Whitepaper

Enhancing Live, Virtual and Constructive Simulations with XMPP Based Transport and Capture

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Abstract

This paper discusses the advantages resultant of extending Extensible Messaging and Presence Protocol (XMPP) based Multi-User Chat (MUC) rooms, to “TeleCollaboration” rooms. With this, trainees and instructors can synchronously view, record, and/or manipulate any number of live or recorded media/data streams from globally distributed, network-enabled, live, virtual, and constructive simulations.

Introduction

Today, it is almost universally believed that in the 21st century live-virtual-constructive (LVC) environments will play an increasingly critical role in the training and preparation of globally distributed forces, for the purpose of international assignments of joint forces operations, and otherwise. The United Stated Joint Forces Command (USJFCOM) states that it already has began

"us[ing] a mix of live, virtual, and constructive models and simulations…to provide the most realistic collective joint mission experience possible…and [create] an environment where every level of training is orchestrated in a joint context to provide the highest level of training for seamless future military operations."

Given the key role LVC simulations are going to play in the future of training and simulation, the need for an effective networked brief/debrief system has never been greater.

This paper discusses the extension of Extensible Messaging and Presence Protocol (XMPP) based Multi-User Chat (MUC) rooms, to Multi-User "TeleCollaborationTM" (MUT) rooms, for the purpose of establishing a flexible control protocol for networked LVC brief/debrief systems. Brief/debrief systems based on synchronized streaming, recording, and playback of video, audio, and data sources increase manyfold the efficiency and value of expensive training systems. They provide an in-depth learning experience through better and clearer event correlation, quicker access to key events, and multi-site and multi-type synchronized brief/debrief. As a result, students are better prepared for the battlefield.

Requirements for Networked LVC Brief/Debrief Systems

Modern training systems make use of the latest in audio-visual technology, such as high-resolution screens driven by powerful computers. Being able to transport, capture, and visualize all ongoing actions and data, i.e. audio, high resolution and frame rate video, and data streams, during training sessions for remote participation with globally distributed forces, immediate after action reviews (AAR), and effective and powerful analysis is a challenging task that makes building brief/debrief systems a daunting undertaking. However, this is exactly what the MUT extension enables in addition to fulfilling various other requirements of modern day brief/debrief systems.

State-of-the-art networked LVC brief/debrief systems must fulfill the following requirements:

- The connection of physically separated training centers and equipment, without the use of dedicated assets, to dynamically create brief/debrief environments.
- Time-synchronized recording and playback with Personal Video Recorder (PVR) control of data from the training session, including DIS/HLA data (from simulators), computer (video) screens (out the window, god's eye view, instrument panel, radar, etc.), video (pilot position, etc.), audio channels, etc. All video must be captured directly from the screens the student is seeing in full resolution and frame rate, and visually lossless quality so that during the AAR he/she can immediately identify with the content. The perfect example of this in practice today is the method employed by the USAF AWACS Mission Training Centers. All crew consoles are recorded in sync and stored alongside a DIS recording of the same mission. During playback, instructors can display a DIS viewer that exploits the recorded DIS data stream in real-time. This gives the instructor the ability to pan, zoom and tilt the view of the unaltered truth data in the viewer, while simultaneously displaying the student's perspective of that same data. A typical finding in this venue might be how a student missed a critical event due to an inappropriate radar sensor setting, or perhaps the student simply was not looking in the proper geographic location.
- Interoperability with various state-of-the-art and legacy simulators and brief/debrief systems. The use of custom, home-grown solutions, as opposed to a common standards based approach is still one of the biggest challenges in the way of realizing the full potential of LVC environments. With that being said, regardless of the type of simulation, the various interfaces to the simulators, and/or the various communication protocols that might be in play, a modern networked LVC brief/debrief system must be able to transparently interact with the LVC environment to later, or in parallel, setup brief/debrief environments.

Scalability from single-site single-simulator events to large training events incorporating hundreds of sites, simulators of different types, and/or participants.

- Access control to ensure that participants only receive information they specifically have been entitled to access.
- Local training mode, where instructors can observe on-going events in real time in a briefing room. This allows "overflow" students to observe their peers in an academic setting while missions are taking place in the next room. Instructors can pause the real-time display when needed and utilize the PVR functions of the system to illustrate a specific event without interfering with the actual recording.

