A Framework for Effective, Interoperable Collaboration

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Abstract

Collaboration is essential for effective command and control (C2). Understanding collaboration and the needs of collaborative groups is fundamental to implementing effective collaboration environments capable of supporting a spectrum of team activities and fostering team effectiveness. Mapping collaboration activities to tools and technologies requires a fundamental understanding of how effective teams operate. Implementing interoperable collaboration environments that provide these capabilities poses unique interoperability challenges.

This paper examines the literature concerning effective teams, addresses emerging technologies that make effective, interoperable collaboration feasible, and poses a framework for additional development of the requisite environment to achieve effective, interoperable collaboration. The paper concludes with a discussion of challenges to be addressed through research, prototyping, experimentation and process development to realize effective collaboration required by complex, distributed C2.

Introduction

The Department of Defense (DoD) Report to Congress on Network Centric Warfare (NCW) [1] identified several key tenets:

- A robustly networked force improves information sharing.
- Information sharing enables collaboration and enhances the quality of information and shared situational awareness.
- Shared situation awareness enables self-synchronization and enhances speed of command.

Collectively, these conditions are expected to dramatically increase mission effectiveness. In other words, once there is a robustly networked force, collaboration and information sharing are the espoused keys to improved command and control and hence to improved mission effectiveness.

Organizations such as the Net-Centric Operations Industry Consortium (NCOIC) have focused on helping establish the ‘robustly networked force’. The resolution of issues addressing technical standards, transport architectures, data and metadata, and Service Oriented Architectures (SOAs) using web services are all necessary contributing components. The next level of interoperability that needs to be addressed is interoperable collaboration. Collaboration is essential for effective C2. Understanding collaboration and the needs of collaborative groups is key to implementing

[1] U.S. Department of Defense, Report on Network Centric Warfare (July 2001).

effective collaboration environments capable of supporting a spectrum of team tasks and activities. Mapping collaboration activities to tools and technologies requires a fundamental understanding of how effective teams operate. But implementing integrated collaboration environments that provide these capabilities poses unique interoperability challenges. This paper addresses these topics in the interest of contributing to a framework for effective, interoperable collaboration.

Collaboration and Command and Control

In general terms, command and control is a process that comprises the ability to recognize what needs to be done in a situation and to ensure that effective actions are taken. Actions result from decisions that are made from alternative courses of action. Decisions are made by commanders after reducing their uncertainty about the operational environment and increasing their understanding of the complexities of the operating environment. Executing the decision generates a revised operating environment and the process of command and control is repeated. Hence, command and control is a regenerative process. A critical factor is the time available in which to make the decision and initiate the action. The Observe-Orient-Decide-Act (OODA) model of command and control captures the continuous and cyclical nature of C2. [2]

Collaboration is simply involving two or more people in the command and control process. The purpose of collaboration is to bring additional perspectives to decision making processes and to achieve shared situational awareness and understanding faster (i.e. in parallel as opposed to sequential). Hence, collaboration promises faster and better decisions; faster and more effective actions. The very nature of collaboration promotes teams and the decentralization of command and control, which in turn promises increased initiative, adaptability, and tempo of operations without losing synchronization among the participants.

Collaborative Information Environment (DoD Strategy)

For collaboration to work, a Collaborative Information Environment (CIE) is required. The CIE is a subset of the emerging global information environment. By enabling full collaboration in near-real time across multiple networks, the CIE provides the necessary conditions for creation of actionable knowledge throughout the organization. While, as a concept, the CIE encompasses the entire command and control collaborative environment, many systems are not part of the core CIE system, but are accessed via the core CIE. The CIE provides tools and protocols to enable the sharing of quality information among and across disparate organizations. The CIE consists of five elements:[3]

- People: Members of the team conducting activities to gain understanding of the environment,
- Rules: The customs, laws, procedures and policies that govern behavior in the collaborative environment,
- Architecture: The virtual connectivity structure designed to deliver, process, and function,

[2] John Boyd COL (ret.), "Patterns of Conflict, Briefing on Competitive Organization" (1986).
[3] CJCS, "Joint Command and Control Functional Concept" (2004).

- Infrastructure: The hardware, software, communications links, and supporting equipment, the networks,
- Information: The data representing potential knowledge in the environment.

The remainder of the paper focuses on these elements by grouping them into three categories (namely, people, activities, and supporting capabilities) and exploring critical factors essential to effective, interoperable collaboration in each of these categories.

Collaboration: People Factors

A collaborative team or group has a social component that is strongly correlated to its performance as a team/group. A number of research efforts (representative summaries provided below) have examined the social dimension of group activity and collaboration.

