

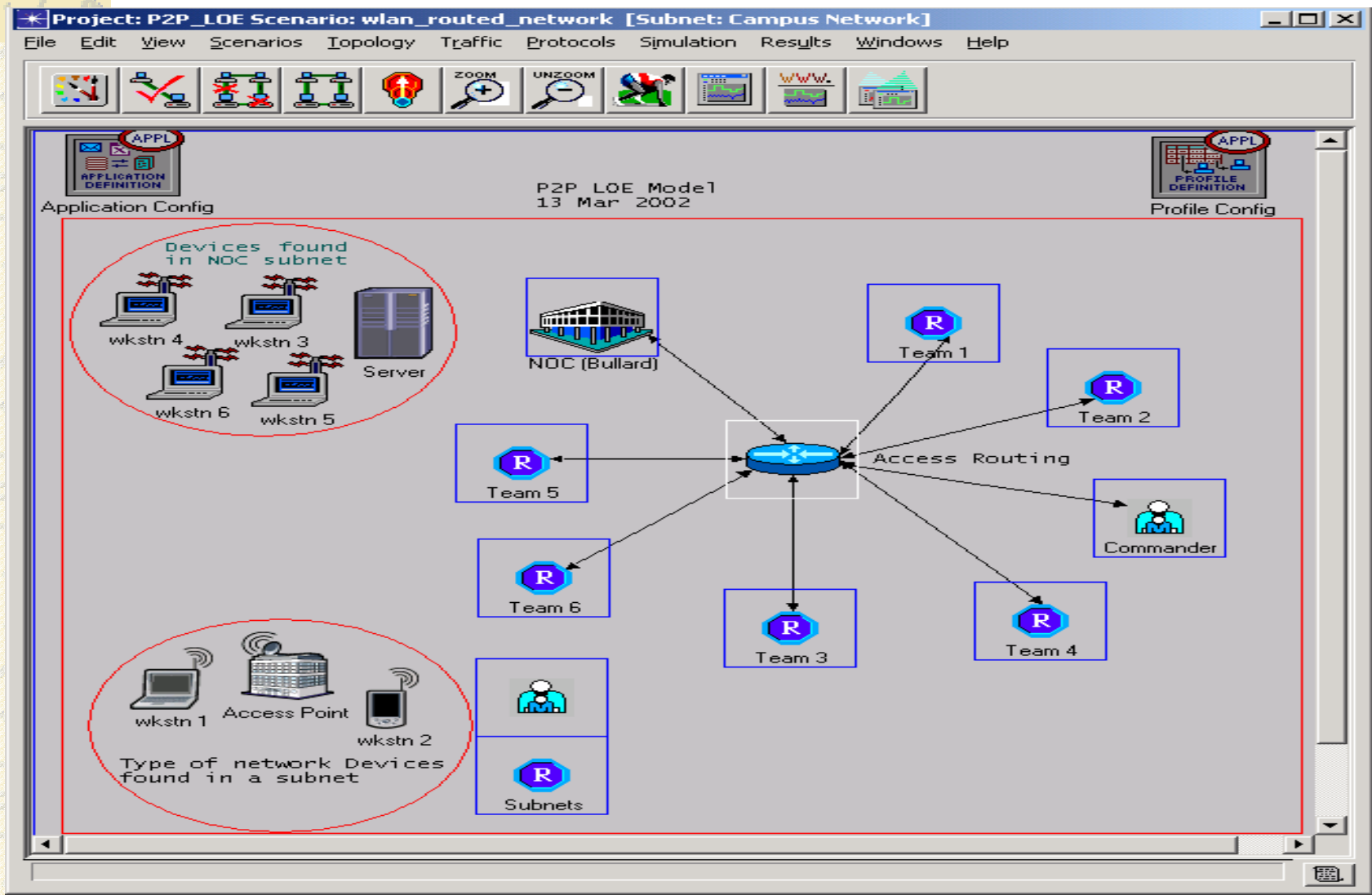
P2P Tactical Grid Nodes: Small Unit Members with PDAs

- Sharing Situational Awareness with Small Expeditionary Unit Members
- Enabling Adaptive Wireless Networking for Support of P2P Collaboration on rescue phase of S&R

P2P Collaboration via Groove: Maintaining Location Awareness Feedback to Small Unit Members

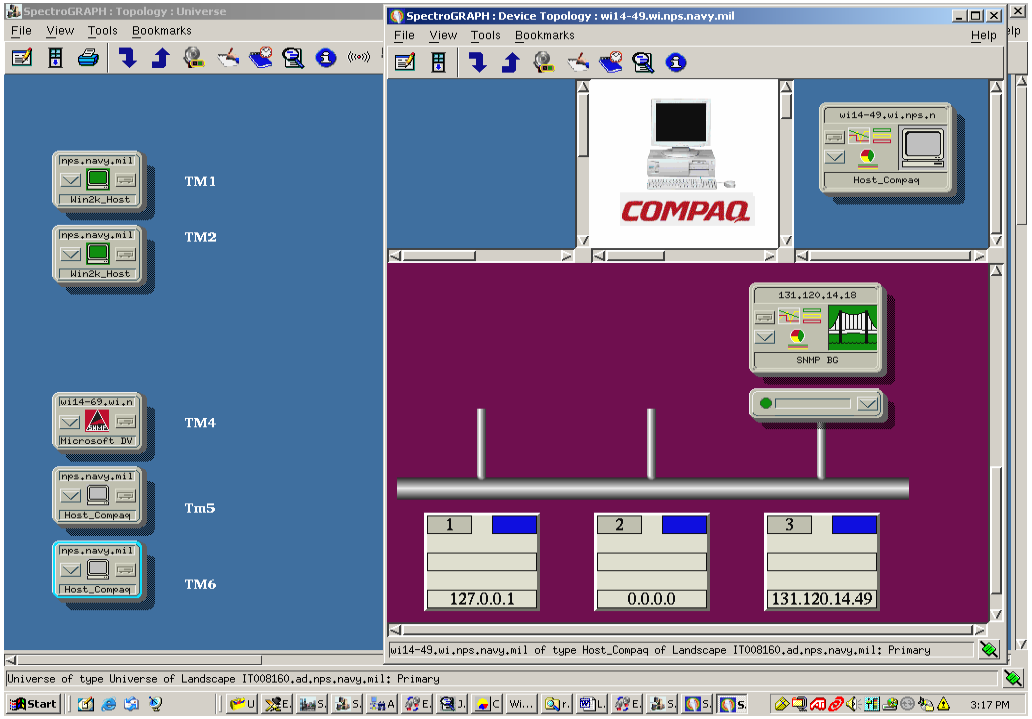


P2P Tactical Collaborative Environment Topology

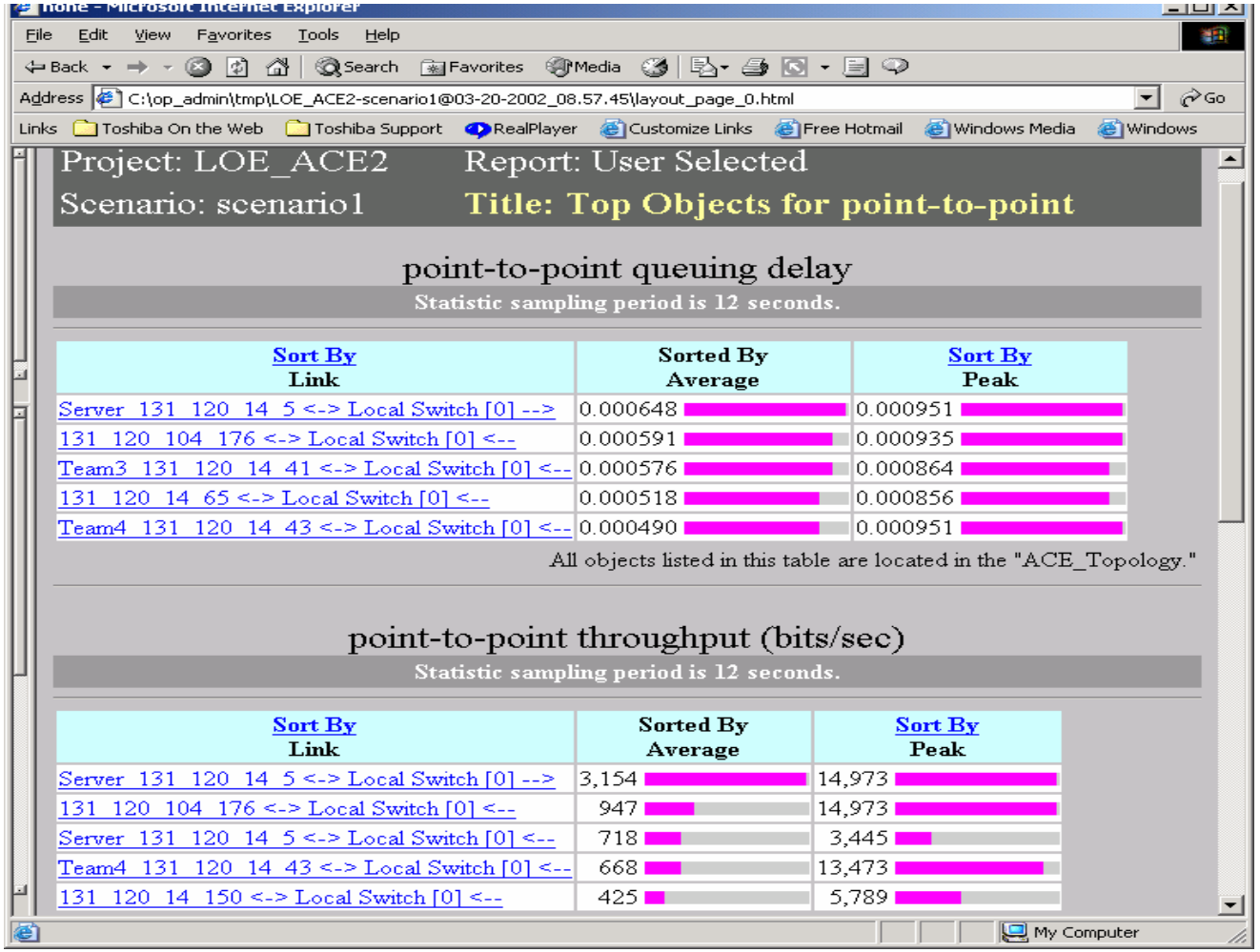


Tactical Operations Center View of P2P Collaborative Network

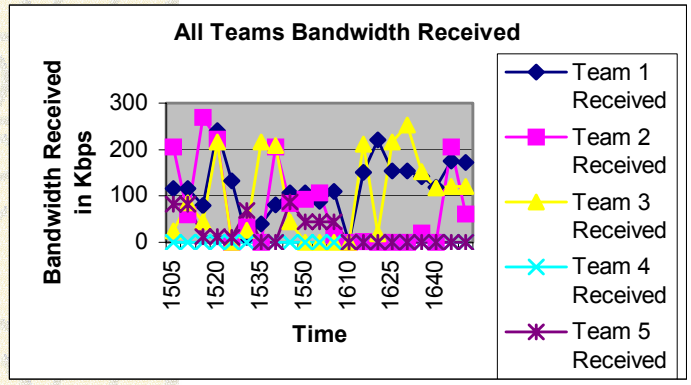
- Network Management System Snapshot of P2P Topology during the experiment
- TM1-TM5 are S&R team members mobile units

