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Topic: TNT Maritime Interdiction Operation Experiments: Enabling Radiation Awareness and Geographically Distributed Collaboration for Network-Centric Maritime Interdiction Operations

Authors:

Dr. Alex Bordetsky
Naval Postgraduate School

Dr. Arden Dougan
Lawrence Livermore National Laboratory

Dr. Foo You Chiann
DSTA, Singapore

CDR. Andres Kilberg
Swedish Naval Warfare Center

Abstract

The paper addresses technological and operational challenges of developing a global plug-and-play Maritime Domain Security testbed. This joint NPS-LLNL project, supported by partners from Sweden, Austria, and Singapore is based on the NPS Tactical Network Topology (TNT) comprised of long-haul OFDM networks combined with self-

forming wireless mesh links to radiation detection sensors, and real-time radiation awareness collaboration with geographically distributed partners. In the center of our discussion are networking, sensor, and collaborative solutions for the Maritime Interdiction Operation (MIO) Experiments in which geographically distributed command centers and subject matter experts collaborate with the Boarding Party in real time to facilitate situational understanding and course of action selection. The most recent experiment conducted in the San Francisco Bay jointly with partners from Sweden, Singapore, and Austria proved feasibility and good potential of the proposed key technologies aimed at improving MIO.

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In our discussion of TNT MIO Experiments, Dr. Alex Bordetsky presents TNT MIO Testbed, ship-to-shore and ship-to-ship networking solutions and collaborative technology for net-centric MIO.

Dr. Arden Dougan discusses experiences using radiation detection and explosives detection sensors during the experiments and the associated reachback from technical experts.

Dr. Foo Yu Chiann elaborates on the TNT MIO node in Singapore and its role in the experiment….

Singapore participated in the Experiment through a Virtual Private Network (VPN) connection established between the Defence Science and Technology Agency (DSTA) and NPS. Singapore not only observed the Experiment but also provided injects in the role of the shipping company that had unknowingly transported the radioactive cargo as part of its shipment.

Cdr. Anders Kilhberg elaborates on the TNT MIO testbed node in Southern Sweden and, it's role and the plans for unfolding collaboration with SNWC.

Swedish Naval Warfare Centre (SNWC) has participated in the TNT experiments since TNT 06-2 both as observers and as collaborators. Sweden participates through a Virtual Private Network (VPN) connection with is established at the Naval Warfare Centre in Karlskrona in the southern part of Sweden. Sweden acts as a counterpart Maritime Security Organization (MSO) and will conduct Maritime Interdiction Operation (MIO) within the Baltic Sea. SNWC provides injects and live video feed into the network. Radiation data is posted in the collaboration tool for reachback organization to analyze. The long running aim with Sweden's participation in the TNT MIO testbed is to have a full scale, 2 day, experiment during fall 2008 under the heading "Wireless Broadband supporting Maritime Security in Littoral Waters". The aim with this experiment will be to set up an ad hoc network in an area in the Baltic sea supporting cooperation between the military and civil authorities (e.g. police, coast guard) solving attempt to smuggling (e.g. CBRN, people). To reach that goal Sweden will use the experiments as stepstones to try to fulfill that goal. For the next experiment in this series 07-2, we will try to test a CBRN sensor and communication jacket (prototype) and try to hoc it up on the network.

1. Introduction

Since 2004 a joint team of Naval Postgraduate School and Lawrence Livermore National Laboratory researchers is operating a plug-and-play testbed, which enables discovery, integration, and demonstration experiments for a broad range of Maritime Interdiction Operation scenarios including mesh and long-haul wireless networking with radiation detection sensors, boarding party collaboration with remote expert teams, reachback to different locations around the globe.

The operational focus of NPS-LLNL experiments is on finding viable solutions for MIO connectivity and collaboration providing for rapid radiation awareness, biometrics identification, non-proliferation machinery parts search , and explosive materials detection on the board of the target vessel during the boarding party search phase

The testbed contains a tactical, OFDM 802.16 backbone, terminating in various locations within the 200 mi length in Northern California (Fig. 1), which provides for the ad hoc plug-in of UAVs, boats, ships, small SOF and Marine units, including airborne and ground self-forming mesh communications. It contains an expanding set of domestic and overseas remote command and tactical centers with global reach back capabilities and rapidly deployable self-forming wireless clusters (including student network operation services 24/7). The Maritime component being developed jointly with the Lawrence Livermore National Laboratory extends the testbed capabilities to ship-to-shore, ship-to-ship, ship-UAV (Unmanned Aerial Vehicle)-ship, ship-USV (Unmanned Surface Vehicle)-ship, and ship-AUV (Autonomous Underwater Vehicle), sensor mesh mobile networks (Fig. 2).

