eSports: Collaborative and Synchronous Video Annotation System in Grid Computing Environment

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Abstract

We designed eSports—a collaborative and synchronous video annotation platform, which is to be used in Internet scale cross-platform grid computing environment to facilitate Computer Supported Cooperative Work (CSCW) in education settings such as distance sport coaching, distance classroom etc. Different from traditional multimedia annotation systems, the eSports system provides the capabilities to collaboratively and synchronously play and archive real time live video, to take snapshots, and to annotate video snapshots using whiteboard and to play back the video annotation synchronized with original video stream. eSports system is designed based on the grid based collaboration paradigm—the shared event model using NaradaBrokering, which is a publish/subscribe based distributed message passing and event notification system. eSports system is a component based system so that new functional components can be plugged in easily. In addition to elaborate the design and implementation of eSports system, we analyze the potential use cases of eSports system under different education settings and the future deployment at several universities in United States and China, we believed that eSports will be a very helpful system to improve the online coaching and distance education experiences for students and professors.

Keywords: Collaborative, Synchronous, Video Annotation, Grid Computing, Distance Coaching

1 Introduction

With the continuous increase of Internet's bandwidth and the various multimedia tools available, the text world of Internet is not enough to fulfill people's desire for more lively content--such as video and audio content in their applications. There is a huge demand of using multimedia technology over Internet scale to support group's collaborative work in which members are distributed at different geological locations, such as distance learning, e-coaching, virtual classroom, video conferencing etc. Distance multimedia based learning and coaching is different from traditional classroom learning and coaching, the professional coaches are at different locations from sport players and students, they collaboratively work together for coaching using multimedia and internet technologies. Digital annotation of multimedia objects is an activity central to such collaborations in distance e-coaching.

Currently, there are many annotation systems for textual documents, web pages—Annotea[1], Virtual Notes[2], images[3][4], audio--MARSYAS[5] and video resources, most of them have been designed for use within stand-alone environments, eSports is designed for users to collaboratively do the annotation, also, for video annotation, they all deal with the archived video clips on servers, none can implement playing and annotating a real time live video stream when archiving that stream into storage servers.

In present days, the geological span of multimedia collaboration systems is not limited to a city or a country, they spread across several continents, and the number of users and processes in a collaborative session increases to hundreds. This growing need for large scale interactive and collaborative multimedia systems presents several interesting research challenges in computer science such as: design of good collaboration framework with advantages of high scalability, extensibility, reliability and security, design of synchronization and composition mechanisms to synchronize multiple video/audio streams, how to build collaborative annotation tools with high performance, how to employ or design a suitable metadata system for video annotation.

This paper elaborates an innovative video annotation system developed at Community Grids Lab at Indiana University. This system enables real time collaborative video browsing, archiving, annotating and replaying based on NaradaBrokering[6] and Global-MMCS[7] systems which support large scale message based group collaboration and real time live video broadcasting respectively.

eSports system's main application area is in distance sport coaching and education, but not limited to this, it can also be used as virtual classroom and discussion platform with support of some tools from GlobalMMCS system.

The paper is organized in the following way: Section 2 describes the application scenario of eSports system. Section 3 lists the related work. Section 4 elaborates the eSports architecture design. Section 5 explains the implementation of eSports collaborative tools. Section 6 provides a preliminary deployment and use cases discussion about eSports system. Section 7 presents conclusion and future work.

2 Application Scenario

Our video annotation system's initial application is being developed in conjunction with Indiana University's School of Health, Physical Education, and Recreation (HPER). The goal of this effort is reverse outsourcing: HPER educators provide their expertise in popular American sports to international students via distance education technologies. This often involves broadcasting, annotating video streams. Sometimes we need to synchronously view a real time live sport video such as a football game with the coach and students at different locations and do some annotation about the interested highlight/snapshots in the sport video to coach students and exchange comments about the skills, tactics and strategies in the sport video. eSports system aims at this demand for distance training and coaching.

eSports is mainly used in the following application scenarios:

- Collaborative real time live video watching, archiving, annotating and replaying

The professional sport coaches want to interact with sports players or students who are at a distance about a sport game.

