COLLABORATIVE PLANNING OVER LOW BANDWIDTH TACTICAL NETWORKS

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ABSTRACT

Collaboration planning (CP) and the Inmarsat on the move satellite system were key enabling technologies for Corps and Division level commanders during Operation Iraqi Freedom (OIF). CP consists of planning tools such as whiteboarding, chat, voice conferencing, and file sharing with numerous collaborative tools commercially available today. The DoD standard for collaboration is the Defense Collaboration Tool Suite (DCTS). While the Inmarsat and DCTS capabilities provided significant improvements in capability for the warfighter, the scalability of these technologies is limited. The commercial CP tools within DCTS such as Microsoft's Net Meeting are optimized for operation on high speed wired networks, and consequently do not operate well over low bandwidth tactical networks. Additionally the Inmarsat architecture employed is very cost prohibitive when scaled beyond a handful of Army commanders. This paper provides an overview of a prototype Tactical Collaboration Tool (TCT) that was developed to operate over low bandwidth wireless networks, along with recommendations for improving the Inmarsat satellite architecture. The paper includes an analysis of the performance of the TCT over a simulated Inmarsat network, and contrasts it against commercial CP tools.

INTRODUCTION

Collaboration software provided an invaluable capability during Operation Iraqi Freedom. Users of these systems were situated at locations from garrison to command and control vehicles (C2V) performing on the move operations. The overall capability was very successful, but there were some problems that in general can be traced to bandwidth and communication architecture issues.

Most collaboration software tools have been designed for enterprise networks. These networks are characterized as having high bandwidth (measured in Mbps) and low latency, bit error rates, and jitter. Tactical communications channels are often characterized as quite the opposite, especially at the lower echelons (e.g., 10^{-5} bit error rate, 500+ msec round trip delay, and <64 kbps between geographically disbursed locations). With these communication channels being shared for traffic other than collaboration, it becomes difficult to support enterprise class collaboration software.

The Tactical Collaboration Tool was implemented with methods typically not found in enterprise collaboration tools. These methods support the nature of tactical communications and significantly reduce the bandwidth consumed over these communications channels.

OVERVIEW OF COLLABORATION TOOLS

The Defense Collaboration Tool Suite is the current standard for collaboration in the DoD. DISA is the lead for maintaining this standard, and providing a method for other collaboration tools to be interoperable with DCTS. Only those tools interoperable with DCTS, or those with exemptions are permitted on DoD networks after October 2003[1].

DCTS is a place-based system providing synchronous and asynchronous collaboration capabilities. Synchronously, DCTS users have access to text chat, instant messaging, audio chat, whiteboard, shared applications, video, and shared files using Microsoft's NetMeeting or Sun's SunForum software. All but the Instant Messaging capabilities are based on the T.120 and H.323 standards. Instant messaging, along with presence and awareness is provided by Asynchrony's Envoke product. Asynchronously, users have access to navigating a virtual, hierarchical space, sharing files, launching meetings composed of the synchronous tools, viewing an information banner, and creating accounts.

Interoperability with DCTS is achieved through standards. including HTML, HTTP, XML, T.120, H.323, and the Envoke API. JITC is tasked with testing for interoperability with these standards across fifteen criteria[2]. To date, twelve commercial products are certified interoperable. These products include both full-featured collaboration systems and specialized systems. IBM's Lotus Web Con-

[1] Memorandum from John P. Stenbit, "DoD Collaboration Interoperability Standards," November 1, 2002

[2] For more detailed information, see http://www.jitcwashops.disa.mil/projects/JTCD/DCTS/documentation/Certification_Matrix_V8_7.xls

ferencing System and Ezinia's IWS are full-featured. Specialized systems include both Webbe for text and audio messaging and Tandberg's 1000 VTC for video teleconferencing.

Existing collaboration systems provide a subset of the asynchronous and synchronous capabilities specified above for DCTS. They typically differ in the feature set of each capability. The majority of these systems rely on a client-server architecture. The client-server architecture typically provides a set of centralized management functions and often provides a capability to connect servers. Connecting servers can increase the number of supportable users, create a fault-tolerant environment, and/or save bandwidth.

