SHARED SITUATION AWARENESS FOR NETWORKED DISMOUNTED SOLDIERS

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ABSTRACT

The effectiveness of the network-edge dismounted soldier is maximized when the soldier acts as both a consumer and producer of Situation Awareness (SA) data within the larger tactical network. Providing this degree of information sharing in a tactical military environment presents unique technical challenges. This paper will discuss the design of a prototype demonstration system, jointly planned by the Army's Electronics Research Development and Engineering Center (CERDEC) and Lockheed Martin's Advanced Technology Laboratories (ATL), that integrates CERDEC's C2MINCS tactical information sharing framework, and ATL's data fusion and Grapevine intelligent data dissemination technologies to more fully address the problem of bringing shared situation awareness to a team of networked dismounted soldiers.

1. INTRODUCTION

The effectiveness of the network-edge dismounted soldier is maximized when the soldier acts as both a consumer and producer of Situation Awareness (SA) data within the larger tactical network. As force-multiplying technologies increase the capabilities of the individual, a dismounted soldier may increasingly encounter a view of the battlefield that is unique compared to that of other team members. This is particularly true in an urban environment, where the view of the battlefield may change greatly with just the turn of a corner. However, for a team to perform effectively, each individual needs to have awareness of all areas of the battlefield that are relevant to the individual and the team's security and mission objectives. With network connectivity extending to the front-line dismounted soldier, the opportunity exists for the individual soldier to benefit from information available from the tactical network and also to act as a sensor, providing information back to the network and benefiting teammates and echelons above.

Providing this degree of information sharing presents unique technical challenges. The tactical military operates in an environment that is hostile to computing platforms and networks. With the new wealth of data available, the warfighter is in danger of suffering information overload without some intelligent, automated means of selecting, managing and presenting the information relevant to the individual. In order for the warfighter to be an effective provider as well as consumer of SA information, a convenient, intuitive and effective interface is required.

Recent work by the Army's Communications Electronics Research Development and Engineering Center (CERDEC) has resulted in a demonstration prototype system that provides an information sharing framework in which soldiers, carrying Personal Digital Assistant computing devices can share situation awareness data with both peers and echelons above. Independently, Lockheed Martin Advanced Technology Laboratories (ATL) has for several years been maturing sensor data fusion and intelligent information dissemination technologies that support situation awareness in tactical environments. This paper will discuss the design of a prototype demonstration system, jointly planned by CERDEC and ATL, that integrates the capabilities from both organizations to address the problem of bringing shared situation awareness to a team of networked dismounted soldiers. After discussing the operational context of the planned system, the paper will discuss the individual constituent technologies, followed by a description of the planned demonstration system as an integrated whole.

2. OPERATIONAL CONTEXT

The operational context for the planned system, illustrated in Fig. 1, includes a small team of dismounted soldiers, accompanied by a Multi-purpose Utility/ Logistics Equipment (MULE) vehicle. Dismounted soldiers carry handheld devices that provide a personal tactical situation display, data entry capability, limited

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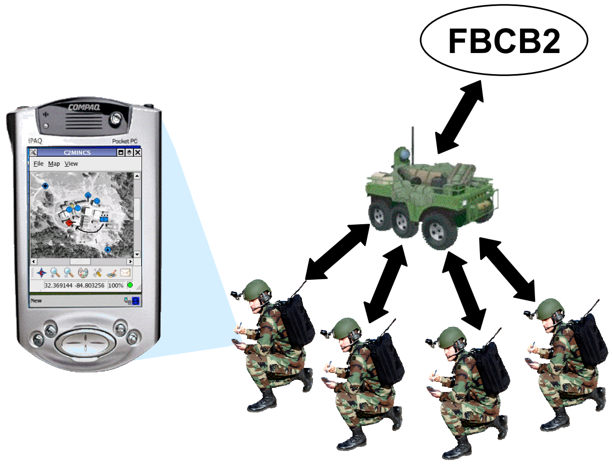

Fig. 1. The context for the demonstration system includes a small team of PDA-equipped dismounted soldiers, networked with a MULE.