  - Video Watching and Annotation Session

When the game begins, the coach and students all go to the eSports portal website, they log in using their usernames and passwords, then, the coach select and play the real time live game transmitted from TV through Global-MMCS, both the coaches and students can then watch the game. During the game watching, the coach takes snapshots of valuable video frames for coaching and discussion, those snapshots are loaded to the collaborative whiteboards, coaches and students can then add graphic and text annotations collaboratively and synchronously

using the whiteboard tool. During annotation, the coach creates and saves a new composite annotation stream by binding the annotation snapshots with the original game stream using timestamp information. This procedure is repeated till the whole game stream is over.

- Replay Annotated Video Session

After the video watching and annotation session, the coach or students can select and play back the new generated composite annotation stream, in which students can watch the original game with the annotated snapshots in a synchronization way. In this way, all the students can learn by watching the comments with the original video stream.

- Archived video clip watching, annotating and replaying

This is almost the same as real time live video stream procedure, the only difference is at the beginning, the coach open an archived video clip instead of a real time live one to be collaboratively played in eSports, then all the users follow the same procedure as real time live video one to watch, annotate and replay the video stream and annotations.

3 Related Work

There are several annotation systems developed for digital videos, most of them are only for use within stand-alone environment in which the annotations can be saved and shared asynchronously, some systems can support collaboratively annotation as our system, but our system has many specific features not seen in those systems. Many of them are built to deal with situations in education context. We will briefly examine the different digital video annotation systems:

- VideoAnnEx---IBM MPEG-7 Annotation Tool[8]
- Microsoft's MRAS(Microsoft Research Annotation System)[9]
- Classroom 2000[10]
- iVas[11]
- SMAT[12]

IBM's VideoAnnEx annotates MPEG video sequences with MPEG-7 metadata framework[13][14][15]. VideoAnnEx takes an MPEG video file as an input, the video sequence input is segmented into smaller units called video shots. Each shot in the video sequence can be annotated with static scene descriptions, key object descriptions, event descriptions, and other lexicon sets. The annotated descriptions are associated with each video shot and are put out and stored as MPEG-7 descriptions in an XML file. VideoAnnEx can also open MPEG-7 files in order to display the annotations for the corresponding video sequence. VideoAnnEx is different from eSports, it's a stand alone video annotation system using MPEG-7 metadata framework, while eSports is a distributed collaborative video annotation system using subject based comment to annotate key video snapshots.

Microsoft's MRAS system is designed to support annotation of multimedia content about a lecture asynchronously. A user can download a lecture along with the comments added by other students, TA and professors. Users add their own annotations and save them onto the annotation server. The MRAS system focuses on users' asynchronous on-demand training, not like live synchronous online discussing and annotation in eSports.

Classroom 2000 project implemented a software infrastructure that captures much of the rich interaction during a typical university lecture including all aspects of a lecture in classroom--audio, video, blackboards, etc. All activities are captured and recorded with timestamps, then students can access the 'lecture' by replaying the recorded video, audio and slides etc.

iVas system can associate archived digital video clips (dvd, tv, etc) with various text annotations and impression annotations using the client server architecture, The system analyzes video content to acquire cut/shot information and color histograms. Then it automatically generates a Web document that allows the users to edit the annotations. It's also a stand alone system.

SMAT system is a collaborative annotation system which allows users to collaboratively add annotation to multimedia contents such as archived video clips using text, whiteboard, it's similar to our eSports system, however, eSports allows collaboratively annotating not only archived video clips, but also real time live video stream.

The eSports system is similar to the above system in some aspects, they all focus on video annotation, some of them provide the collaboration between annotators. Compared to eSports system, there are still some limitations of the above related video annotation systems, most of the above system only support the stand-alone environment,

even if some of them do support collaboration, usually they use the asynchronous mode and client-server architecture. As we all know, the client-server architecture doesn't scale well and has a single point of failure problem. The eSports system supports synchronous, collaborative video annotation based on the shared event grid collaboration model which can scale over the Internet. In above systems, only archived video clips can be annotated. The more valuable contribution is that eSports system can support archiving, playing and annotating the real time live video stream collaboratively at the same time. Currently, there are still many open challenges in video annotation system: communication platform, metadata framework, storage of streams and metadata, QoS control mechanism to improve usability. We will explain our method to deal with these challenges in the following sections.

4 eSports Architecture Design and Implementation

The problems that we try to solve is to build the collaborative multimedia annotation system over heterogeneous grid computing environments, which can scale very well with support of large number of users and across the internet. eSports system is designed to support not only the archived video streams but also the real time live ones. Also, eSports supports composite streams composed of original video streams and their annotation snapshots. We want to provide a component based platform to support easily plugging-in different collaborative tools for annotation.