INMARSAT OVERVIEW

The current generation of Inmarsat (Inmarsat-3) satellites provide worldwide coverage through a fleet of five satellites. The Inmarsat-3 system consists of the satellite components and a series of Land Earth Stations (LES). Inmarsat-3 offers several service types based on the terminals utilized. The service that was utilized during OIF, providing a data rate of 64 kbps, is the Global Access Network (GAN) service. There are three services offered within the GAN service, 1) on demand dialup, 2) mobile packet data service (MPDS), and 3) dedicated channel leasing. The on-demand mode, which is of interest within this paper, provides a dedicated, full duplex, 64 kbps link between the mobile terminal and an ISDN modem (i.e. a point to point connection). While this service provides a reliable, dedicated channel to each terminal, it comes at a price of approximately $6-$12 per minute.

The Inmarsat-4 satellites are the next generation of Inmarsat satellites that will provide numerous improvements over the Inmarsat-3 satellites. Of most importance will be increased data rates to 432 kbps per channel and a packet based shared access. The service is referred to as Broadband GAN (BGAN), and the high data rate capability is achieved through the use of higher gain satellite spot beams, analogous to a cellular network. The packet based shared access will allow multiple terminals to dynamically access the satellite, resulting in a reduced cost model when contrasted to operation over a dedicated ISDN connection.

EXAMPLE CP ARCHITECTURE

During Operation Iraqi Freedom (OIF), DCTS capabilities were deployed to Command and Control Vehicles (C2V) to provide an on-the-move collaboration capability to field commanders. Inmarsat satellite communications were incorporated into the C2V's to support access to the DCTS server as well as other operations.

Figure 1 illustrates a notional architecture using Inmarsat-3 with dedicated circuits between each mobile user and an ISDN destination in a Sanctuary. This architecture provides a robust capability due to the dedicated full duplex 64 kbps circuit provided per mobile user. It suffers though from cost (i.e. service and equipment), scalability issues, as well as inefficient use of the bandwidth for multicast traffic. The cost/scalability issue arises from the fact that each user needs a dedicated circuit. Therefore, for a typical Brigade deployment consisting of nine nodes, requires nine dedicated Inmarsat circuits. In addition, this architecture would require nine suites of electronics (i.e. COMSEC and ISDN modems) at the Sanctuary. Furthermore, all multicast traffic must be sent from the sanctuary multiple times individually to each mobile user.

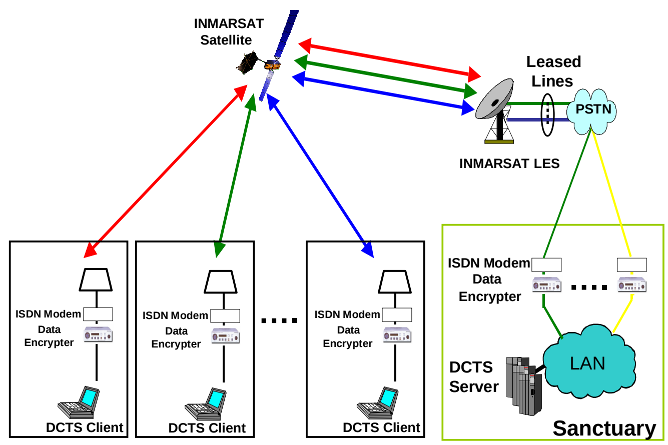

Figure 1. CP/Inmarsat Notional Architecture

An improved CP architecture is depicted in Figure 2. The proposed architecture would provide a more scalable, and cost effective solution. This architecture is similar to that shown in Figure 1, but has two fundamental differences. First, each mobile user no longer has a dedicated channel. Instead "n" mobile users share a single common forward channel (i.e. mobile to Hub) that is dynamically assigned based on user traffic demands. Access to the forward channel is controlled by a network controller collocated with the Inmarsat hub. Secondly, the return channel (i.e. from Hub to mobiles) will broadcast traffic to all mobile users. This architecture offers several significant advantages: 1) the sharing of the forward channel provides an efficient use of the BW by allowing users with traffic, to capture the resources while other users are idle and thus reducing the required number of channels from "n" to a single shared channel, 2) The use of broadcasting on the return channel allows an efficient transport for traffic that is destined to all or some of the mobile users such as white boarding and voice conferencing, and thus reducing the need to transmit the same information multiple times, and 3) The sharing of the forward channel reduces the required hardware in the hub from 'n' receivers (required for the architecture illustrated in Figure 1) to only a single receiver (required for the architecture illustrated in Figure 2).