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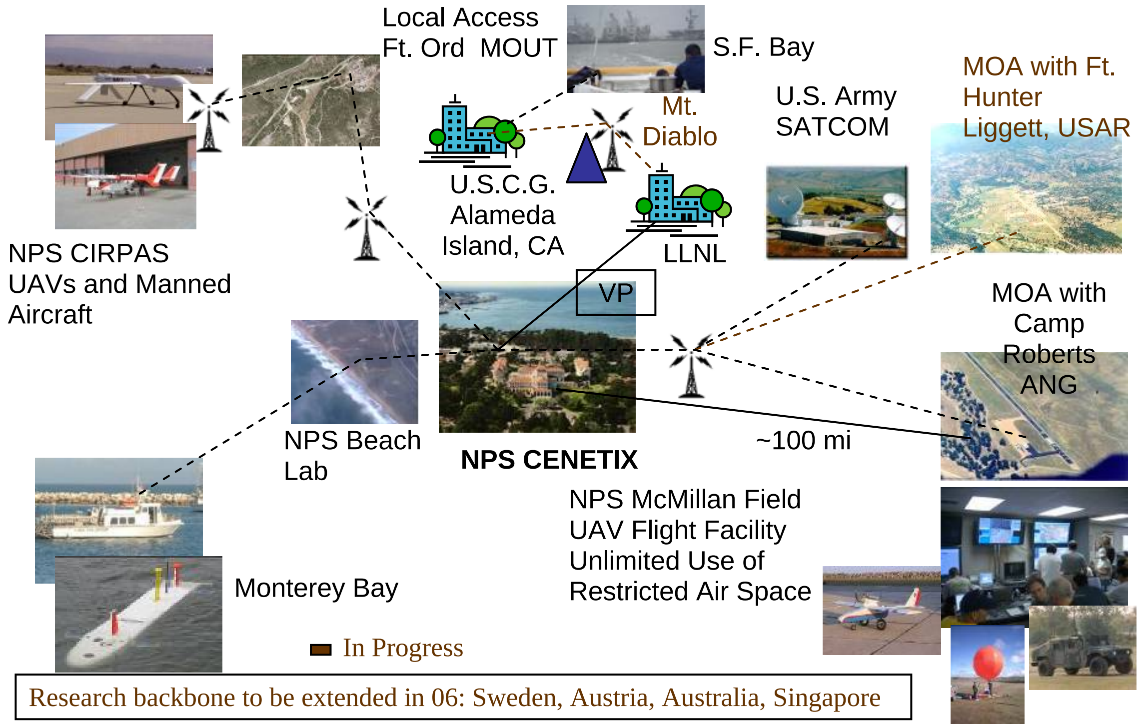

Figure1. Plug-and-Play TNT MIO Networking Testbed

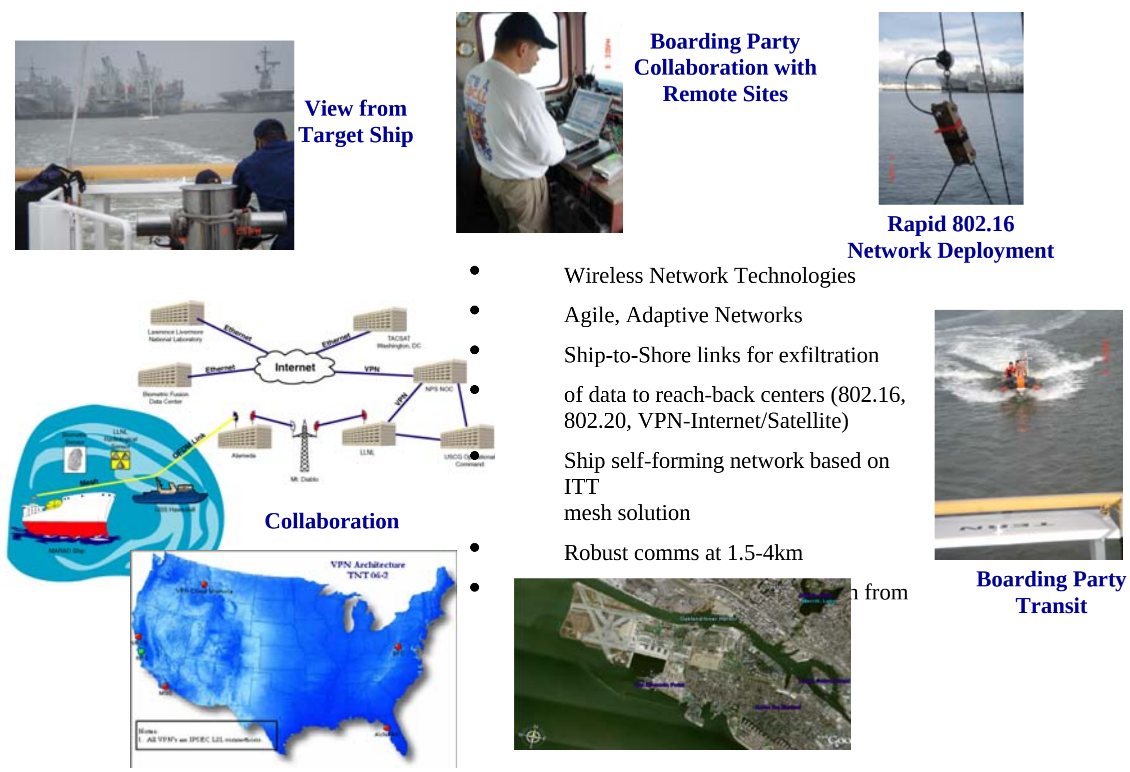

Figure 2. Testbed in Action During the MIO 06-2 Experiment

2. Typical Scenario for Maritime Radiation Awareness and Interdiction Experiments

Over the course of 6 consecutive discovery and demonstration experiments the MIO scenario evolved into script which employs coordinated actions of multiple agencies and institutions involved in homeland security operations and especially those related to maritime interdiction, interception and control:

According to intelligence, a cargo vessel that departed country X in early February is carrying a terrorist cell with hazardous (radiological) material and is attempting to enter the country via a West coast port. The Vessel's name and port of arrival are unknown.

Multiple boarding operations are ongoing (and updates are posting to Maritime Intelligence Fusion Center - MIFC via E-Wall). Intel has updated information and has high confidence that a vessel entering Washington State has the terrorists onboard. Simulated deception event is that USCG and NSWC are coordinating the vessel's takedown and that is happening with updates to E-wall.

