Distance Learning of P2P-based Live Media Streaming

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***Abstract*— Distance learning is a brand-new pedagogy which the government is energetically popularizing right now. Different from the traditional teaching modes which need students gathering in class, distance learning is a pedagogy using multimedia and network service to eliminate the limitations of time and space. Furthermore, distance learning uses the network digital system to send messages point-to-point or point-to-multipoint. Presently, distance learning has gained remarkable results in universities and colleges. However, traditional teaching modes are still often used in junior and elementary schools.**

This paper experiments the operation of P2P Live Media Stream, a distance video system based on P2P structure. In addition, we also compare it with Co-Life Video Conferencing System developed by the National Center for High-Performance Computing and Marratech Online Video Conferencing System developed by a subsidiary company of Google. The comparisons focus on the smoothness of video signals, stability, connection recovery and transmission situations. We prove that P2P Live Media Stream is an ideal and feasible system which can be used in campuses. Furthermore, it combines all kinds of video teaching modes and benefits the teaching diversity in campuses.

I. INTRODUCTION

Distance learning is a new way of teaching which the government recently puts much emphasis on. Different from the traditional teaching modes which need students gathering in class, distance learning is a pedagogy using multimedia and internet to eliminate the limitations of time and space. Furthermore, distance learning uses the network digital system to send messages point-to-point or point-to-multipoint. Most universities and colleges in Taiwan have set up distance learning websites; for example, NTU (National Taiwan University), NTHU (National Tsing Hua University), NCTU (National Chiao Tung University), NCCU (National Chung Cheng University), NCKU (National Cheng Kung University), and NCU (National Central University). The distance learning has gained remarkable results in universities and colleges. However, distance learning does not own such position in junior high and elementary schools because traditional pedagogies are still usually used in compulsory education. In recent years, the government policy aims to make computers standard equipments in each and every classroom. Moreover, most schools are heading to multimedia teaching, hoping that projectors can also be equipped in every classroom. Teachers are expected to make good use of digital teaching equipments to let students gain more knowledge. By the assistant of video teaching and high-speed network, distance learning can set up virtual classrooms, make course on demand (COD) practicable and reach the goal of

multicast. All of these can make teachings in junior high and elementary schools more variable and improve students' learning capabilities.

At first, distance video is not widely applied to education; but as the NCHU (National Center, for High-performance Computing) developed the Co-Life system, distance video learning began to own an important position. Formerly distance learning costs too much on extra transmission equipments and broadband network so that schools could not afford it. But by the assistant of Co-Life system, schools need only one webcam and microphone for live broadcasting. Due to the improved convenience, more and more schools are willing to give courses by distance video learning. In recent three years, fifty-two courses using Co-Life system gain quintuple [2] students than without Co-Life system (originally only about one thousand students). We can see here that distance video learning brings huge learning effect for it needs only computers and network to let users all over the world enjoy this service. From the example above, we can know that distance video learning is a very usable pedagogy; it is very convenient and easy to use. The future tendency of education may become learning at home, so distance video learning will be a great model.

a. Co-Life Video Conferencing System

Co-Life [13] is a system which focuses on distance desktop-sharing, electronic whiteboard, and words and video communication. It is a multi-people, multi-function online video conferencing system which combines calendar, conference function and community function together; it can simultaneously provides more than twenty-nine video images during net conference. In the cause of getting the best quality during multi-point connection, the NCHC sets the video servers in three different places (north, central and south) by using TWAREN (Taiwan Advanced Research and Education Network). Every unit only needs to connect to the nearest server then video streaming from different places (servers) will be received. It makes distance courses more sustainable and the connection becomes smoother and stronger. Co-Life system is generally used in lectures, distance video learning.

b. Marratech Online Video Conferencing System

Marratech [10, 14] is also a video conferencing system which is similar to Co-Life in user interface. It provides video communication, word chat, internet phone and electronic whiteboard. The headquarters of Marratech is set in Stockholm (the capital of Sweden) and it was purchased by Google on April 19, 2007. After the purchase, Marratech is mainly used by Google's employees for cross-country communication. But it still release trial version for people or can be purchased by companies. Marratech online multi-media video conferencing system mainly contains two parts: server-end software and client-end software. Once the client-end software is installed and microphones and webcams are equipped, users can easily join the conference.

II. P2P LIVE MEDIA STREAMING

The P2P LMS discussed in this paper uses CoolStream as main framework. Conclude from [5, 9]

that the basic framework of CoolStream can be divided into: Basic Components、Multiple Substreams、Buffering、Overlay Construction and Content Delivery.

A. Basic Components

It contains three basic modules show in Figure 1, (1) membership manager: to preserve the member in net; (2) partnership manager: to establish and preserve the TCP connections between partners, also delivering some information by buffer map (BP); (3) stream manager: the core of information transmission.