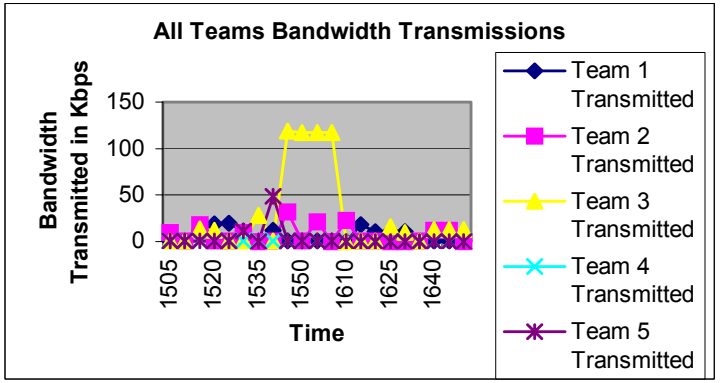


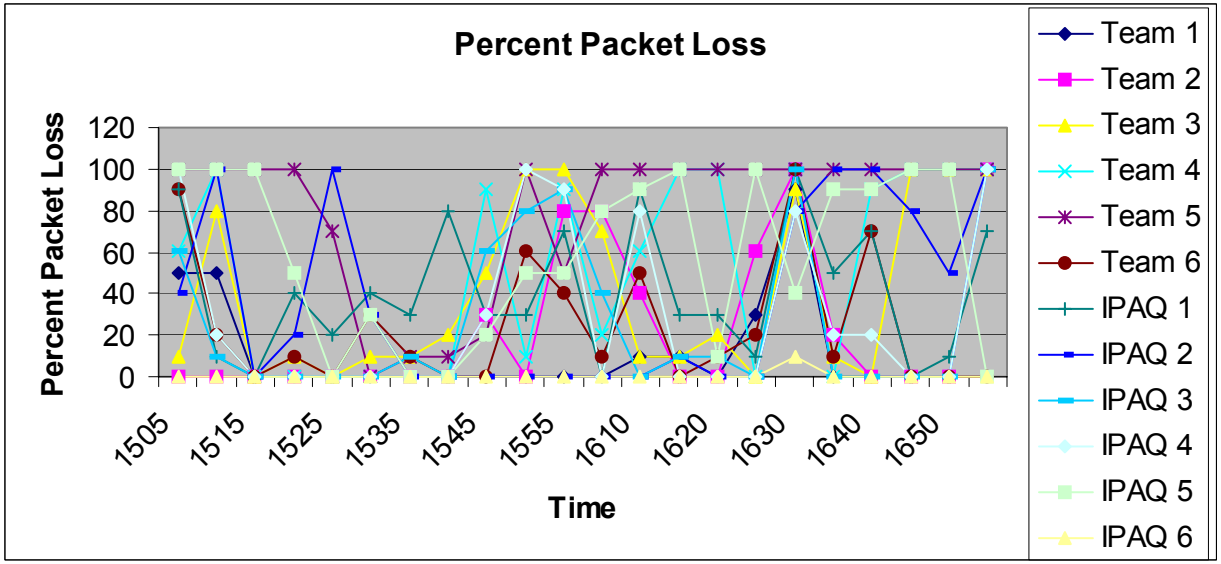
P2P Throughput Analysis



Monitoring bandwidth and packet loss: performance awareness feedback







First findings: challenges of sharing network performance awareness, making collaborating users aware of network behavior

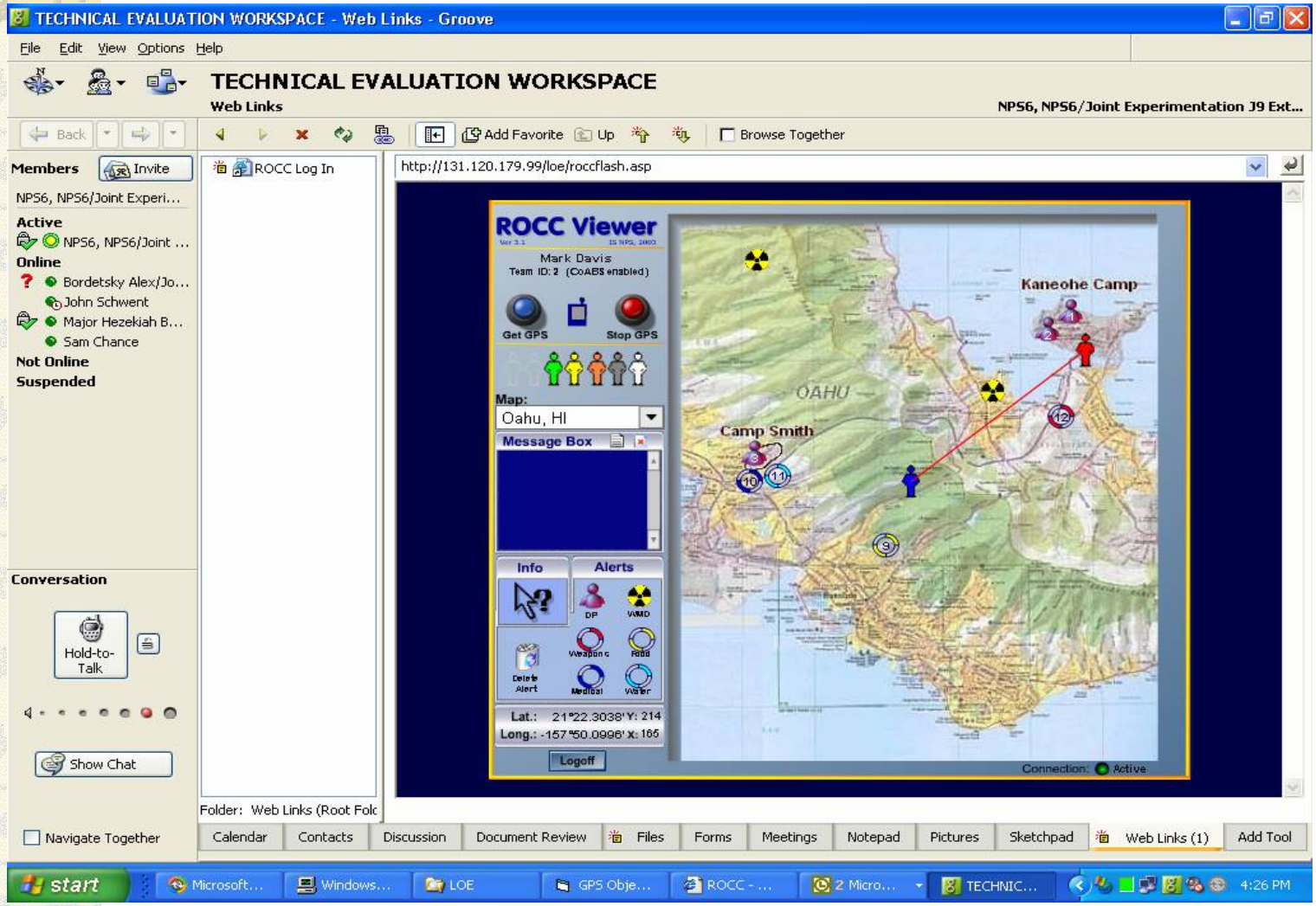
- Overwhelming multiple views on performance and configuration constraints
- Lack of time, bandwidth, and qualification to interpret network awareness data by mobile collaborating users
- Help in filtering and interpretation of network management data is needed

Establishing P2P Networking Facilitator

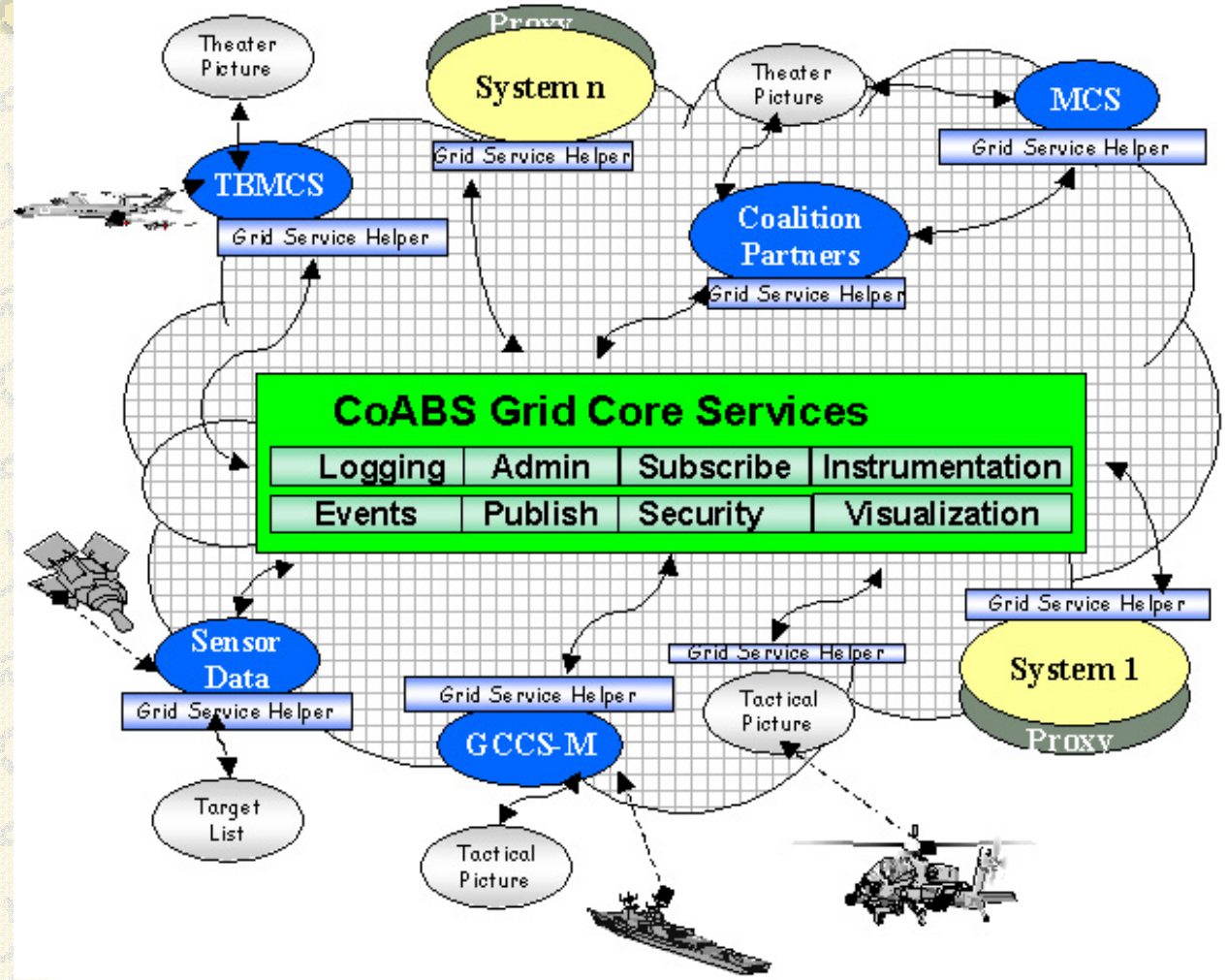
- ***We observed self-organizing behavior of R&S team members in switching the modes of communication***
- ***The strongest and unexpected effect of self – organizing behavior emerged on the Tactical Operation Center site: the P2P team created system Facilitator***
- ***Facilitator interpreted and shared in fly selected network performance data in order to synchronize the voice and data sharing calls between the team members***

PACOM Experiment: Humanitarian Operations

Tactical Grid Nodes: MEU Members Augmented by Situational Awareness Agents



Improving the P2P Collaborative Node Status Awareness via the Agent Representatives: DARPA CoABS Grid Model



Different Agent Service Models

- **DARPA CoABS Grid:** CoABS Grid Scalability
- Experiments (Kahn and Cicalese)
- **NASA KAoS:** Human-Agent Teamwork and Adjustable Autonomy in Practice (Sierhuis, et. al.)
- **NOMADS:** Toward an environment for strong and safe agent mobility (Suri, et.al.)
- **DARPA Cougaar** framework (http://www.cougaar.net),
- **CORBA** (http://www.omg.org), and
- **Voyager** (http://www.recursionsw. c o m / o s i . a s p)