4.1 Multimedia Annotation in eSports

From the user-video stream interaction point of view, an annotation is a means of marking up the objects and scenes in video streams in order to facilitate the interpretation and the understating of its content. The multimedia annotation usually has two main categories, metadata association and content enrichment. Metadata association method uses specific metadata models to build a semantic structure which supports operations such as content search [16][17][18], MPEG-7 is such an metadata based annotation framework defined by ISO/IEC. MPEG-7 offers a comprehensive set of audiovisual description tools to create descriptions (i.e., a set of instantiated Description Schemes and their corresponding Descriptors), which will form the basis for applications enabling the needed effective and efficient access (search, filtering and browsing) to multimedia content. This approach requires the user to understand the underlying semantic metadata structure model in order to perform annotations that

conform to the framework. Moreover, the user must spend much time and effort in order to perform the marking on the multimedia object, which is a laborious and tedious task.

The second method--content enrichment, uses other multimedia elements such as graphic shapes, text, audios to enrich the multimedia objects in a multimedia stream and generate a new composite stream. Users usually interactively add annotations by using text, lines, rectangles and other shapes to the key snapshots in a video stream. In this way, the original stream's content was enriched by the new content added to the stream. This method is more straightforward for viewers to understand and can be done in a collaborative way.

The metadata association method is for computer programs to understand the content of a multimedia stream to support searching and aggregation, etc. The content enrichment method is to assist people to understand the multimedia stream more thoroughly and deeply. eSports system uses the content enrichment method by annotating extracted snapshots from a video stream in the shared whiteboard, users can add text, lines, circles, any other shapes to the images just like a video highlight in a sport video which can explain the sport movement and tactic more vividly.

4.2 eSports Collaborative Architecture

We use a component based design on top of NaradaBrokering shared event collaboration model to make eSports system scalable and extensible for new functional plug-ins. eSports is designed to run in grid computing environment, which spans different organizations across different countries. The architecture is shown in Figure 1.

Figure 1 denotes a live distance coaching session, a coach and three students who are at different universities in different countries have a live coaching and discussion about a live basketball match broadcasted by TV or capturing devices through GlobalMMCS. All of the participants of this session share the same applications such as eSprot Player, eSports Whiteboard, Instant Messenger etc.

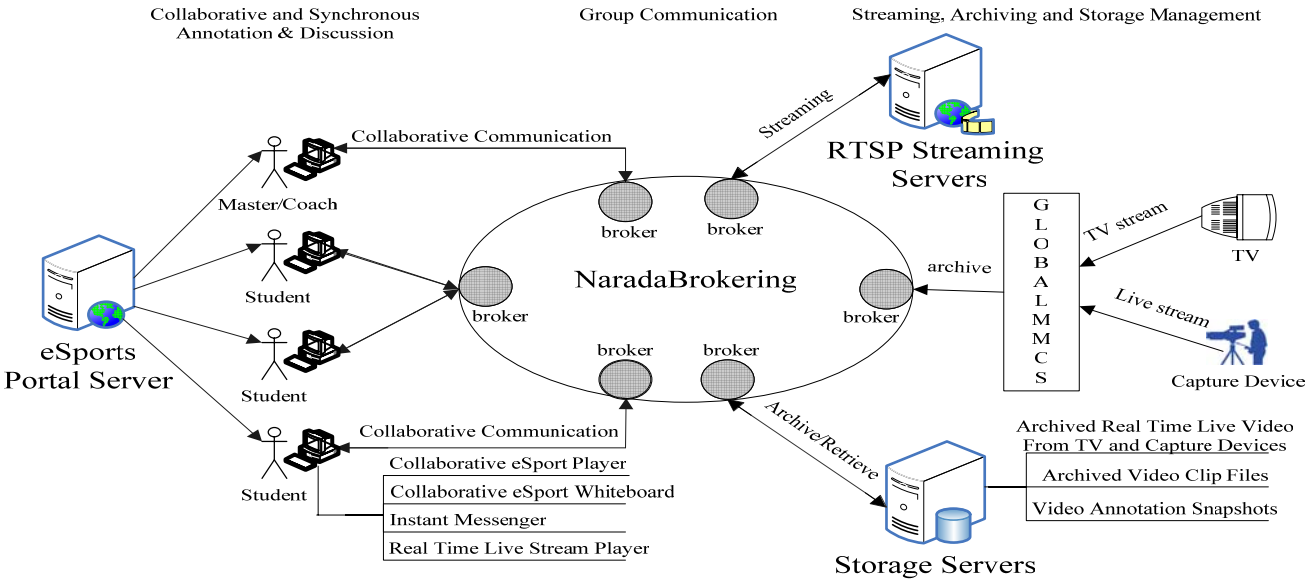

Figure 1 eSports Architecture

The main functions that eSports provides are:

- All the participates (coaches and students) can watch and annotate a real time or archived video steam
- The coach can save annotations of a video stream to generate a new composite annotation stream which synchronized the original video stream with its multiple annotation snapshots by timestamp information
- All users can retrieve and playback the annotation steams.

All these operations can be done collaboratively and synchronously. NaradaBrokering is responsible to support the platform for group communication for all the peers (coaches and students) in an annotation session. GlobalMMCS can publish real time stream either from TV or capturing devices through NaradaBrokering to all the peers' eSports player for watching and annotating. We can see the main components of the eSports system include the following:

- NaradaBrokering
- GlobalMMCS
- Storage Server
- RTSP Streaming Server
- eSports Collaborative Tools---eSports Player, Whiteboard, Instant Messenger

The data flow and process procedure in a typical eSports annotation session is shown in the following Figure 2:

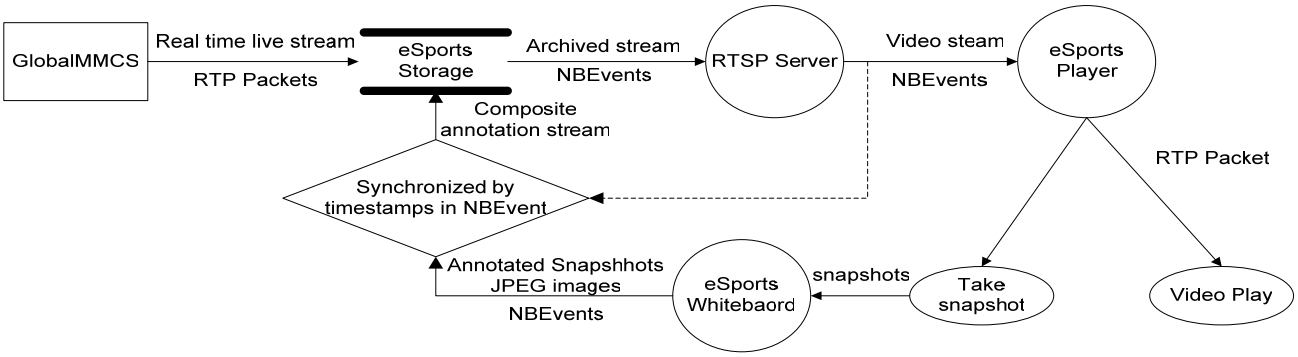

Figure 2: the data flow of a typical eSports annotation session

We'll explain each component of eSports respectively in the following sections:

4.2.1 Shared Event Collaboration Model based on NaradaBrokering

Collaboration applications such as eSports needs group communication. But current Internet cannot support group communication very well because IP multicast seems to have a long time to become ubiquitously available, deployment of network-layer multicast has not been widely adopted by most commercial ISPs, and thus large parts of the Internet are still incapable of native multicast more than a decade after the protocols were developed. Therefore application level multicast is a better choice for eSports collaborative application. Application multicast has many advantages, it doesn't change the underlying network infrastructure, it implements multicast forwarding function at end-hosts with good performance. Also, application level multicast can easily go through firewalls. A messaging middleware which supports application level multicast is definitely necessary and useful for group communication over heterogeneous networks; especially topic-based publish-subscribe model which defines a general API for group communication.

NaradaBrokering [6][19][20] from the Community Grids Lab is adapted as a general event brokering middleware. It supports publish-subscribe messaging models with a dynamic collection of brokers which are organized in a hierarchical way. It is capable to support transport protocols such as TCP, UDP, Multicast, SSL and RTP. It also provides the capability of the communication through firewalls and proxies. It can operate either in a client-server mode like JMS or in a completely distributed JXTA-like peer-to-peer mode. By combining these two disparate models, NaradaBrokering can allow optimized performance-functionality trade-offs for different

scenarios. In our eSports system, we use NaradaBrokering in a peer-to-peer mode, shown in Figure 3, the coaches, the students and different types of resources are peers in the system.