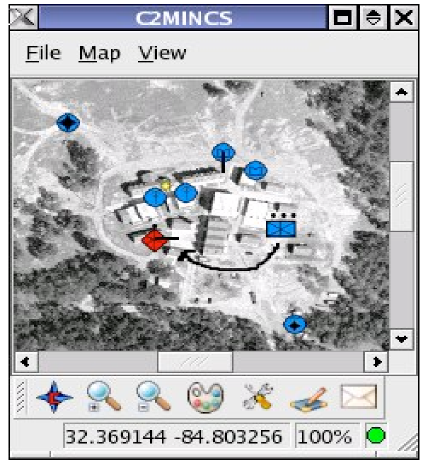

Fig. 2. The handheldC2MINCS interface allows soldiers to share real-time situation awareness, including "John Madden" whiteboard drawings.

computational power, and local network connectivity with the MULE and other team members. The MULE provides greater computational resources and network connectivity to higher-echelons. Through the MULE, the team has access to the larger Tactical Internet and associated information systems such as the Force XX1 Battle Command Brigade and Below (FBCB2) system.

3. C2MINCS

The underlying information sharing framework and the soldier interface are provided by the CERDEC-developed Command and Control Mobile Intelligent Net-Centric Computer System (C2MINCS). The C2MINCS application, shown in Fig. 2, provides real-time tactical situational data to the dismounted soldier, sending and receiving red and blue force entities through the MULE to and from upper echelons, connected to BCB2. Standard mapping products, provided by the National Imagery and Mapping Agency (NIMA) and MILSTD 2525B icons are used to display all situational data. Users can perform all customary map display functionality, including pan, zoom, and view icon details. This allows a common operational picture to be displayed at each node on the network. Dismounted soldiers report their position and have the ability to send Spot Reports. C2MINCS also provides a Peer-to-Peer Whiteboard, or "John Madden" capability. It allows team members to collaborate in formulation of on-the-move COA plans, and to share ideas remotely.

C2MINCS has been designed to exploit commercial software technology appropriate for emerging handheld computing hardware. This design is based upon requirements for an open distributed systems software framework for information sharing, and an extensible application for dismounted warfighter tactical use. The present design configuration matches the representative operational context of the Future Force in which mobile handheld devices interoperate with the MULE and FBCB2.

Figure 3 depicts the C2MINCS tactical information sharing architecture. The architecture follows a service-based, publish-subscribe paradigm with "push-based" content to support an open framework. Each subsystem, or service, encapsulates its responsibilities to provide autonomous functionality, producing a flexible design to allow extensibility in both features and implementation. C2MINCS is component driven, where each component is independent and modularized. All data exchange uses W3C compliant XML. A standard parser is utilized to parse, read and create XML messages.

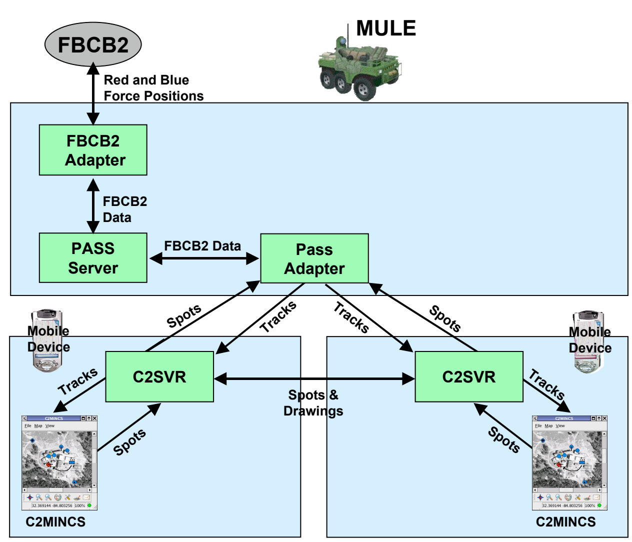

Fig. 3. C2MINCS Architecture diagram.

A CORBA compliant server, residing on the Mobile Device (C2SVR), is responsible for sending and receiving messages to and from the MULE. All client component communication is accomplished using the C2SVR. It maintains the master subscriber list for all components residing on the client and forwards messages appropriately. The C2SVR is the sole client subscriber to the PASS Server residing on the MULE.