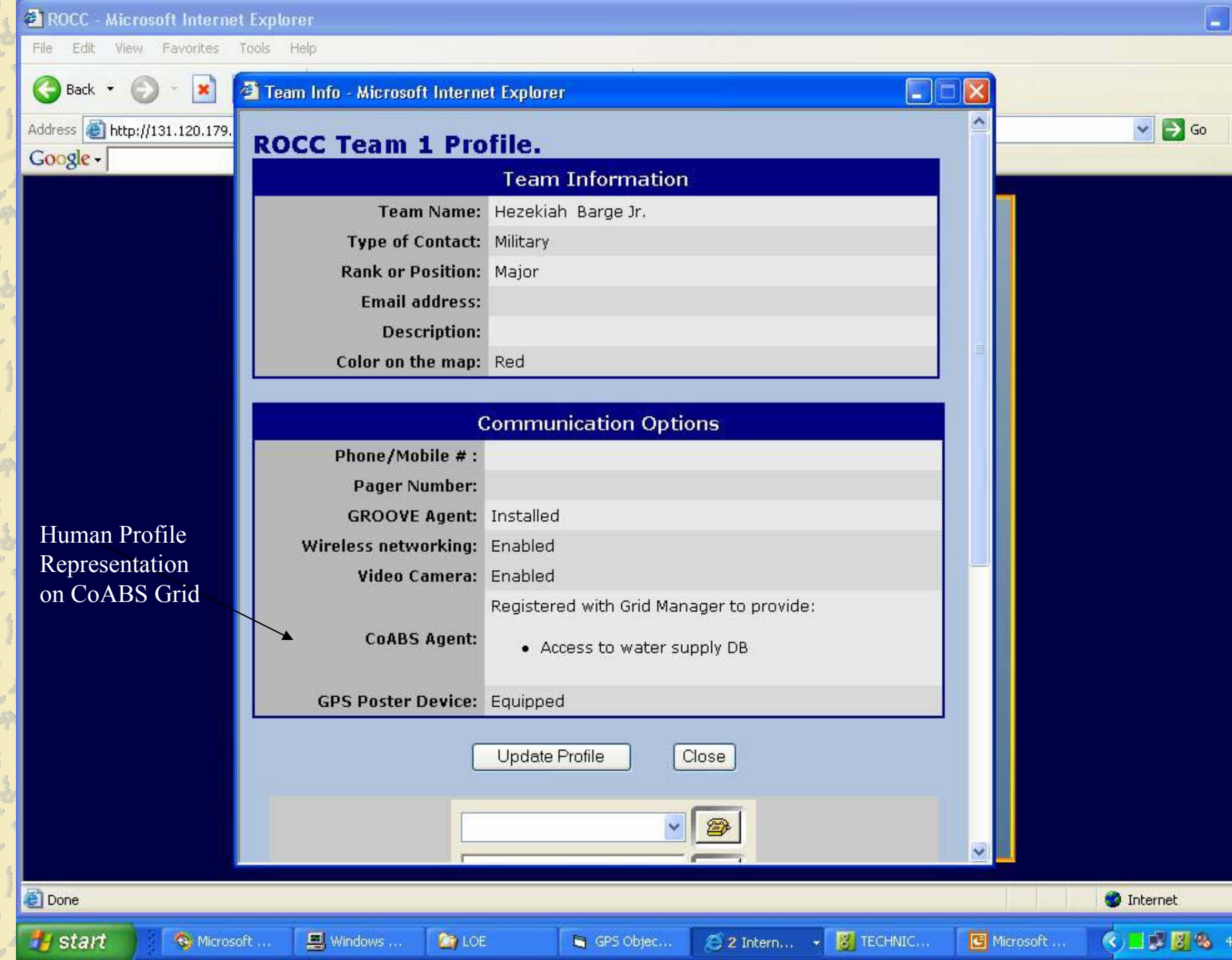
Application Awareness Solution Based on the CoABS Grid Model

Agent Representatives on the CoABS Grid

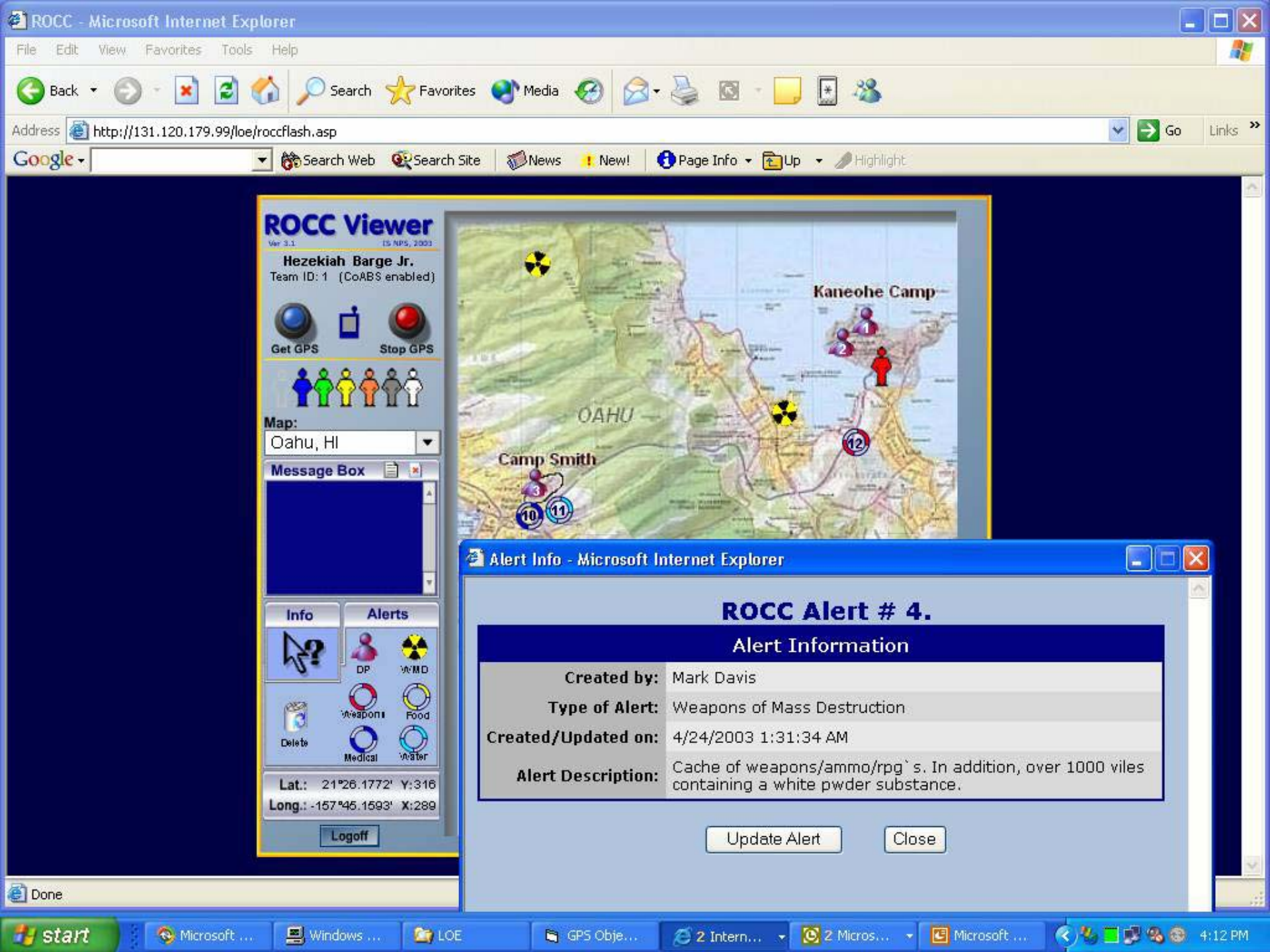
- CoABS Grid Representative for Human Operator Profile
- CoABS Grid Representative for GPS Tracking Agent
- CoABS Grid Representative for ISR Events
- CoABS Grid Representative for Text Messaging

Agent Wrappers Representing Remote Data Base and Expert Sources

- CoABS Wrapper for the remote Application Database
- CoABS Representative for the Expert Profile Management Agent