Stages of Team Maturity (Johnson)

People, either by someone's selection or voluntarily, form teams to address a problem. The team must develop internal relationships among the people to accomplish the task. Teams mature as their members learn to work together on the assigned task. During the process of maturing, teams tend to go through predictable stages that result from the rules that apply to the task at hand and from the relationships that develop as the team grapples with an understanding of the situation, develops possible courses of action, and reaches a decision. These stages have been identified as follows:[4]

- "Stage 1: Forming – Individuals who have agreed to be team members initiate their activities as an immature group getting acquainted. The main emphasis for the people is to determine if they have membership, i.e. develop a sense of belonging. They have already decided that they will contribute to the group once others recognize their potential value. Sometimes too much agreement occurs during team forming, and in almost all cases, minimal actual work is accomplished.

- During this stage, task behaviors focus on understanding goals and can be described by the word **orientation.** Relationship behaviors focus on establishing value and understanding roles, and are described as **dependency**.

- Stage 2: Storming – Individuals jockey for influential positions within the group. The honeymoon is over. Conflicting goals and ideas emerge. Again, minimal work is accomplished during this stage. Task behaviors of the storming stage can be described as **organizational**. The relationship behaviors focus on influence and can be described as **conflict**.

- Stage 3: Norming – The group becomes a unit as code of behavior is agreed upon and conflicts resolved. The coalition of individuals begins to become more productive as the

[4] Vern R. Johnson, "Understanding and Assessing Team Dynamics," IEEE-USA Today's Engineer Online, Mar. 2005, 1 Dec, 2007 <http://www.todaysengineer.org/2005/Mar/team_dynamics.asp>.

members share ideas and belief more freely. During the stage, moderate levels of work are accomplished. Task behaviors include sharing skills and knowledge and can be described as **open data flow**. Relationship behaviors are characterized by efforts to work together and are referred to as **cohesion** during this stage.

- Stage 4: Performing – The group has become an effective team, capable of solving problems. As the group of individuals becomes a closely-knit team, synergy is created. The result is a high level of work accomplishment. For the performing stage, the task behaviors are defined a **problem solving**, and the shared leadership-based relationship behaviors is **interdependence**.

The forming, storming, and norming stages produce minimal substantive results. Nonetheless, these stages are inevitable and, although they may vary in duration depending upon the urgency of the mission and the team's makeup, must be traversed before the team becomes truly functional."

Once a task is completed and the team members go on to another task, or if the team's membership changes, the team will likely digress from the performing stage to one of the previous stages; even reverting all the way back to the forming stage. Hence, the development of collaborative teams prior to their actual need, is of paramount concern as the decision making paradigm that involves collaboration through net-centricity evolves. But this is not always feasible. Alternatively, collaborative information environments and trained facilitators could provide structure and content that mitigate the time and effort needed to achieve the forming-storming-norming stages. The reality of time critical operations is that collaborative teams need to operate in "performing" mode as quickly as possible.

Social Aspects of Group Decision-Making (DeSanctis and Gallup)

Two decades ago, DeSanctis and Gallup[5] outlined a Group Decision Support Systems (GDSSs) taxonomy that involves increasing levels of support for group interactions. They identified metrics for meetings (group interactions) that include decision quality and timeliness, satisfaction with the decision, cost of ease or implementation, member commitment to implementation and the group's willingness to work together in the future. They noted that groups whose members are dispersed versus face-to-face demonstrate more equal, uninhibited participation and that such distributed interaction can foster decisions that deviate further from personal preference, At the same time, more dispersed teams can exhibit more social problems and their collective satisfaction with the group's process can start to decline. DeSanctis and Gallup emphasized the need to maintain healthy group satisfaction to ensure that group members are willing to work together again and that GDSS research should be concerned with both performance and satisfaction variables. Distributed collaboration is a fundamental component of C2 conducted in a net-centric environment. Similar concerns must be addressed in the collaboration environments developed and employed for C2.

[5] Gerardine DeSanctis and R. Brent Gallupe, "A Foundation for the Study of Group Decision Support Systems," Management Science Vol.33 No. 5 May 1987.

The Team and Mission Domains (Noble, Buck and Yeargin)

As part of their effort to develop metrics for evaluating collaboration tools, Noble, Buck and Yeargain developed a dual-feedback collaboration model. This model emphasizes that collaborating teams work simultaneously in two different domain, team and mission and that execution monitoring, feedback, and adjustment are central in both domains.

"In the mission domain teams are working to accomplish the tasks that the team was formed to do. In the team domain, the teams carry out additional activities required to maintain effectiveness as a team. These additional activities are the source of much of the collaboration overhead. They include allocating and adjusting roles, coordination, meetings and negotiation. Note that though teams are not formed to maintain themselves, they cannot achieve their mission goals without doing so" [6]

Team Composition and Team Performance

Research conducted by Huber[7] et al. examined the relationship between individual and team characteristics and team performance. The individual characteristics considered included Locus of Control, Ambiguity Tolerance and the four personality dimensions underlying the Myers-Briggs Type Indicator (MBTI) typology. The team-specific characteristic of team cohesion was examined. Social cohesion resulted in team members enjoying working with each other and being positive about working with the original team on another task; social cohesion was important even for 'ad hoc' teams. Task cohesion, the cohesion that motivates team members to complete the team task successfully and enables them to use their resources efficiently, was an even better predictor of team performance. Team performance was driven by shared commitment to the team goal and to mission purpose. The findings are highly relevant to operating in net-centric environments and distributed collaboration.

