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碩 士 論 文

基於 P2P 即時媒體串流技術運用在遠距教學之研究與實現

Research and Implementation of Distance Learning Based on P2P Live Media Stream

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摘要

遠距教學是政府積極在推廣的一種新型教學方式，它是指使用影音多媒體和網際網路等傳播媒體的教學模式，突破了時空界線，有別於傳統需要安坐於教室的教學模式，將人類行為中非常重要的互動關係，經由網路數位化系統的協助，在點對點，或是點對多點之間進行全方位的傳遞，遠距教學在大專院校裡實施的成果相當顯著，但在國中小來說，主要還是以傳統教學為主。近幾年，在政府的政策帶動下，班班有電腦已是教室的標準配備，多數學校正朝向校園多媒體教學方向在前進，希望達到班班有單槍投影機的目標，充實設備，能讓教師多利用多媒體科技，融入教學裡，加速學生學習的能力，獲取更多的知識。遠距教學類型輔以視訊教學和運用高速資訊網路，可以即時群播、虛擬教室或課程隨選等方式，以輔助學校行政以及教師教學，讓國小教學能更多元化，提升學生學習力。

本文實作 P2P Live Media Stream，是一套以 P2P 架構為主的遠距視訊系統，並與國家高速網路與計算機中心開發的 Co-life 視訊會議系統及 Google 子公司開發的網路視訊會議系統 Marratech 兩套軟體做實際比較，從視訊流暢度、穩定性、自我恢復情形及頻寬傳輸狀況上來做比較，證明 P2P Live Media Stream 運用在校園內，是一套很理想、很實用的系統，而且可以融合各類型的視訊教學方式，供學校做多樣化的教學。

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. In recent years, the government aims to make computers standard equipments in each and every classroom. 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 media technology in teaching nowadays; thus, students' learning capabilities will be improved and will obtain 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. Moreover, we expect distance learning can help the schools' administration and teachers' instructions to make teachings in elementary schools more variable.

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.

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Chapter 1 – Introduction

1.1 Background

As the scientific technology quickly develops, computers and network have gained important positions in our daily lives. For example, most of us use Microsoft Word when dealing with document processing. Furthermore, computers and network are definitely needed while sending e-mail, programming and watching entertainment videos. Lives and works today without computers and network could be very inconvenient. So, it is obvious to see that computers and network are very indispensible nowadays.

Nevertheless, computers and network as assisting tools are not so common used in education. Most teachers still use traditional ways while teaching students; only a few teachers begin to give computer-assisted instruction. Frankly speaking, teachers do not have enough time teaching in class. So, how to provide students various teaching materials and information and to give them more knowledge in a short time has been an important issue. Nowadays we pay much attention to high efficiency, thus, to combine good teaching methods and multimedia technology will be the best teaching policy. Good craftsmanship depends on use of the right tools; using multimedia in education is surely a new tendency in the future.

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). We can see that 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.

1.2 Motivation

The Computer Center of the MOE (Ministry of Education) has already set up the media server of distance video learning. In the future, teaching films will be sent to schools and students can choose more vivid and livelier teaching programs to watch. It is easy to figure out that the government indeed places much importance on distance learning. Presently many video conferencing systems can be put into practice to distance video learning. And it is believed that the use of distance video learning will be more unhindered as long as the plan officially comes into effect.

Seeing that some schools plan to set up distance video learning systems, junior high and elementary schools in Yi-Lan should be able to do so for information equipments of schools in Yi-Lan are complete and enough. Moreover, Yi-Lan County

Government renewed the information equipments in junior high and elementary schools in 2007. The new equipments are highly helpful to the development and promotion of distance video learning. By this opportunity, this paper begins to study and experiment the distance video learning in campuses.

Yi-Lan County is mountainous and the territory is fairly wide; thus, it is considerably inconvenient for teachers in rural areas because if they are going to attend a conference, they have to set out one to two hours in advance in order to be on time. So, distance video learning is the best solution to this problem. If distance video learning can be practiced and popularized in schools, time will be saved and problems caused in transportation will be reduced.

In order to keep up with the tendency of digital pedagogy and provide teachers and students various ways or learning, this paper invites some developed elementary schools in Yi-Lan to experiment the execution of distance video learning. One the one hand, this paper aims to analyze whether distance video learning is workable or not in campuses; we hope distance learning can break through the limitation of traditional pedagogies and provide an advanced way of teaching. On the other, the experiment results can be displayed to Education Bureau of Yi-Lan; the operation of distance video learning can be tried in some conferences to serve teachers in rural areas.

P2P (peer-to-peer) system is the most popular point-to-point online transmission system. Most downloading and sharing programs use P2P system to deliver and receive information such as BitTorrent (BT), FOXY, eMule and eDonkey. They all support the transmissions of multi-people and multi-cable at the same time.

Online video-sharing mode is mainly divided into two ways. One is the videos will be watched on computer after downloading. The other one is that videos are watched online. However, watching videos online often faces the problem of sudden stops and lags. The reasons of these stops and lags may be insufficient bandwidth

(server-end or client-end), too much online users (different watching timing causes reading busy of server) and the packet loss during transmission. Thus, watching videos online is not an ideal mode. For example, when we watch videos on YouTube, often it takes long time of waiting, and the qualities of videos is not very good as well.

But now, video-sharing mode has significant changes. Seeing that P2P system works outstandingly, we combine P2P system and video-sharing mode together. This paper uses P2P Live Media Stream (LMS) [1, 3, 4, 5, 7, 8, 9] on distance learning, delivering the videos by P2P system. The server-end sends out only one information group, peers will share with each others. It is a brand new way of online video-watching, the smoothness and qualities will make great progress, sudden stops and lags happen not as often as before. The use of P2P LMS is chiefly separated into three parts: (1) online distance learning; (2) online television station (it can be use as video on-demand, the displaying of videos can be scheduled in advance); (3) broadcasting TV programs by installing TV-card. The third part is not often seen and practiced because it may violate the Intellectual Property Rights.

The P2P LMS in this paper is a distance video system based on P2P system structure. It is compared here with Co-Life (Collaborative Life) system which is developed by NCHC (National Center for High-Performance Computing) and Marratech which is developed by a subsidiary company of Google. The comparison will focus on image quality, video smoothness, practicability and transmission efficiency. This paper intends to prove that P2P LMS is an ideal and feasible system that can be used in campuses.

The second chapter of this paper reviews related works of the discussion of distance learning and the execution of distance learning. Chapter three, P2P Live Media Stream, introduces the basic system structure of P2P LMS. The fourth chapter studies how P2P LMS disposes and works in campuses. Chapter five shows the

results of the execution of P2P LMS. The last chapter put results together and shows the pros and cons of each system.

Chapter 2 – Related Works

2.1 Discussions of Distance Learning in Taiwan

The execution of distance learning by using technology and medium can be separated into four stages: (1) the sending of books and prints; (2) the transmission of video and audio by broadcast and television (the well-known NOU, National Open University, and teaching programs are included here); (3) the use of computer: teaching materials can be more abundant than only video and audio; (4) online teaching materials, teachings can be done on the internet.

The flourishing of distance learning is closely connected to the development of computer and network technology. The first and second stages of distance learning are hard to be popularized because of their inconvenience and the limitation of time. But as the quick development of computer and network technology, wireless network and broadband network are quite common in each and every family. Consequently, the implementations of the third and forth stages of distance learning become much easier. Also, the MOE has great impact here for it makes every endeavor to popularize information education. Since 1995, the MOE has commissioned NTHU, NCTU, NTU, NCCU and NCKU to start the pre-experiment researches. Most researches focus on higher education. Only NTNTC (National Tainan Teach College), the predecessor of NUTN (National University of Tainan), has made researches on “The Application of Distance Learning in Elementary Schools” under the supports of NSC (National Science Council). In the meantime, the government actively popularizes the TANET (Taiwan Academic Network) to junior high and elementary schools. Later, the government subsidizes the junior high and elementary schools so that computers can be seen in every classroom. For many years, the government brings up several research plans and tries to connect the higher education to compulsory education. In

June 2001, the government addressed the prospect of information education "Make Information Be Readily Available, Active Learning; Cooperation Makes Originality, Let Knowledge Be With Us For Life," hoping information education in junior high and elementary schools can be improved and can be used in different subjects. Accompanied with this tendency, distance learning began to develop in campuses.

In May 2003, the former Minister of the MOE addressed the prospect of future development of information education:

(1) To construct the basic information environment and to share the digital learning materials;

(2) To blend the information education into innovative teaching mode;

(3) To ascertain the application and development of e-learning;

(4) To diversify the ways of learning and to break through the limitation of time and space.

In addition, the government also sets up Online Media Resources Center and Teaching Archives such as the NSC's Digital Archives and the MOE's Six Learning Websites for internet users. Obviously distance learning has gained more and more importance than before.

2.2 The Application of Distance Video on Education

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.

For the time being, there are many different online video systems; the most common ones used by internet users are SKYPE, MSN (Microsoft Network) and Yahoo Messenger. But these three systems belong to point-to-point structure and allows only two people connect to each other at a time which do not fulfill our request. The distance video learning studied in this paper should have two characteristics: (1) images can be played in full-screen mode; (2) systems support point-to-multipoint or multipoint-to-multipoint webcam so that it can easily support plenty users of distance video learning at a time. Besides to P2P LMS, this paper also discusses two often-used multi-people distance video learning system, Co-Life Video Conferencing System [29] and Marratech Net Video Conferencing System [26, 30]. Next, this paper will introduce the functions of these two video conferencing systems.

2.2.1 Co-Life Video Conferencing System

Co-Life [29] 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.

On purpose of making up the need of six to ten thousand people who are professional at high technology, the Engineering Department of NSC drives "Cross-Fields Technology Education Platform Plan." In this plan, the "Co-Life Multi-Function Education Platform System" developed by NCHC integrates the network and digital learning, aiming to strengthen the growth of high technology professions in colleges and universities.

In the future, NCHC will continue to run a system which is able to operate distance learning, online learning and a mutual-help, mutual-sharing system by using the high-speed calculating computer, high-bandwidth and high storage capacity. Likewise, the NCHC hopes teachers with different professional specialties can find their teaching partners here and even form a "teaching association." If the fascinating teachings can be linked together, knowledge undoubtedly will be extended and shared all over the world [2].

Co-Life has six characteristics:

(1) Totally free;

(2) The video conferencing system combines project system, lecture system and conference system together;

(3) Each system has document-management function;

(4) Images can be enlarged, narrowed or played in full-screen mode at any time;

(5) Word communication and file-sharing function;

(6) The functions of electronic whiteboard, film-playing mode, distance remote-control desktop and the transmission of audio and video.

The system can only be call-to-use on the website when JRE(Java Runtime Environment) program is installed for the system is mainly written in JAVA.

Co-Life system is generally used in lectures, distance video learning. It is now open for every college and university to apply for. The website is “Interdisplinary Science & Technology Education Platform [27].” More and more companies, academies and government administrations begin to use this system. The system developer believes that Co-Life can be used in much more ways with the increase of users. If teaching resources in every university link together, not only excellent teachers will emerge, but also the students from different schools may exchange experience with each others.

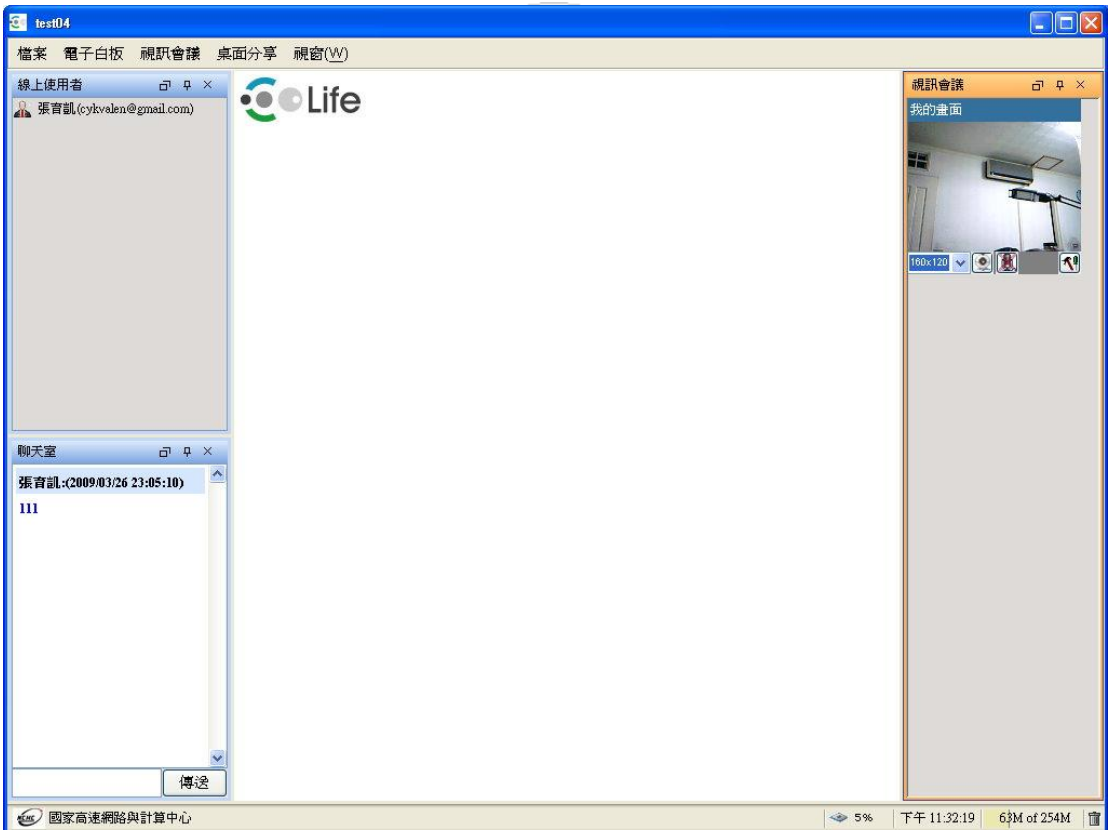

Figure 1. The operation system of Co-Life.

2.2.2 Marratech Online Video Conferencing System

Marratech [26, 30] 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 is separated into three types:

(1) Marratech-Free: provides basic video conferencing system function;

(2) Marratech Time-To-Meet: customer can rent it with charge depending on the number of users and the using time;

(3) Marratech Full License: full-function multi-media video conferencing system.

Marratech online multi-media video conferencing system mainly contains two parts: server-end software and client-end software. Marratech uses client-server framework, users can interact with remote users through internet. The operation is quite simple; it is easy to learn and use. Marratech can be operated under Windows, Linux and Mac. Once the client-end software is installed and microphones and webcams are equipped, users can easily join the conference. Since Marratech is similar to Co-Life for they both provide online video, electronic whiteboard and chat module. Some people begin to use Marratech as the tool of distance video learning online. Chiefly the courses are private, but some academies use Marratech as well.

Presently, Marratech no longer provides free server-end installation-software, but free conference room online is still free for users. However, the servers are set in Europe, America and Canada; it may immensely decrease the connection quality.