- Bookmarking capabilities during recording and/or playback for quick access to key events so that during the brief/debrief, one can play from/to these events. This makes the preparation of AAR(s) quick and efficient.
- Auto-indexing of events, e.g. based on Protocol Data Units (PDU) or data provided by the simulators. This can further help in getting quick access to key events during the training mission.
- The ability to make annotations, so that during the AAR it is possible for the instructor to visually explain these correlations or make other notes.

Implementation Technologies

In order for any brief/debrief system to function, the following technologies will have to be a part of the final solution. The following are needed in order to enable the transport and capture of audio, video, and data streams:

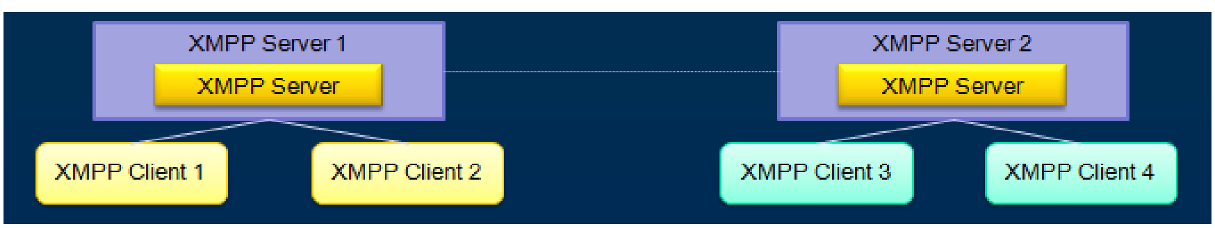
- Ultra High Definition (UHD)/Standard Definition (SD) Codec: The first critical technology is future-safe, advanced encoding that can interface with various video interfaces to encode UHD (4 megapixels and beyond) and SD video. The encoding must safeguard the visual quality, run at a high frame rate to retain smooth motion, and work at low latency. The compression should also be easily adaptable to different network situations and offer the possibility of reducing bandwidth on-the-fly so that different destinations can be served with different bandwidths.
- Digital Media Server (DMS): The next piece of core technology is a Recording and Review System that can manage many simultaneous streams. Simulators can have many video channels and in order to be cost-effective, the recording system must be able to record many streams in sync. It must also be able playback all these streams synchronously with all playback capabilities (pause/resume, skip back/forward, etc.). The system should provide the sync capabilities between different media types so that any type of data can be played to any receiving device in sync with any other receiving device that is part of the same session.
- Management and Control Server: The last piece of core technology required (and the main focus of this paper in the following sections) is a powerful and flexible management and control system which facilitates all the functions necessary to make the brief/debrief environment operational and controllable.

XMPP Overview and Benefits

XMPP is an open-source and standards-based protocol maintained by the XMPP Standards Foundation and is used in wide scale chat applications such as Google Talk (Google), ichat (Apple), and Jabber (Cisco Systems). In addition, XMPP is the mandated standard of the United States Department of Defense IT Standards Registry (DISR) for IM, chat, and presence/awareness. XMPP, as defined by the aforementioned XMPP Standards Foundation, is

"an open technology for real-time communication, which powers a wide range of applications including instant messaging, presence, multi-party chat, voice and video calls, collaboration, lightweight middleware, content syndication, and generalized routing of [Extensible Markup Language] XML data."

Figure 1. XMPP Architecture



The XMPP architecture has similarities to other application-layer protocols like the Simple Mail Transfer Protocol (SMTP). In these architectures, a client with a unique name communicates with another client with a unique name through an associated server. Each client implements the client/server form of the protocol, where the server provides routing capability. Figure 1 with XMPP Server1, Client1, and Client2 illustrates this simple architecture. In this case, each client is part of the same domain of XMPP Server1. The link between XMPP Server1 and Server2 represents the server/server protocol that exists for the servers to communicate for purposes of routing between domains (e.g., communication between Client 1 and Client 4 in domains XMPP Server1 and Server2 respectively).