Under that course of action, USCG has ordered one of its vessels (simulated by MARAD SS Gem State) to stop, board, and search a ship (simulated by USCG Tern) suspected of transporting radiological material as well as a terrorist cell. In order to do that, while the suspect vessel is underway, a RHIB with a boarding team is employed.

Level I boarding team have conducted a search of the vessel due to its status as an HIV. They were equipped with RadPagers. During the inspection, a neutron alarm was triggered on a RadPager. The alarm was a constant alarm, not spurious counts. The level I team practiced SMAC and called in a Level II team to resurvey the ship with their additional radiation detection equipment. This is an LE mission.

So, in order to assist in locating suspects, uranium enriching equipment and explosives, the USCG Operations Center, Alameda has directed its Level II boarding team to employ radiation detection, explosives detection, and biometric equipment to help expedite this at-sea search. Since there are numerous commercial uses for certain radioactive sources and positive identification of the source in a short time is imperative, a network extension capability is utilized from the suspect vessel to the boarding team's launch vessel and ashore. This rapidly deployable, collaborative network is reaching back to LLNL and the Defense Threat Reduction Agency (DTRA) to assist in identification of suspect cargo. Support from the National Biometric Fusion Center must be used to quickly and accurately discriminate between actual vessel crewmembers and non-crew suspects.

The tasking for Level II boarding team is to conduct a survey of the cargo ship and identify the source of the neutron readings utilizing Radpager, identiFINDER and RadPack devices. Also, using biometrics recording devices, crew members must be taken their fingerprints and that biometrics data is to be to BFC for identification.

The expected boarding scenario events are the following:

- Hidden neutron source in engine room and hidden gamma source as cargo. BFC fingerprints Captain and crew.
- First gamma spectrum of gamma source taken is poorly done because the boarding party took too short of a spectrum. Reachback can ask for second spectrum for analysis). Gamma spectrum of neutron source and photos sent to reachback and export control for identification.
- Once the identification of the items is passed to the boarding team and fed to MIFC, the cognitive process clock starts where the experts work in collaboration with MIFC and USCG support vessel to understand the situation and come up with a course of action to deal with the threat.
- Once the captain of the ship is located, he can inform the boarding party that he had a soil density gauge that emitted neutrons (but only after we send spectra and photos of item).(Export control should identify it as soil density gauge.) Unfortunately it was stolen. The captain can't explain the gamma source- possible terrorist threat? Captain's fingerprints show him to be on a watch list.

The radiological material will be simulated by detection files that will provide the LLNL analysis team with some ambiguity about the severity of the material. Once that determination is passed to the boarding team and fed to MIFC, the cognitive process clock starts where the experts work in collaboration with MIFC, USCG and boarding team to understand the situation and come up with a course of action to deal with the threat.

3. Major Networking Segments of the TNT MIO Testbed

A. **OFDM/802.16** mobile man-portable network extension connecting providing ship-to-shore and ship-to-ship broadband communications. Short for ***O****rthogonal* ***F****requency* ***D****ivision* ***M****ultiplexing*, an FDM modulation technique for transmitting large amounts of digital data over a radio wave. OFDM works by splitting the radio signal into multiple smaller sub-signals that are then transmitted simultaneously at different frequencies to the receiver: multiple carrier waves take the place of and carry the data of one large wave. One of the key benefits of OFDM is that the multiple carrier waves overlap, which provides a very efficient use of the frequency bandwidth by packing more data into the bandwidth compared to what can be achieved with a single larger carrier wave spread across the same spectrum. Also, OFDM reduces the amount of crosstalk in signal transmissions. Among others, the IEEE 802.11a and 802.11g Wi-Fi standards also use OFDM as well as IEEE 802.16.

B. <u>ITT Mesh</u> connecting the boarding party onboard the RHIB during their transition to Target Vessel and on board the Target Vessel providing wireless mesh capability to the boarding party members.

Not much data exists on the aforementioned wireless mesh technology that uses a center frequency of 900 MHz since it's a proprietary technology of ITT (owned by Motorola).

C. <u>802.20 FLASH OFDM</u> (Fast, Low-Latency Access with Seamless Handoff Orthogonal Frequency Division Multiplexing)

Introduced by Flarion Technologies, Inc. (owned by QUALCOMM Incorporated) FLASH-OFDM utilized in the 802.20 standard is a direct competitor to the yet to arrive 802.16e mobile broadband standard. IEEE 802.20 standard is capable of providing connectivity to the BS of SS moving up to speeds of 200-300 knots. FLASH-OFDM differs from 802.16 OFDM applications, in that it is vertically layered across the network, link and physical layers of the OSI model. This implementation is possible because in an IP network, only the layers above the network layer need to be layered horizontally to ensure interoperability across multiple link layer technologies. The 802.16 standard utilizes multiple MACs for multiple Physical layers and has run into design challenges because of the large amount of internetworking needed between the 802.16 MAC and PHY layers. 802.20 on the other hand utilizes a non-contention MAC together with OFDM which allows for the support of many low bit rate dedicated control channels. Therefore, IEEE 802.20 standard isn't subject to various performance variations and inefficiencies when dealing with mobile users like IEEE 802.16 because it provides a fully scheduled uplink and downlink air resource to the user while IEEE 802.16 MAC is provided primarily through a contention-based access scheme.

During the TNT 06-02 experiment the utilized frequency was approximately 700 MHz and the EIRP was 20 W. The 802.20 frame is 26 bytes, of which 2 bytes form the frame header.

<u>D.</u> <u>UWB</u> portable data communications equipment.