The MULE contains a web-based PASS Server to maintain subscribers and forward messages published by clients. Adapters are used to translate one message format and connectivity into another, allowing multiple non-homogeneous systems to communicate with minimal impact to each system.

The PASS Adapter is implemented as a CORBA Server to all Mobile Devices, maintaining a master list of devices connected to it. It implements a web-based connection to the PASS Server. This allows multiple adapters to be executing, minimizing a single point of failure and maximizing scalability.

The FBCB2 adapter implements a web-based connection to the PASS Server to send and receive messages from the mobile devices. It converts XML data messages to VMF messages and vice versa.

C2MINCS software is initially targeted for use on ruggedized Personal Digital Assistants (PDAs) in conjunction with a Linux-based MULE-mounted computing platform. However, through DII-COE compliance and an architectural paradigm emphasizing modularity, extensibility and platform independence, C2MINCS software is intended for operation on a variety of operating systems and hardware platforms, both legacy and future, and permit all or portions of its functionality to be embedded in other systems.

4. MULTI-SENSOR DATA FUSION

The task of battlefield situation assessment requires the ability to take reports from a variety of sensors, (RADAR, Infrared, IFF, Spot Reports, etc.), and combine them into a single composite view of the position and identification of all of the targets, (tanks, aircraft, air defense unites, etc.), within the battlespace. To illustrate, consider the situation depicted in Fig. 4. Figure 4 presents a hypothetical battlefield situation display onto which reports from two different sensors, S1 and S2, are plotted. Due to errors inherent in the sensor measurements, the plotted position of each sensor report really only represents the center of an ellipse that defines a region in which the actual position of the target is expected to lie, with some high confidence.

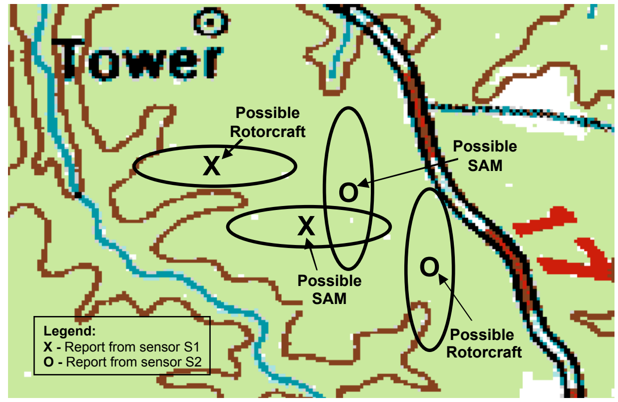

Fig. 4. Battlefield situation display with plots, (including error ellipses), from two sensors.

Given that the actual positions of the targets may be significantly displaced from the sensor-reported positions, and that some targets may be invisible to some sensors, it may be reasonable to interpret the sensor reports to represent two, three, or four actual targets on the battlefield. The problem of sensor data fusion is to choose the best interpretation of the collection of available sensor reports.

In the case of our example it is apparent from the relationships between the error ellipses that the best interpretation of the scene is likely to be as depicted in Fig. 5. Notice that the two center-most sensor reports, or tracks, were interpreted to represent a single actual target. By comparing the expected-error regions of the two sensor tracks, the expected error in the position of the resultant "fused" track has been greatly reduced. Notice also that the corroboration between the two sensors, in the classification of the target, results in a higher confidence in the classification of the fused track [Hofmann, 1997]. The result of sensor data fusion is a single, de-cluttered representation of the battlefield with every known target plotted only once, with higher accuracy than could be achieved with any single sensor.

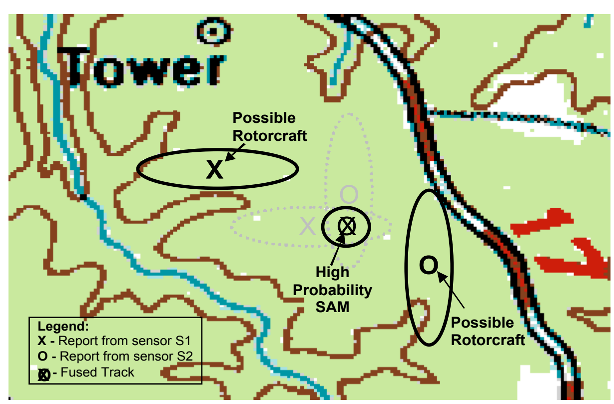

Fig. 5. The result of fusion is a de-cluttered display with higher confidence in position and identification of targets on the battlefield.