The following are the various benefits inherent to XMPP:

- Provides an easily extensible framework of exchanging XML messages via XML streams. XML is a markup language similar to the HyperText Markup Language (HTML) in which users define their own tags and document structure. An XML stream is a container for the exchange of XML elements between any two entities over a network. By adding elements or attributes to elements in the XML schema, the scope or use cases for XMPP can easily be extended.
- Data confidentiality is key in many government and military environments, and XMPP supports data confidentiality via Transport Layer Security (TLS). Utilizing the STARTTLS protocol, an extension for plain text communication protocols (such as XMPP) a plain text connection can be upgraded to an encrypted connection, such as TLS. With TLS, the security of the stream can be ensured free from purposeful tampering and/or eavesdropping in both client/server and server/server communications.
- Peer Authentication can be mandated via the Simple Authentication and Security Layer (SASL) protocol. SASL provides a generalized method for adding authentication support to connection-based protocols to ensure that the senders/recipients of the data are valid.
- XMPP provides near real-time presence information to all parties on the network, indicating the state and health of a session and all clients.
- The server/server architecture and communication protocol via TCP allows for a distributed and decentralized environment, which fulfills potential needs to coordinate with partner organizations and/or partition network environments for security reasons.
- The client/server architecture routes all information through one or more servers and enables servers to control messages and presence information from the client to ensure they only go to appropriate recipients, essentially ensuring that clients only receive information they are entitled to have.
- Gateways are available to bridge the XMPP protocol with various other protocols. A gateway is a special-purpose server-side service whose primary function is to translate XMPP into the protocol used by a foreign non-XMPP messaging system, as well as to translate the return data back into the XMPP protocol. Examples are gateways to email, Internet Relay Chat (IRC), SIMPLE, Short Message Service (SMS), and legacy instant messaging services such as AIM, ICQ, MSN Messenger, and Yahoo! Instant Messenger.
- XMPP messages, as compared to other communication protocols such as SIMPLE, are extremely lightweight and hence, XMPP can easily scale to support an extremely large number of low bandwidth and network efficient connections.

XMPP MUC

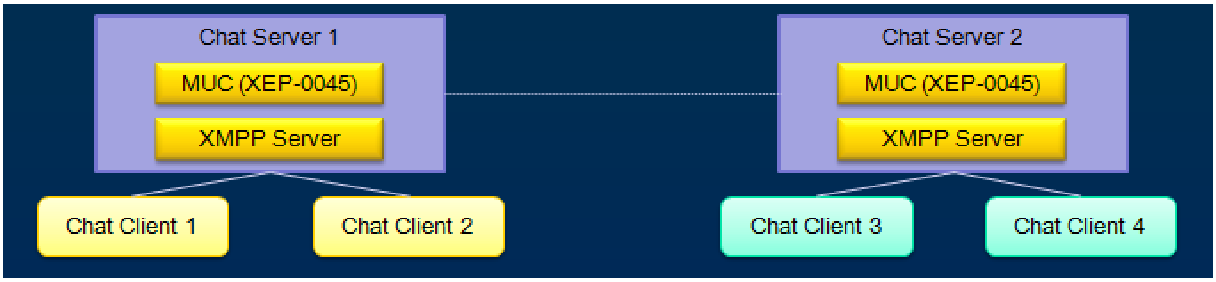
The XMPP MUC is an extension for multi-user text chat which allows various users to exchange messages in the context of a room or session, a virtual space that users enter to participate in real-time text based conferencing with other users. The MUC service is critical to many XMPP deployments, in particular military, where sharing of information in groups (e.g. decisions on whether to engage) are made using MUC rooms.

As shown in Figure 2, architecturally the MUC does not require any change to an existing environment

and can be run transparently as a service on the existing XMPP servers. The MUC room can consist of any number of clients within a single-server or multi-server environment, where clients in multiple domains can communicate via the XMPP servers, which function as routers.

The MUC service comes with almost all standard chatroom functions such as room topics and invitations. In addition, it also provides strong room control, with the ability to ban users, name room moderators and administrators, and require membership or passwords in order to join the room.