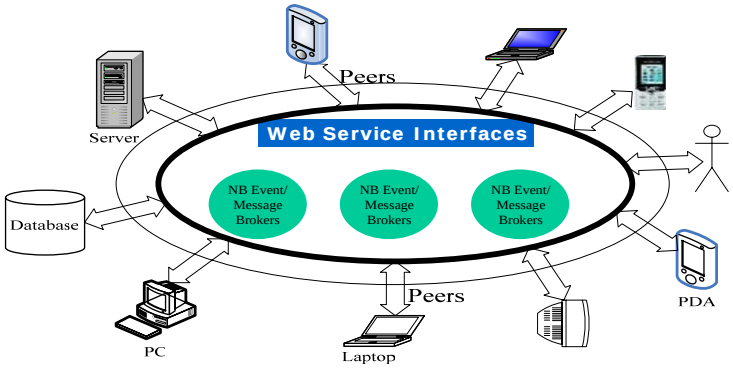

Figure 3 The Shared Event Collaboration Model based on NaradaBrokering

All the peers in the grid computing environment must be linked together in a flexible fault tolerant efficient high performance fashion. The Grid Event Service of NaradaBrokering is appropriate to link the clients (both users and resources of course) together. Events are messages – typically with timestamps, in NaradaBrokering, the messages exchanged between peers are NBEvents which contain a header and payload, the timestamp is saved in the header. The NaradaBrokering messaging system scales over a wide variety of devices – from handheld computers at one end to high performance computers and sensors at the other extreme. The well-known publish-subscribe model such as NaradaBrokering shared event model in Figure 3 is an attractive approach.

4.2.2 GlobalMMCS

GlobalMMCS[7] is based on the XGSP web-services framework[21]. It integrates various services including videoconferencing, instant messaging and real time live video broadcasting. It supports multiple videoconferencing technologies in heterogeneous collaboration environments. The architecture of Global-MMCS is shown in Figure 4. It provides an extensible platform for collaboration applications and services, new application can be plugged into the system easily as a component. GlobalMMCS provides the real time video streams to eSports users for watching and annotating (as shown in figure 1 and figure 2), eSports users can also use instant messenger to discuss about a video stream. eSports is an application which can be plugged into GlobalMMCS using its shared application interface. GlobalMMCS use real time video stream data topic in Figure 5 to publish the real time video through NaradaBrokering to storage servers for archiving.

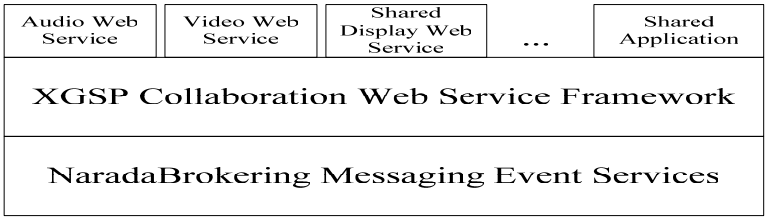

Figure 4 GlobalMMCS Architecture

4.2.3 Storage Server

The storage server in eSports system has three main functions. First, it archives real time live video stream published from GlobalMMCS through subscribing the real time video stream data topic (shown in Figure 5) in NaradaBrokering. The real time live videos such as TV broadcasting or streams captured by cameras are streamed as RTP packets which are directly saved to the storage server. When a real time live video is selected to be played, the storage server archives that video immediately and at the same time, the RTSP server publishes the real time video using NBEvent which stores RTP packet as payload through archived video stream data topic (shown in Figure 4 and Figure 5) for user to watch in eSports player. Each NBEvent has a timestamp attached to it. When creating the new composite annotation stream, this timestamp is used to synchronize a snapshot with the video stream from which the snapshot is taken. Secondly, it stores archived video clip files, these video clips can be streamed by the RTSP server and played in the eSports Player. Third, it stores the annotated snapshots from the whiteboard as JPEG images into the annotation database by subscribing a whiteboard data topic (shown in Figure 5). These annotation snapshots can be played back with the original video stream synchronously from the composite annotation streams.

The storage servers are created and used in a distributed manner, each broker in NaradaBrokering overlay network has its own storage component, all of them can act as storage servers for eSports. The data can be saved on any of the storage servers, when retrieving the data, user only need to provide the topic name (which is used when saving the data to storage servers) and timestamp information, then NaradaBrokering overlay network can find the broker (storage server) that stores the data through discovery service and return the data. This improves the eSports system's reliability and fault-tolerance.