UWB has its origins in military secure communications. While in Spread Spectrum (DSSS / FHSS) the bandwidth is in the range of MHZ, in UWB it's in the range of GHz. Instead of modulating a continuous wave form RF signal with a specific carrier frequency (narrowband communication systems), UWB use carrierless, short duration pulses with very low duty cycle (Ton/(Ton+Toff) < 0.5%) that spread their energy across a wide range of frequencies (while in SS carrier is always present).

Therefore, mainly because of the obstacle penetrating capabilities as well as the extremely high throughput over short distances (as said, UWB might replace USB 2 and IEEE 1394 wired connections between peripherals) providing the ability of excellent streaming video quality, UWB is ideal for use inside a ship's hull.

4. Collaborative Network for Maritime Radiation Awareness and Interdiction Experiments

The diagrams in Figure 3 and Figure 4 below show the MIO Logical Network set up in San Francisco Bay, which Stiletto joined as a mobile command post pier sided in San Diego (Fig. 3). Each of these nodes had a specific role in the scenario and participated differently in the collaborative environment. Their roles are described following the diagrams.

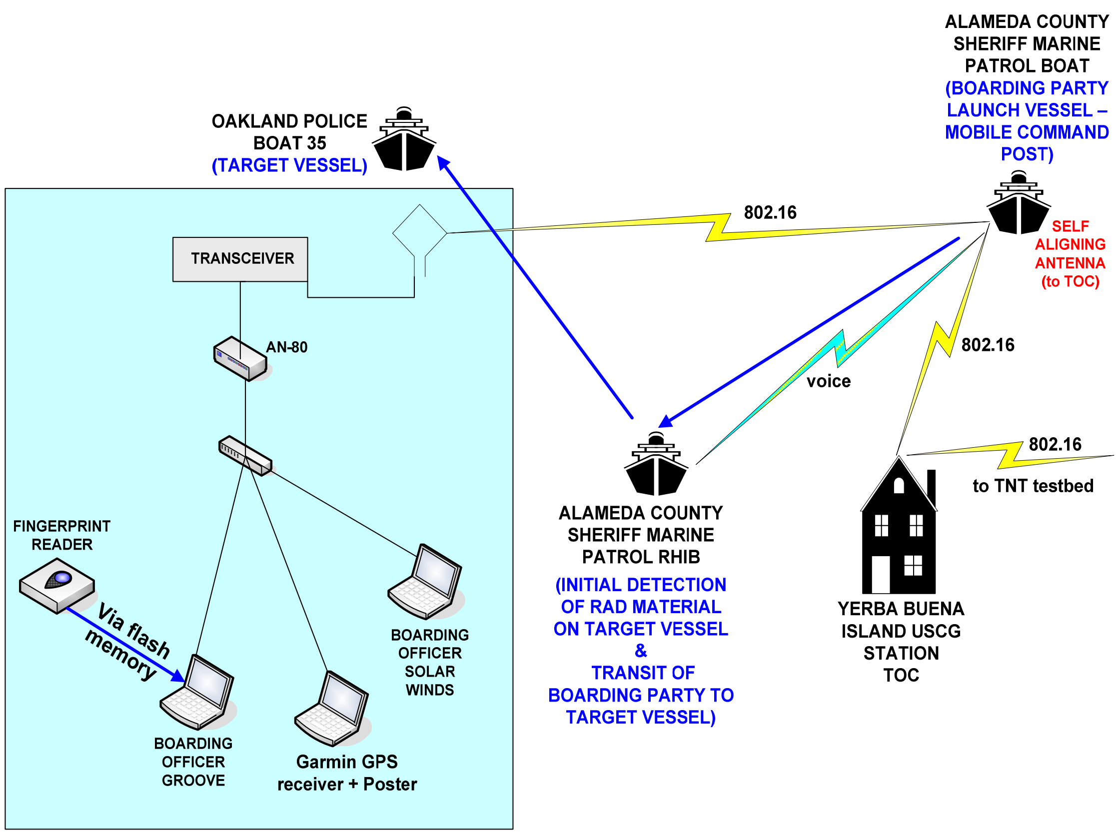

Figure 3. TNT 06-4 MIO Network in SF Bay Area

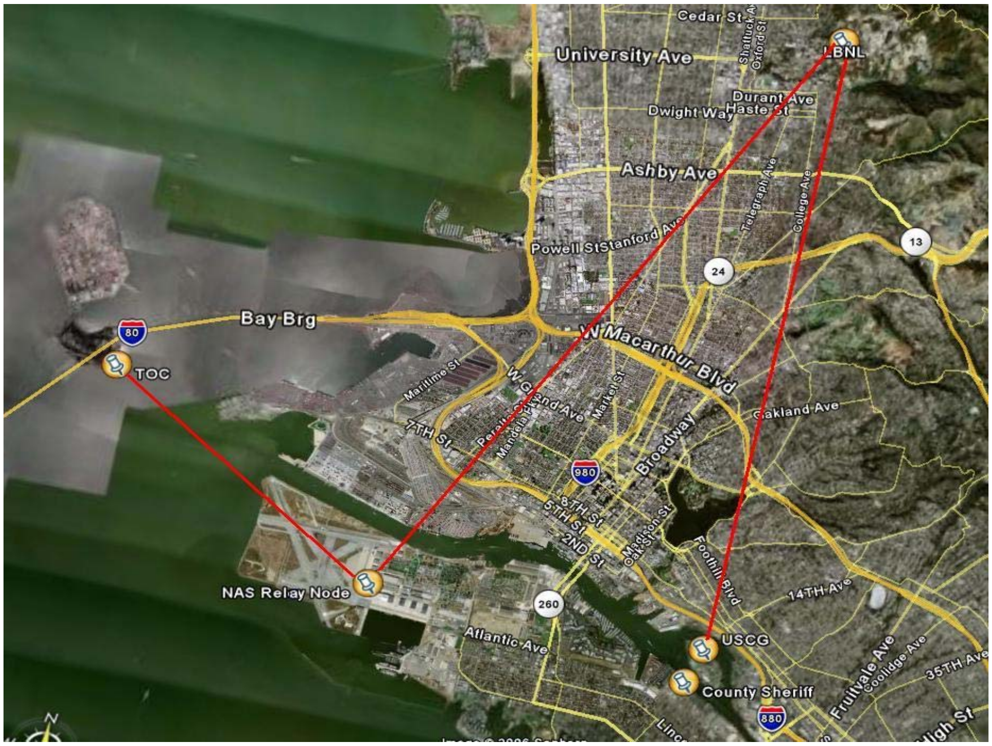

Figure 4a. OFDM Wireless Network in SF Bay Area

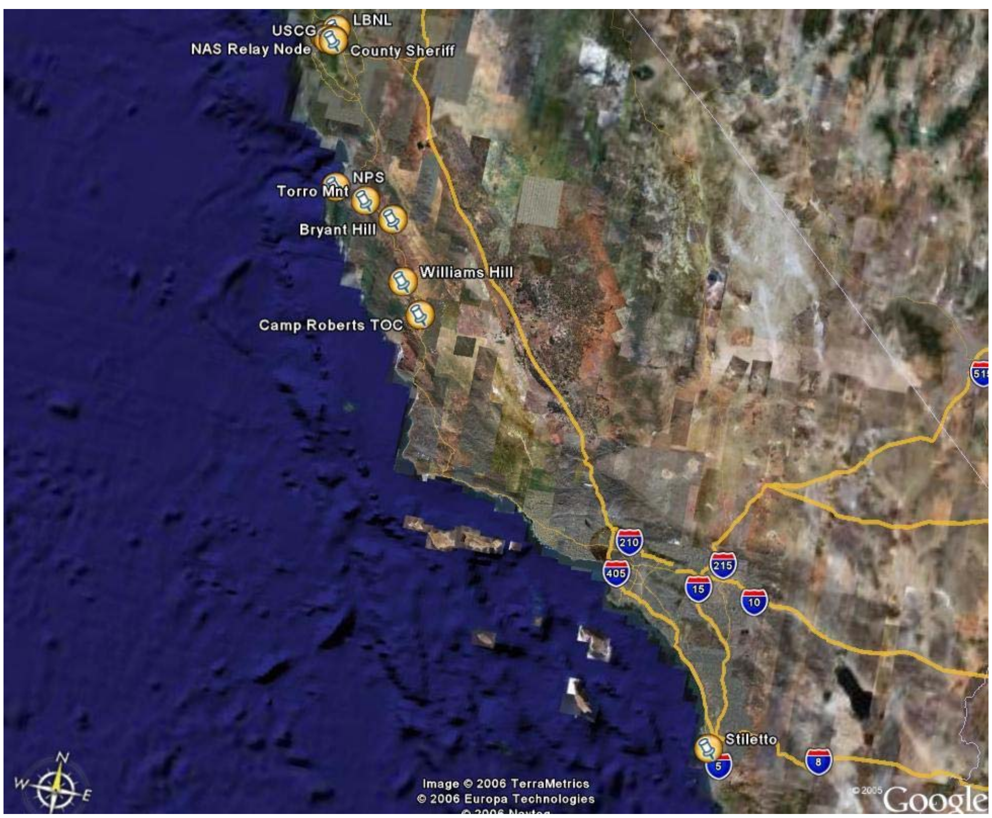

Figure 4b. OFDM Nodes along coastline from SF Bay to Camp Roberts

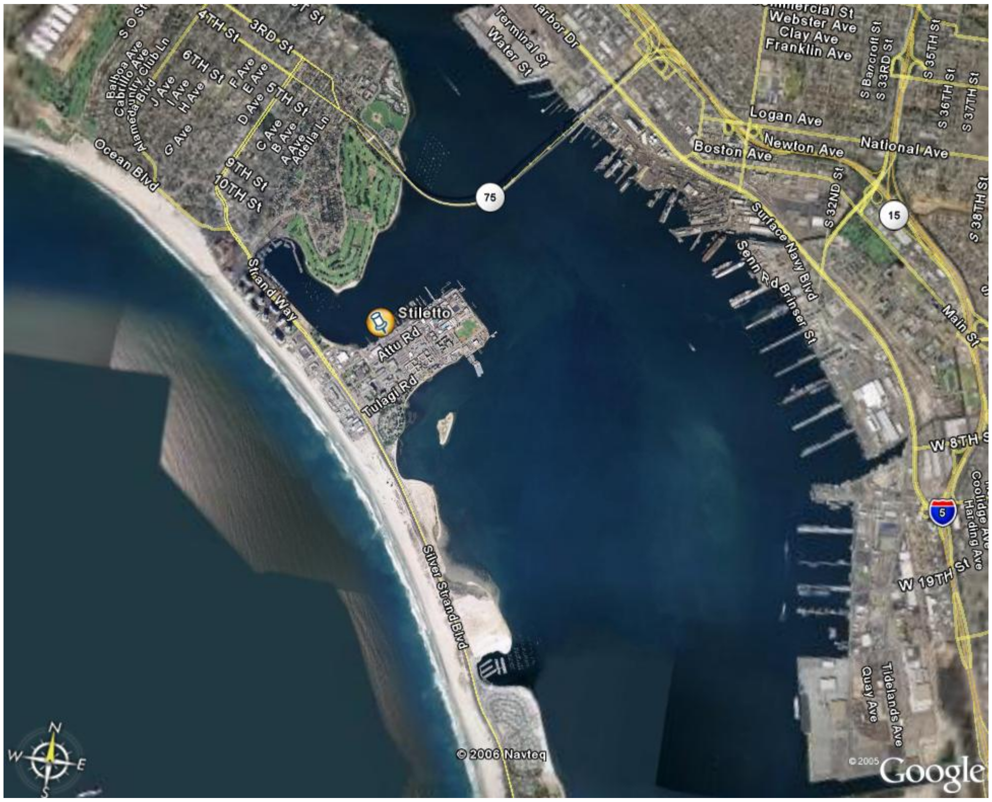

Figure 5. OFDM Wireless connection to Stiletto in San Diego

5. MAJOR EXPERIMENT PLAYERS AND ROLES

Networking / Technical Advisors (NOC (NPS) & TOC)

Role: to provide their expertise to the Boarding Party (BP) to deal with complex networking problems that might arise at any point of the boarding operation that would obstruct them from exploiting the unique capabilities offered by the network.

Lawrence Livermore National Laboratory (LLNL)