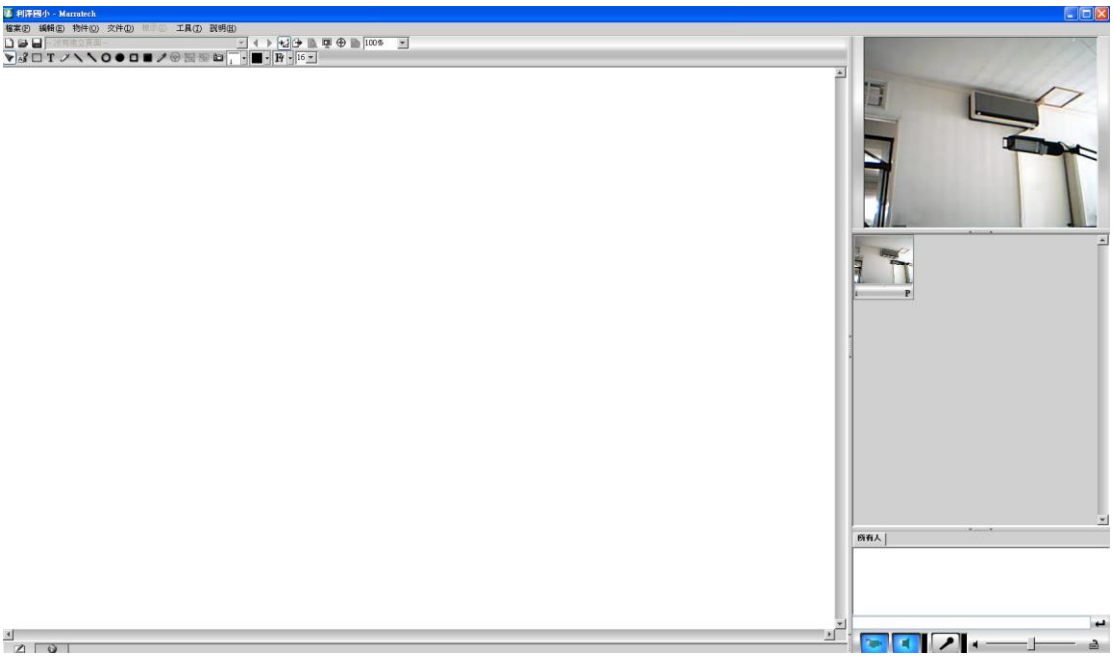

Figure 2. The operation of Marratech.

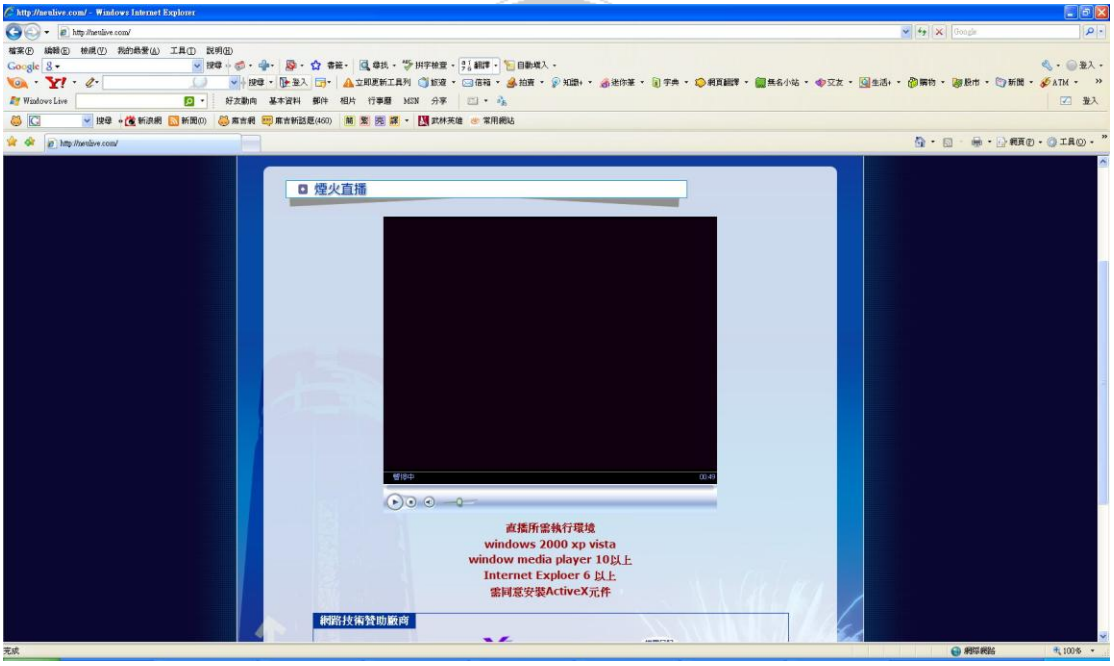

Figure 3. The operation system of P2P Live Media Stream.

2.3 The Comparison of P2P LMS, Co-Life and Marratech

The main function of P2P LMS is video broadcasting. It also supports online live video-playing and can be used as web-TV, continuously replaying scheduled video

programs. The transmission mode is peer-to-multipeer – points share videos with each others; so the system will be steadier followed the increase of online users. The client-end mostly uses Windows and Internet Explorer to play the videos.

As implied by the name, Co-Life Video Conferencing System is generally used in video conference. Co-Life has built-in electronic whiteboard and word-chat mode, also allowing file-sharing online and switching to video-lecture environment in full-screen mode. The online transmission mode is client-server mode. Each client-end connects to the server and exchange information. The system is written in JAVA so that it supports all kinds of OS (Operation System).

Marratech Online Video Conferencing System is similar to Co-Life. They both are video conferencing systems and have built-in electronic whiteboard and word-chat mode. Moreover, Marratech allows file-sharing online and switching to video-lecture environment in full-screen mode as well. The transmission mode is client-server mode. Client-ends share information through servers. Marratech has different versions for Windows, Linux and Mac. The comparison of these three systems is shown in Table 1.

Table 1. The Comparison of P2P LMS, Co-Life and Marratech

	P2P LMS	**Co-Life**	**Marratech**
Online Video	**V**	**V**	**V**
E-Whiteboard	**X**	**V**	**V**
Conference Function	**X**	**V**	**V**
Online Broadcasting	**V**	**X**	**X**
Video on Demand	**V**	**X**	**X**
Full-screen Mode	**V**	**V**	**V**
Transmission Mode	peer-to-multipeer	client-server	client-server
Video-Playing Mode	Explorer + Windows Media Player	Co-Life(Java)	Marratech
Client-end Operation System	Windows Linux Mac	Windows Linux Mac	Windows Linux Mac

Chapter 3 – P2P Live Media Stream

Peer-to-peer network topology is mainly divided into three ways:

(1) Tree-based topology [20];

(2) Mesh-based topology [3];

(3) Gossip-based topology [7, 12, 21, 23].

The algorithm of tree-based topology is very efficient; however, it has a critical problem. The P2P system allows users to leave at any time; but as long as the node which is quite near the server leaves, it may cause system crash. As shown in Figure 4, when node A leaves, fourteen nodes lower than node A disconnect with the server and cause system crash. Mesh-based topology is constructed based on tree-based topology. It hugely reduces the problem happened when nodes disconnect to the server. Nevertheless, it cannot thoroughly solve the problem for it is still based on tree-based topology. Gossip-topology is a mode that connects nodes in random selection. It uses push-and-pull technique so that speed of sending data is much faster. Gossip-topology does not choose neighbor node, instead, it considers global scope for the optimization of choosing nodes, avoiding the wastes of bandwidth. As shown in Figure 5, node S choose the more ideal nodes W, X, Y and Z to connect to instead of neighbor nodes P, Q and R. Nowadays, P2P LMS mostly uses gossip-topology such as CoolStream [7, 23], GridMedia [12] and Chunkyspread [21]; they all belong to large-scale video streaming. GridMedia emphasizes the preservation between nodes and optimizes the push-and-pull technique for a better efficiency. Chunkyspread pays attention to the structure between parent-node and child-node for the sake of the smoothness of video transmission. Furthermore, Chunkyspread will set up connection limit according to the bandwidth of nodes to avoid the system crash. The P2P LMS discussed in this paper uses CoolStream as main framework. The discussion will be shown later.

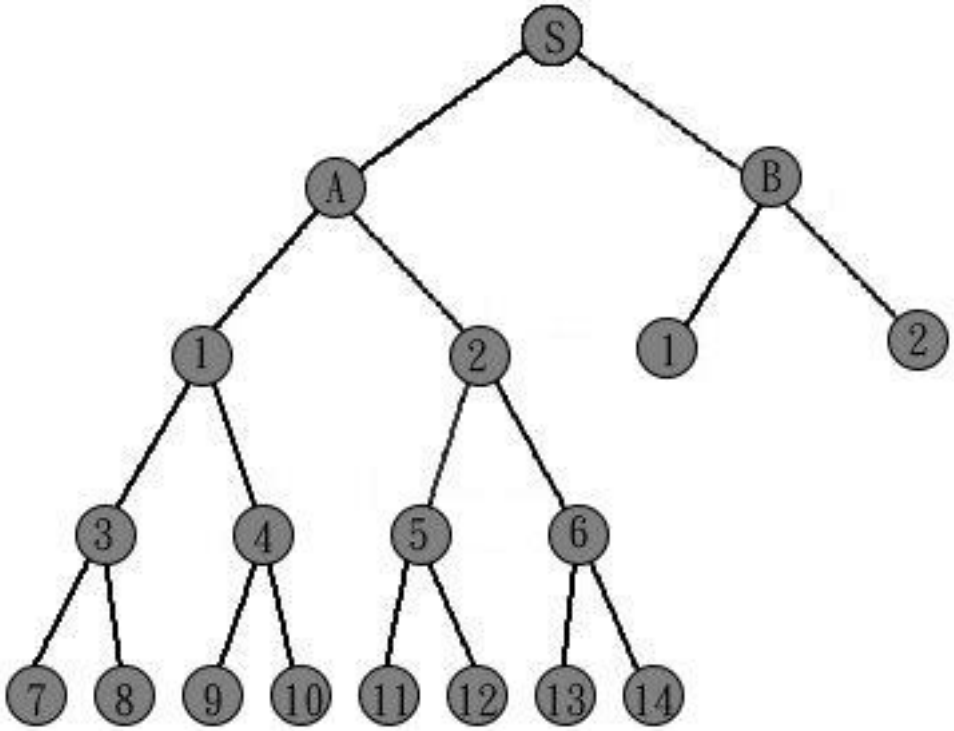

Figure 4. Tree-based Topology Diagram

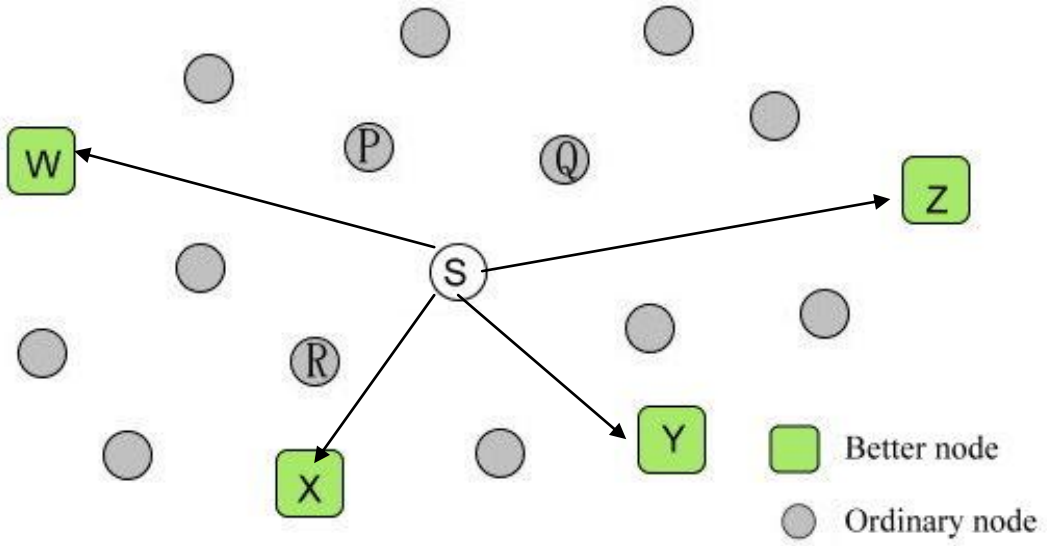

Figure 5. Gossip-based Topology Diagram

3.1 The Structure of CoolStream

We can conclude from [7, 23] that the basic framework of CoolStream can be divided into:

(1) Basic Components;

(2) Multiple Substreams;

(3) Buffering;

(4) Overlay Construction;

(5) Content Delivery.

3.1.1 Basic Components

The formation of CoolStream [7, 23] system is represented in Figure 6; it contains three basic modules, (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.

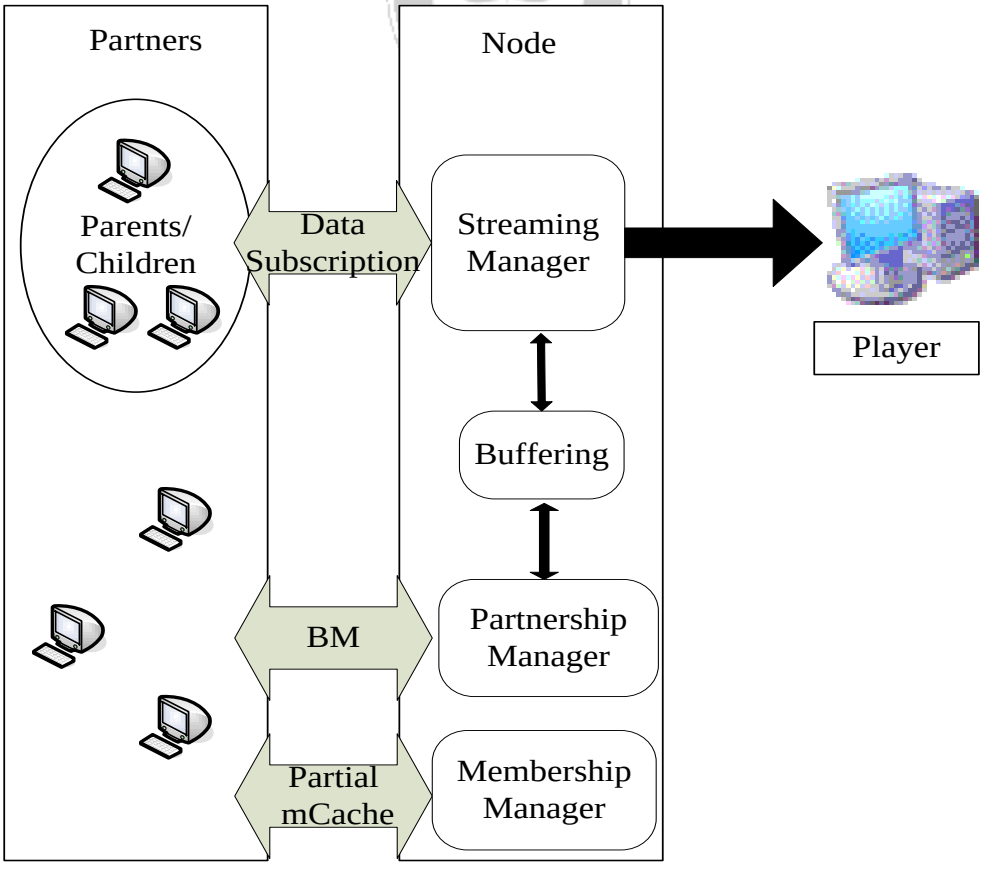

Figure 6. CoolStream System Framework Diagram

3.1.2 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.

In CoolStream system, there is an important differentiation – the differences between parent-children relationship and partnership (as shown in Figure 6). Partnership means two nodes exchange useable blocks through the connection of TCP. Parent-children relationship means one child node completely receives the video streams from another parent node. At the same time, a parent node should deliver all substreams to the child node. Figure 7 is the diagram of how a video is cut into four substreams. If the original image has thirteen blocks, the system would re-arrange it into four substreams $\{S_1, S_2, S_3, S_4\}$ and sent it out. Nodes will reform the original image according to the sequence number after the receiving.