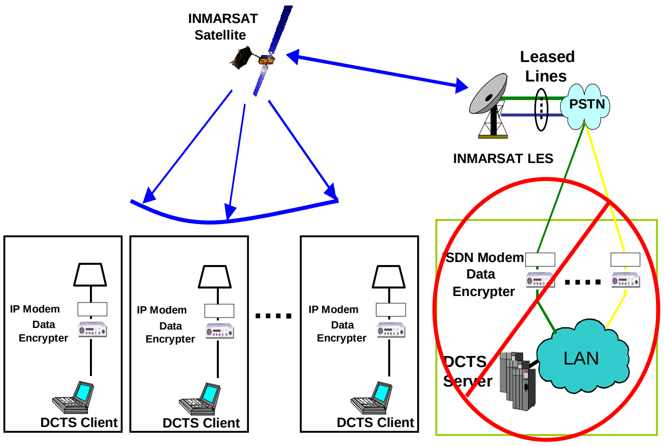

Figure 2. CP/Inmarsat Notional Architecture

To support tactical collaboration, not only must the communication systems improve, but the CP tools must also be modified. For example, commercial CP tools such as those within DCTS distribute information in a unicast fashion, typically between the client and a CP server. Much of the CP data though is intended for a wide distribution and results in multiple unicast transmissions to each recipient. For example, if a single host in one of the vehicles from Figure 1 speaks to participants in a collaboration session in eight other vehicles, a 21 kbps stream of unicast Voice over IP (VoIP) packets is transmitted from the originating vehicle through the Sanctuary to a DCTS server. From the DCTS server, nine unicast copies of the audio are sent out, one to each vehicle (including the speakers vehicle). Each copy of audio to each recipient is identical, other than header information (i.e., destination IP address). This results in a significant growth in the amount of information that must traverse the communication links. In this instance, 21 kbps of information will require 21*9 kbps of bandwidth. The CP tools must be improved to allow for more efficient dissemination of data.

TACTICAL COLLABORATION TOOL (TCT) PROTOTYPE

The Tactical Collaboration Tool (TCT) prototype provides a new approach to collaboration software for tactical users. TCT provides an efficient data transport mechanism in austere network environments for Whiteboard, Text Chat, and Audio Chat tools. While the prototype's emphasis is on distributing information in an efficient manner for tactical users, it contains features in demand by more traditional collaboration users as well.

The collaboration tools used in OIF for audio and whiteboard relied on robust networks. Their transmission of data via unicast TCP and UDP would place a burden on the tactical networks to the point of not working consistently, if at all. Several products built on the T.120 and H.323 collaboration standards, do not allow for efficient distribution of data over tactical communication channels.

The TCT Prototype departs from the standards to provide functionality to the tactical user. These requirements came out of an exercise in 2003 for Brigade-level users preparing to deploy to Iraq. Specifically, these troops required up to nine users in a collaboration session with whiteboard, text chat, and audio chat. Brigade users have limited communications capabilities, and current DoD certified COTS and GOTS tools (e.g., DCTS, IWS, Groove, Webbe) did not efficiently provide this functionality over the expected communications capabilities.

TCT departs from existing standards and practices in two significant ways. First, TCT moves data around using a reliable multicast method, and second, it does so without centralized servers (decentralized architecture). Reliable multicast is provided by Jgroups[3], an open source, Java-Based library. Session synchronization is the responsibility of the Synchronized Multicast Transport Service layer (SMTS), a MITRE developed distributed state function which leverages JGroups. TCT provides the ability to coordinate sessions without a central server, and supports network segmentation and session re-joins without loss of data and coordination - something systems relying on centralized servers do not currently support.

TCT COMMUNICATIONS

Communication among TCT peers is through the SMTS layer. SMTS leverages a MITRE-developed application layer protocol that is layered upon JGroups reliable multicast to ensure the integrity of TCT sessions. Each TCT peer, upon instantiation, first joins a preconfigured *Guide Session*. The guide session provides each peer with the list of available active sessions they can join. Responsibility for advertising which sessions are active and available is one of the roles of the TCT *Session Leader*. The current TCT session leader is defined to be the first listed member

[3] For more detailed information, see: http://www.jgroups.org

of a session *view* as provided by JGroups. The leader is not a single point of failure, and traffic for the session does not route through the leader. The role of the leader is two-fold: (1) to advertise session availability for its session by multicasting session advertisement packets in the guide session, and (2) to provide a synchronized view of the session by periodically multicasting session state packets which relate the current state of the TCT session to all members currently in that session. If the leader is dropped from the session, another leader is selected from the new view received from JGroups.