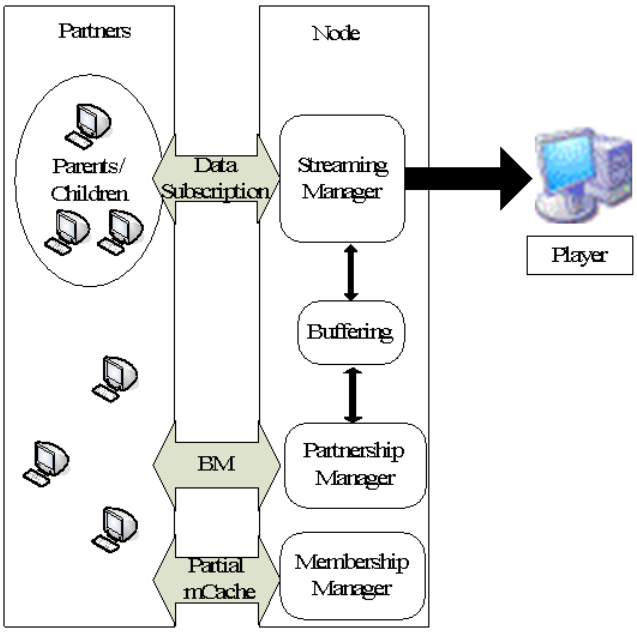

Figure 1. CoolStream System Framework Diagram

B. Multiple Substreams

Before the video is delivered, it would be cut into some equal blocks. A sequence number is attached on each block for the convenience of assembling and recording after receiving. This sequence number is equal to timestamp and will be delivering through TCP (Transmission Control Protocol). After the video is cut into blocks, some substreams will reform. When one video is cut into several substreams, one node can ask for different substreams from other nodes. For example, node A wants substream S_1 from node B, then node B delivers S_1 to node A; meanwhile, node A wants substream S_2 from node C, then node C delivers S_2 to node A.

C. Buffering

Buffer map (BM) represents the received newest block of different substreams. In BM, partners will exchange information for acquiring their needed substreams. Basically, BM is formed of continuous 2K byte; K means the number of cut substreams. The first continuous K byte records the sequence numbers received by substreams. For instance, video is cut into K substreams $\{S_1, S_2, \ldots, S_k\}$, the last received blocks are {2K+1，3K+2，…，4K}. Then "2K+1" means that S_1 receives the 2K+1 block; "3K+2" means S_2 receives the 3K+2 block…and so on. The second continuous K byte means the substreams it asks for from the partners. For example, node A does not receive block 1 and 2 well, then node A will ask its partner, node B, for block 1 and 2. Later node A sends message {1, 1, 0, 0, …, 0}, which represents the request of block 1 and 2, to node B.

Every node has its own buffer area; it consists of synchronization buffer and cache buffer. Synchronization buffer puts the received substreams to the

right places and sends it to cache buffer for combination. During the combination, the sequence number will be the basis. The combination will immediately stop when it meets blocks have not been received. The combination will resume after the missing block is received. The video is cut into *d* blocks; but block 8 and 9 are not received yet. So, block 1 to 7 will reform the video stream first. After receiving block 8, it will make a combination with block 8.

D. Overlay Construction

In overlay construction, one membership manager is needed for preserving the nodes. Each node has a unique ID and preserves its own membership cache (mCache) to record the active nodes. Nodes also use mCache to set up the connection with TCP. mCache system consists of three parts:

(1) Source nodes: to provide the nodes of video;

(2) Boot-strap nodes: to serve the newly joint node;

(3) Member nodes: all nodes in the system.

The TCP is mainly used in overlay construction; this technique is widely applied in BitTorrent (BT)[3] and other P2P systems [1, 5 ,6 ,7 ,8 ,9] to solve the random error and disperse the operations. In CoolStream system, a newly joint node will first contact with boot-strap nodes and ask for a node list to save in its mCache. In boot-strap nodes, there are two chief operations: (1) to randomly provide the nearest active node for new joint nodes; (2) to renew the nodes in mCache as often as possible and add new nodes. After receiving the node list, the newly joint nodes will randomly set up TCP connection to the nodes in the list and it is called partnership. When two nodes establish partnership, they will exchange their node information in the mCache. It happens only at the initial stage and will not last long. The maximum argument M is decided by the system. M is the upper bound of partnership; but the size of mCache is limited. Thus, mCache needs to remove the inactive nodes and update the nodes frequently so that the nodes in mCache are all the newest and most active for sure.

Partnership could be broken by the time; for example, when the disconnection happens or the bandwidth is lowered then enough blocks cannot be obtained, partnership will be broken and cause the partner reselection. Meanwhile, the node will be removed from mCache. Gradually, after a time of exchanging, each node will remove it from its own mCache.