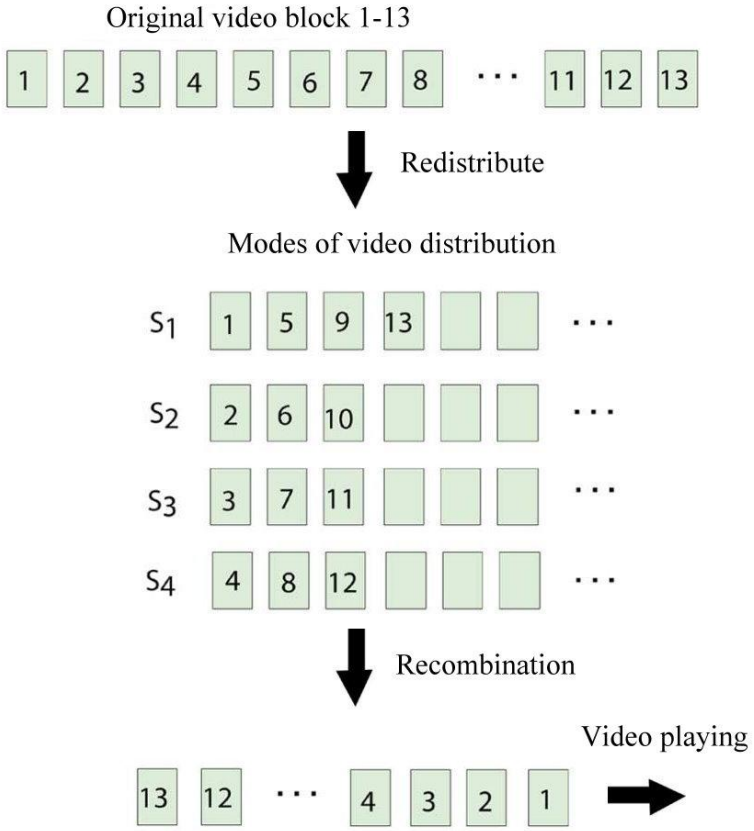

Figure 7. The Diagram of the Dissolution and Reforming of Video Streams

3.1.3 Buffering

As shown in Figure 7, 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 (the structure is shown in Figure 8); 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. As shown in Figure 8, 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.

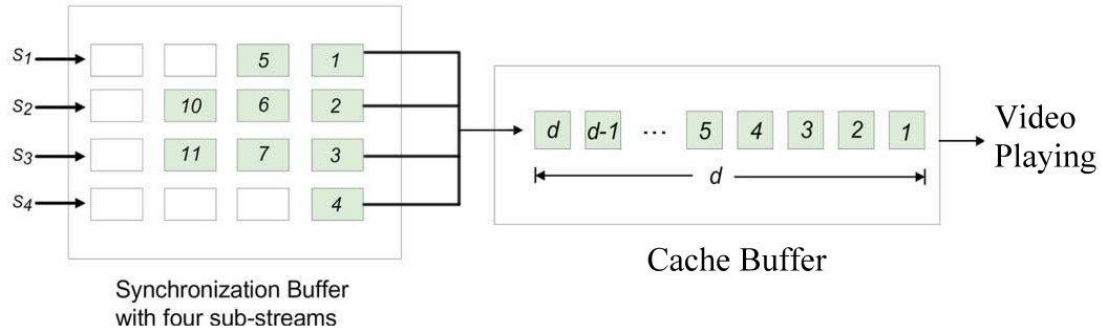

Figure 8. The Structure of Node Buffering Area and the Example of Block-Receiving

3.1.4 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) and other P2P systems [1, 4] 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.

3.1.5 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.

Figure 9 shows how new nodes download the videos. At first, new nodes join the system and refresh the nodes list. Then they establish connection with each node to download the video blocks. Next, the received blocks will be temporarily saved at the right places in buffer areas. At last the video begin to play after re-assembling.

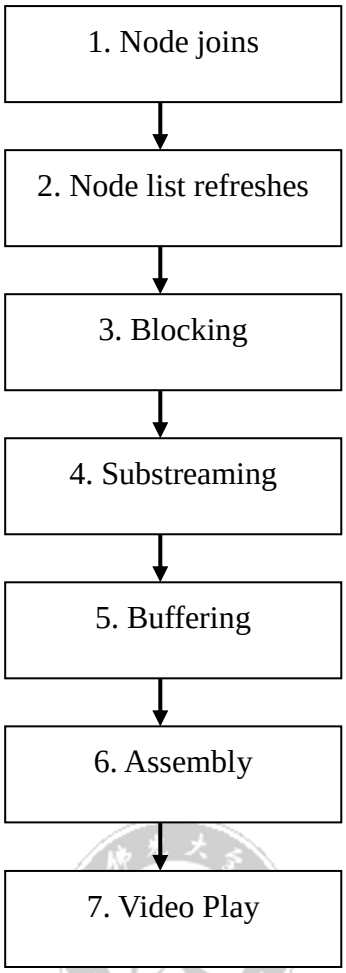

Figure 9. The Process of Video Downloading when New Nodes Join P2P LMS

3.2 System Dynamics

CoolStream system's operation can be separated into two parts: (1) peer adaptation; (2) peer dynamics. The arguments and the explanations are represented in Table 2.

Table 2. Arguments and Explanations of CoolStream System

Argument	Explanation
O	The source of video streams
R	The bit rate of video streams
K	The number of cut substreams
B	The length of node buffer area in a given time
V	The maximum difference between substreams
W	The maximum difference of substreams between partner and parent node
U	Presently the nearest block in the buffer area
T	The cycle that one node takes for parent reselection
M	The Maximum number of partner
up	Upload
down	Download

3.2.1 Peer Adaptation

Congestions often occur on the internet. When congestions happen, nodes are hard to receive streaming so the problem of peer adaptation appears. Each node should keep monitoring the condition of receiving substreams. If the request cannot be fulfilled, the parent reselection happens to satisfy the need.

In [7], two thresholds {*V, W*} are set up to monitor the insufficiency of bandwidth. V represents the block number's maximum difference of the substream received by one node. W stands for the maximum difference of block number between a node's partner and the parent node. Here we make Hs_i, A represent the serial number of the substream S_i which received by node A. Then we compare it to parent node P's substream S_j, two formulas will appear:

$$\max\left\{Hs_i, A - Hs_j, p \mid: i \le K\right\} < V \qquad (1)$$

$$\max\left\{Hs_i, q : i \le K, q \in \text{partners}\right\} - Hs_{j,} p < W \qquad (2)$$

Inequality (1) is used to monitor the condition of substream in buffer area of node A. If the inequality does not sustain, it means one video streaming delays and it is lower than the threshold V. Also it shows that the bandwidth narrows so that peer

adaptation occurs for substreams are not sufficiently received. Inequality (2) mainly monitors node A's parent node. Node A compares the serial number received from the nearest block of parent node with the partners. If the inequality does not sustain, it means the parent node is far behind its partners. For this reason, it no longer qualifies for being the parent node of node A. Again, peer adaptation occurs and node A will have a parent reselection from its partners.

When a new parent node is chosen, it must sustain these two inequalities. If two or more partners qualify the conditions of being the parent node, it will be decided randomly. As a parent node, it never rejects what its child node's requests. Moreover, the parent node constantly sends the streaming it has to the child node. Obviously, the happening of peer adaptation may cause the overlay topology instability or crash. So we induct a new argument "T" to be a cool-down timer. T means the longest time of parent reselection when peer adaptation happens.

Before the partner argument M of one parent node is full, it should always accept the requests from the child node. One parent node may contain many child nodes at a time; these child nodes shares one parent node's bandwidth. However, the bandwidth cannot always satisfy the request from the child nodes. At this moment, peer competition occurs. Later it may cause one or more nodes which are not satisfied with their needs from the parent node. This condition leads to the chain reaction of peer adaptations. During the chain reaction, two inequalities can be violated. At this time, many temporary parent nodes would occur. The status returns to normal till a stable and capable parent node is selected.

3.3.2 Peer Dynamics

The peer adaptation mentioned above is mainly used to deal with the congestions of network and nodes. So, the argument development and collision inside the system

should be considered.

Referring to [7], considering one parent node P delivers information to child node Q, the average bit rate of every substream is R/K.

Hypothesis 1: Node P has enough bandwidth for delivering streaming to node Q, the upload bit rate of node P $r_{up} >$ R/K .

In this hypothesis, node Q fully keeps up with the transmission condition of node P, including the time of getting back the missing blocks. This is called "catch up process." If there are l blocks missing in transmission (compared to the blocks that node Q has received to node P), the catch up time is t_{up}; then, according to [7], the transmission equation is:

$r_{up} \cdot t_{up} = R/K \cdot t_{up} + l$ (3) t_{up} can be Figured out

➔ $$t_{up} = \frac{l}{r_{up} - R/K} \quad (4)$$

The formula above appears under normal condition when bandwidth is enough and the information transmission is balanced. Next the discussion will focus on the happening of peer adaptation.

Hypothesis 2: Node P failed from peer competition and cannot obtain enough blocks from parent node. The average download bit rate is $r_{dowm} < R/K$. Now chain reaction could happen on node P. If P could not find a new parent node in a time, then the child node, Q, of node P will also fall behind. Given t_{down} to represent the time that node Q needs to find a new parent node after abandoning node P. In other words, if node P can find a new parent node in t_{down}, then peer adaptation will never happen, nor does the chain action. So, we can know the transmission equation

according to [7]:

$t_{down} \cdot r_{down} + l = t_{down} \cdot R/K$ (5) t_{down} can be Figured out

→ $t_{down} = \frac{l}{R/K - r_{down}}$ (6)

Let D_p be the node P's speed of substreams transmission. P originally satisfies all child nodes' transmission bandwidth. But when new node Q asks for being P's child node, the bandwidth of sending substreams to each child node would be lower because P's bandwidth is fixed. The bandwidth goes down from R/K to r_{down}. It is written as:

$$r_{down} = \frac{D_p}{D_p + 1} \cdot R/K \qquad (7)$$

If one node violates inequality (1) and lost peer competition after a time t_{lose}, the blocks in buffer area is *U* to *V* away from its partners. The result of competition would appear in the buffer area since the beginning of this competition. According to [7], the transmission equation can be written as:

$$R/K \cdot t_{lose} - \frac{D_p}{D_p + 1} \cdot R/K \cdot t_{lose} = (V - U) \qquad (8)$$

$R/K \cdot t_{lose}$ is the amount that are supposed to transmit. After the minus of the amount after the joining of node Q, $\frac{D_p}{D_p + 1} \cdot R/K \cdot t_{lose}$, it equals to the difference of blocks when peer adaptation happens.

→ $t_{lose} = \frac{(D_p + 1)(V - U)}{R/K}$ (9)

We have mentioned above that peer adaptation should be done in a time T or the

blocks in buffer area would be insufficient to play. So t_{lose} must be shorter than T. By this, we can figure out the probability of the happening of peer adaptation:

$$P(t_{lose} \le T) = P\left(\frac{(D_p + 1)\cdot(V - U)}{R/K} \le T\right) = P\left(U \ge V - \frac{T \cdot R/K}{D_p + 1}\right) \quad (10)$$

3.3 The General Situation of System Operation

Commonly speaking, users online can be divided into four types:

(1) Direct-connect: users owning public IP, being able to upload/download with their partners;

(2) UPnP (Universal Plug and Play): users owning private IP, being able to upload/download with their partners;

(3) NAT (Network Address Translation): users owning private IP, only being able to download from their partners;

(4) Firewall: users owning public IP, only being able to download from their partners.

According to [7], the network overlay construction can be shown as Figure 10. {A, B, C, D} are users from Direct-connect / UPnP; while {a, b, c, d} are users from NAT / Firewall.

We can see from Figure 10 that {A, a} is easy to face the problem of instability; once node A delays, it could cause peer adaptation and need to find a new parent node. As the system works for a time, certainly most nodes become Direct-connect / UPnP nodes' child node for they provide relatively more stable video streaming.

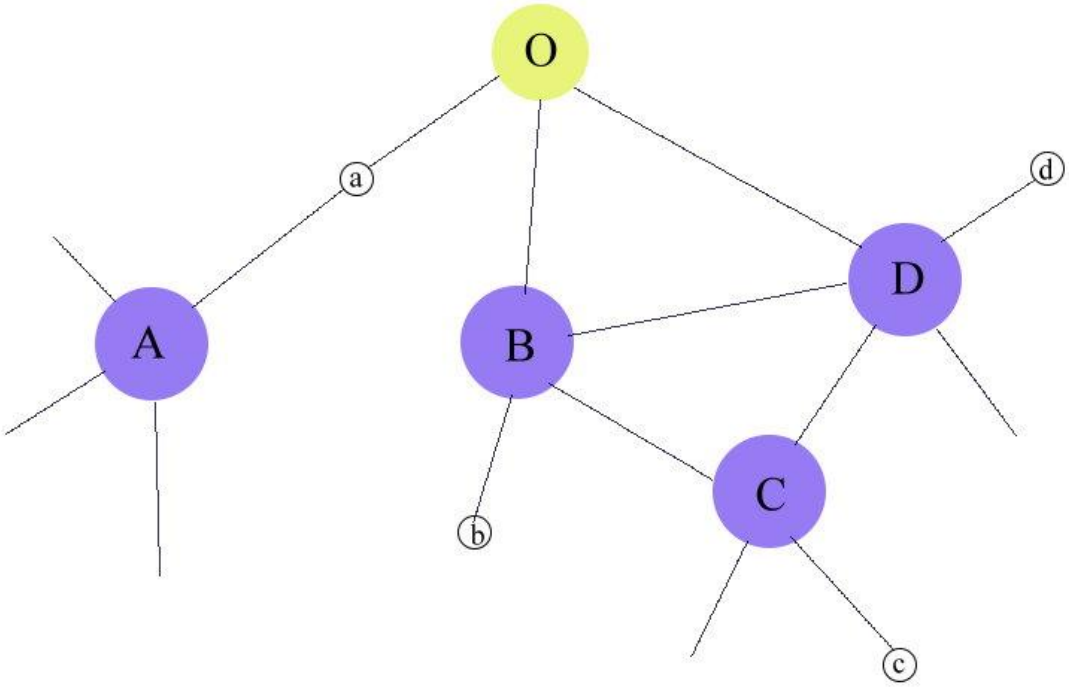

Figure 10. The Conceptual Overlay Construction

Chapter 4 – The Deployment of P2P LMS

4.1 The Usage of P2P LMS

Frankly speaking, distance video learning in campuses can be separated into two modes –non-synchronous mode and synchronous mode (as shown in Table 3). Non-synchronous mode contains three different ways. (1) Watching teaching videos by the whole school: if we want the whole school watch the videos at the same time, whether we gather students up or give every class a DVD to do the activity. No matter which way we choose, they are not ideal solutions for it may need a large place or waste resources. Thus, if we can use distance video learning to broadcasting the program, students can watch the program through the help of projector in the classrooms. It is very convenient and it saves many resources. (2) Interactive whiteboard teaching: directly broadcast the recorded teaching program. (3) Teaching review: sending the recorded teaching videos to the internet, students can review the courses online after school. The video sources here are mainly the recorded image-files (Mpg, Mp4 and Avi) and they can be directly broadcasted through the multi-media servers.

Synchronous mode has four different parts. (1) Real time teaching activity: such as English good sentence a week or Taiwanese good sentence a week. These activities often use broadcasting so that students only get audio information. If these activities use direct video images, students must be more impressive. (2) The principle's story time: the principle goes to every class to tell stories, but only one class at a time. If distance video learning is used here, the video can be sent to each classroom at the same time. It is much more convenient and effective. (3) When the teaching activities limited by location which cannot allow all classes to participate in, distance video provides live broadcasting. (4) Outdoor broadcasting: schools often hold activities,

parents may not participate in the activities due to their work. But distance video system can let parents watch the activities held in the campuses. These image sources are mainly filmed by digital video camera. Next the images will be transmitted to the multi-media server then, at last, broadcast.

Table 4 shows the common display location and equipments. Different equipments can be used according to the change of display location.

Table 3. The Operation of P2P LMS in Campuses

Display Mode	Teaching Situation	Image Sources
Synchronous	Real time teaching activities	DV camera Webcam Interactive e-whiteboard Digital multi-media e-lecterns
	Principle's story time	DV camera Webcam Digital multi-media e-lecterns
	Activities that are limited by location	DV camera Webcam Digital multi-media e-lecterns
	Outdoor Activities	DV camera Webcam Digital multi-media e-lecterns
Non-synchronous	Watching teaching videos by whole school	DVD/VCD Player Digital multi-media e-lecterns Image files (mpg、avi、mp4…)
	Interacting e-whiteboard teaching	Image files (mpg、avi、mp4…) Interactive e-whiteboard
	Teaching review	Image files (mpg、avi、mp4…)

Table 4. Common Modes of Video-Displaying

Location	Equipment
Video Hall	Projector
Classroom	Projector
	LCD TV
	Television
Home	LCD TV
	LCD Monitor
	CRT
	Television

4.2 The Structure of Deployment

The structure of deployment of P2P LMS system can be divided into five parts:

(1) Video Provider: chiefly provides the sources of image. Digital video camera, image files (mpg, mpg4 and avi…etc.), DVD/VCD player and interactive e-whiteboard can all make and provide video signals;

(2) Video Encoder: re-encodes the image output format to wmv (Windows Media Video) format and delivers to the assigned sever of P2P LMS.