The TCT supports disconnected operations through SMTS synchronization services. New members of a session are provided a history of all session events from the current leader of the session. Previously joined members are provided only new session events missed while disconnected. Any additional session events that the joined/rejoined session member has that the current leader does not have are multicast to the session in the following manner. Each new session event is assigned a randomized timeout at which time the event will be retransmitted (multicast) to the session. While awaiting this timeout, the sending peer listens for incoming session events. If the received event matches the queued retransmission event, the retransmission event is removed from the resend queue. This approach reduces the possibility of network flooding even if multiple sending peers have the same new events to re-transmit.

TCT WHITEBOARDING

The prototype's whiteboard provides features unique to collaboration tools of this ilk. In addition to being built on a reliable multicast layer, the whiteboard provides pre-distributed, geo-referenced maps. Existing systems, such as DCTS, require maps to be distributed in real time (often each time a network link is broken). Each map transfer in existing tools often consumes a megabyte or more of bandwidth to each user. Maps in existing systems are not geo-referenced; in fact they are usually uncompressed bit-map images. The TCT whiteboard also supports placement of text, geometric figures, and a subset of MIL-STD-2525B symbology on a geo-registered map background. The ability to save and restore sessions supports planning operations. An efficient multicast-based file transfer capability is also provided.

TCT TEXT CHAT AND VOICE OVER IP

The prototype includes a text chat feature through which a user can send text messages to all members of a session or to selected individuals in the session. New members or re-joining members receive the text of the entire session. As with whiteboard session events, members receive only those messages/events they currently do not have (delta events).

The tool, depicted in Figure 3 is undergoing testing at the CERDEC (Fort Monmouth, NJ), the CTSF (Fort Hood, Texas), and the MITRE facility in Eatontown, NJ. An evaluation version of the TCT Prototype is available, and the distribution includes documented code for the transport layer (SMTS) which is licensable through MITRE.

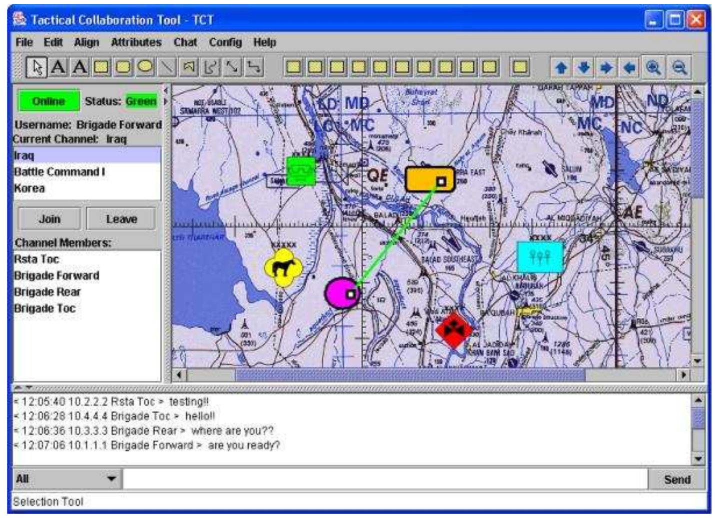

Figure 3. TCT Prototype

HARDWARE TEST RESULTS

The TCT performance was analyzed over an emulated satellite network. The network architecture is depicted in Figure 4. A network of nine computers hosting both DCTS and TCT was developed. Each host was connected to a router which was then connected through a pair of additional routers to an Adtech SX-12 channel simulator. The Adtech channel simulator was utilized to replicate the bit error rate and latency introduced by the satellite. The routers were configured so that all packets flowed from the originating host across the channel simulator and then back through the channel simulator to replicate the flow through the Inmarsat LES. The routers on either side of the Adtech also performed the multiplexing function that would be characteristic of a shared access IP modem.