Observations

Collaboration involves activities that support the mission as well as activities that support the operations of the team, across the evolution of both mission and team. The research discussed in the previous sections all stress the importance of managing the health and status of the team and implementing measures to foster social performance and satisfaction. Yet the discussion of C2 collaboration often ignores the social aspect of collaboration, tending to focus primarily on the mission domain. Essential collaboration functionality includes features implemented to manage team activities and monitor team performance. Common mission objectives, shared battle rhythm, and clear team relationships and responsibilities all factor into team situational awareness. But what other features should be included in collaboration environments to promote social and task cohesion? What other features could help a team quickly evolve from the forming

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[6] David Noble, Diana Buck, and Jim Yeargin, "Metrics for Evaluation of Cognitive-Based Collaboration Tools," (Annapolis, MD: 6th International Command and Control Research and Technology Symposium, 2001).

[7] Reiner K. Huber, Petra M. Eggenhofer, Jens Romer, Sebastian Schafer and Klaus Titze, "Team Composition: Linking Individual and Team Characteristics to Tam Decision-Making and Performance," (Newport, RI: 12th International Command and Control Research and Technology Symposium, 2007).

stage to effective performing? Perhaps the following information should be shared to support and enhance team social performance:

- Unambiguous presence information that spans collaboration tools;
- Group roster and contact information;
- Profile information for individual team members; and
- Social networking information (associates and colleagues).

A better understanding of how to enhance the social domain to realize even more effective collaboration could redefine how collaboration environments are integrated with other data sources and tools. For example, user profiles (contact information, biographical information, access privileges, etc.) are often not shared across applications but rather are stored and maintained locally. A common, interoperable user profile service may be very valuable. What is clear from past research is that the information and capability needs of the team social domain must be considered in order to achieve effective, interoperable collaboration.

Collaboration: Activity Factors

Rules are the customs, laws, procedures and policies that govern behavior in the collaborative environment. Group behavior occurs in the context of both mission-oriented tasks and tasks conducted to ensure the health and status of the group itself. Effective collaboration requires an understanding of collaboration processes, optimal mapping of processes to collaboration tools and the development of tactics, techniques and procedures (TTPs) that capture best practices for future operations.

Collaborative Group Tasks

A number of research efforts have focused on characterizing the collaboration processes. They include:

- Nobel, et al, also developed an individual-team interplay model that integrates individual and team activities and characterizes interactions between team members. Per the model, when team members interact during decision-focused tasks, they perform seven types of cognitive functions: information exchange, brainstorm, review, negotiate, consolidate, handoff, decide and disseminate. In terms of collaboration features, some of these require synchronous human-to-human interaction (e.g., brainstorm) while others might be conducted in a more asynchronous manner (e.g., information exchange and handoff).

- Macrocognition is the "internalized and externalized high-level mental processes employed by teams to create new knowledge during complex, one-of-a-kind, collaborative problem solving" [8]. A significant body of work has focused on building

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[8] Michael Letsky, Norman Warner, Stephen M. Fiore, Michael Rosen and Eduardo Salas, "Macro-cognition in Complex Team Problem Solving," (Newport, RI: 12th International Command and Control Research and Technology Symposium, 2007) 2.

and extending a conceptual model of team collaboration based on macrocognitive processes demonstrated in team collaboration. The original model developed by Warner, Letsky, & Cohen[9] included 23 collaboration processes mapped to four phases of collaboration: individual knowledge building, developing knowledge inter-operability, team shared understanding, and developing team consensus.

Complimentary research has addressed mapping processes to tools to achieve optimal collaboration (Wroblewski andWarner)[10], developing joint TTPs for virtual teams to facilitate effective use of collaboration environments (Jensen)[11] and capturing workflow to support dynamic, distributed collaboration.

Observations

DoD missions are defined by activities and tasks, some of which require collaboration. Mission activities can be mapped to the underlying collaborative processes used to complete these activities. In 1987, DeSanctis and Gallup mapped a common set of group tasks to GDSS features. Subsequent efforts have mapped mission and team activities (generalized and operation-specific) to underlying collaborative processes and then appropriate collaboration tools. These mappings can be used to develop a catalogue of mission and operation-tailored patterns or templates that serve as "blueprints" for heterogeneous, integrated collaboration environments.

DeSanctis and Gallup envisioned that GDSSs would provide "rules for controlling the pattern, timing and content of information exchange"[12]. Rules patterns would provide guidance for how effective teams operate and individuals interact with each other. They would address the authority and privileges associated with different assigned roles within the group. As needed, pre-defined rules "patterns" would be customized to meet the unique needs of specific groups. Others have since explored collaboration TTPs that would embody best practices for collaboration (e.g., Jensen has identified candidate Joint TTPs for virtual teams). Collaboration patterns discussed above would provide pre-defined mappings of collaborative processes to tools as well as best practices for interactions. These patterns would address both mission tasking and team management and would themselves represent information and data that would be characterized, managed and exchanged. The idea of collaboration patterns is an integral component of the Dynamic Collaborative Action Team (DCAT) Framework explored by the Johns Hopkins University Applied Physics Laboratory (JHU/APL)[13].