Role: to provide Weapons of Mass Destruction (WMD) expertise and specifically radiological material detection, identification, categorization, origin tracing, their correlation with other related findings worldwide, and evaluation of their associated dangers and implications from their discovery. That expertise also includes the identification of certain materials that can lead to the development of WMD, such as machinery and other non-proliferation materials.

MIFC (Maritime Intelligence Fusion Center)

Role: to provide maritime traffic information such as ships' registries, cargo and crew manifests, ports of call, and shipping schedules. This information is helpful in order to designate a vessel as suspect, locate it, make its interdiction possible, and confirm discrepancies onboard, such as fake documentation.

Command Center (NPS) & District 11 (tactical / operational commanders)

Role: Primary decision makers concerned with decisions before, during, and after the boarding, with particular emphasis on post-sensor analysis of the suspect vessel. The boarding officer is their "tool" onboard the ship, making decisions at the lowest level, following pre-established SOP's including how to organize and conduct the search using the best resources at his/her disposal. The decision making level of the tactical or operational commanders may differ depending on the context of each boarding case, their parental organizations, relevant policies and standing orders. The primary purpose of the collaborative network is to enhance the Boarding Party's situational awareness, even more importantly that of the boarding officer.

Boarding Party

Role: to physically enter the vessel and carry out a thorough visual and sensor inspection to locate the source of radiation detected by the drive-by sensor. The BP will then pass sensor data to LLNL for analysis and evaluation of the type and severity of the source.

Stiletto 1

Role: to act (experimentally) as a MIO unit, capable of fast transfer of the BP to the target, providing launch vessel and intermediate node capabilities.

Singapore (as Shipping Company)