E. Content Delivery

During the delivery of video streams, CoolStream uses “push and pull” mixed mode. When one partner sends out request, another partner will keep providing the needed blocks. As a parent node, it will unconditionally send video streams to child node constantly. The decision is made by the child node for it can determine to have a parent reselection or not.

By the information exchanging of BM, the newly joint nodes can get their needed blocks from the parent node. Before receiving the blocks, new nodes need to decide which block they want to start with. Now the sequence number of existing blocks

is from *n* to *m* (*n* is the smallest number, *m* is the biggest number), if the new node directly asks for block *m*, this request may not be fulfilled for every node is asking for downloading block *m*. If the new node starts the download from block *n*, it may cause two problems: (1) block *n* may have been played and abandoned, so the download will be invalid; (2) even the download starts, the video would be over when the download finishes. In consideration of these problems, CoolStream uses a simpler way to solve them. The new node examines partners' BM, if one partner has finished download, then it will ask the partner for downloading the block. Once the first block is decided, the node will keep on examining partner nodes' BM. Furthermore, the new node will see them as parent node and acquire video streams from them

III. Experiment Result

The P2P LMS system used here is developed by NTHU, supporting HD (High Definition) output. The P2P encoder is put in Li-Tse Primary School. The hardware specifications are: Intel Core2 Duo 2.2GMHz, 512M RAM, Windows XP. The server-end is placed at the NCHC. P2P LMS uses Windows Media Encode as the video encoder; Marratech uses H.264 format to encode the videos; the video encoder of Co-Life is purchased aboard and has not been disclosed.

This paper use one webcam and one microphone as filming equipments. The webcam is Logitech intermediate webcam which costs NTD 590. It supports maximum 30 fps, 1.3 mega pixels, and 640X480 dpi.

The pre-setting is set at high-quality output. The settings of Co-life and Marratech are not adjustable for they are determined by systems. The output mode of P2P LMS is adjustable; the settings of in-line mode are 1000 Kbps output for throughput and 30 fps for frame rate. The settings of non-synchronous mode are 1128 Kbps for throughput and 30 fps for frame rate. The experiment is long-time filming; we record the data every fifteen seconds, four times a minute. We put all data in order every ten minutes. The total filming time is one hundred minutes.

We judge the stability by the standard deviation used in probability and statistics. Larger standard deviation means that the wave motion is stronger. The formula of standard deviation is:

$$\sigma = \sqrt{\frac{1}{n}\left(\sum_{i=1}^{n} x_i^2\right) - \bar{x}^2}$$

n represents the total number of population sequence. x_i indicates the *i*-th number. $\bar{x}$ is the average value of population sequence. The formula is:

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

At this moment, projectors are equipped in each class of higher grades in Li-Tse Primary School so we can experiment the distance learning in the campus to measure how these three systems work. There are nine classes in the higher grades, locating in the same building from first to third floor. The network distribution is shown as Figure 2, nine servers and projectors are included. The experiment is to film the class time of Class Chung, Grade 4 and broadcast it to the nine classes of higher grades through the server.

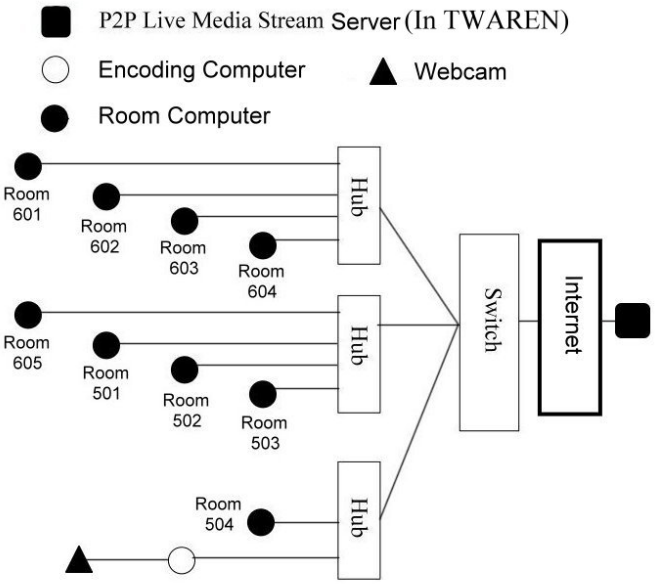

Figure 2. The Network Distribution in Campus

The experiment of LAN is chiefly divided into four parts, the live broadcasting of P2P LMS, Co-life and Marratech which mainly filming the class time and the playing of teaching videos through P2P LMS. The performance of frame rate is shown in Figure 3 and Table 1. We can see that Marratech has better performance on frame rate with an average of 22 fps for the server is set in the campus. Co-life has an average of 16 fps and P2P LMS has 14 fps in average. From the perspective of standard deviation, P2P LMS is the most stable system in ten experiments, the standard deviation is 0. The second is Co-life with 0.46, while the standard deviation of Marratech is 1.1, the worst. As for throughput (shown in Figure 4 and Table 2), P2P LMS has the best performance with 972 Kbps, Co-Life with 602 Kbps, Marratech with 413 Kbps (all in average). P2P LMS also stands out with the standard deviation lower than 10 in ten experiments. The worst performance is Marratech with the standard deviation of 62.67. From the performance of throughput, we know that Marratech abandons more video qualities in order to gain the good smoothness. Though P2P LMS does not perform well at frame rate, the video quality is the best. It means that the image has better dpi and is suitable for students to watch.