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[9] Norman Warner, Michael Letsky and Michael Cowen, "Cognitive model of team collaboration: Macro-cognitive Focus," (Orlando, FL: 49th Annual Meeting of the Human Factors and Ergonomics Society, 2005).
[10] Elizabeth M. Wroblewski and Norman Warner, "Team Collaboration Tools: Addressing the Need for Macro-Cognitive Support," 20 Oct. 2007 < http://www.onr.navy.mil/sci_tech/34/341/cki/publications.asp>.
[11] Jens Jensen, "Joint Tactics, Techniques, and Procedures for Virtual Teams," 3 Nov. 2007 < http://www.onr.navy.mil/sci_tech/34/341/cki/publications.asp>.
[12] Gerardine DeSanctis and R. Brent Gallupe, 594.
[13] Christine Salamacha, N. Ray Briscoe and Steve Forsythe, "Managing Dynamic Collaborative Action Teams in a Net-Centric Environment," (San Diego, CA: 10th International Command and Control Research and Technology Symposium, 2005).

Collaboration: Supporting Capability Factors

The collaboration software includes[14] communication tools, conferencing tools and collaborative management (coordination) tools. Communication is the unstructured interchange of information. Electronic communication tools send messages, files, data, or documents between people and facilitate the sharing of information. Examples includes e-mail, Instant Messaging (IM), faxing, voice mail, Wikis, Web publishing and Really Simple Syndication (RSS). Conferencing is interactive work toward a shared goal (e.g., brainstorming or voting). Electronic conferencing tools facilitate the sharing of information, but in a more interactive way. Examples include Internet forums (also known as message boards or discussion boards), on-line chat, voice (landline, mobile or Voice over Internet Protocol (VoIP), video conferencing, whiteboarding, application sharing and electronic meeting systems (EMS). Finally, coordination refers to complex interdependent work towards a shared goal. Collaborative management (coordination) tools facilitate and manage group activities. Examples include electronic calendars, workflow systems, project management systems, workflow systems, knowledge management systems and social software systems. Figure 1 illustrates[15] Internet trends that are shaping collaboration processes. The diagram provides a Web 2.0 Meme Map posted on the Internet, annotated with examples of potential impacts on collaboration.

DeSanctis and Gallup outlined the concept of a GDSS Shell; "in addition to task-oriented support, features intended to address the social needs of groups should be included in GDSS shell systems"[16]. They anticipated the concept of User-Defined Operational Pictures (UDOPs) and the strategy reflected in the Global Operations Center-Collaborative Environment (GOC-CE) implemented by the Unites States Strategic Command (USSTRATCOM). The GOC-CE was implemented with portal technology. Portal technologies allow for creation of workspaces equipped with a variety of services and tools that can be customized for decision-making groups. Geo-spatial visualization tools are utilized extensively in warfighting environments and can also serve as the primary framework for organizing diverse information relevant to an operation or mission. Geo-spatial mapping and visualization tools have been adapted for collaboration management and are often bundled with other collaboration tools. For example, JHU/APL has conducted research to seamlessly integrate text chat, geo-spatial visualization and semantic technologies into an advanced, integrated collaboration environment that operates as a UDOP.

Collaboration interoperability (e.g., common standards, etc.) is essential to realizing seamless sharing of information across different tools. Common, ubiquitous services should address[17]:

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[14] "Collaborative Software", *Wikipedia*, 1 Oct. 2007 <http://en.wikipedia.org/wiki/Collaborative_software>.

[15] Web2MemeMap: Result of a "What is Web 2.0?" brainstorming session at FOO Camp 2005, 1 Oct. 2007, <http://www.thisisgoingtobebig.com/2005/09/web2mememap.html>, *Meme maps adapted from business model maps developed by Beam Inc.*.

[16] Gerardine DeSanctis and R. Brent Gallupe, 597.

[17] The 2007 Net-Centric Operations Industrial Consortium (NCOIC) report titled "Findings and Recommendations for Mobile Emergency Communications Interoperability" identified rights management, access control and locater/directory as essential core services for mobile emergency communications.

- ***Presence awareness,*** i.e., the awareness that a given individual is actively using or monitoring a collaboration tool. The term “actively” implies that a given individual is logged onto a session/ workspace, chat tool, etc. Whether the individual is actually paying attention to the content being shared is harder to discern. Historically, presence has not been shared across collaboration tools.

- ***Permissions management and access control:*** i.e., authorization granted to individual or functional role that controls access to tools, workspace, data, etc.

- ***Locater or Directory Service:*** i.e., directory that contains information about individuals and organizations, in particular, contact information

Collaboration interoperability is also critical if disparate tools are to be integrated into a common, collaboration environment.