Role: to provide the above information to maritime intelligence / maritime domain law enforcement agencies such as MIFC (in this experiment, to explain the presence of specific materials and/or personnel onboard the suspect vessel).

Sweden

Role: to act as a counterpart MIO agency, conducting the same operations and exchanging real time information that might be useful to them or to the TNT operation.

Based on the observations of the MIO team members after having the opportunity to both observe and actively portray the roles in each node, Figure 1 was re-created as Figure 4 (below) to reflect the team's perception of the collaborative network that existed during the experiment. Note the high number of arrows between the Technical Reach-back nodes – those entities supporting the technical aspects of the experiment – and the Coast Guard nodes. The expertise housed in the Technical Reach-back nodes is a resource in high demand from multiple operational nodes, but is also an extremely constrained resource. The ability to simultaneously “deploy” the technical expertise to multiple locations/events through the collaborative environment is an essential benefit for military and Homeland Security operations.

The one major deviation from the “real world” Coast Guard structure during this experiment environment is the role of the Yerba Buena Island node. In the actual Coast Guard chain of command, Sector San Francisco would replace the YBI TOC and would exercise some of the command and control (C2) role played by D11. In addition, the critical logistics role played by the YBI node for the experiment would not be necessary because the technology and network management issues would be addressed before this collaborative environment was fielded. During future experiments, it may be beneficial to gradually decrease the dependence on this node by slowly distributing its responsibilities to the District 11, Boarding Vessel (BV), Boarding Team (BT), and NOC nodes.

Student watchstanders at the NOC were prepared to serve as surrogate role players for the various foreign partner nodes, in addition to facilitating their connectivity and ensuring that they clearly understood their roles.