Human Profile Representation on CoABS Grid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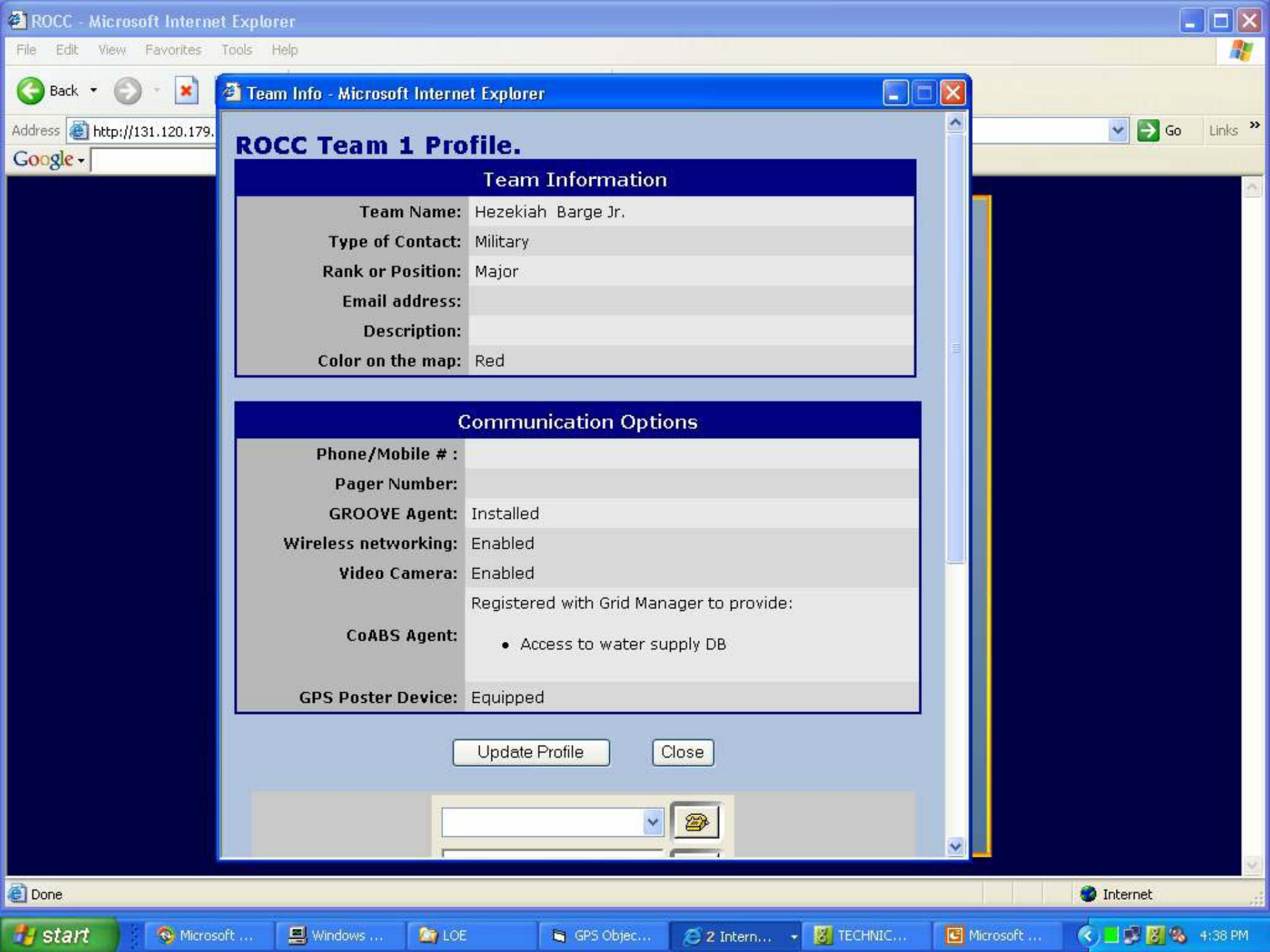
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Type of Contact: Military
Rank or Position: Major
Email address:
Description:
Color on the map: Red
Communication Options
Phone/Mobile # :
Pager Number:
GROOVE Agent: Installed
Wireless networking: Enabled
Video Camera: Enabled
CoABS Agent: Registered with Grid Manager to provide:
• Access to water supply DB
GPS Poster Device: Equipped
Update Profile
Close
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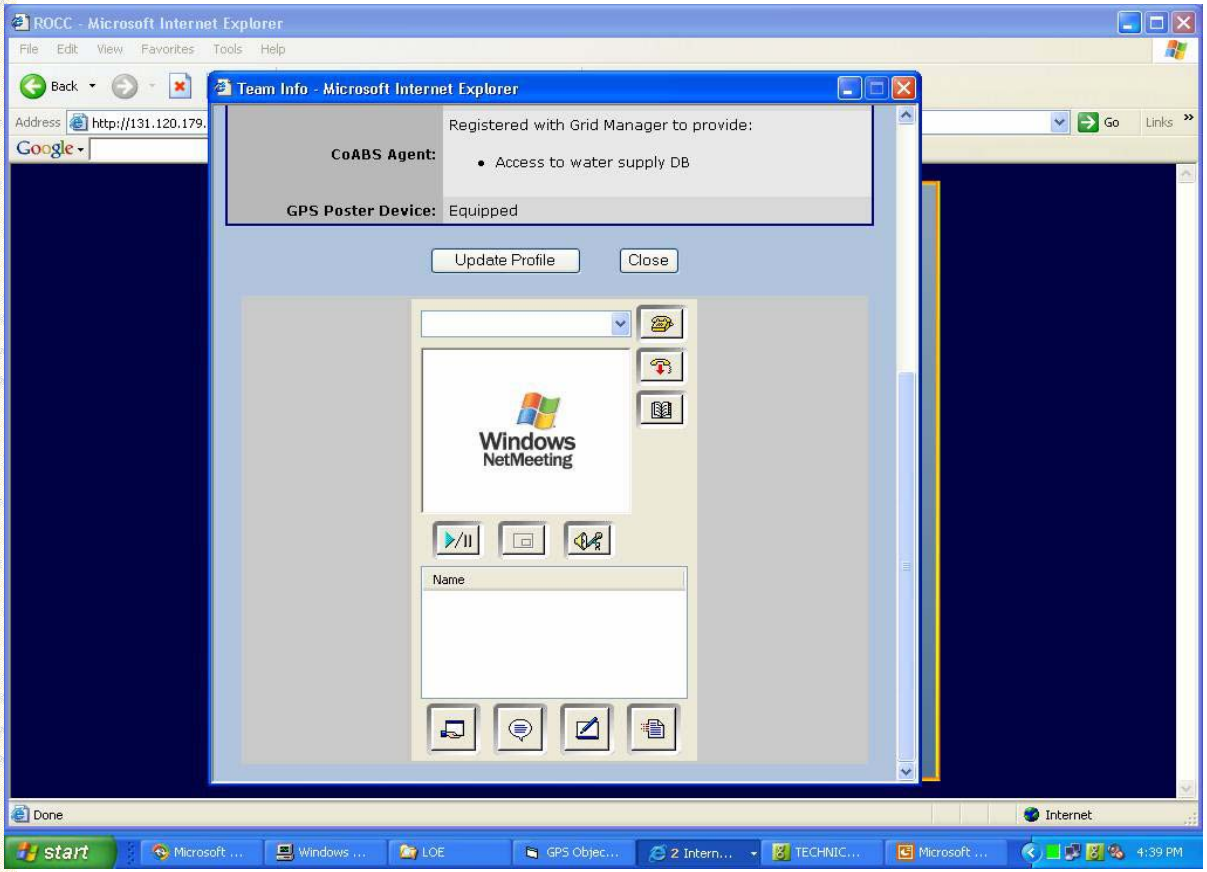
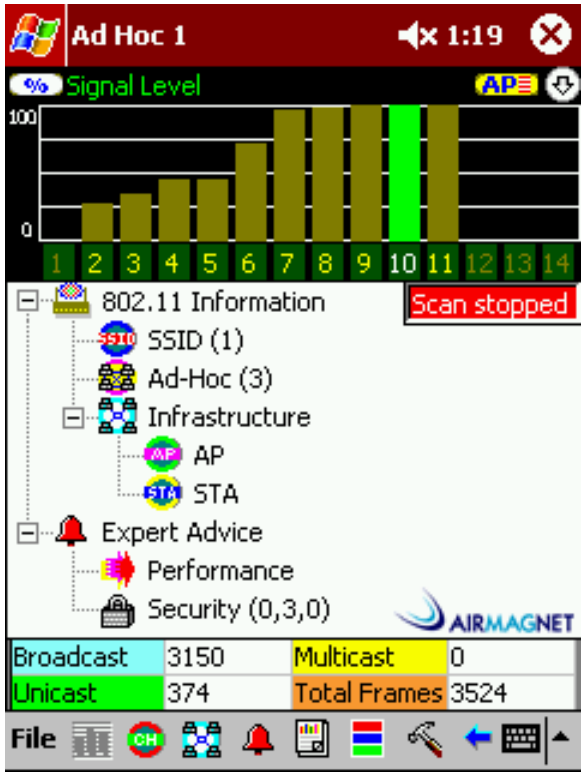
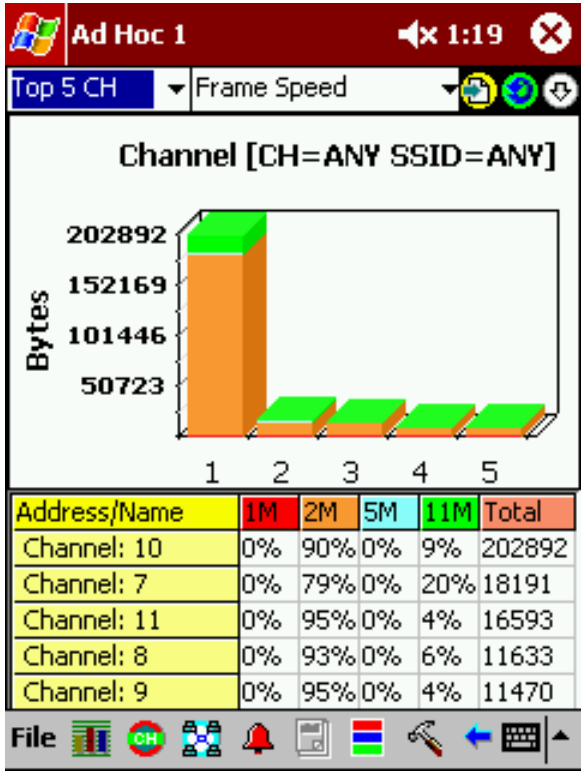
MEU member profile with embedded video access



Displaced Person Alert

Network Awareness Feedback: PDA View of Network Performance ("Micro NOC")





Findings: CoABS Model Success and NA Feedback Problems

- **Bandwidth management for P2P Groove clients**

  This issue appeared to be critical form of operational feedback to the team members. They frequently used "Micro NOC" feedback to identify the coverage and adjust their operations to the failing coverage.

- **Scalability through CoABS**

  The experiments proved scalability of CoABS multiagent platform for maintaining P2P collaborative awareness. The MEU members were able to seed and respond to multiple surveillance events using the grid agents

- **Problems with rapid understanding of network behavior**

  Interpretation of technical detail contained in the "Micro NOC" views appeared to be extremely inefficient, slowing down surveillance data sharing process. The network performance data should be filtered and delivered directly to the main Situational Awareness interface

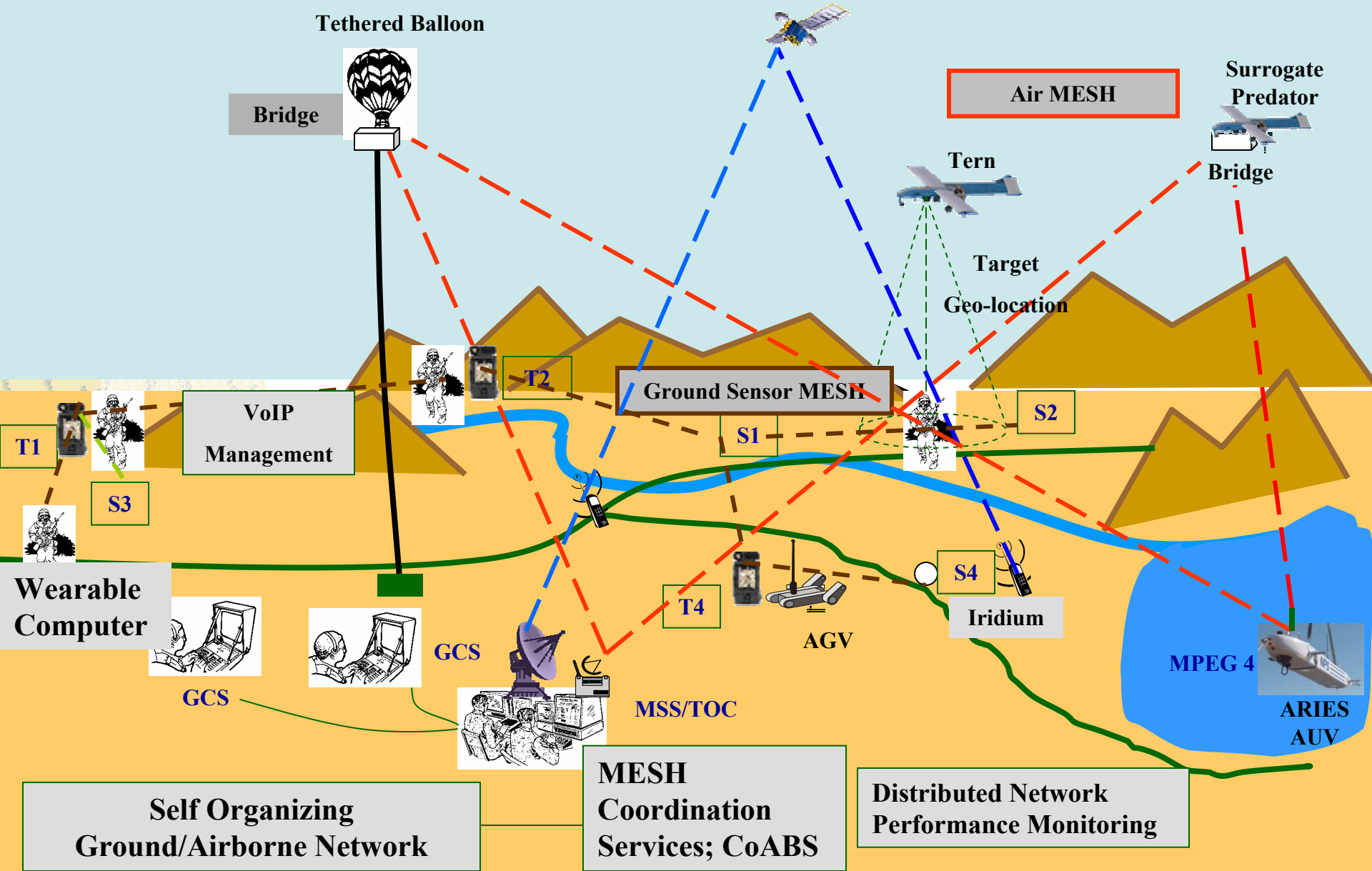
SOCOM Experiment: Sensor-UAV-Decision Maker Collaborative Grid