Table 1. The Average Frame Rate of Each System

	P2PLMS-Video	P2PLMS-live	Co-Life	Marratech
Output	30	30	X	X
Average Input	30	14	16	22
Maximum	30	14	16	23
Minimum	30	14	15	20
Biggest Difference	0	0	1	3
Standard Deviation	0	0	0.46	1.1

Unit：fps(frame per second)

P.S. P2P LMS-video means the broadcasting of teaching videos, not live broadcasting.

Table 2. The Average Throughput of Each System

	P2PLMS-video	P2PLMS-live	Co-Life	Marratech
Output	1128	1000		
Average Input	1123	972	602	431
Maximum	1127	980	677	522
Minimum	1122	964	527	338
Biggest Difference	5	16	150	184
Standard Deviation	1.47	9.32	42.78	62.67

Unit：Kbps (bit per second)

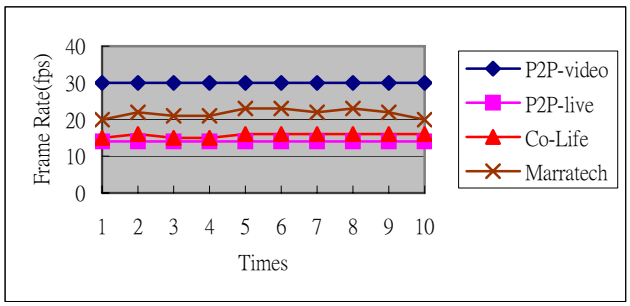

Figure 3. The Comparison of Frame Rate

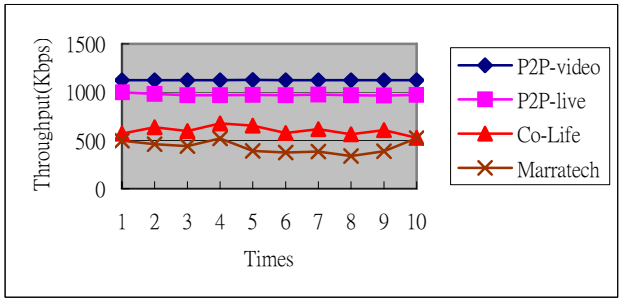

Figure 17. The Comparison of Throughput

IV. CONCLUSION

We can conclude the advantages of P2P LMS from Table 3:

(1) The throughput of P2P LMS stands out in every kind of network service which represents that P2P LMS has good quality in video output;

(2) P2P LMS is very stable in each network service for it always remains the output of around 1000 Kbps;

(3) P2P LMS performs well in connection recovery. In the best condition, it can keep the video playing after network disconnection of 10 seconds.

Maybe the P2P LMS does not work well on frame rate; but it is much more stable than Co-Life and Marratech in every kind of network service. Especially in the video quality, P2P LMS far exceeds Co-Life and Marratech. P2P LMS system is even more outstanding in playing teaching videos. It transcends in every parts – frame rate, throughput and stability. From the results, it is better to use P2P LMS in distance video learning than using Co-Life and Marratech. The high image quality provided by P2P LMS allows less shape-changing and distortion of images when playing in full-screen mode; also, the video will also be clearer through projectors. Co-Life and Marratech have worse image qualities. Images may look good on a small screen; but after being enlarged, images squares may occur and it is not easy to watch.

From the perspective of connection recovery, P2P LMS keeps playing for seconds after the disconnection owning to its operation system. P2P LMS saves images of a few seconds in the user-ends in advance in order to respond to the possible stops caused by the network problem. It is indeed a very outstanding mechanism.

The education in the future will be focused on a multi-dimension education. The cooperation of distance learning is also an important tendency for it has great potential. In addition to distance video live broadcasting, P2P LMS can be used in the cycle-playing of teaching videos. As a result, P2P LMS is indeed very practicable and helpful for schools which want to develop the distance video learning and e-learning.

Table 3. The Overall Comparison of Each System

	P2PLMS	**Co-Life**	**Marratech**
Frame rate	Normal	Normal	Good
Throughput	Excellent	Good	Normal
Stability	Excellent	Good	Normal

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