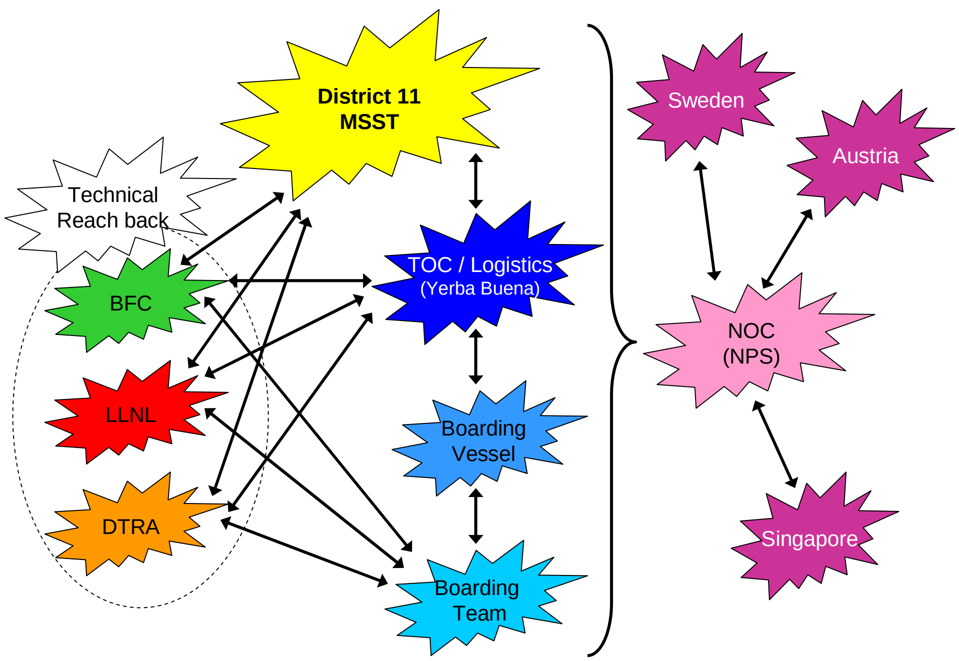

Figure 6. MIO TNT Collaborative Network Nodes (courtesy Rideout, Creigh, and Dash)

6. Application environment of MIO collaborative network nodes that Stiletto joined.

Groove Virtual Office provided the majority of the collaborative tools for this experiment. The following workspaces were created to perform the tasks listed below:

1) TOC and Networking

- To resolve network malfunctions/issues and optimize network performance
- To coordinate logistics and issues outside the scenario environment

2) Boarding Party (BP)
   - To analyze and compare spectrum files (among remote experts)
   - To track radiation materials (among remote experts)
   - To share atmospheric modeling and predictions (among remote experts)
   - To consider emergency medical actions (among remote experts)
   - To post biometrics matches (NBFC)
   - To post radiation files/photos (BP)
   - To post responses/expert evaluations (LLNL)
   - To post recommendations on BP's further actions / when additional search information is required (LLNL-NBFC)
3) District 11
   - To command and control assets
   - To direct agencies and assets not directly under the commander's authority
   - To command BP to appropriate actions

Each of the collaborative network nodes utilized a subset of the available CT tools. The section below provides a breakdown of each node and a description of their collaborative environment.

District 11 – Rusty Dash.

The combination of the tools listed below provided the ability to remotely monitor both the status of operational assets (boats/vessels) and the progress of scenario events. This resulted in excellent situational awareness for the decision maker.

Groove was used in the following ways or to perform the following functions:

- *Discussion Board / Chat* – for text communication between nodes. The discussion board is better than chat because it enforces hierarchy relationships of the different posts. This makes it much easier to follow information in the asynchronous and distributed decision making environment.
- *File Transfer* – primarily for distributing data files from the BT to/from the Reach-back facilities.
- *Task Manager* – using this tool in the control (TOC and Networking) workspace gave participants an easy and informative way to monitor the progress of the scenario. It was an excellent use of a previously unused Groove tool.

SA Agent provides the geographic positions of the assets and status of the network links for the mobile nodes.

EWall was used to monitor information alerts. However, the sparse number of alerts posted in EWall limited the effectiveness of the tool during this experiment.

VOIP phone was an excellent tool for voice communications. Video streams were monitored from various nodes, but this functionality was not critical to the D11 decision making process.

Boarding Officer – Brian Rideout and George Stavroulakis.

Of the various features (often referred to as "tools" within various collaborative applications) there are 3 fundamentals in the Groove application that apply specifically to the MIO scenario. They are:

1) Discussion. Utilize standardized naming conventions and SOPs for introducing new threads. Employ the thread technique to better organize data (decreases look-up time of information thereby speeding up the Orient/Decide processes within the OODA loop). It provides excellent, near-real-time "chat" capability while archiving all discussions for all parties. Additionally, person-to-person discussions can be established and continued to cover communications not pertinent/appropriate for the entire workspace.

2) Task-Manager. Create a flexible, scalable MIO model that can rapidly expand to cover all aspects of the various boarding missions: one for a radiation scenario, counter-drug, weapons, suspected terrorist(s), etc. With an adaptable template, users will become familiar with those components most frequently used while retaining the option of expanding the task-manager's options depending on the situation. Familiarity breeds confidence and increases our orientation/decision cycle in the OODA loop.

3) Files. This tool is used primarily to transfer data (photos, video, biometrics, radiation data, etc) to be collaborated on by reach back analytical agencies. Features like pictures, notepad, and sketch (in Groove) are redundant and bog down users. Workspaces can be configured to reflect only those features the users intend to use thereby minimizing the temptation to open another feature. Additionally, fewer features in the workspace will force users to use only those available with the option of expanding the workspace through the additional of more tools; less features equals less to review equals less time spent with a head buried in the computer.

On another note, a camera acts more like a sensor and less like a collaborative "tool." The data it captures can be collaborated on (by humans) once it has been disseminated via the network (Groove has capability of posting/sharing the file but the humans using Groove then collaborate on the data presented in the file). Whether still imagery or streaming video, we tend to categorize cameras in the collaboration realm rather than "sensor" domain.

Additionally, the laptop that was supposed to be used for Situational Awareness Agent (SA Agent) aboard the BV was not brought along for the boarding. The lack of Alerts, Geospatial data, Network connection (Agent information) and video had a noticeable impact on the BT's situation awareness. SA Agent's capabilities would be especially beneficial in a complex MIO with multiple surface craft on the water.