STAN: Surveillance and Target Acquisition Network

- Tactical Grid Collaborating Nodes: SOF unit operators, unattended ground sensors, UAVs, OFDM Towers, and TOC
- Long-haul terrestrial wireless (802.16) and airborne 802.11 data communications
- Multipath networking capabilities augmented by the Iridium satellite links
- Long-haul (30-100 mi) sensor/operator P2P mesh
- Ubiquitous video surveillance and shared SA

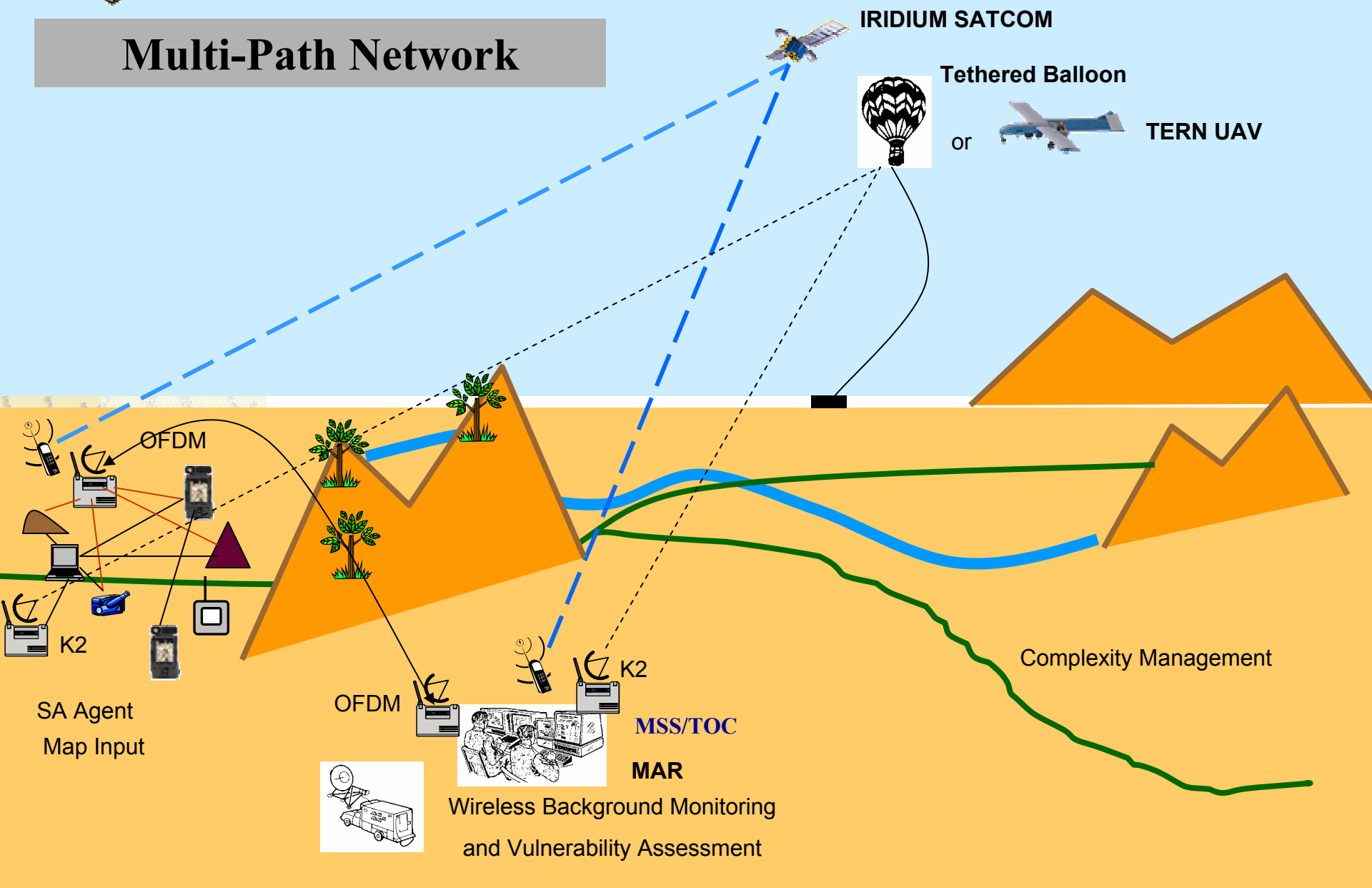
STAN 5 Feb. 04 Camp Roberts, CA

NPS with Contractor Team Support