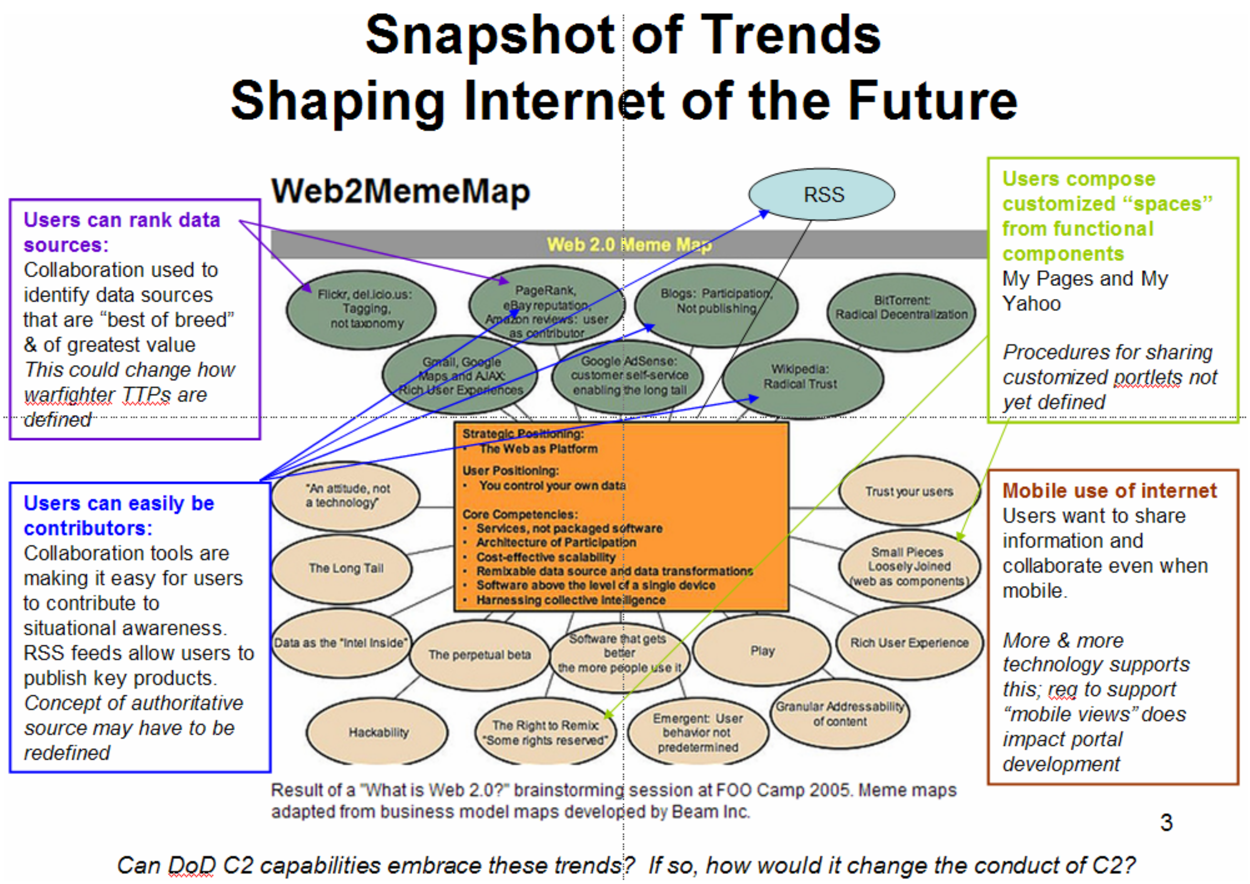

Figure 1: Internet Trends Shaping Collaboration

Achieving Interoperable and Integrated Collaboration Capabilities

Are current collaboration capabilities sufficiently interoperable to yield integrated environments and seamless collaboration for users? The following examples highlight key concepts that are contributing to seamless collaboration.

Can someone using one instant messaging (IM) tool text chat with someone else using a different IM tool? Today, the answer depends on the tools. Figure 2 depicts a case where ubiquitous interoperable IM is realized because connections have been allowed and established by IM services, namely America On-Line (AOL) and Live Communications Server (LCS). In this example, 'transparency' is enabled explicitly by the IM service providers.