Having that kind of SA (especially at night) would be beneficial to law enforcement and collaborators alike.

Boarding Vessel – Bob Creigh.

The BV primary CT Tools were Groove and the VOIP phone. The BV was a coordination entity that provided a bond between the TOC, D11 and the BT. The BV also provided the physical network link between the TV and YBI 802.16 node. The BV also provided a video feed. This camera was placed on the bridge of the BV but in a real situation would probably stay locked on the TV. The BV did not make use of the SA Agent during this experiment but it should be used in the future.

Groove proved to be a very valuable tool for the BV team. The first day of the experiment the network latency was unacceptable and we primarily used cell phones for communications. On the second day these problems were rectified and both Groove and the VOIP phone proved exceptionally valuable. The VOIP phone is an outstanding tool and should be used even more widely in future experiments.

Stiletto Ship (specific type of BV) – Jeff Withee.

Groove provided the majority of the CT tools. It was utilized for Chat, discussion, File Sharing, pictures, and task management. Video and Voice communications were provided by VStream. Additional voice communications were conducted using Cell phones.

CENETIX NOC – Dave Schilling, RJ Simmons, Ed Pena, Doris Alvarez, Ed Macalanda, Mike Farrell.

The NOC utilized all of the available collaborative tools for the experiment: Groove, E-Wall, SA Agent, Video Conferencing, and Audio Conferencing. Groove was used for file sharing, messaging, chat, discussion board, pictures, and web links. This constituted approximately 80% of the CT utilization. EWall was used about 10% and teleconference another 10% mainly for coordination during the initial experiment setup.

The Austrian team utilized Groove, E-Wall, SA Agent, a live Video link, and occasional Cell Phone communication.

Sweden participated in the SA agent as number 26.

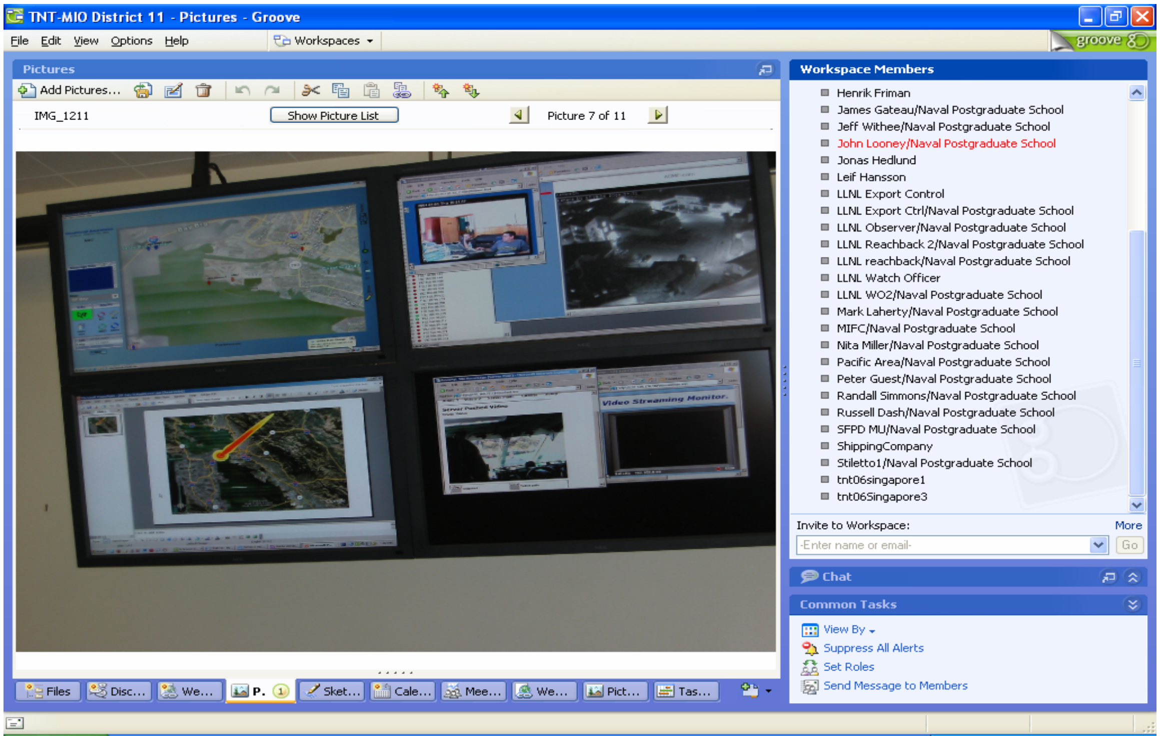

Figure 7. Collaboration with remote sites involved in drive-by radiation detection

7Conclusion

The last experiment proved feasibility of integrating new Radiation Detection sensors in the improved tactical MIO network and provided vital requirements for configuring networking and operations support capabilities onboard Boarding Vessel and remote Expert and Command Centers. The ship-to-ship and ship-to-shore OFDM wireless network between Boarding Vessel and MIO TOC allowed the Boarding Party team in SF Bay to communicate with the geographically distributed network of MIO command posts. Also, the NPS CENETIX-developed first self-aligning broadband wireless solution (SAOFDM), was successfully tested at SF Bay on board the Alameda County Sheriff's boat, in a configuration similar to Stiletto. The MIO network provided sufficient bandwidth for collaborative tools and multiple video feeds (1.5-3Mbps level), even when subjected to additional sharp zigzag movement of the vessel, to as far as 4.5 miles off shore. In addition, the members of the Stiletto TOC were able to communicate and observe video/radiation detection from the remote warning sites in Sweden, Austria, and Singapore.

Acknowledgements

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