We use the open source MySQL database to save the metadata used to save and retrieve streams. The metadata used are shown in the following table 1.

metadata name	templateID	timestamp	sequenceNumber
Type	int	bigint	bigint
Function	unique id for a stream	timestamp for an NBEvent	The event sequence number
metadata name	eventID	event	templateBytes
Type	int	blob	Blob
Function	The NBEvent type	The content of an NBEvent (include header and payload)	The annotation snapshots data

Table 1: The metadata of eSports

4.2.4 RTSP Streaming Server

The RTSP streaming server is an implementation of RTSP[22] protocol, it has the basic functions of a standard RTSP server, it supports pause, rewind, fast forward of a video stream. It is responsible for streaming the videos from storage server to eSports users. In fact, RTSP server stream a video by publishing NBEvents of a real time captured video or TV stream archived on the storage server through an archived video stream data topic (shown in Figure 5) to eSports player on each participant's computer. The control information exchange between RTSP server and eSports player are transmitted by an rtsp control info topic (shown in Figure 5).

4.2.5 eSports Collaborative Tools

The eSports collaborative architecture is in fact a peer to peer collaboration system based on NaradaBrokering. The eSports users are identical peers in the system, they communicate with each other to collaboratively annotate a real time or archived video stream. Each peer shares the same collaborative applications which include:

- eSports Player
- eSports Whiteboard
- Instant Messenger

All of the above eSports collaborative tools will be downloaded from the eSports portal server after logging in. There are two roles in eSports collaborative tools – 'coach' and 'student'. We'll examine these tools respectively

- eSports Player

eSports player is composed of four components—stream list panel, real time live video panel, RTSP player panel, video annotation snapshot player panel. The stream list panel contains the real time live video stream list, archived video stream list and the composite annotation stream list. All of the stream lists information is published by RTSP server using the RTSP control info topic (shown in Figure 5). Real time video play panel plays the real time video that is selected by user in the real time video list. It subscribes the real time video stream data topic (shown in Figure 5) to get real time video data published by GlobalMMCS. RTSP player panel play the archived video streamed from RTSP server by subscribing the archived video stream data topic (shown in Figure 5). RTSP player can take snapshots on a video stream. When taking a snapshot, the timestamp is associated with the snapshot to generate a new NBEvent. These snapshots are loaded to whiteboard to be annotated collaboratively. When playing back the composite annotation stream, the original video stream is played in the RTSP player panel, at the same time, video annotation player play the annotation snapshots synchronized with the original video stream by the timestamps.

The eSports Player is collaborative, each participant will view the same content in his eSports Player, the only difference is that only the participant with the ‘coach’ role can control the play of a video stream(to pause, rewind, take snapshot).

- Whiteboard

The whiteboard works collaboratively in peer to peer mode as the eSports Player does, each peer has the same view of the current whiteboard content. One user’s draw on the whiteboard can be seen immediately in all other users’ whiteboard. Each action in one peer’s whiteboard will generate an NBEvent that will be broadcasted using whiteboard communication topic (shown in Figure 5) through NaradaBrokering to all other peers in this session, so all the peers get a consistent and synchronized view of the shared whiteboard. The user with the ‘coach’ role can control the save and erasure of whiteboard content, other ‘student’ users can only add comments (text, any shape, pictures etc) to the whiteboard, the whiteboard is where all the users do the annotation on a snapshot of a video stream taken from RTSP player, annotated snapshots will be saved as JPEG images with timestamps to generate a new composite annotation stream, this composite annotation stream is composed of the video stream plus the annotation snapshots, they are synchronized using the timestamps.

- Instant Messenger

Sometimes, the users in a coaching session want to chat with each other to discuss the video and snapshot, the collaborative instant messenger provides a multi-user chat room for all users, each user can post its message and can view all messages posted by all the users.

The group communication and collaboration between storage server, RTSP streaming server and eSports collaborative tools can be clarified in the following Figure 5. From this figure, we can see all the communications between different system components are through NaradaBrokeing topics.