In such a simple case, it is not difficult for a human to interpret the scene mentally, without the aid of automation. However, as the numbers of sensors and targets increase to realistic values, the complexity of the problem quickly increases to a level that requires automation.

From 1993 to 1999, ATL participated in the Army's Rotorcraft Pilot's Associate (RPA) Advanced Technology Demonstration program, sponsored by the Army Aviation Technology directorate (AATD) [Malkoff et al., 1996]. ATL developed the multi-sensor Data Fusion system to provide a fused track picture to the RPA pilot and the RPA decision aiding systems onboard AH-64/D helicopters. In the RPA Data Fusion system, data representing as many as 200 battlefield entities, from 14 different types of onboard and offboard sensors, is correlated and fused in real time into a consolidated picture of the battlespace. The RPA system, including ATL's Data Fusion system, was successfully flight demonstrated in 1999. Since then, ATL's Data Fusion system has been applied to a number of additional programs including the Army's Airborne Manned/Unmanned Systems Technology – Demonstration (AMUST-D) [Jameson et al., 2002] program and the Survivability Planner Associate Rerouter (SPAR) program.

5. GRAPEVINE INTELLIGENT INFORMATION DISSEMINATION

The Grapevine architecture [Jameson, 2001] was originally developed by ATL for use on DARPA's Small Unit Operations (SUO) program, and has been extended as part of many other Army programs such Dismounted Warrior C4I STO, and AMUST-D. It makes maximum use of bandwidth for information sharing by providing each node with a description of the information needs of its peers, so that each node can selectively transmit only those bits of information that it understands to be of real value to its neighbors. By sharing relevant sensor data, each participant can build a common tactical picture that is consistent between participants, and is as complete as the sum of all participants' information sources can make it.

The implementation of the Grapevine architecture (Fig. 6) builds upon our previous work combining multi-sensor Data Fusion with intelligent agent software. Each node in the architecture contains a Data Fusion process that fuses locally obtained data (from local sensors and data sources) and data received from other peer nodes. The Grapevine Manager at each node manages the interchange of data with peer nodes. For each peer node, it contains a Grapevine *proxy agent* that represents the