(3) Server of P2P LMS: delivers the re-encoded images to the internet and intranet by P2P system for user-end to receive.

(4) Video Player: receives the images sent by P2P LMS servers and broadcasts them after reforming.

(5) Player's Equipment: Images can be displayed by several equipments for users to watch. For example, projectors, LCD TV, LCD monitors and televisions.

The process of how P2P LMS system works is shown as Figure 11. The detailed operation steps are depicted below:

(1) Source: means the image sources. By using DVD/VCD players, DV cameras and e-whiteboards, images can be delivered to video encoder for displaying.

Video encoder mainly re-encodes video signals to the formats that can be broadcasted on P2P LMS. The steps are shown in (2) and (3).

(2) Revising: after video encoder receives the images, it uses Windows Media Encode to encode the images. First it adjusts the assigned throughput. The higher the throughput is, the better the video quality is. But it also needs more bandwidth.

(3) Resizing: after adjusting the throughput, adjustment of video image's size begins. Commonly it depends on the dpi (dots per inch) of the image sources. If the video image is adjusted too small, the dpi would be poor when the users use full-screen mode. After the re-encoding, images will be sent to P2P LMS's server and wait for broadcasting.

The operation of CoolStream system is divided into P2P LMS server-end and Video Player user-end. P2P LMS server, the video signal sharing-host, shares the video signals to every user-end on the internet. The operations are written in (4) and (5).

(4) Blocking: after the P2P LMS server receives video signals, it first cut video signals into blocks with the same size. Each block has its own serial number for being indentified when delivering.

(5) Substreaming: video signals reform the blocks into some substreamings before transmission. It makes video-sharing more convenient and let every user download enough video signals from partners. After they combine the video signals, video will be put on the internet to be shared with every user.

Video Player, the user-end, will take step (6) and (7) after receiving the video signals.

(6) Saving: when user-ends receive the video signals, firstly they will put the blocks to the right positions according to the serial numbers and wait for

receiving another blocks.

(7) Buffering: when video signals blocks are received, blocks will be reformed to the origin video signals for displaying. Blocks that are received first will be reformed earlier. Those blocks which have not been received will be stored in saving area, waiting other blocks for next reforming. When the reforming of blocked finishes, video signals will stay in buffering area for a moment. By the time the playing time is enough, it start to broadcast the video signals. Owning to the reservation of some playing time, sudden stops and lags can be avoided when the internet delays.

(8) Player's Equipment: the equipments that user-ends use for watching video signals such as projectors, LCD TV, LCD monitors and TV sets.

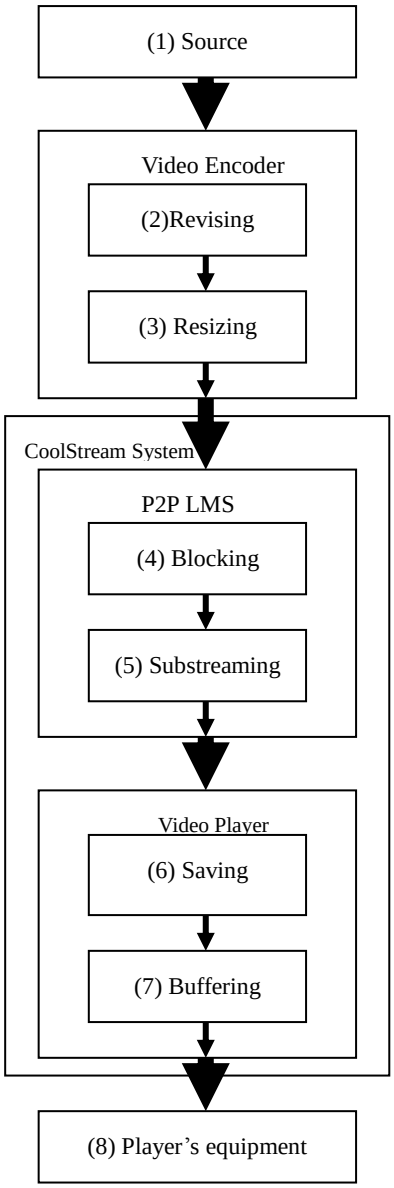

Figure 11. The Operation Process of P2P Live Media Stream System

The structure of deployment is shown as Figure 12:

Step 1: Camera sends the recorded images to video encoder for encoding.

Step 2: After encoding, video signals will be sent to P2P LMS servers by the Intranet and Internet. The P2P LMS servers will wait for users' request after receiving the video signals at the server-end.

Step 3: When users have requests, they connect to the internet for receiving streaming files and operate decoding and reforming.

Step 4: When user-ends finish reforming, signals will be sent to displaying systems for film-watching.

For instance, when distance learning is needed, first we film the teaching video and send it to video encoder for encoding (1). After encoding, the video signals will be sent to the P2P LMS server through the Internet and ready for broadcasting (2). When users request for video signals, P2P LMS will immediately send encoded images to user-ends (3). After receiving the encoded images, user-ends begin to decode and reform the original video signals, and then send to displaying system (4).

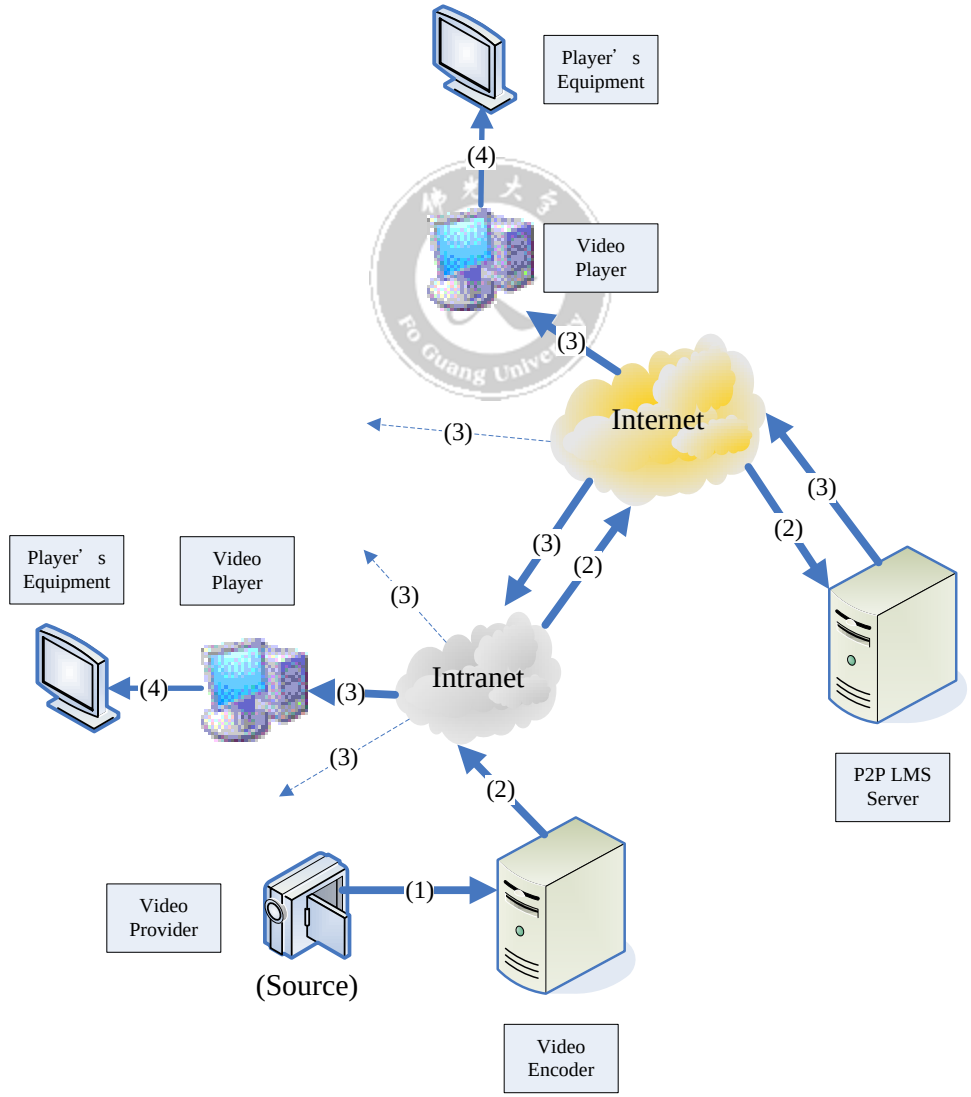

Figure 12. The Structure of Deployment of P2P Live Media Stream System

The operations of each part of P2P LMS system can be divided into synchronous mode and non-synchronous mode. The flow chart of synchronous mode is represented as Figure 13. The processes are:

(1) User-ends need to watch videos so they send requests of joining P2P as a member to P2P LMS.

(2) The P2P LMS server answers the requests and accepts.

(3) User-ends ask members of P2P LMS for video signals.

(4) The P2P LMS server asks the video encoder for video signals.

(5) The video encoder requests images from the displaying system for encoding.

(6) The displaying system sends images to the video encoder for encoding.

(7) The video encoder sends encoded images to P2P LMS for further sharing.

(8) After receiving the video signals, the P2P LMS server uploads them to the internet for every user.

(9) User-ends can start watching after receiving the video signals.

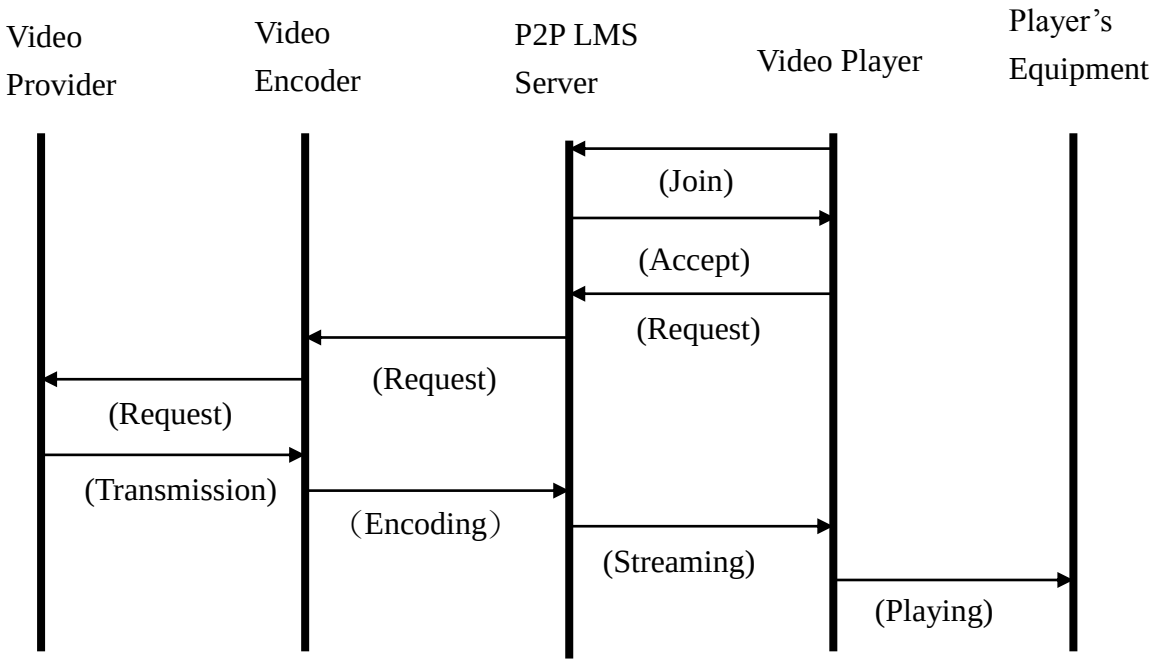

Figure 13. The Flow Chart of the Operation of P2P LMS System (Synchronous Mode)

The flow chart of non-synchronous mode is represented in Figure 14. The processes are：

(1) The P2P LMS server will play video signals so it asks the video encoder for video signals.

(2) The video encoder requests images from the displaying system for encoding.

(3) The displaying system sends images to the video encoder for encoding.

(4) The video encoder sends encoded images to P2P LMS for further sharing.

(5) After receiving the video signals, the P2P LMS server uploads the video signals to the internet, waiting for users to watch.

(6) User-ends need to watch videos so they send requests of joining P2P as a member to P2P LMS.

(7) The P2P LMS server answers the requests and accepts.

(8) User-ends ask members of P2P LMS for video signals.

(9) User-ends can start watching after receiving the video signals.

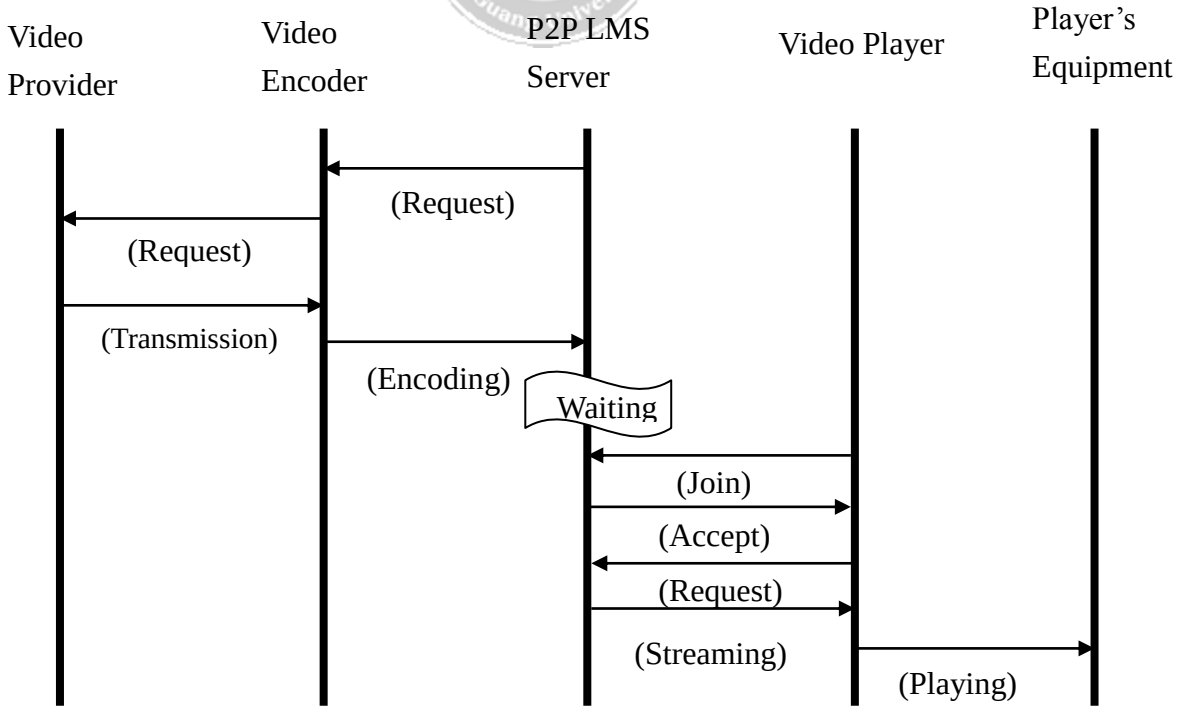

Figure 14. The Flow Chart of the Operation of P2P LMS System (Non-synchronous Mode)

Chapter 5 – Experiment Results

5.1 Experiment Scenarios and Measurement Methods

5.1.1 Scenarios

In order to understand the operation of P2P LMS system and compare it to Co-Life Video Conferencing System and Marratech Online Video Conferencing System, this paper plans four scenarios:

(1) LAN (Local Area Network);

(2) WLAN (Wireless Local Area Network);

(3) MAN (Metropolitan Area Network);

(4) WAN (Wide Area Network).

In LAN, Local Area Network, we mainly use the network in campuses for we have to experiment video teachings in campuses. In WLAN, we mainly use the wireless network in campuses to experiment the wireless online videos and to know the quality of wireless online videos. In MAN, we focus on the Center of Information Education & Networking, experimenting distance learning with schools from different levels to reach the goal of mutual help education. In WAN, we focus on teaching and administrative staff or students who surf the internet at home. We experiment the distance learning by using ADSL, Cable Modem and FTTx to connect to the internet.