Figure 2. XMPP MUC Architecture



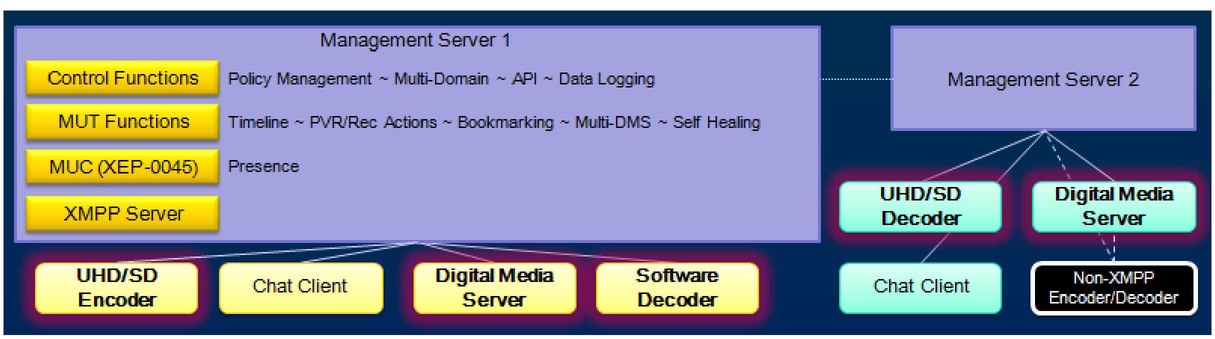
XMPP Based MUT and Control Layer for Networked LVC Brief/Debrief Systems

The XMPP MUT is an extension of the MUC, which inherits all standard MUC features and functions, and XMPP's inherent scalability, reliability, and security. The MUT enables multiple users and devices to exchange messages in a room context. The inclusion of devices such as UHD/SD encoders/decoders and Digital Media Servers into the room environment is the biggest enhancement to the MUC protocol and is a prerequisite for the creation of a modern LVC brief/debrief system. Now, the XMPP server hosting the MUT service (referred to as the Management Server in Figure 3) can manage the encoders, decoders, digital media servers, and more with the exchange of lightweight XML messages for various purposes such as setup of connections, stream switching, etc., all of which are standard MUT functions.

The other major enhancement to the MUC that the MUT brings is the concept of a session timeline, which essentially is the time between room creation and teardown. The session timeline is the foundation for all of the time related features of the MUT, which require time synched actions across devices.

Given the MUT layer, an additional application layer for custom control functions can be built on top to provide extra features and functions that go beyond the scope of the MUT. Figure 3 lists just a few of the different control functions that can be built on top of the MUT layer.

Figure 3. XMPP MUT and Control Layer Architecture and Benefits



Benefits and Features of XMPP Based MUT and Control Layer

The following are the benefits and functions that can be realized by networked LVC brief/debrief systems specifically because of the XMPP MUT layer:

- Quick and easy setup of all connections at the start of a session i.e. creation of the room: this is simple for small local environments, but can become complex in larger, multi-site environments. The MUT layer takes care of all connection setup regardless of the various network infrastructures devices may be located in, e.g., multicast and/or NAT enabled or disabled. As an aside, it is imperative that as a control function, key sessions can be saved so that they can be set up quickly without any further configuration.

- The Management Server, through the MUT layer and the presence feature, which comes built in with XMPP, provides presence information to all parties involved, showing them the state and health of the session and devices. The use of presence to detect if a source, relay, or destination goes down ensures that all such events are broadcasted into the room.
- Near-instant stream switching towards software or hardware decoders, so that instructors can quickly switch from one view to another in order to correlate events and views. This feature is possible through the ability to avoid the overhead of room creation every time a connection is to be established, and allow for the creation of rooms with idle sources.
- Time synchronized PVR, recording, and playback of various streams across multiple devices with recording controls of start, pause, and stop recordings and PVR controls of play, pause, pause at, skip back, skip forward, and catch-up are resultant of the timeline embedded in the MUT. With the timeline, the management server is able to broadcast time synchronized messages to all devices within the room for specific PVR actions.
- Since large training environments will potentially require the recording and playback of hundreds of streams, one system will never be able to scale these levels. Hence, the ability to time-synch actions across multiple devices (referred to as Multi-DMS in Figure 3) is an extremely important feature. The multi-DMS solution is also important because generally each site will record and playback its own data streams. But given the architecture, these independent devices streaming unique audio/video/data streams will share PVR control information to make multi-site brief/debrief a possibility.
- Another benefit realized because of the timeline is the ability to place bookmarks on recordings for quick access to key events. Bookmarks can be placed on recordings either during the actual recording or during playback of the file, and then can be used to later find specific recordings because they are fully searchable. Because the action of playing from or playing to a bookmark is also simply a time-specific action, just like PVR bookmarks can be placed on sessions that involve multiple distributed devices.
- As a result of the presence information of the devices being available within the room, the MUT has the ability to automatically repair connections in the room, if a device comes back online, and as long as the room exists and the MUT is aware of the connections.