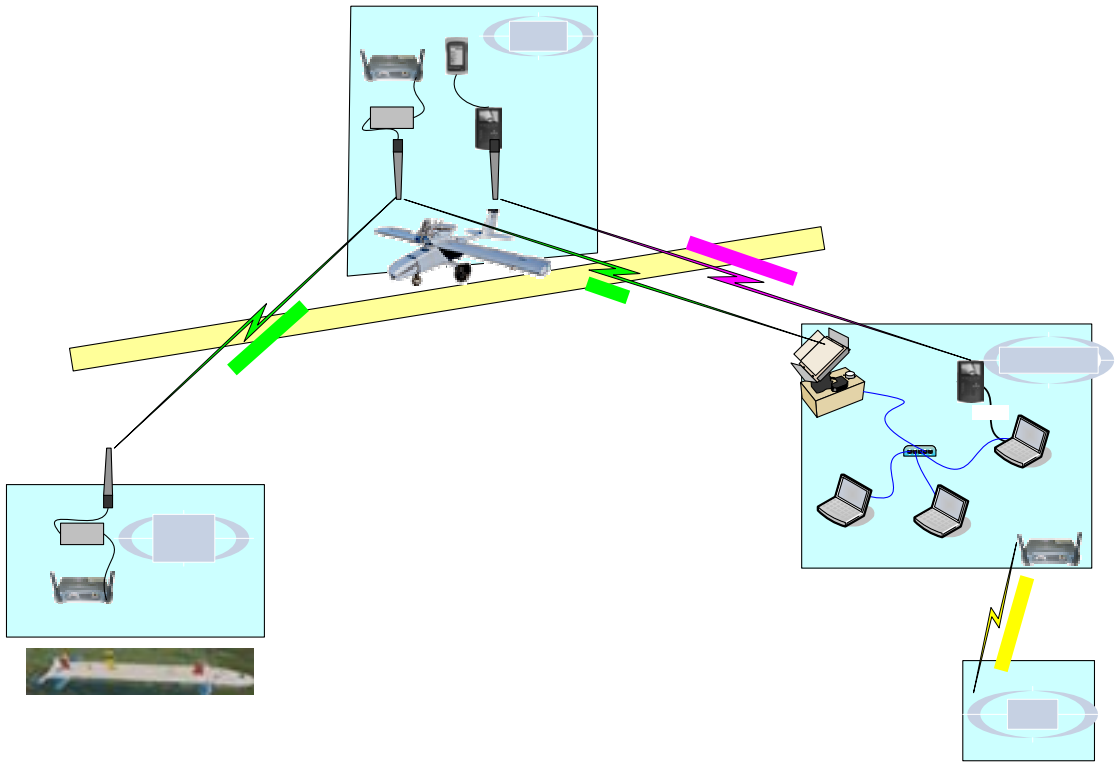


STAN 6 May 04 Camp Roberts, CA

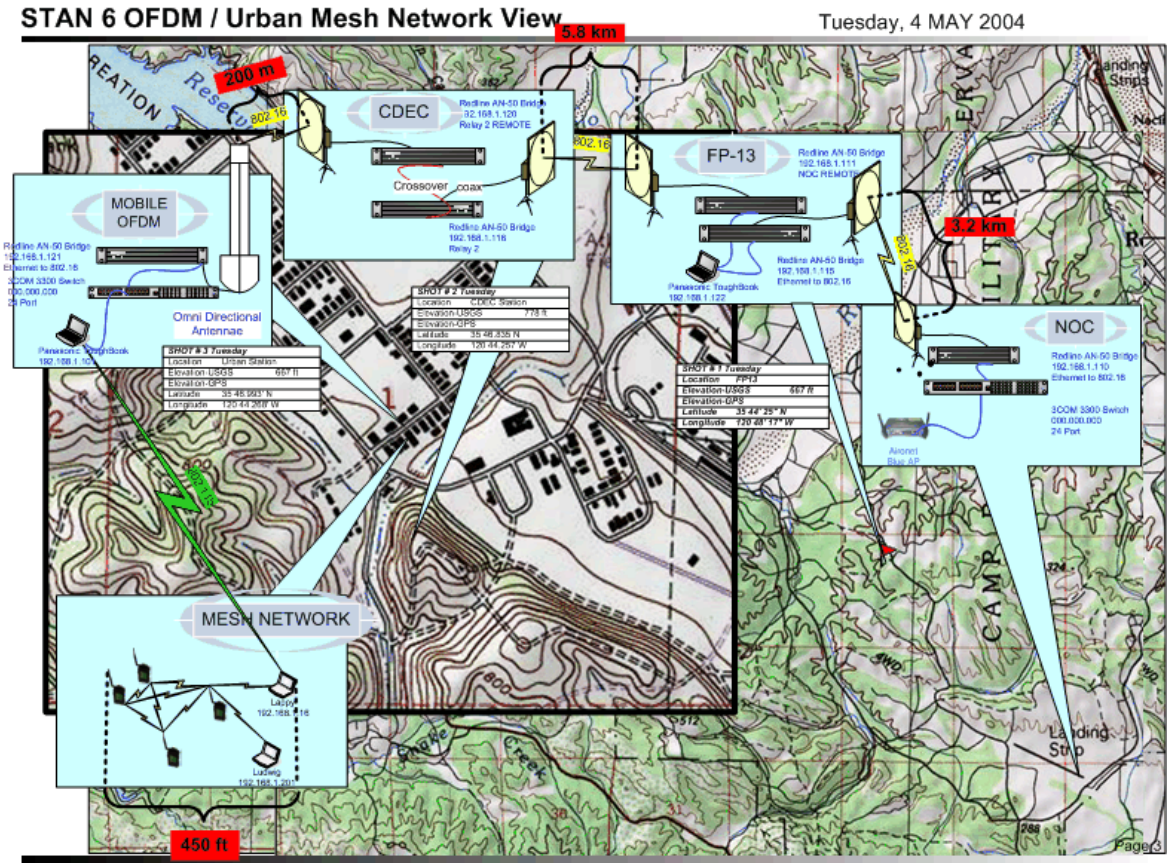
Multi-Path Network



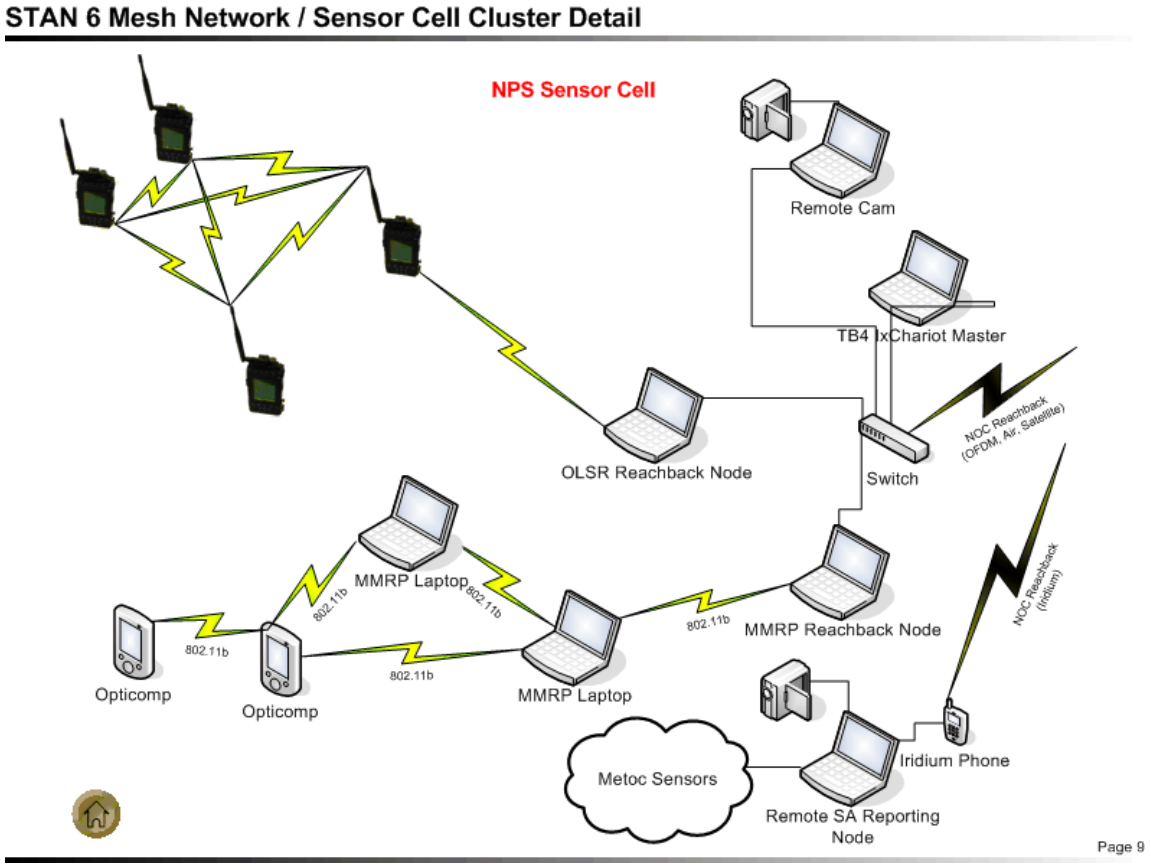
Networking with Unmanned Vehicles (designed by LCDR Axel Schumann, German Navy)



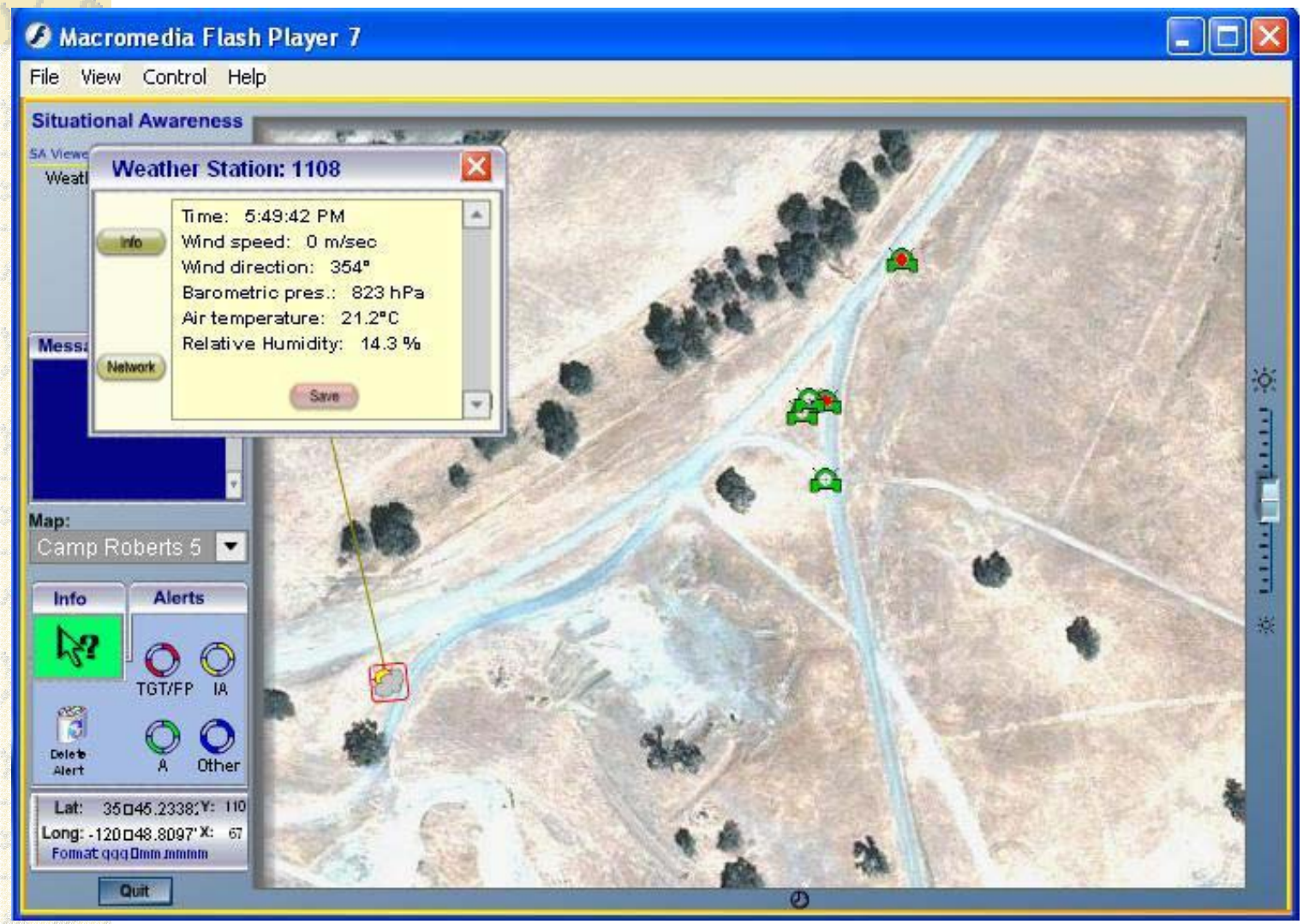
OFDM Components of Grid (designed by LT Ryan Blazevich)



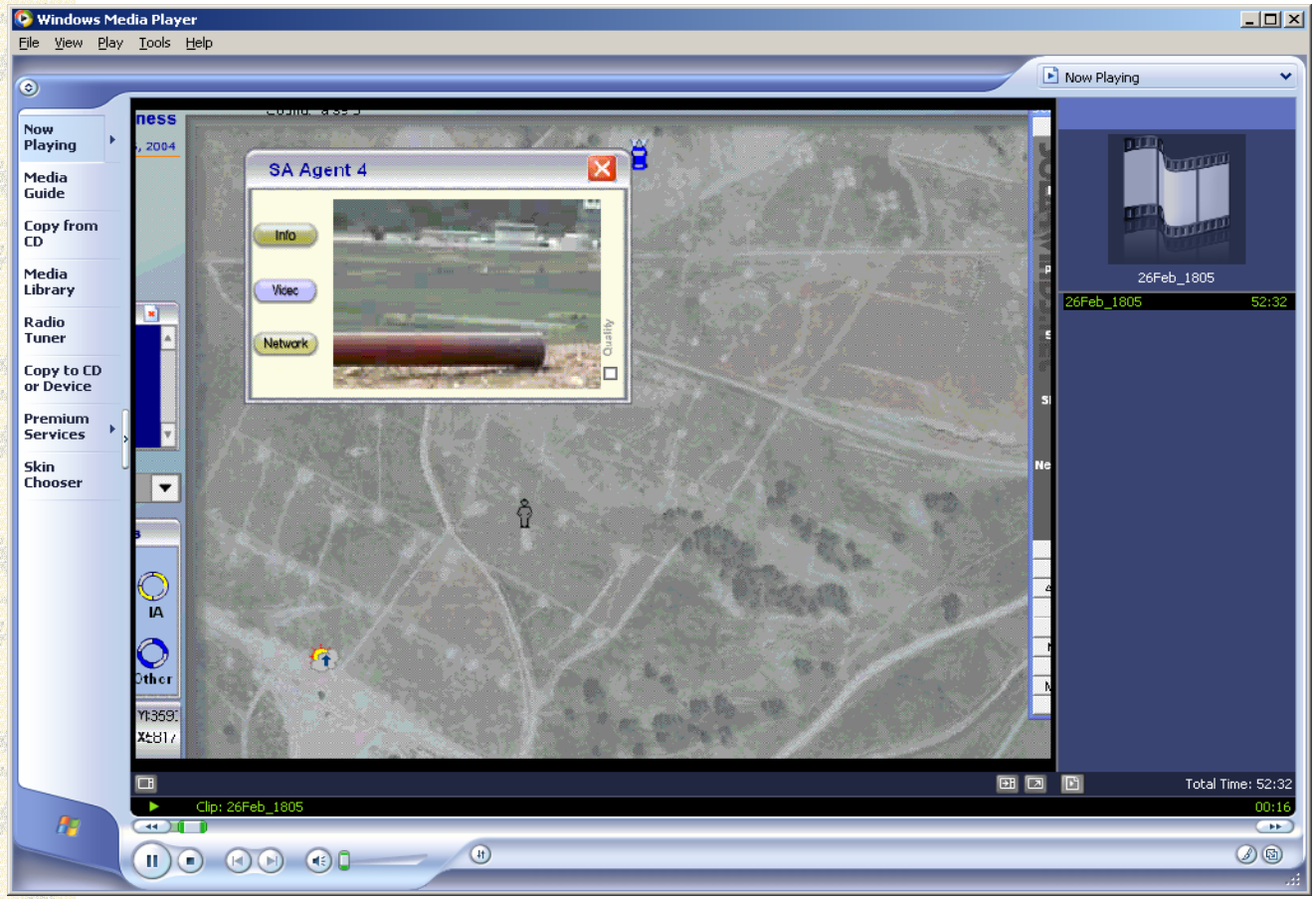
Sensor Cluster Mesh
(designed by LCDR Eric Bach)



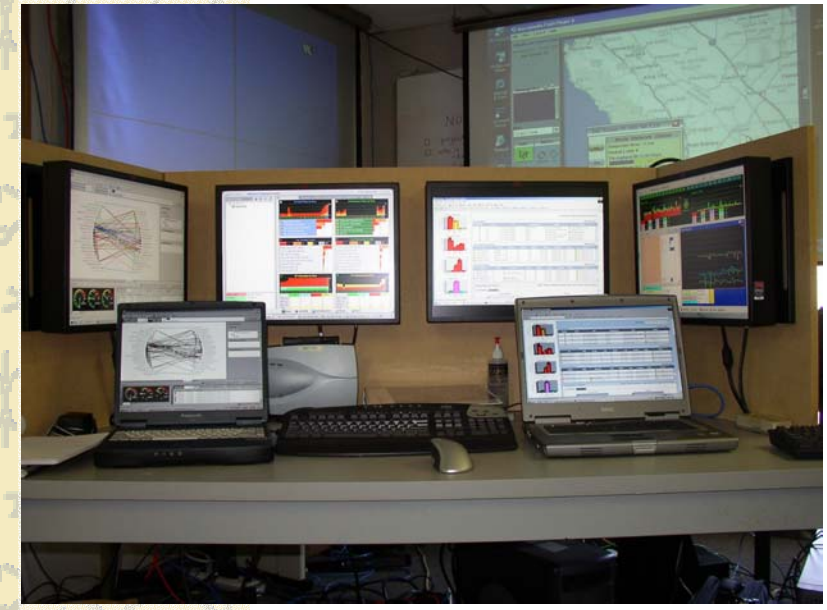
Shared SA screen with Weather Station agent reporting to the Grid