5.1.2 Measurement Methods

We have set up the experiment environments above; now we list the items we want to measure:

(1) Smoothness

When operating distance learning, often it is a lecture in full-screen mode; meanwhile, students all sit at their seats. In this situation, we hope that the video's

quality is good and smooth. Thus, we pick up the image data from each system for comparison. The picked data are:

(1) Frame Rate, Fps (Frame per second).

(2) Throughput, Kbps (Kilobits per second).

Higher frame rate stands for that the video is smoother without motion blurs. The motion blur means played images remain in people's vision. The maximum fps that human can identify is twenty-four. Thus, people see continuous movements when the fps is higher than twenty-four. On the contrary, if the fps is lower than twenty-four, some images will stay in people's vision which we call it a "motion blur." By the comparison of frame rate, we can easily know that which system has the best smoothness when playing videos.

When delivering the images, higher throughput represents that the smoothness, sound quality and video quality are better. So it is simple to indentify the quality of the received videos from the data of throughput.

Higher dpi benefits the broadcasting in full-screen mode. Videos with lower dpi look rough when being played in full-screen mode. So we can realize which system is better when using full-screen mode by comparing the dpi of videos.

All three systems have built-in the data results of frame rate, throughput and dpi. It is very convenient because we can easily record the data without downloading the packets from the internet.

(2) Stability

Regarding stability, we mainly analyze the frame rate and throughput when three systems work on single server and then make line charts. The analyses focus on the vibration and wave rate of frame rate and throughput. Furthermore, we analyze the wave motion of three systems under different network environments.

(3) Connection Recovery

Distance learning is established on network service; nevertheless, the stability of network service is unpredictable. Network is formed by many communication servers and they are placed in different locations. Thus, one little error can slow down the whole network or even makes serious disconnection. This paper emphasizes this problem a lot for distance learning hugely relays on the smoothness of network. Once the error occurs, distance learning may suddenly stop. Due to this reason, this paper especially implements the video connection of three systems when facing network error in order to compare the performance of these systems. We cut the network connection for five to ten seconds to know the conditions that how each server receives video signals. In addition, we want to know that after the disconnection of network service, whether the system will automatically re-connect to network and keep playing the videos, totally disconnected to network service until re-connect to the server, or other situations will happen.

The experiment methods are shown in Table 5. About connection recovery, because the ways of reconnection are the same, we only implement it in LAN.

Table 5. The Experiment Methods Table

		LAN	WLAN	MAN	WAN
Smoothness	Frame rate	V	V	V	V
	Throughput	V	V	V	V
Stability		V	V	V	V
Connection Recovery		V			

5.2 Experiment Results

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

$$\sigma = \sqrt{\frac{1}{n}\left(\sum_{i=1}^{n} x_i^2\right) - \bar{x}^2} \qquad (11)$$

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:

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \qquad (12)$$

5.2.1 The Experiment in LAN

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 15, 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.

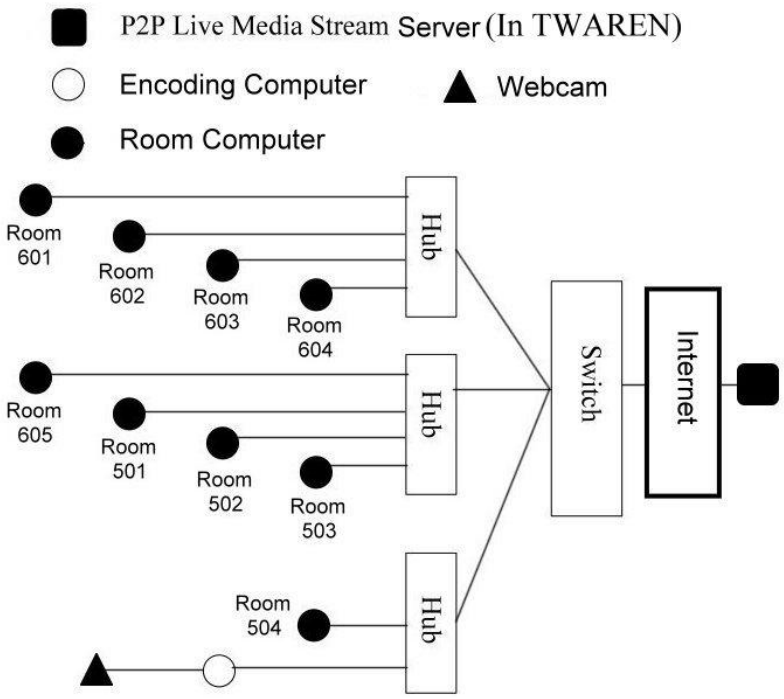

Figure 15. The Network Distribution of LAN in Campus

(1) The Experiment Results of the Smoothness of LAN

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 16 and Table 6. 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 17 and Table 7), 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 6.267. 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. In Table 7, we can see that the broadcasting of teaching videos through P2P LMS has an outstanding frame rate of 30 fps. In Table 8, the average throughput is 1125 Kbps, a notable statistics. Compared the broadcasting teaching videos to live broadcasting, the frame rate is half left in live broadcasting. We can reasonably conjecture that the filming equipments and environment limit the performance much; if better filming equipments are used, P2P LMS may have better performance in live broadcasting.

Table 6. The Average Frame Rate of Each System in LAN

	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 7. The Average Throughput of Each System in LAN

	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)

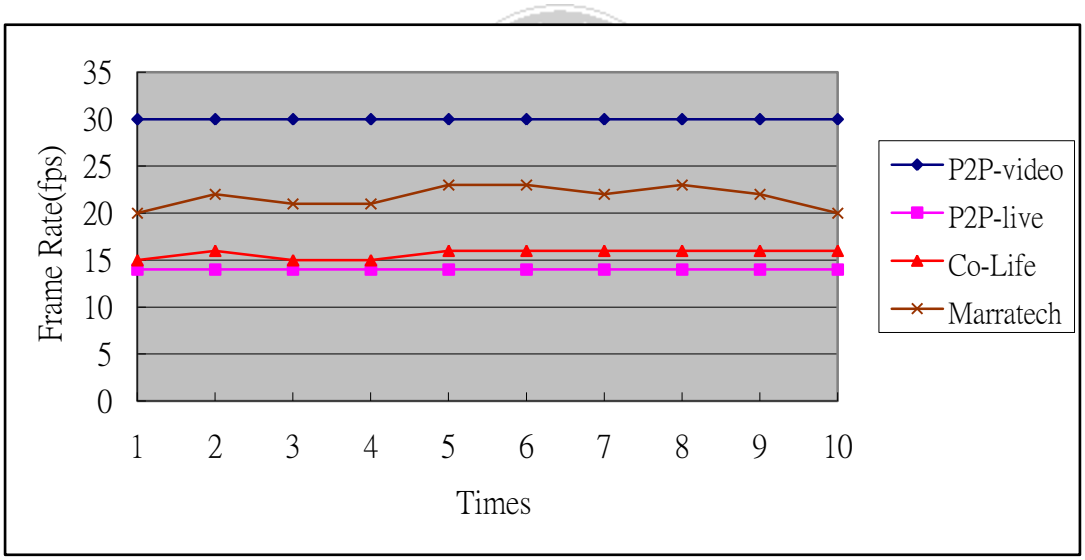

Figure 16. The Comparison of Frame Rate in LAN

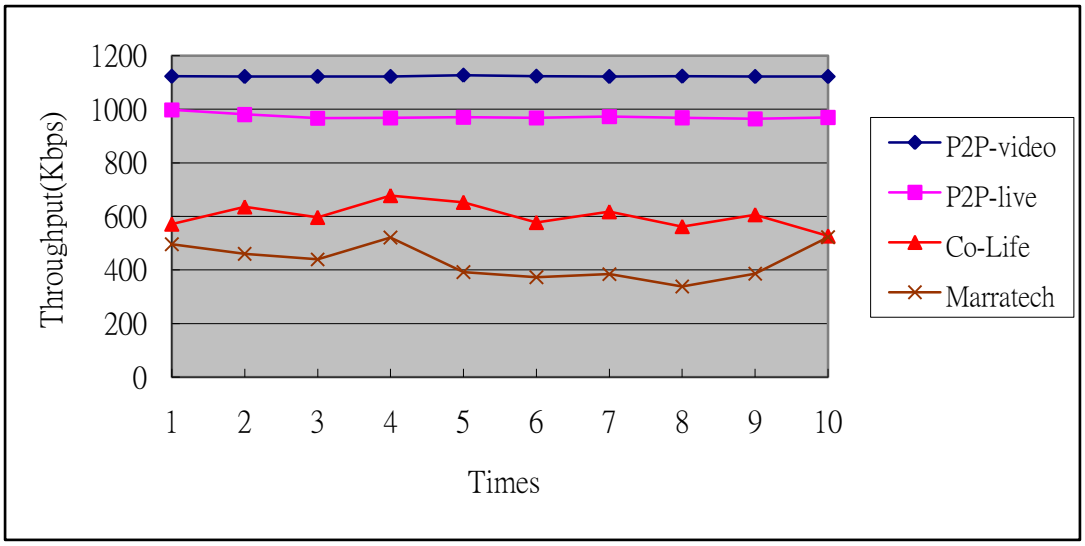

Figure 17. The Comparison of Throughput in LAN

Figure 18 is the accumulated chart of the frame rate in LAN. We can see the accumulated performance of frame rate is steadily going up. Figure 19 is the accumulated chart of throughput in LAN. Obviously the growing of P2P LMS is much higher than Co-Life and Marratech.

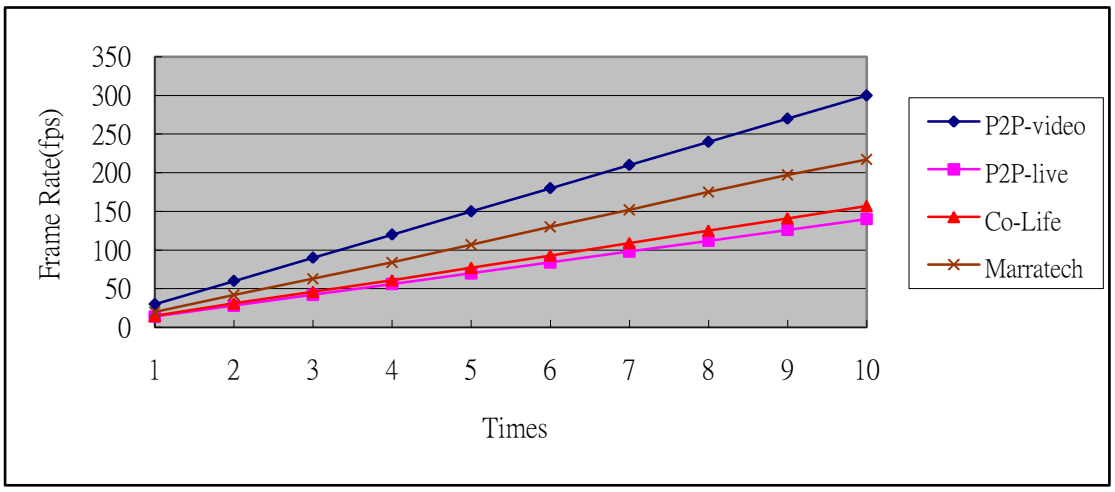

Figure 18. The Accumulated Chart of Frame Rate in LAN

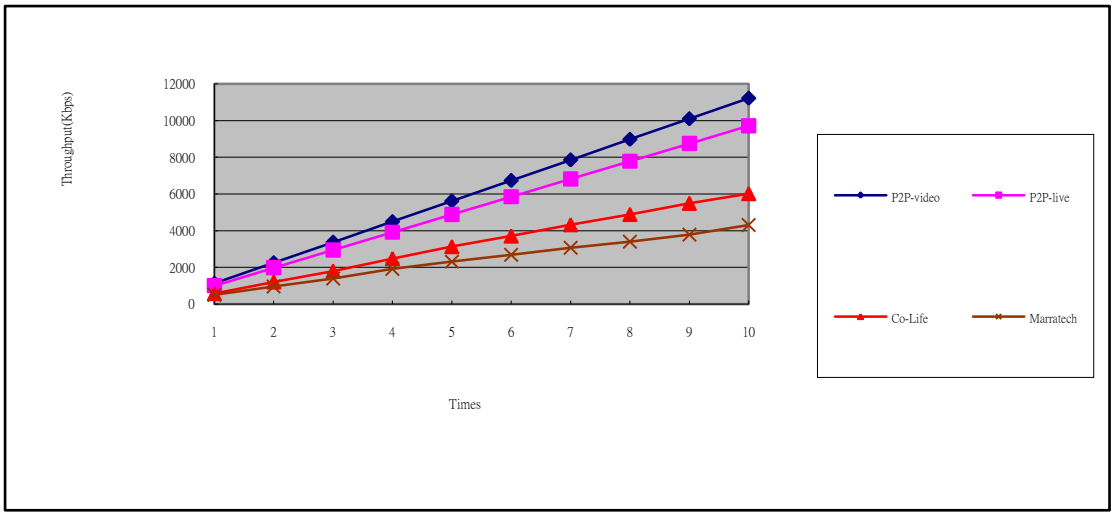

Figure 19. The Accumulated Chart of Throughput in LAN

(2) The Experiment of Stability in LAN

The frame rate performance of each single server is shown in Figure 20 to 23 and Table 8. We can see in Table 9 that the standard deviation of P2P LMS system is 0 which means the high stability with a certain frame rate without any wave motion. But Co-Life and Marratech have obvious variations. Especially Marratech, the standard deviation is 4.53, representing the wave motion is apparent. And the biggest difference is 16, performing badly in stability.

Table 8. The Frame Rate of Each Single Server in LAN

	P2PLMS-Video	P2PLMS-live	Co-Life	Marratech
Average	30	14	15	21
Maximum	30	14	17	25
Minimum	30	14	10	9
Biggest Difference	0	0	8	16
Standard Deviation	0	0	1.47	4.53
Stability	Good	Good	Medium	Bad

Unit：fps(frame per second)

The throughput performance of each single server is shown in Figure 24 to 27 and the integrated statistics are represented in Table 9. We can see that the standard deviations of throughput of P2P LMS-video and P2P LMS-live are 24.96 and 72.09 which means the wave motions are low. The standard deviation of throughput of Co-Life is 348.5 which shows the wave motion is obvious. The standard deviation of throughput of Marratech is 233.54; though it is more stable than Co-life, the wave motion is high. Referring to table 8 and 9, P2P LMS undoubtedly has the best stability.