The following are the benefits and functions that can be realized by networked LVC brief/debrief systems specifically because of a custom application layer built on top of the MUT:

- Due to the client/server architecture of XMPP and the fact that upon login, XMPP registers both a user name and a resource (the device the user is logging in from), an intricate policy based media management system for user and/or resource based access control can be built in the application layer. With this, various training sites can be connected for large debrief sessions with the assurance that only data the users at other sites are entitled to see is available to them.
- Building a policy management system may be less important initially because various organizations may require data to be “physically secured” at each site.
- A multi-domain implementation which enables the communication of devices across Management Servers at each site or base is inherently possible through XMPP and the MUT layer. However, in order to allow multi-domain in an environment where security is of utmost importance, it must be built on top of the policy management system in the application layer. A complete multi-domain solution must allow control of all data going in or out of the site with the same granularity of the single-site policy management system.
- An API providing a simple and powerful way to control brief/debrief from external devices registered as XMPP clients and allowing integration with third party applications. The API would provide distributed PVR, record, and bookmark control, room creation and teardown, exchange of presence information, device information, monitoring and configuration, and time synchronization between devices.

All messaging in the brief/debrief environment will be required to pass through the XMPP server, and hence a simple data logging scheme of recording all information can be built into the Management Server. Site operators can log accurate information regarding room creation/teardown, actions within the room such as PVR/bookmarking, and playback of streams to the level of by whom, from what device, and when.

Lessons Learned From Initial Deployments

A networked brief/debrief system utilizing an XMPP MUT backbone is deployed in 3 AWACS MTCs in Tinker, 1 AWACS MTC in Elmendorf and 1 AWACS MTC in Kadena. The initial feedback in using the new system is very positive. These are some of the comments of the staff who used the system:

- "The Chenega bubbas spent three hours debriefing the IRON TRIAD yesterday and found some holes in their mission that need correcting. Holes they haven't seen before."
- "Our crews are also responding well to the new install. They are seeing value in this system and use after almost every mission".
- "I think down the road having EMRRS available to all CAF DMO players will be a big help and the brief / debrief front, not to mention standardization of systems!"
- "According to our resident Instructor ECO, Capt Cynthia Foley, they have received more training in the last two days than they have in the last three years. The real-time viewing and debriefing capabilities have stepped training up to a new level."
- "The 962 Commander went out of his way to say that we are in danger of providing more and better training than they get on the airplane."
- "Our combined DIS/HLA and [mission record and review] playback is what makes the system work for our customers."

Path Forward

In conclusion, a 21st century networked LVC brief/debrief system is a realization of various existing TeleCollaboration technologies and the extension of a flexible control protocol that is XMPP. It facilitates the transport and archiving of all activities in multi-site, multi-station, networked simulations, and plays an important part in debriefings through the correlation of events by syncing streams, providing quick access to key events, and allowing the distribution of local or synchronized debriefings.

Initial systems have been successfully used in the DMO environment. The following are additional features that can be implemented as steps towards wider deployments

- The incorporation of a scalable vector graphics (SVG) based white boarding format into the MUT layer. In this way, instructors and students will be able to synchronously annotate over live streams from multiple locations across the globe. And because the annotations will simply be XML streams that will be routed through the servers, they can easily be archived for later playback of the training event, with or without the added annotations.
- Allow the creation of MUT rooms that include a mix of live and recorded streams from previous sessions, and have the ability to manage multiple timelines. Instructors could then playback multiple simulation events together for comparison of various students' performances with one another, or one student's performances over time

It should be obvious that a networked LVC brief/debrief system is a valuable tool for both local and distributed training alike. Likewise, this is not just an Combat Air Forces DMO application. Operational surveys conducted with the US Army Apache and Longbow programs clearly define a need for such a system. This capability would greatly enhance local training value by providing comparative examples between pilots and mission execution results. It is a reasonably safe assumption to say that all military branches share common training goals that such systems would enhance.

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Johan Pirot, President of IP Video Systems, brings together more than 25 years of experience in data networking and digital video. Mr. Pirot is the key strategist leading new product development and innovation. Formerly, as President of TeraBurst Networks, Mr. Pirot successfully launched the company in the visualization networking market. Previously, as vice president of IP strategy at Alcatel, Mr. Pirot successfully developed and implemented strategic relationships and acquisitions of IP companies. Mr. Pirot holds an MSEE from the Catholic University Leuven, Belgium and an MBA from the Handelshogeschool Antwerpen, Belgium (associated with Northwestern's Kellogg School of Management).

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