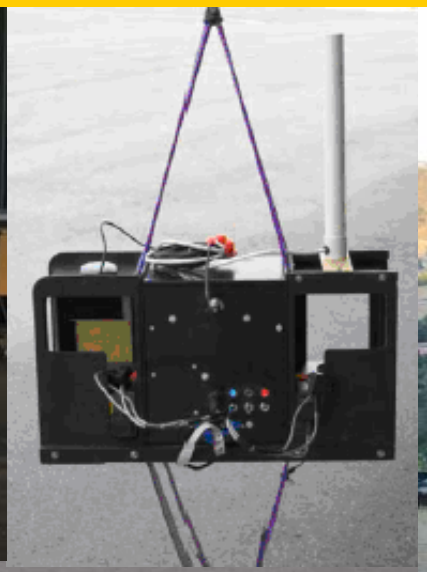
Situational Awareness with Video Sensor Agent reporting to the Grid



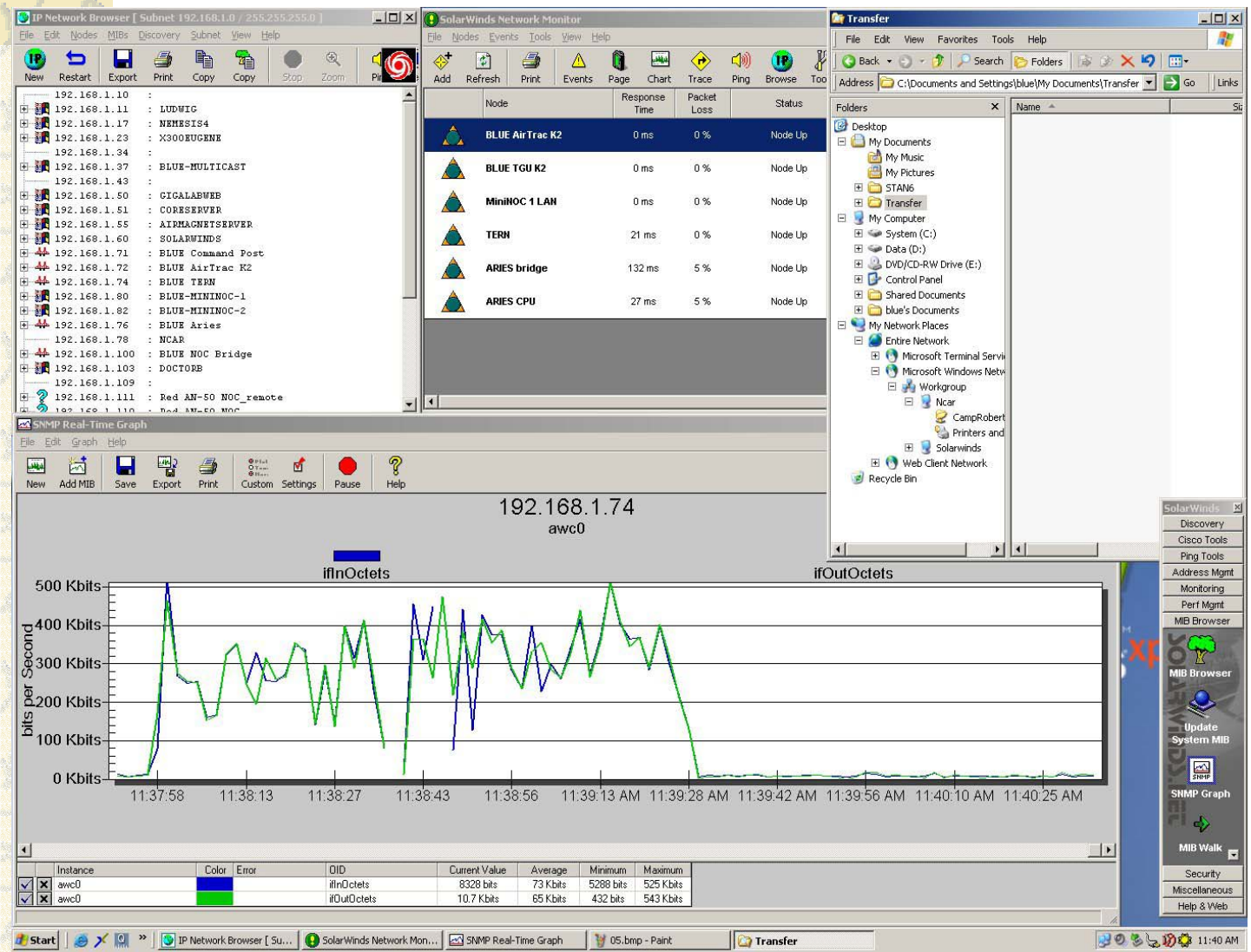
Grid NOC



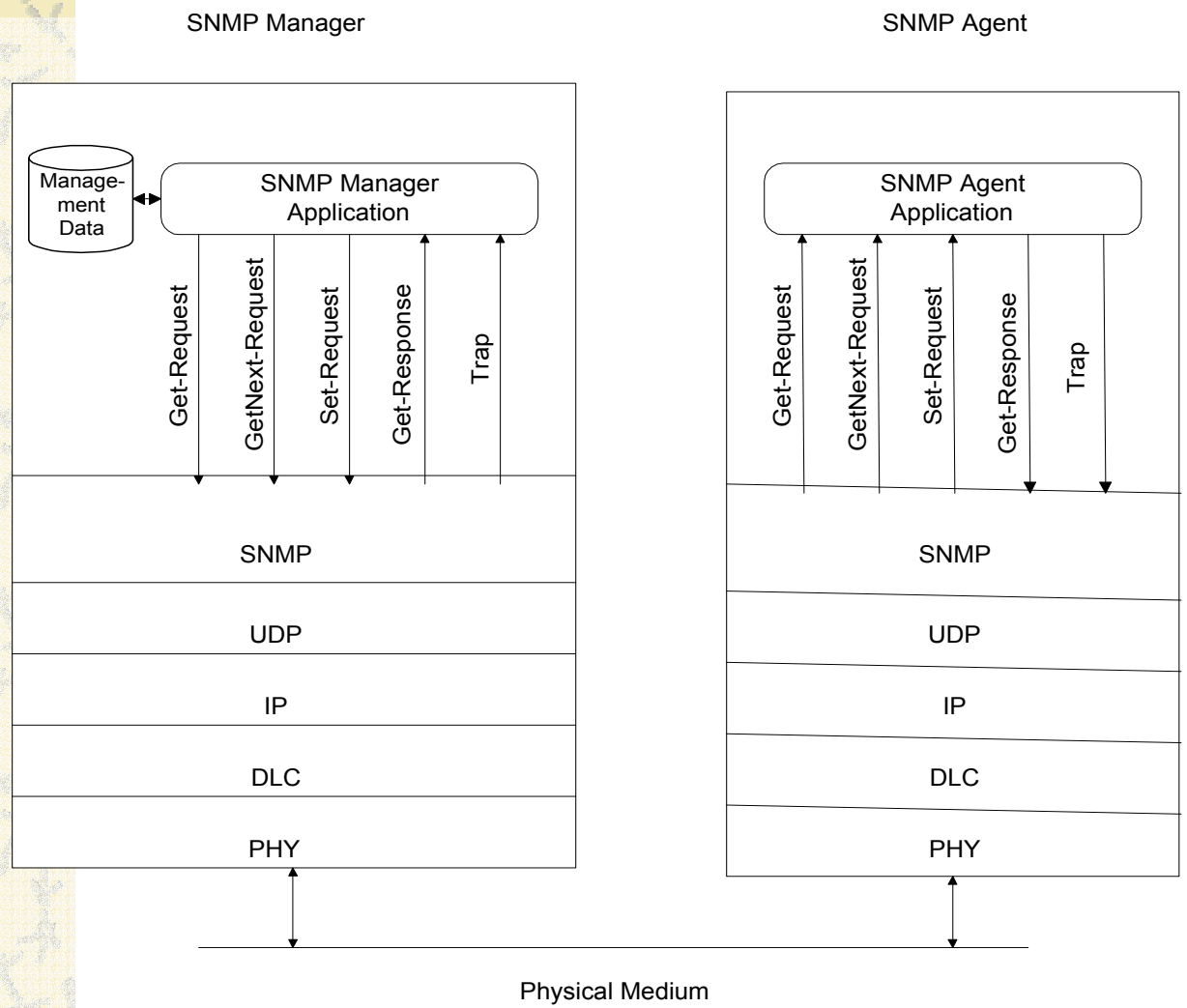
UAV Link Portable NOC



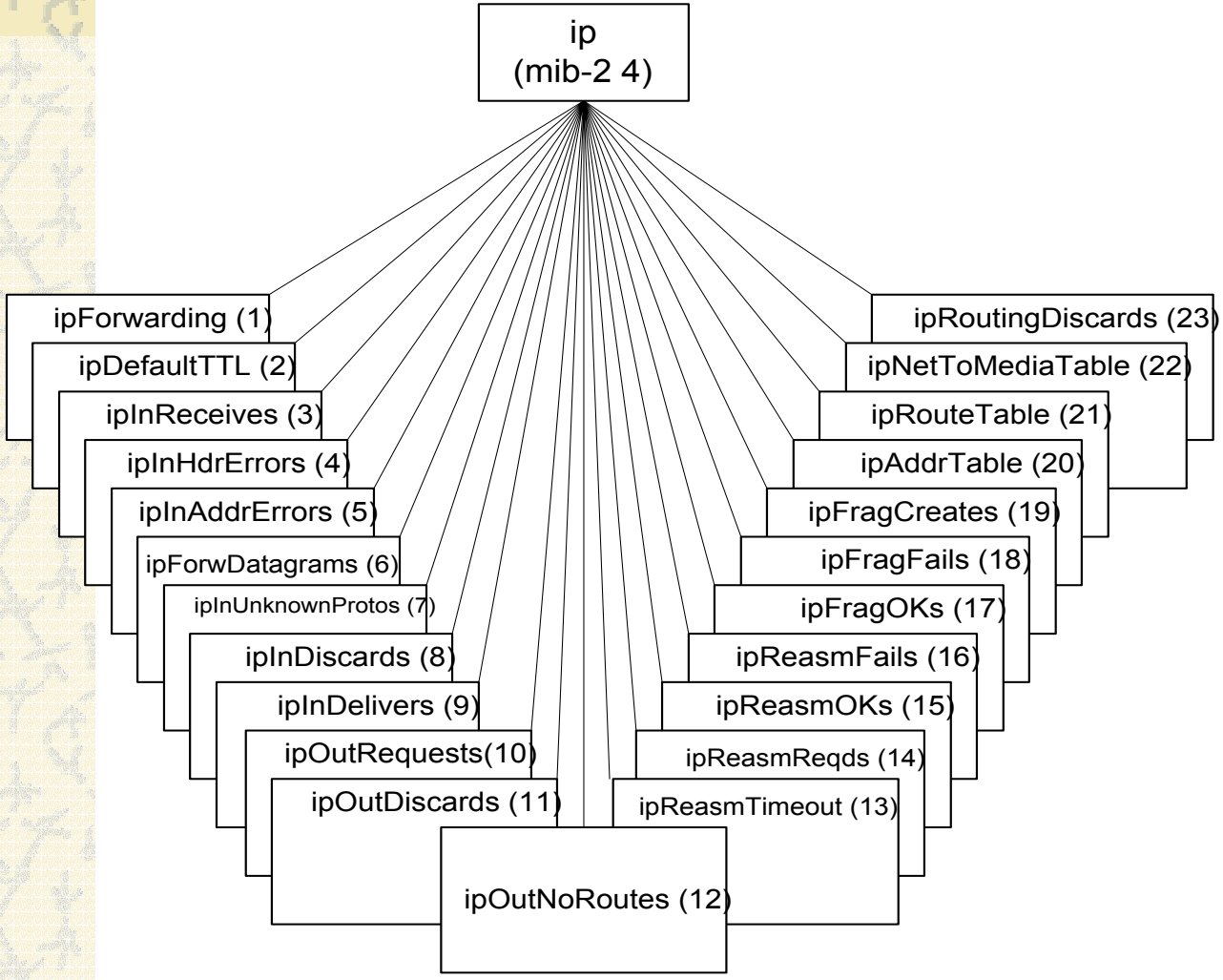
UAV Behavior as a Networking Node



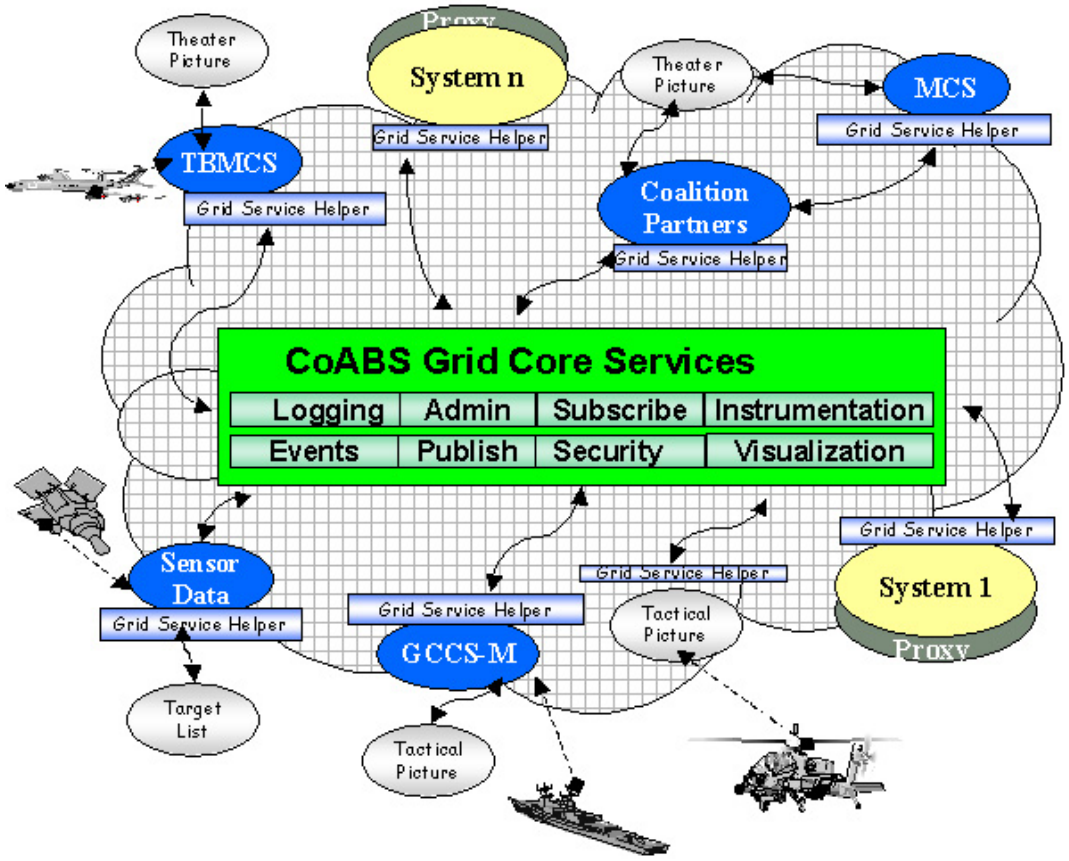
SNMP Agents for Network Mangement



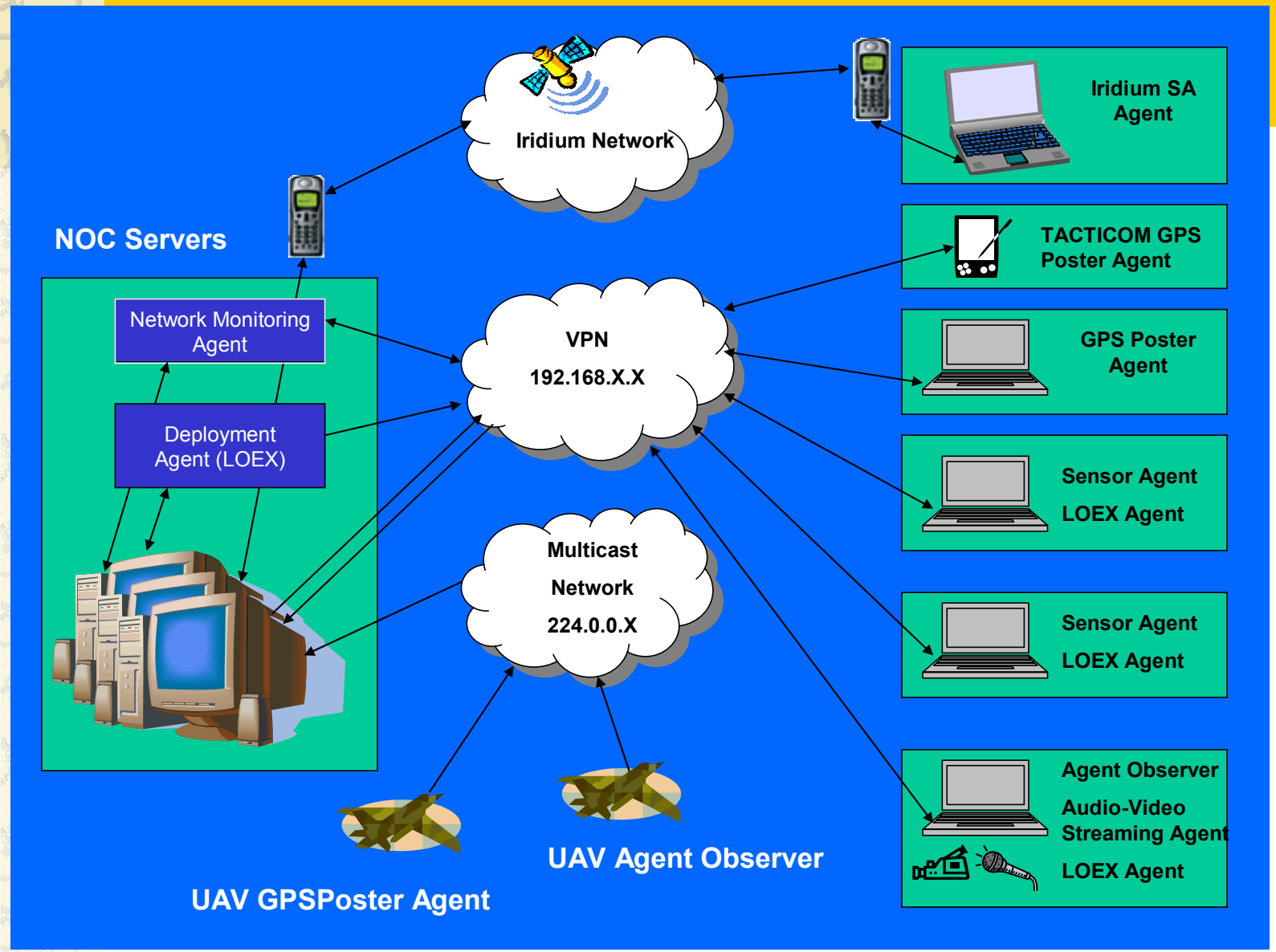
MIBs that SNMP agents manage:



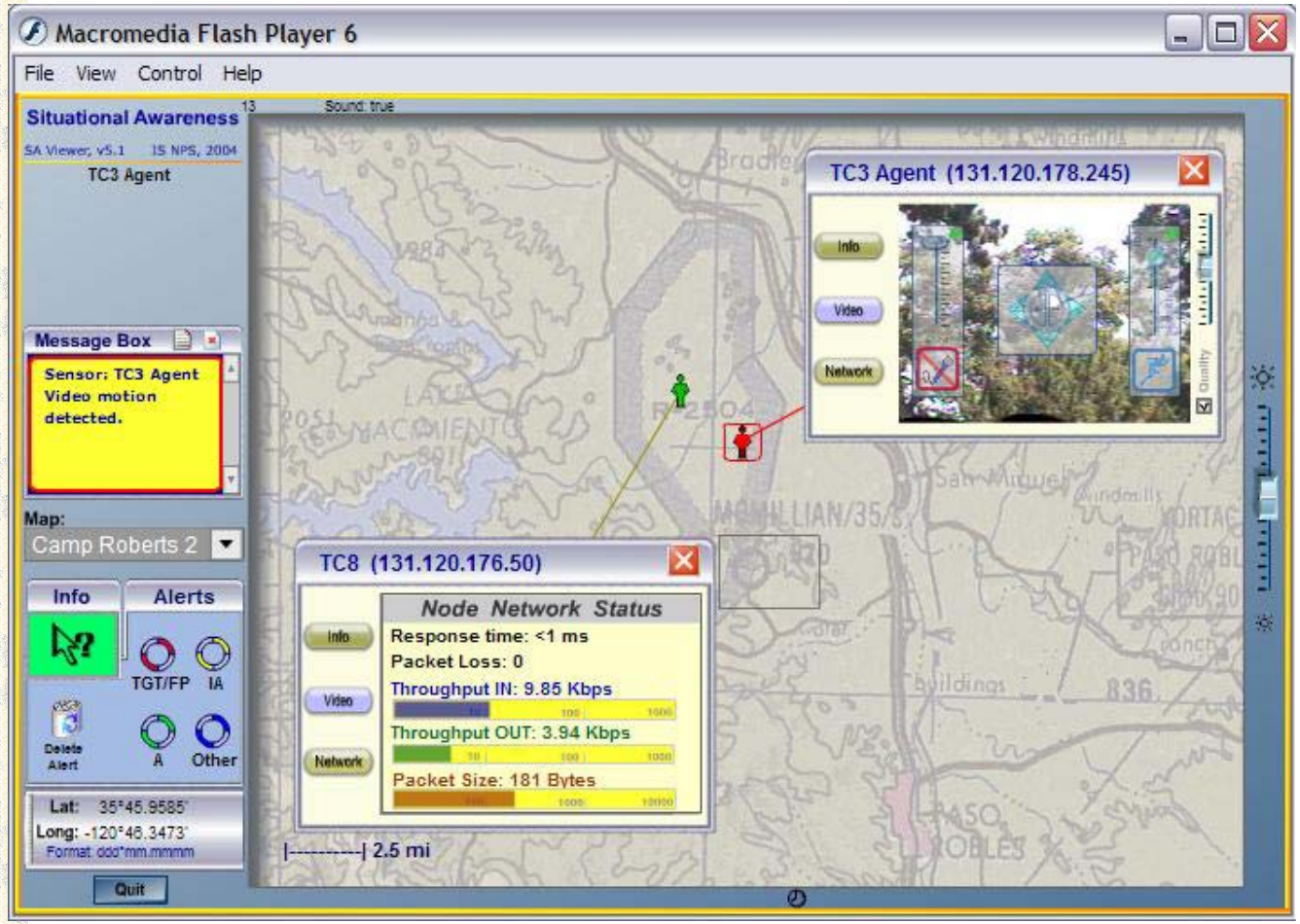
Network Awareness Solution: Extending SNMP communications to SA CoABS Services



STAN SNMP Agents Join the CoABS Services Environment



Combining Situational and Network Awareness in Grid Operation



Sensor SNMP Agents Reporting to SA Grid

Summary

- It is feasible to design network aware collaborative P2P nodes based on the SNMP agents integration with SA CoABS middleware
- The current model is limited by human-in-the-loop solution
- To further automate self-organizing behavior of ISR sensor-DM grid QoS multiple criteria policies for agents are needed
- New level of awareness could be achieved by adding the human-centric solution: collaboration of TOC, vehicle NOC, UAV link NOC, man-portable NOC, etc

Questions?