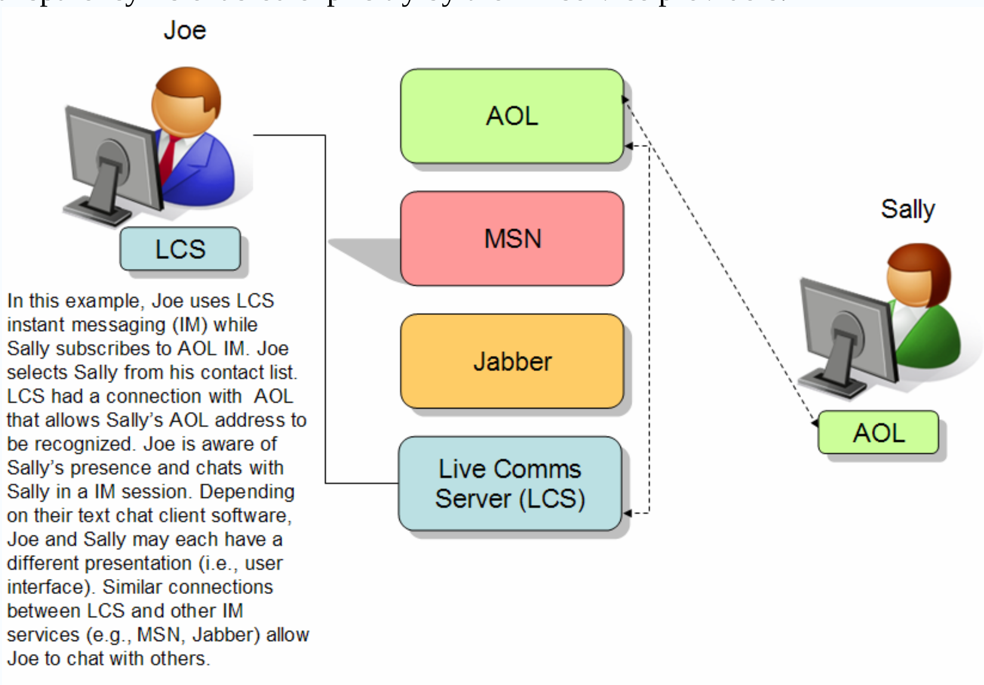

Figure 2: Example of IM/Text Chat Interoperability

Trillian[18] represents another alternative for achieving interoperable IM collaboration where a third-party service transparently implements bridging between IM services. Trillian is a proprietary multi-protocol instant messaging application that can connect to multiple IM services. Users are not required to run multiple clients or register for proprietary accounts. Trillian provides a *mediation* service that accounts for proprietary differences between IM service providers.

The Cross Domain Collaborative Information Environment (CDCIE) is a United States Joint Forces Command (USJFCOM) initiative to provide interoperable collaboration capabilities to warfighters. CDCIE enables interoperability for core collaboration tools such as text chat and whiteboarding by employing an open software architecture standard (i.e. eXtensible Markup Language (XML)) that allows it to interoperate with other systems and to be rapidly modified to

[18] "Trillian (Software)," 11 Oct. 2007 <http://en.wikipedia.org/wiki/Trillian_(instant_messaging_client)>.

meet warfighters' needs.[19] For example, during the Strong Angel III disaster response exercise, a participant group using an open standards based chat tool was able to communicate with the CDCIE chat tool simultaneously. CDCIE is designed to provide seamless interoperability across networks as well as collaboration tools. CDCIE (depicted in Figure 3) employs guard and gateway technology to provide interfaces between networks of varying classifications. Guarding and gateway capabilities reside in key computing facilities around the world, and the *client applications such as the chat and whiteboard tools can be downloaded via a user registration* process. The CDCIE's current client system can be downloaded and used on any computer. As the technology evolves, the various guards, gateways and applications can be replaced or updated. CDCIE follow-on phases will provide a web services guard, assured file transfers, a whiteboard capability and e-mail with attachments as well as a redaction tool that will scrub documents to remove any hidden information. Another CDCIE application under development is a chat tool designed specifically for web browsers that will permit browser-to-browser communications without the need for installing additional software.