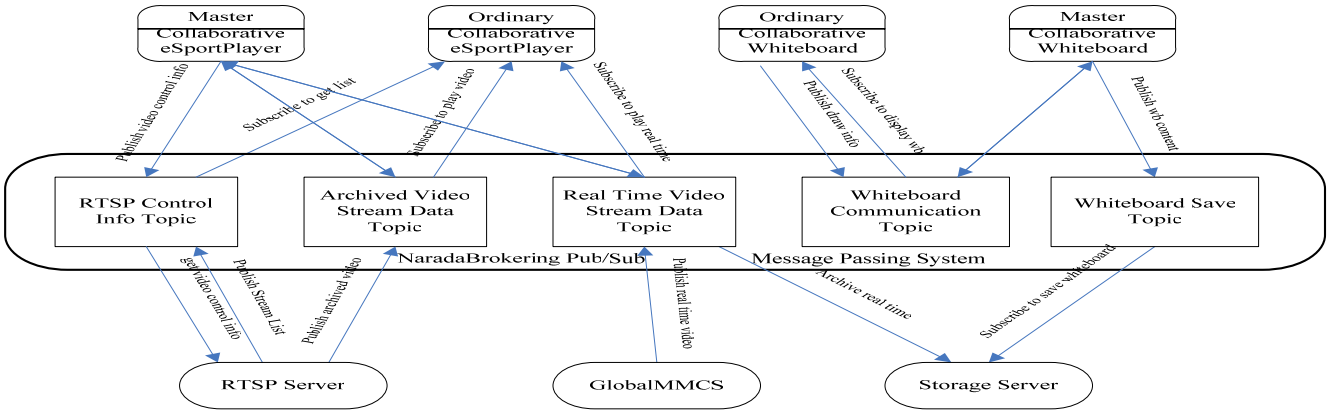

Figure 5 Communication between eSports collaborative tools, RTSP streaming server and storage server

5 eSports Collaborative Tools Implementation and Interface

In Figure 6, the left part is the eSports web portal which is integrated to the GlobalMMCS portal interface, users open this page for log in, after users log in, this interface will be shown to user to let user open eSports player and whiteboard tools for a video annotation session by clicking on the corresponding buttons.

5.1 eSports Player Implementation

- eSports Player Implementation

The eSports Player is implemented using JMF2.1.1e, the eSports player has four sections, the layout of the player is shown in Figure 6 right side:

Figure 6 eSportsPlayer and eSports Whiteboard User Interface

The left top panel is the player for playing archived video streams to be annotated, the archived video stream is selected by user through the archived video stream list, the right top panel is the panel for playing back the annotation of a video stream, the left bottom panel is the real time stream list and archived stream list gotten from the rtsp server and GlobalMMCS through NaradaBrokering, the right bottom panel is the real time video stream play panel for playing real time video selected by user in the real time stream list. Current, we support video types Quick Time (.mov), 'MPEG-1', and AVI (.avi).

5.2 eSports Whiteboard Implementation

eSports whiteboard is implemented using java swing, it supports tools like text input, drawing pen, lines, rectangle, oval tools, and picture load, it also has functions such as change colors, erase or save a whiteboard. The whiteboard interface is shown in the left side of Figure 7.

The upper part is annotation area in which a snapshot of a video stream is loaded. The bottom of the whiteboard interface is the function buttons and annotation tools, users can use these tools to add graphic and text annotations to the snapshot in the whiteboard collaboratively.

After annotation, a new composite annotation stream is generated and saved using the 'save' button on the whiteboard, the new composite annotation stream is stored on the storage server. Users can select this new

annotated stream from the archived stream list of eSports Player to play back the stream with the annotated snapshots synchronously as shown in the right side of Figure 7.