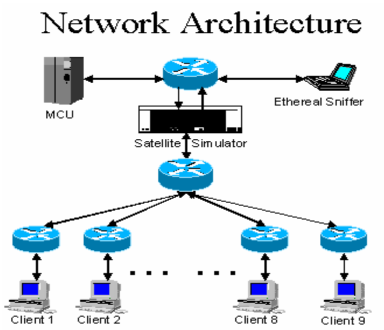

Figure 4. Test Architecture

Figure 5 depicts the aggregate packet flow across the channel simulator during the nine person CP session without voice. Note that the vertical axis represents the total traffic in Kbytes traversing the channel simulator in 1 second increments. It can be seen that the CP session has peaks of only about 32 kbps. A similar session with commercial CP tools would require approximately 8-9 times this.

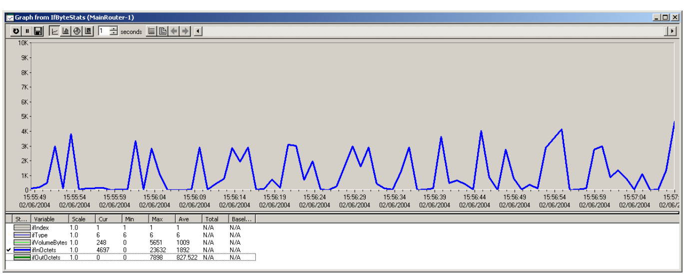

Figure 5. Nine TCT Clients without Voice

Figure 6 depicts the performance of the TCT session with a multicast voice session added. An NRL developed voice tool called IVOX was utilized for this with a 2.4 kbps MELP VoCoder. It can be seen that this increased the peak load to approximately 64 kbps. Again a fraction of the bandwidth which a commercial CP product would require.

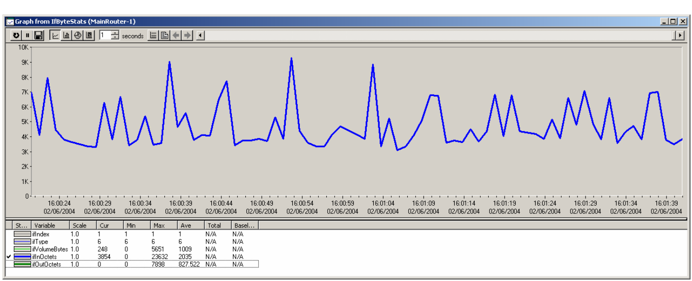

Figure 6. Nine TCT Clients with Voice

To further quantify the TCT bandwidth efficiency, Table 1 depicts the detailed bandwidth usages for several collaboration actions in TCT and DCTS.

Table 1. Comparison of TCT and DCTS

	TCT (Kbps)	capture time (sec)	DCTS (Kbps) out bound	DCTS (Kbps) in bound	capture time (sec)
Background traffic	0.3	231	0.1	0.2	221
Connect					
Launch	4.7	53	11.8	5.6	51
Login	2.2	24	149.9	34.6	92
Keep alive	1.6	81	79.7	30.1	123
1 session					
Create/join	20.8	49	105.3	38.3	59
Keep alive	2.6	83	79.6	29.6	99
Launch netmeeting	NA	NA	132.1	56.6	66
Upload map	NA	NA	6460	900	5
White boarding	4.0	76	85.2	34.2	54
Chat	2.7	46	84.1	34.6	41
2 session					
Create/join	10.1	45	118.4	42.1	41
Keep alive	3.2	88	79.9	29.9	98
White boarding	5.2	71	85.1	35.4	50
Chat	4.5	47	84.9	34.8	36
3 session					
Create/join	4.9	60	119.0	44.1	36
Keep alive	4.7	80	79.9	31.6	103
White boarding	5.8	72	85.1	35.1	86
Chat	4.9	45	84.5	34.6	46
Audio					
Keep alive	3.0	48	80.4	32.2	81
1 person talk	7.1	44	275.2	54.3	51
2 person talk	11.9	55	275.2	75.4	53
IVOX only					
Keep alive	0.4	150	NA	NA	NA
1 person talk	5.0	70	NA	NA	NA
2 person talk	9.5	40	NA	NA	NA

CONCLUSION

A collaboration capability has been developed that is optimized for low bandwidth tactical networks. The tool leverages existing commercial technologies to improve the bandwidth efficiency of the application, while still maintaining comparable capability to the enterprise collaboration tools. TCT keys on two fundamental concepts: reliable multicast dissemination of collaboration data and a decentralized (server-less) architecture to achieve these efficiencies.