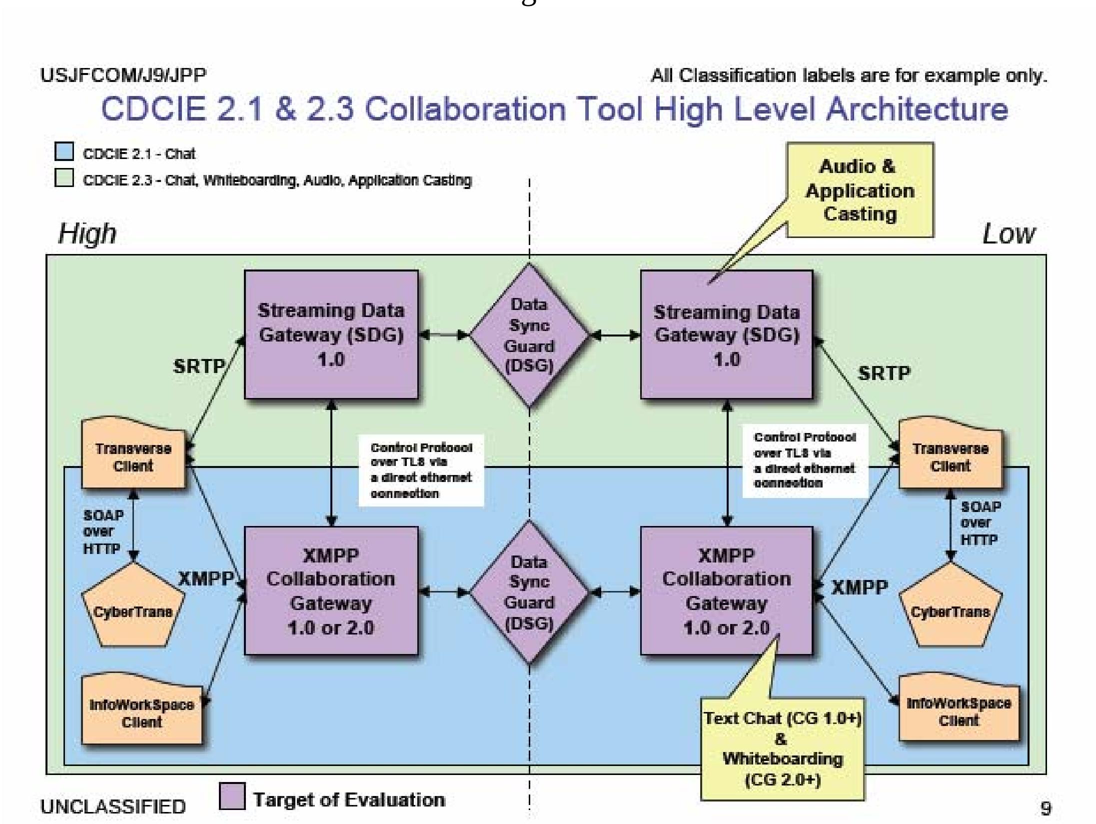

Figure 3 : Cross Domain Collaborative Information Environment (CDCIE) Architecture[20]

The GOC-CE, discussed previously, and the Mobile Tactical Collaboration System (MTCS)[21] are two examples of capabilities that support collaboration by providing *web-browser based*

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[19] Henry S. Kenyon, "Connecting Military Nets Through Open Source Collaboration", LinuxInsider, 5 May 2007, 28 Oct. 2007 <http://www.linuxinsider.com/story/57586.html>.
[20] 14 Feb. 2008 <http://www.sensornet.gov/net_ready_workshop/Boyd_Fletcher_CDCIE_XMPP_Overview _for_Net ReadySensors_Conf.pdf>.
[21] 1 March 2008 < http://www.ordiasolutions.com>.

access to common worskpaces equipped with a collection of common tools. GOC-CE utilized Sharepoint portal technology to provide common workspaces; MTCS workspaces are implemented using Virtual Earth. GOC-CE users operated from fixed sites while MCTS is designed for mobile users. MTCS *integrates diverse collaboration tools* such as drawing, white boarding and voice-over-IP with advanced Geographical Information Systems (GIS) and incident management tools. Using software-radio bridge technologies, MTCS terminals can communicate with other voice systems. The system uses standards-based XML messages and can integrate with other information systems, such as Emergency Operation Center (EOC) software, computer-aided dispatch (CAD) and vehicle tracking systems. By comparison, in the case of GOC-CE proprietary tools limited the integration that could be realized.

Both GOC-CE and MCTS provide common tools with varying degrees of tool integration. The JHU/APL research effort cited earlier has produced a prototype collaboration capability in which a GIS mapping tool integrated with text chat is further enhanced by semantic technology. Even more intriguing, the JHU/APL team successfully demonstrated a *“common data” vice “common tool” approach;* essential GIS data was shared to enable a common picture, allowing users to use preferred visualization tools rather a designated common tool. A comparable approach was also implemented for text chat.

Framework for Effective, Interoperable Collaboration

As evident by the topics presented in this paper, a tremendous amount of research has already been conducted on topics related to collaboration. So what remains to be addressed? This paper has summarized key components that are critical to effective collaboration. What remains is putting these components together into an integrated framework that enables effective collaboration.

- A collaboration framework must acknowledge the importance of the social domain and the mission domain and provide functionality critical to each domain. Figure 5 depicts the initial stage of a framework for addressing key drivers in the two domains.

  The team social domain accounts for team maturity and the level of team homogeneity. Data and tools provided specifically to enhance team performance can be tailored relative to these key drivers. A key consideration is collaboration tools that foster team trust and confidence and quickly move the team from forming to performing as discussed earlier. Key drivers in the team mission domain are the level of team interaction required or that can be supported and the degree to which mission collaboration supports sense-making versus decision-making. Level of team interaction must address disadvantaged users with limited bandwidth or intermittent connectivity; collaboration tools will need to be tailored to ensure that common awareness and understanding is maintained for such users.

- For the framework depicted in Figure 4, a range of attributes would be defined for the key drivers specified. This paper has highlighted examples of research where mission activities have been mapped to collaboration processes and in turn to collaboration tools.

Existing research would be leveraged to make initial allocations. Collaboration technologies and tools, such as text chat, RSS, Wikis, portals, etc., could then be mapped to the domain grids.