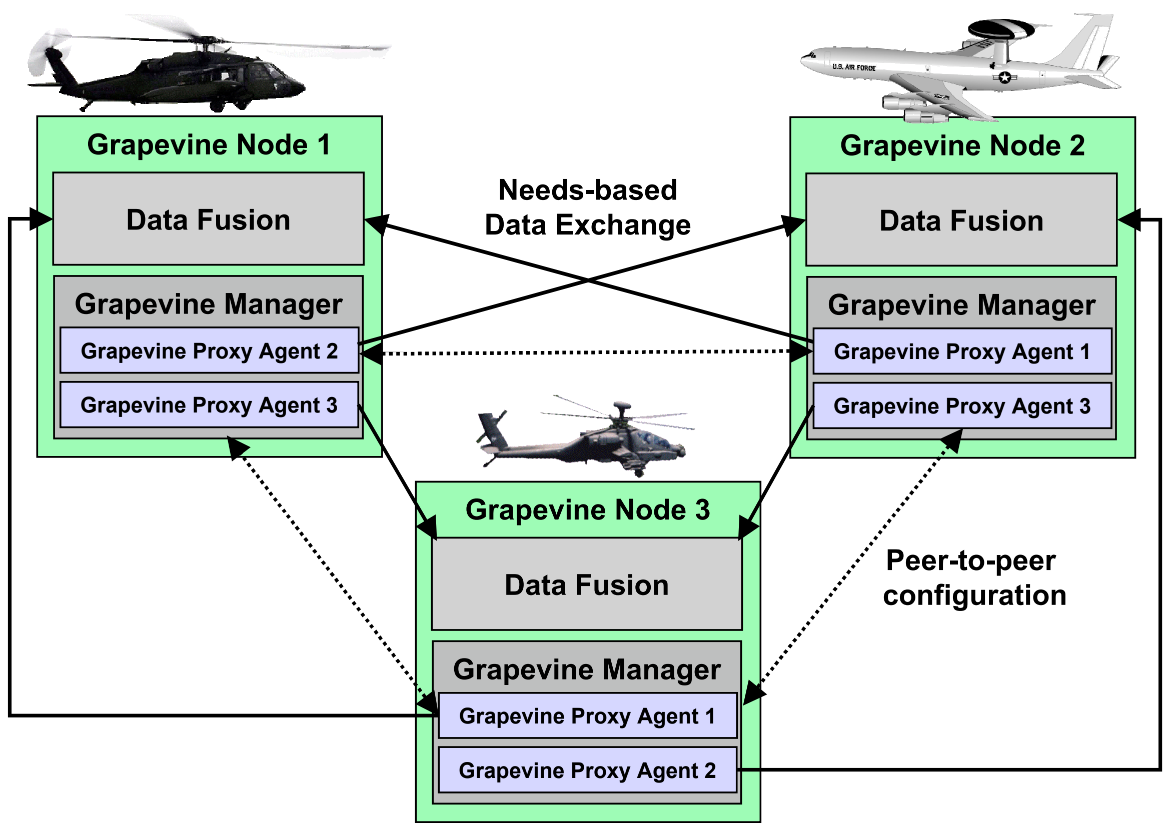

Fig. 6. Grapevine data dissemination architecture.

information needs and capabilities of that peer node. As the sensors or other sources on the platform generate local information, each grapevine agent evaluates that information against the needs of the peer platform it represents for factors such as:

- Sensor type: Data from remote sensors is sent only if the recipient does not already have access to that data.
- Mission Context: For example, the peer platform's mission may or may not require the knowledge of friendly tracks.
- Location: The peer platform may only need information within a geographic or temporal/geographic radius.
- Coverage: The peer platform may need information from outside its own field of view.

In addition, the Grapevine agents are aware of the processing and bandwidth limitations of the peer nodes and communication links. Data identified as relevant to a peer node based on the above criteria may be down-sampled or prioritized to meet resource limitations. Each Grapevine agent propagates the needed information to the peer platform it represents, providing an *intelligent push* of data through the network.

At the same time, the Grapevine Manager has a representation of the local platform's information needs and capabilities, expressed in terms of available sensors and data sources, mission, location, and sensor coverage. A Sentinel Agent within the Grapevine Manager monitors the local fused picture to identify information needs not met by the local picture. Based on this, it sends out updated configuration data for the local platform to the Grapevine Manager on peer platforms. This is used to update the Grapevine Agents on the peer platforms that represent the local platform. This propagation of information needs effects an *intelligent pull* of data to meet the changing information needs of the local platform.

There are several distinctive features of the Grapevine Architecture. First, it is a *peer-to-peer* architecture. Propagation of data occurs between peer nodes in the network. This architecture is easily extended to accommodate a hierarchical C2 control structure. Second, propagation is *needs based*—peer-to-peer data propagation includes only data known to be of use to the recipient node, thus limiting the required processing and bandwidth. Third, the architecture is *extensible*. It can accommodate the addition of peer nodes merely by reconfiguring nearby nodes to reflect the addition of the new nodes. Fourth, it is *survivable*—there is no single point of failure. Since, in general, each node will have multiple peers, data can spontaneously reroute around missing nodes, and thus the loss of any single node will only result in the loss of the data sources local to that node.

The result of this capability is to permit, in the face of stringent bandwidth and processing constraints, the creation of a *User Defined Operating Picture* (UDOP) across all participating platforms. The UDOP is a shared picture of the battlefield, with all participants having a consistent view of the world, and each participant seeing that portion of the picture as it is relevant to their needs. In the case of infinite processing and bandwidth capabilities, this can scale to become a true Common Operational Picture, with all participants seeing the same complete picture. In the case of significant limitations on the ability to exchange and process information, as is the case now and for the near future, the intelligent dissemination capability of the Grapevine ensures that all participants receive the most relevant information.