Table 9. The Throughput of Each Single Server in LAN

	P2PLMS-video	P2PLMS-live	Co-Life	Marratech
Average	1125	997	666	471
Maximum	1176	1125	1448	765
Minimum	1058	829	169	115
Biggest Difference	118	296	1279	650
Standard Deviation	24.96	72.09	348.5	233.54
Stability	Good	Good	Bad	Medium

Unit：Kbps (bit per second)

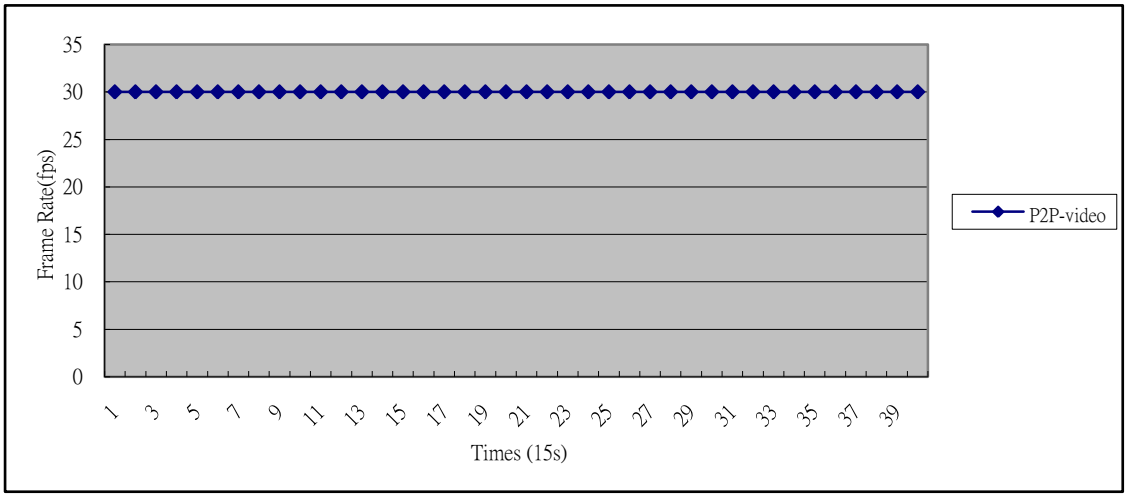

Figure 20. The Frame Rate of P2P LMS When Displaying Teaching Videos in LAN

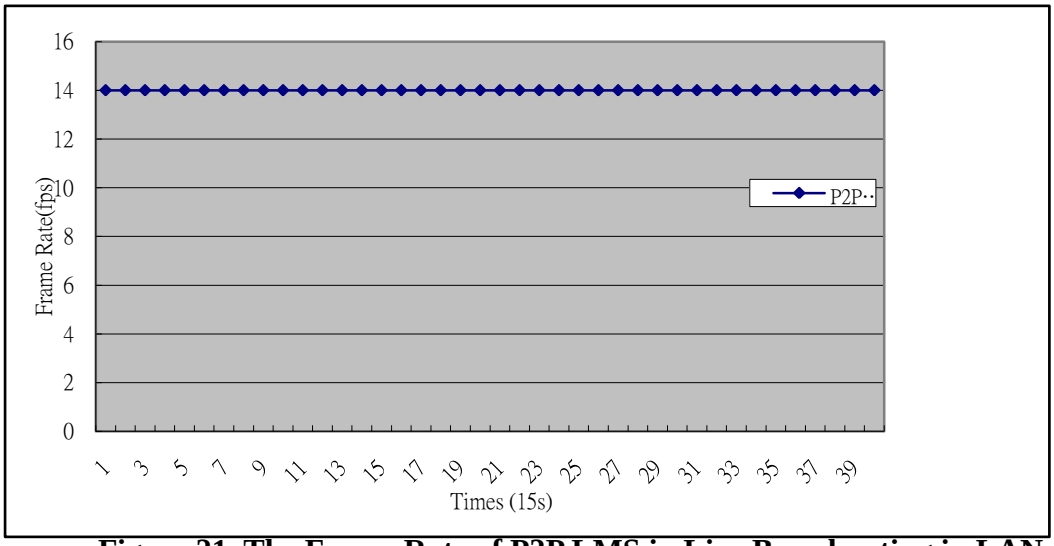

Figure 21. The Frame Rate of P2P LMS in Live Broadcasting in LAN

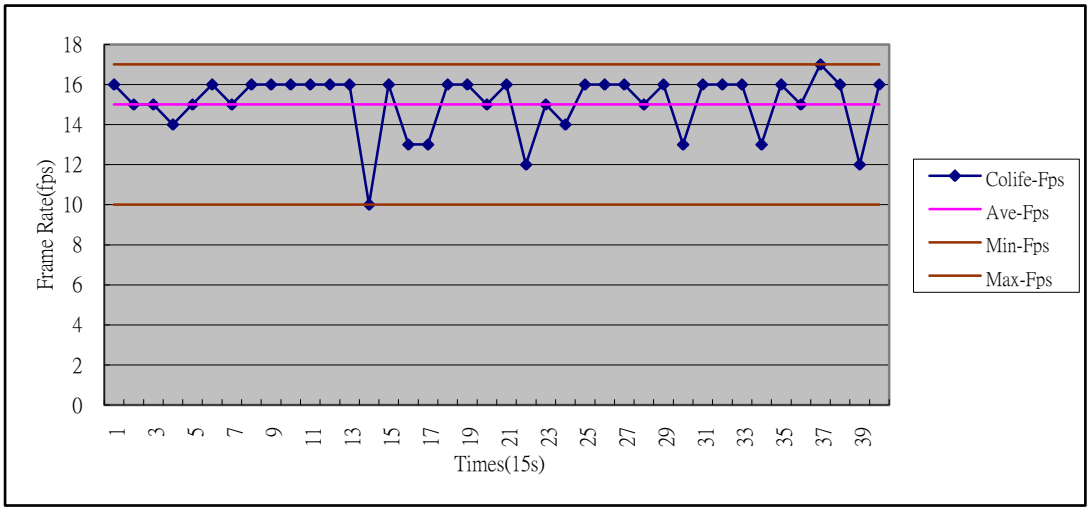

Figure 22. The Frame Rate of Co-Life in Live Broadcasting in LAN

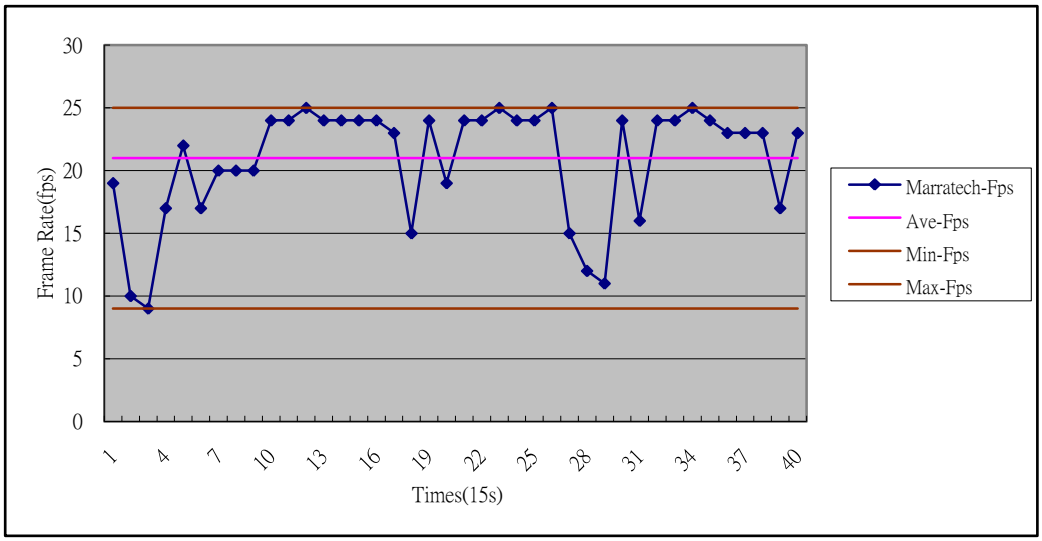

Figure 23. The Frame Rate of Marratech in Live Broadcasting in LAN

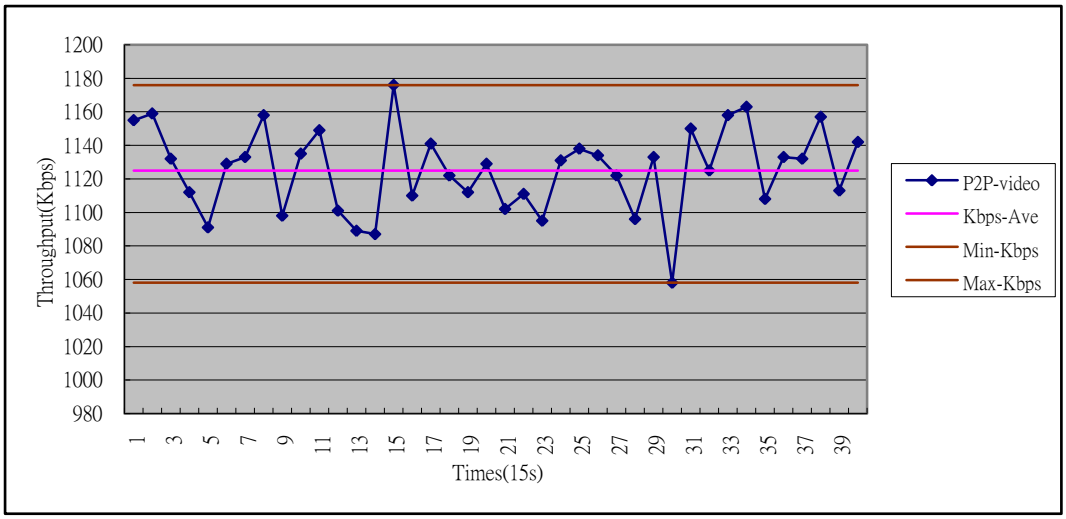

Figure 24. The Throughput of P2P LMS When Displaying Teaching Videos in LAN

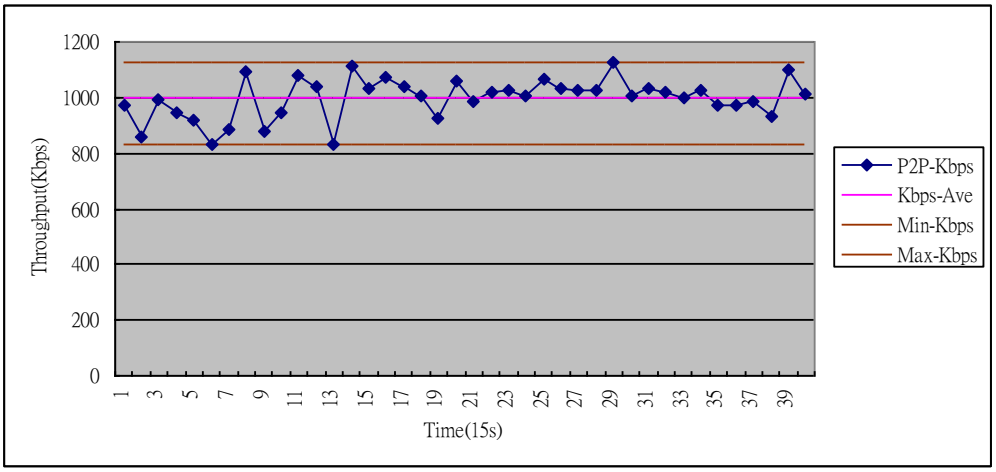

Figure 25. The Throughput of P2P LMS in Live Broadcasting in LAN

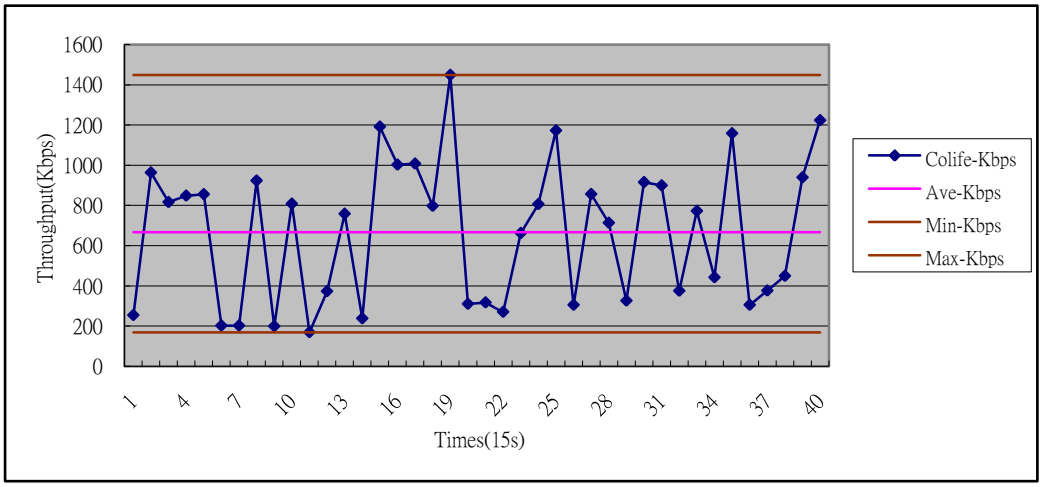

Figure 26. The Throughput of Co-Life in Live Broadcasting in LAN

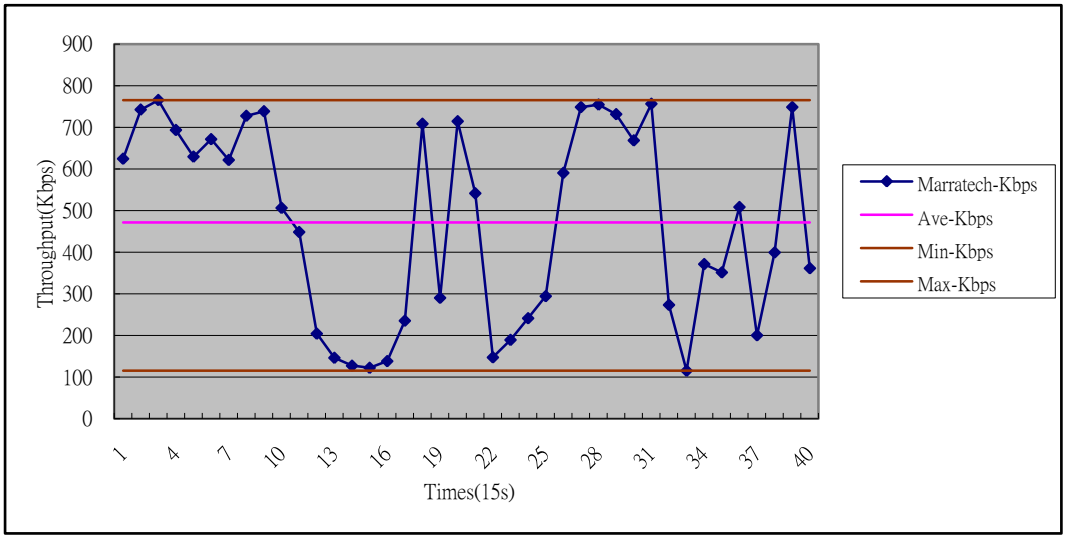

Figure 27. The Throughput of P2P LMS in Live Broadcasting in LAN

5.2.2 The Experiment in WLAN

On purpose of the popularization of network service, schools in Yi-Lan all set up Wireless Network AP (Access Point) which help the spread of network service in campuses. In order to know the situation of distance learning through WLAN in campuses, this paper experiments the distance learning through WLAN and focuses on the teachers' instruction in class and send it to two notebooks through WLAN. The Network distribution is shown in Figure 28.

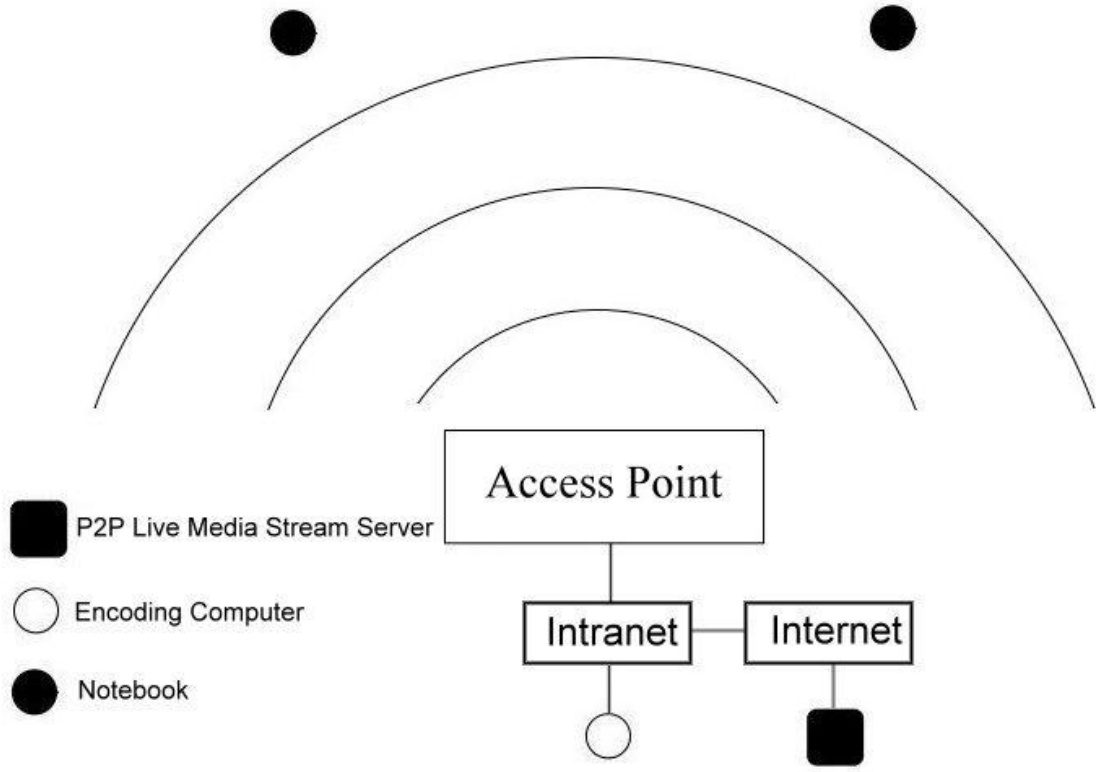

Figure 28. The WLAN Distribution in Campuses

(1) The Experiment Results of Smoothness in WLAN

The experiments in WLAN are about the servers of P2P LMS, Co-Life, and Marratech inside the campus and one Marratech server outside the campus. The previous experiment did not include the Marratech server outside the campus so we have no idea about the situation of the outside server. Here we add the outside server in this experiment and also film the class time in the classroom.