- It is still important to validate the mission and team support provided by collaboration tools and environments. Validation will likely require experimentation and instrumentation. A topic that was not discussed in great detail in this paper is whether UDOPs may at times contribute to degraded shared awareness if individual displays become overly customized.

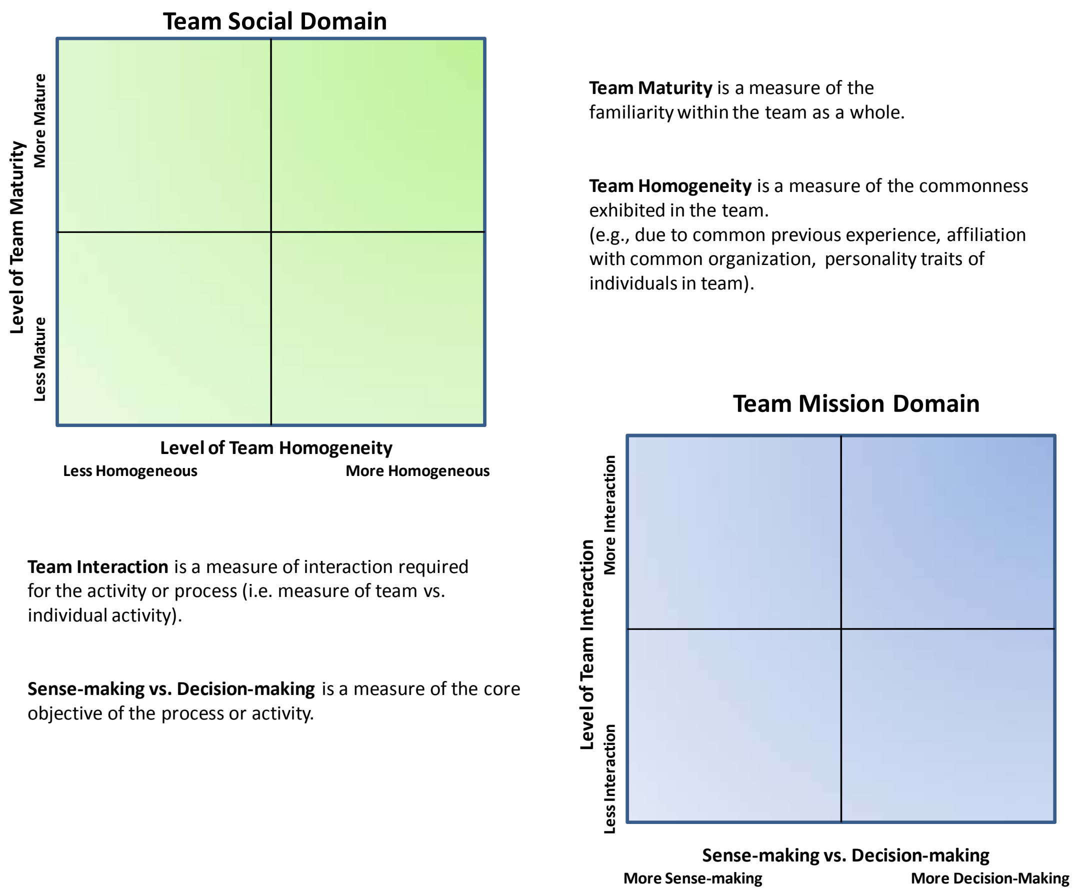

Figure 4: Initial Stage of Framework for Effective, Interoperable Collaboration

- An integrated collaboration environment is a desired end-state. Understanding how a suite of collaboration tools may be used to collectively support mission activities provide a better understanding of the underlying interoperability needs and challenges. Interoperability is required across common tools as well as diverse tools. Focusing on interoperable information sharing allows for collaboration using preferred tools. The development of common services (e.g., presence awareness, permission and access management, and locator or directory capability) would contribute to the development of more effective, integrated collaboration environments.

Collaboration technologies are continuously evolving. While C2 collaboration concepts will define how these technologies are used, it is also true that new technologies will shape future C2 collaboration. In turn, the evolution of collaboration will foster new needs for technology and team member requirements.

Biographies

Christine O. Salamacha is a member of the Principal Staff of the Johns Hopkins University Applied Physics Laboratory. Over the past several years, she has been involved in a number of DoD C2-related initiatives. Her focus areas include collaboration and information sharing for dynamic, distributed teams. She holds a BA in Mathematics from Loyola College, Baltimore MD and a BS in Computer Science from the Johns Hopkins University Applied Physics Laboratory.

H. Bennett Teates is a member of the Senior Staff of the Johns Hopkins University Applied Physics Laboratory (JHU/APL) where he is involved in the development of capabilities addressing distributed, net-centric command and control. Prior to joining the JHU/APL he was the co-founder and CEO of Command Control, Inc., in Atlanta, Georgia, where he led the development of command and control applications for both the military and industrial sponsors. He holds a B. Sc. degree in Electrical Engineering from Virginia Tech and advanced degrees from the George Washington University and the Johns Hopkins University.