6. THE INTEGRATED DEMONSTRATION CONCEPT OF OPERATIONS

Figure 7 depicts the architecture of the planned system. It results from integration of ATL's sensor data fusion and Grapevine intelligent information dissemination technologies into CERDEC's C2MINCS tactical information sharing framework.

In the integrated system, the MULE receives situation awareness data from the higher-echelon FBCB2 system, and spot report data, entered by soldiers using Mobile Devices. On the MULE, FBCB2 reports and spot reports are fused to provide a clear, complete, and coherent operational picture. From the MULE, a tailored view of the total operational picture is disseminated to each individual team member's Mobile Device. Communications bandwidth is conserved through the use of the Grapevine to prioritize and tailor the dissemination of data. This provides each individual with an operational picture that is consistent with the team, but most relevant to the individual. In the event of loss of communications to the MULE, the team members can maintain a level of situation awareness by sharing spot reports and other data directly between their Mobile Devices, in a peer-to-peer configuration.

The architecture allows future extensibility to allow incorporation of additional information sources and configuration to adapt to and exploit the computing environment and capabilities of new and varied host platforms.

7. SUMMARY AND FUTURE CONSIDERATIONS

This system provides a testbed for exploring the tactical payoff of enabling tactical SA and C2 decision making through the adaptation of emerging lightweight mobile computing technologies. Several enhancements

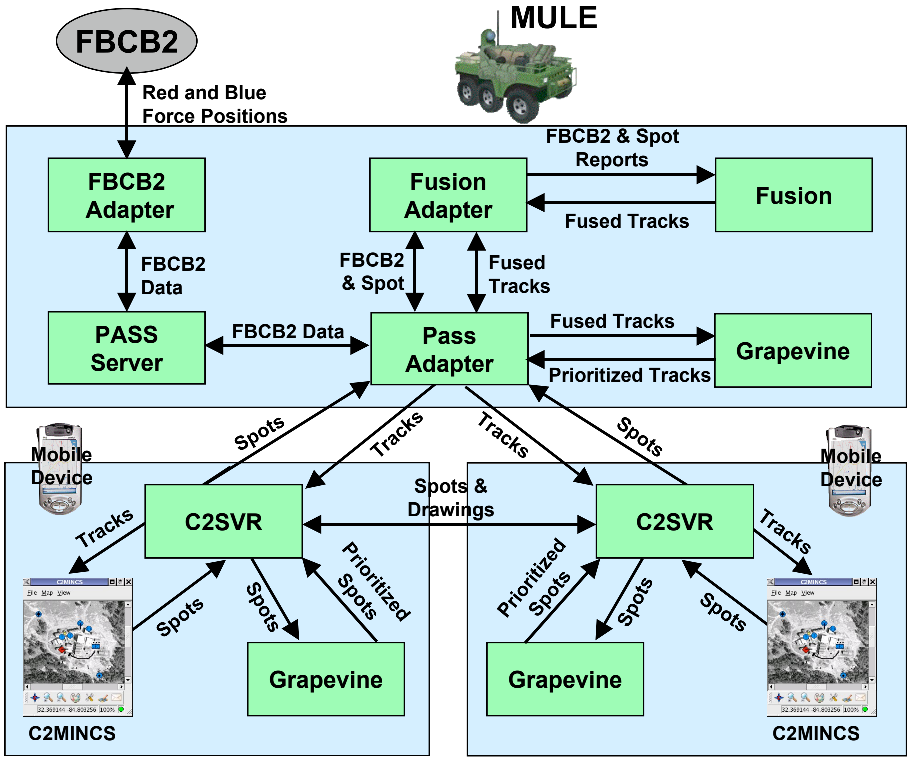

Fig. 7. Illustrates the component architecture of the integrated demonstration system.

have been identified for future implementation at both the architectural level and the application level. Examples of enhancements under consideration include security measures such as role based access control via biometric authentication and incorporation of multimodal interfaces via speech and/or gesture. SA richness and accuracy will be enhanced with integration of additional data sources. Decision aiding will be enhanced by reachback capabilities into additional information systems. C2 Decision Tools that provide theory, models, and tools to assist commanders and teams to adapt to complex situations across the full spectrum of Stability and Support Operations (SASO) environments will be researched to add functionality to the C2MINCS.

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