From the frame rate performance of each system in WLAN in Figure 29 and Table 10, we can see that Marratech in-campus server has the best result of 21 fps. However, when the server shifts outside the campus, the frame rate is down to an average of 13fps which is worse than P2P LMS's 14 fps and only a little bit better than Co-Life's 12 fps. Talking about standard deviation, P2P LMS is still the most stable one with 0 in standard deviation while Co-life's 1 and Marratech's 1.08 and

0.30. It shows that P2P LMS is much better than Co-life and Marratech in stability. From the throughput of each system in WLAN in Figure 30 and Table 11, we can see that P2P LMS's 1000 Kbps is again better than Co-Life's 701 Kbps and Marratech's 329 K bps (outside) and 385 Kbps (inside). We can realize that the transmission (to outside and then send back) of information indeed effects the results. About the standard deviation, P2P LMS's low standard deviation 2.20 is better than Marratech 78.36 and 38.38 and Co-Life's 134.93. Surely P2P LMS has better stability. Although Marratech has better frame rate, it performs badly in video quality. Thus, P2P LMS still has an advantageous position in WLAN and it can be seen in Table 10 and 11.

Table 10. The Frame Rate of Each System in WLAN

	P2PLMS	Co-Life	Marratech-inside	Marratech-outside
Output	30			
Average	14	12	21	13
Maximum	14	14	24	13
Minimum	14	10	20	12
Biggest Difference	0	4	4	1
Standard Deviation	0	1	1.08	0.30

Unit：fps(frame per second)

Table 11. The Throughput of Each System in WLAN

	P2PLMS	Co-Life	Marratech-inside	Marratech-outside
Output	1000			
Average	1000	701	385	329
Maximum	1004	923	472	423
Minimum	997	532	178	277
Biggest Difference	7	390	294	146
Standard Deviation	2.20	134.93	78.36	38.38

Unit：Kbps (bit per second)

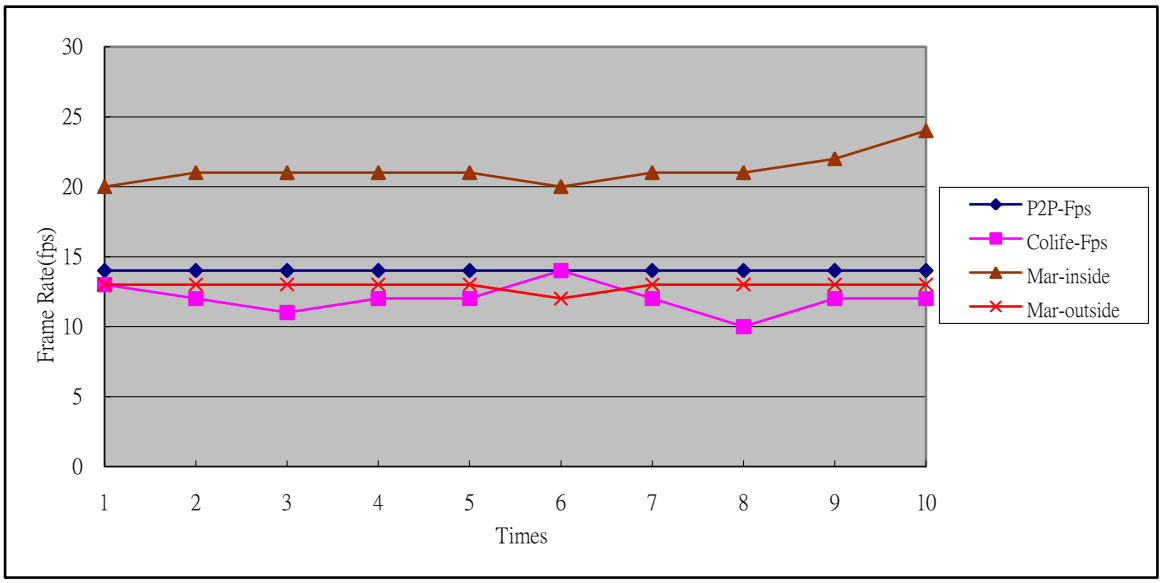

Figure 29. Frame Rate Performance in WLAN

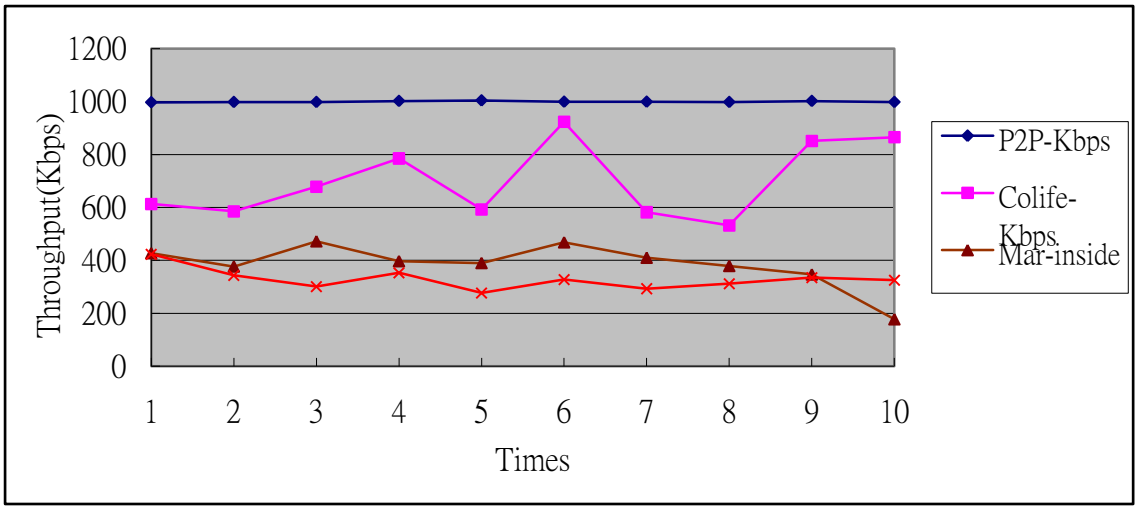

Figure 30. Throughput Performance in WLAN

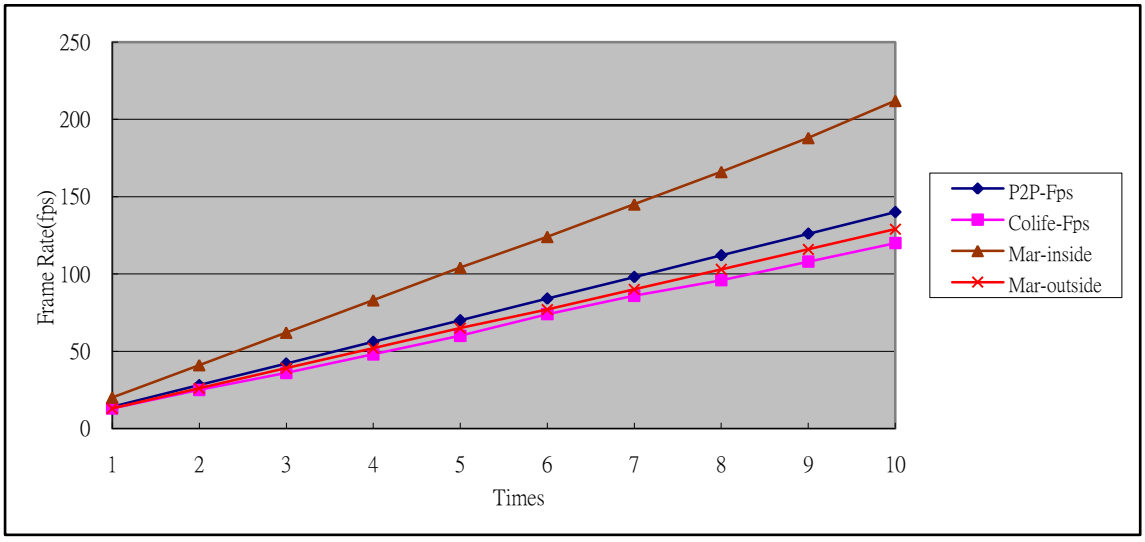

Figure 31. The Accumulated Chart of the Frame Rate in WLAN

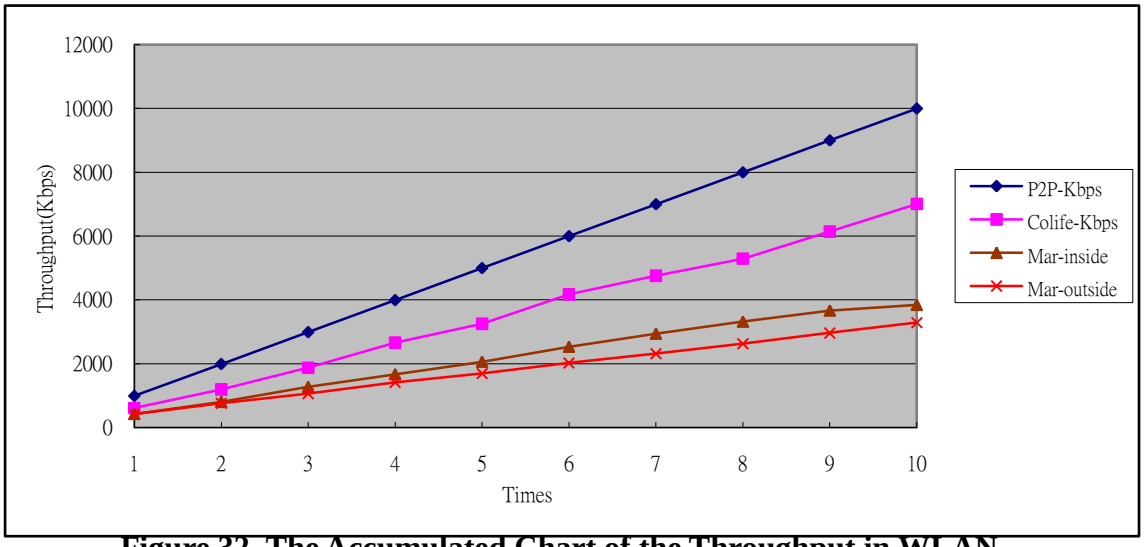

Figure 32. The Accumulated Chart of the Throughput in WLAN

Figure 31 and 32 are the accumulated charts of the frame rate and throughput in WLAN. We can see that the growing of P2P LMS is more stable. Although the frame rate of Marratech in campus is outstanding, it is not so good in the video quality. Especially when the server is put outside the campus, the results are obviously worse than P2P LMS's.

(2) The Experiments of Stability in WLAN

Figure 33 to 36 and Table 12 are the frame rate performance of each system. From the Figures and Tables, we can see that the frame rate standard deviation of P2P LMS is 0, a very stable value. Marratech is 1.29 and 0.84 here while Co-Life has the worst performance with the standard deviation of 2.51.

Table12. The Frame Rate of Single Server in WLAN

	P2PLMS	Co-Life	Marratech-inside	Marratech-outside
Average	14	13	20	13
Maximum	14	17	23	14
Minimum	14	8	17	10
Biggest Difference	0	9	6	4
Standard Deviation	0	2.51	1.29	0.84
Stability	Good	Bad	Medium	Medium

Unit：fps(frame per second)

Figure 37 to 40 and Table 13 are the throughput performance of each single server. In throughput performance, P2P LMS still leads with 997 Kbps and a standard deviation of 15.33, less wave motion and high stability. Co-Life has the second good frame rate of 629 Kbps; however, the high standard deviation of 410.55 indicates the high variation. The least frame rates are Marratech's 427 Kbps and 426 Kbps. But the

standard deviations are 111.58 and 88.74 which are more stable than Co-Life system.

From the two integrated Tables, we can see that P2P LMS has fewer wave motion and higher stability. It is a better distance learning system for the less probability of motion blurs, sudden stops and lags.

Table 13. The Throughput Performance of Single Server in WLAN

	P2PLMS	Co-Life	Marratech-inside	Marratech-outside
Average	997	629	427	426
Maximum	1069	1723	752	640
Minimum	990	139	255	246
Biggest Difference	79	1584	497	394
Standard Deviation	15.33	410.55	111.58	88.74
Stability	Good	Bad	Medium	Medium

Unit：Kbps (bit per second)