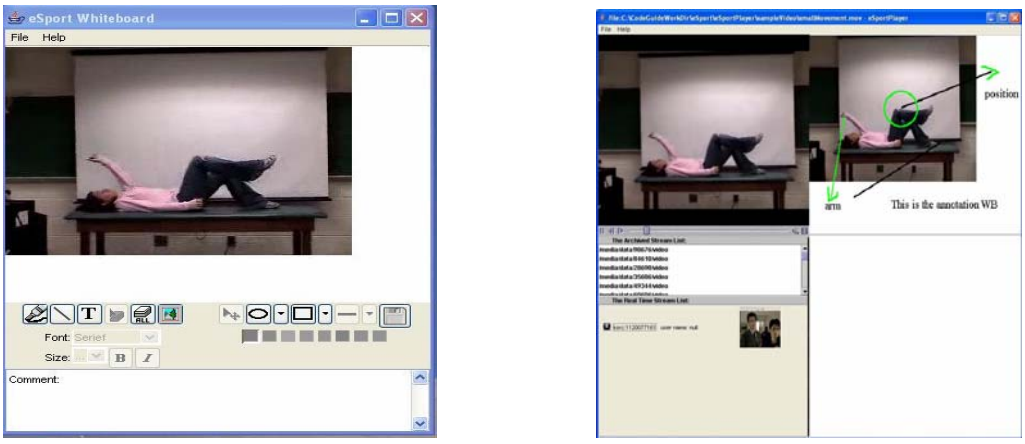

Figure 7 The Synchronous playback of original video stream with annotation snapshots

Currently, the real time streams' frame rate from GlobalMMCS is 20 frames/sec and we use H.261 codecs for the streaming from capturing devices such as web cameras and TVs. The video size we used is 352*288. With this setup, the video play is very smooth without obvious jitter and delay.

6 eSports Future Deployment and Use Cases

The eSports system prototype will be deployed in many different universities across the continents---HPER of Indiana University, Beijing Sport University (BSU), Shanghai Institute of Physical Education (SIPE) etc. There are two cases, one is for live real time stream annotation, the other one is for archived stream annotation.

The preliminary deploy environment is, we use two brokers, broker A at Beijing Sport University, broker B at Indiana University, the eSports portal server, RTSP streaming server and storage server are all hosted at Indiana University, the universities in China all connect to broker A at Beijing Sport University which connects to broker B at Indiana University. The professional coach is at Indiana University, he interacts with sport players whose actions are webcamed at distance. he will the students are dispersed at different universities in China. The topology of the test environment is shown in Figure 8.

The system is used for sport coaching to give a lecture based on a video clip or a real time live match for example 'basketball'. The coach is at HPER of Indiana University, the students are at BSU and SIPE. The application scenario is: the coach opens a video clip about a basketball match, the coach and all the students will

view the video clip collaboratively, during the watching, the coach find some good frames in the video and want to let students to discuss and annotate them, then the coach will take snapshots on those frames and annotate the snapshots in the whiteboard with his students, after annotation, the annotated snapshots are saved, the coach and students can select annotated snapshots to replay the video and annotated snapshots synchronously.

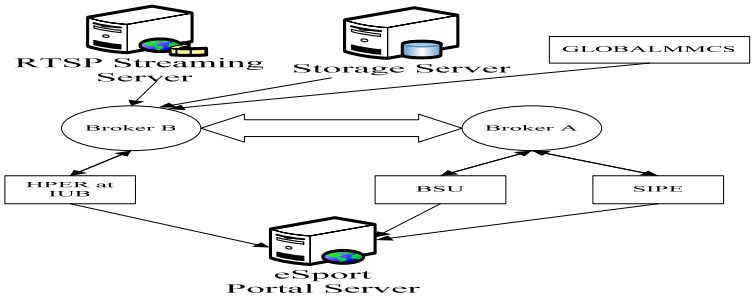

Figure 8: Topology of the eSports deployment

During this procedure, students will interact with the coach using eSports system about a sport video and can express his own annotations/ideas by annotating video frames using whiteboard with others.

Based on this deployment, we will collect usability feedback and performance test result to improve the system better for use.

7 Conclusion and Future Work

The main contributions of our eSports annotation system are: First, it supports synchronous collaborative video annotation. Second, it supports annotation about a live real time stream from capturing devices or TVs. Third, the annotation of video stream can be played back synchronously with the original stream by creating a new composite stream. Fourth, the eSports system scales well by using NaradaBrokering message passing system which has been proved to scale very well on Internet. Fifth, the eSports system provides a framework for integrating different multimedia collaborative tools for e-coaching and e-eduction.

Currently, the eSports system is still an prototype, we found that there are several aspects that we need to improve, now, eSports requires relative high bandwidth to allow collaborative watching of video streams with good quality, we will design and employ QoS control mechanism and better codecs to improve the performance, also, we will try to support other video types besides mpeg1 and asf by developing and plugging in new codecs for other video types. We will deploy eSports system to different universities in United States and China to test the usability.

Also, to make the distance coaching or education more effective, we think in the future we will add several other functions to current prototype: audio collaboration, a metadata framework to support the video annotation discussion, RSS based metadata service maybe a good choice for eSports.

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