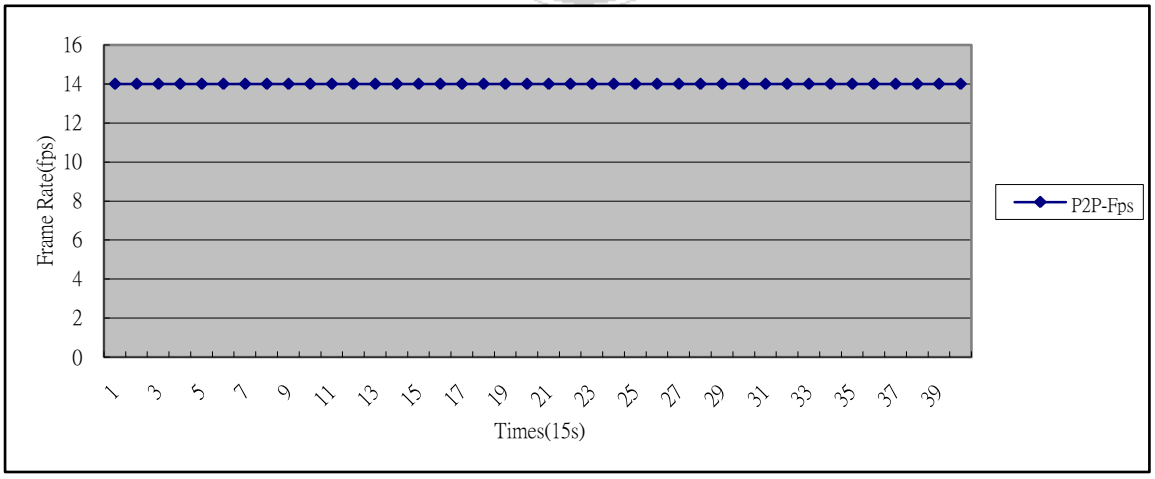

Figure 33. The Frame Rate Performance of P2P LMS Server in WLAN

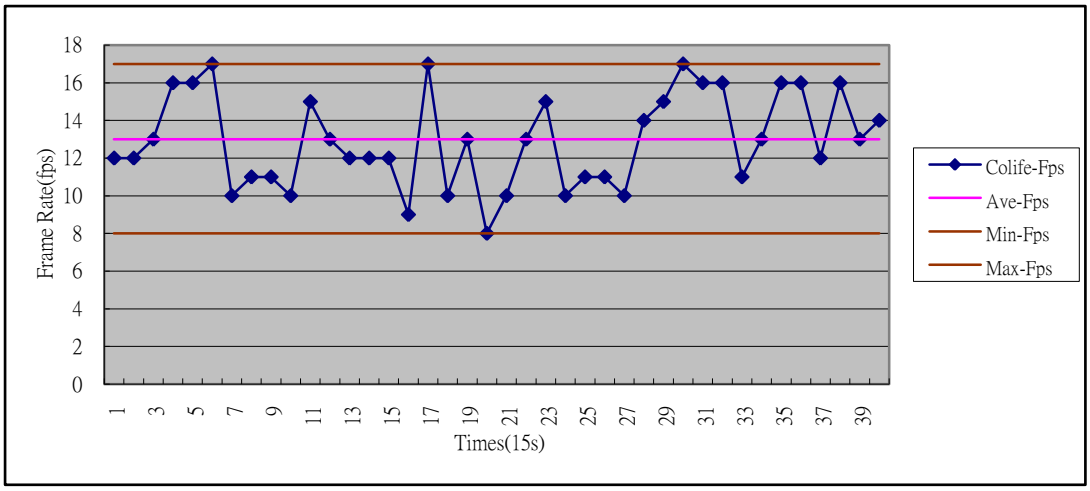

Figure 34. The Frame Rate Performance of Co-Life Server in WLAN

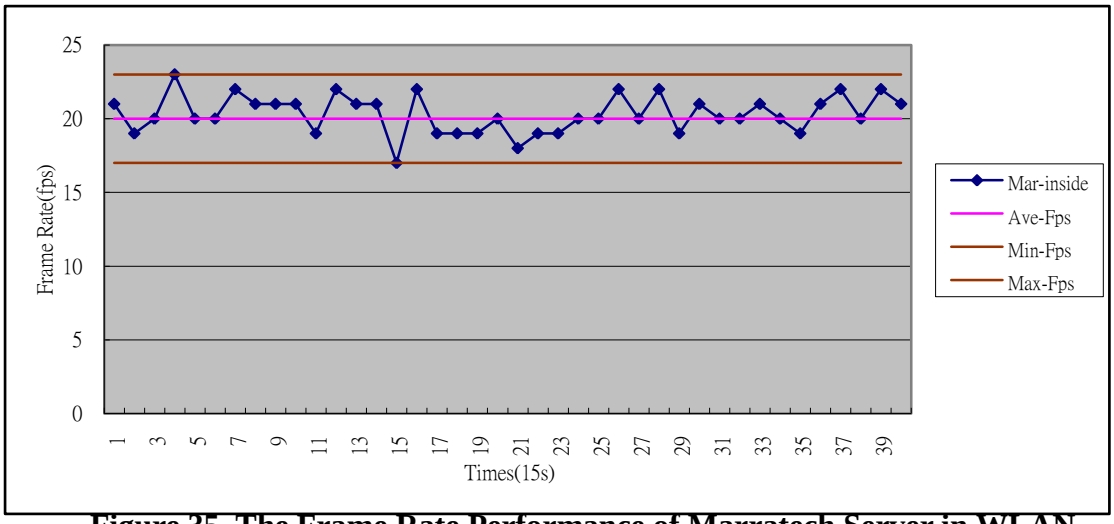

Figure 35. The Frame Rate Performance of Marratech Server in WLAN

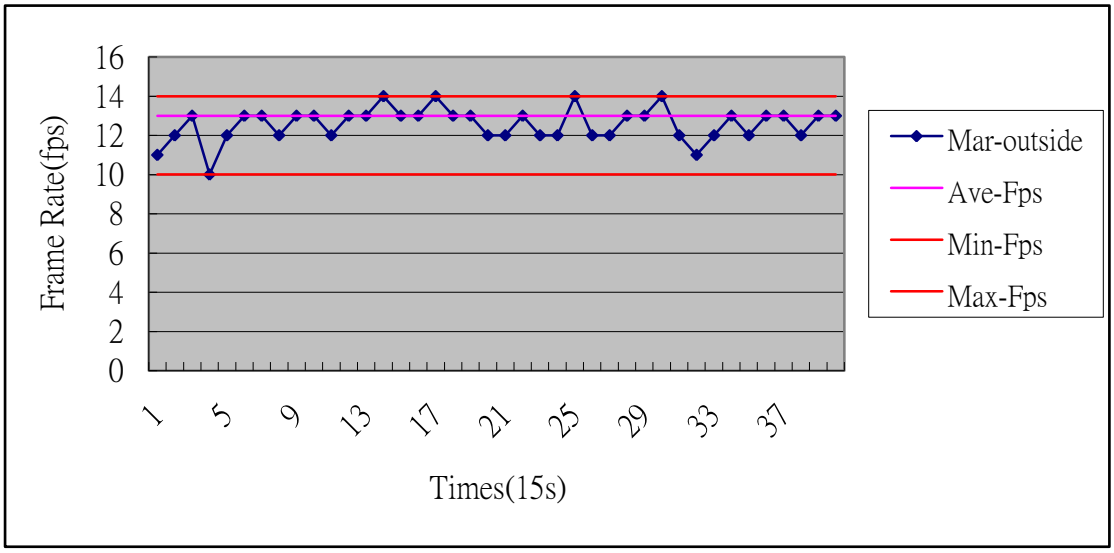

Figure 36. The Frame Rate Performance of Marratech Outside Server in WLAN

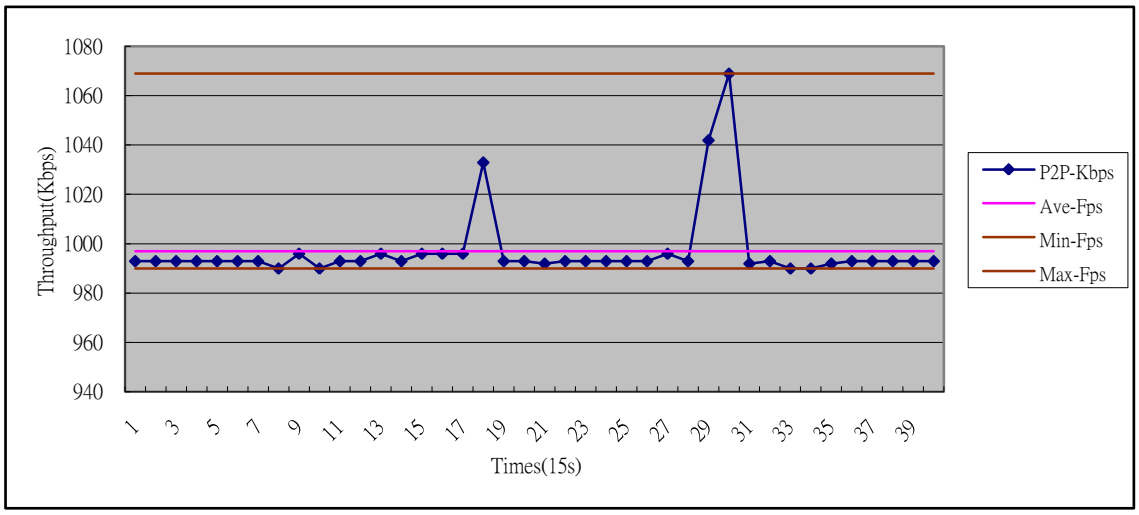

Figure 37. The Throughput Performance of P2P LMS Server in WLAN

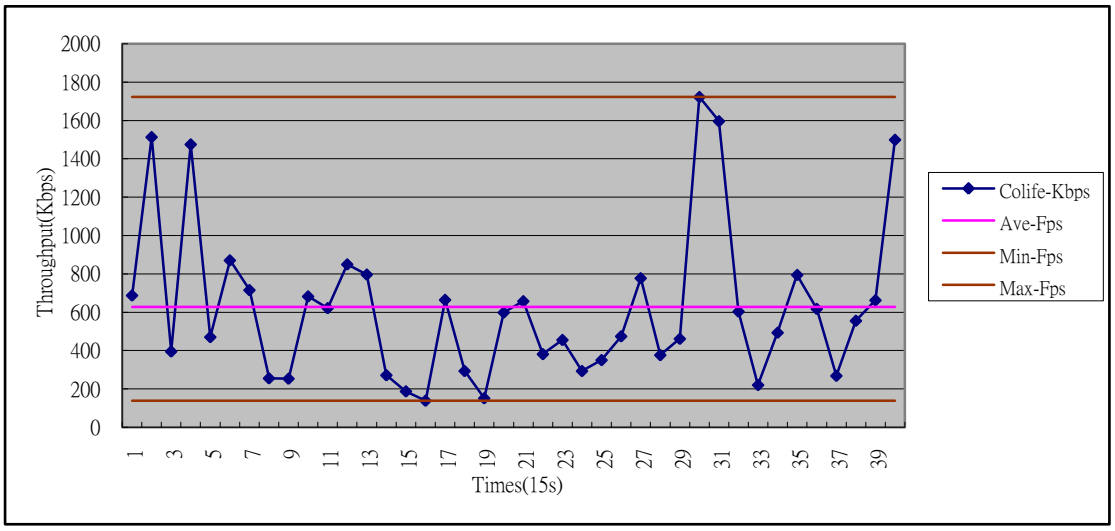

Figure 38. The Throughput Performance of Co-Life Sever in WLAN

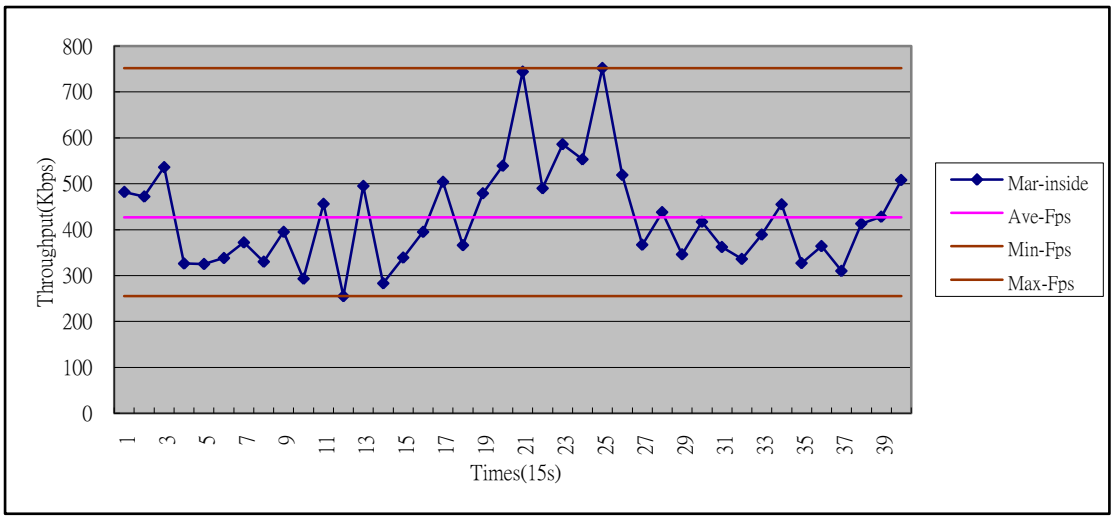

Figure 39. The Throughput Performance of Marratech Server in WLAN

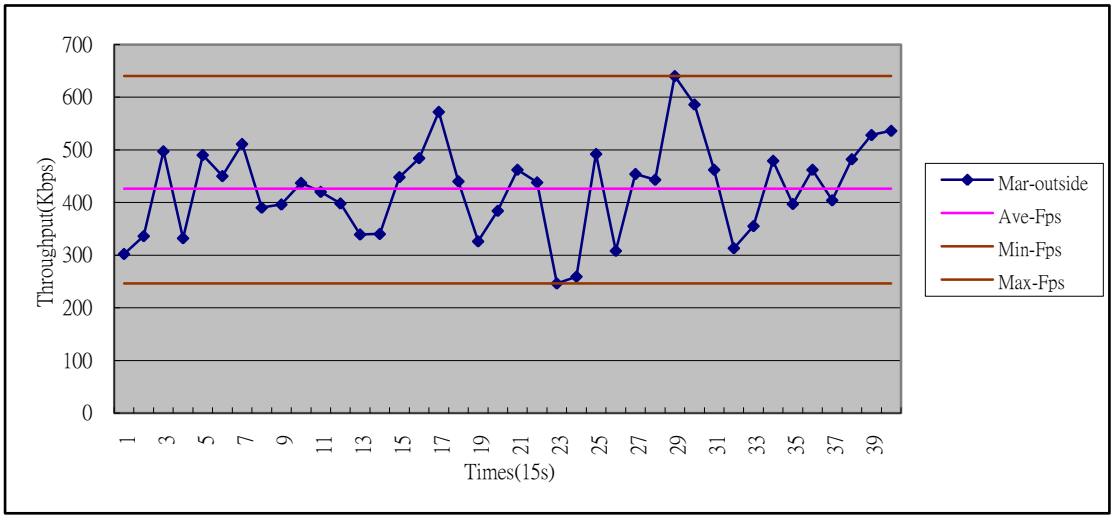

Figure 40. The Throughput Performance of Marratech Outside Server in WLAN

5.2.3 The Experiment in MAN

Because of the teaching contents nowadays are very extensive, schools develop their own characteristic courses so that students usually learn only the characteristic courses in their schools. Now, through the help of the MAN designed by this paper, every elementary school in county can operate distance learning together. Students in rural schools can easily participate in the teaching activities held by town schools by using distance video. Moreover, teachers in rural area will be able to participate in teaching conferences held in town. So, it is a very ideal teaching mode.

We unite several schools for the experiment of distance learning: Geng-Fang Elementary School, Tou-Cheng Elementary School, San-Min Primary School, Lung-Tan Elementary School, Yuan-Shan Elementary School and Luo-Dong Elementary School. The video signals are all delivered from Li-Tse Primary School. Each school prepares one server, six servers in total, to receive the signals. The geographical location is shown in Figure 41 and the network distribution is shown as Figure 42. This experiment films the class time in classroom by webcam. Then we send the videos to six schools through the servers of distance video system. At last we

collect the data of all systems for comparison.

Figure 41. The Geographical Location of Schools in County

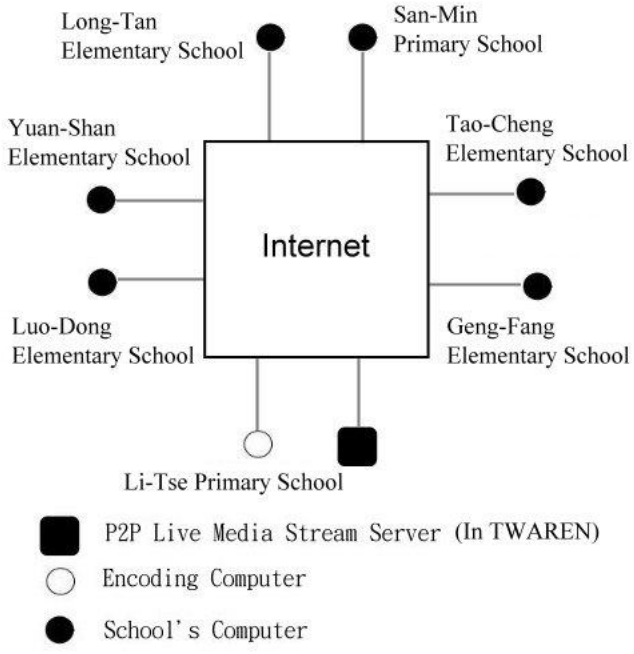

Figure 42. The Distribution of Cross-School in MAN

(1) The Experiment Results of Smoothness in MAN

The experiments in MAN mainly focus on sharing distance video learning with six elementary schools in Yi-Lan County at the same time. We chiefly film the class time in classrooms.

From Figure 43, the frame rate performance, and Table 14, we can see that even Marratech has a better average of 16 fps, the standard deviation of 2.41 shows the insufficient stability. Co-life has the worst performance of 10 fps and the standard deviation is 1.0 which shows the wave motion is also high. Only P2P LMS has an average of 13 fps and steady performance with the 0 standard deviation.

From the comparison of throughput in Figure 44 and Table 15, we can conclude that P2P LMS still works outstandingly. It is two times higher than Co-Life and four times higher than Marratech which represents that P2P LMS performs better in image quality. We can see in the chart that the last four times throughput of Marratech is considerably low. It is because students are out for other classes at those times. But P2P LMS and Co-life keep the same throughput as average; only Marratech will be affected. In standard deviation, P2P LMS still leads by the value of 12.06 while Co-life gets 61.53 and Marratech has the worst performance of 147.31. As a result, P2P LMS still has the best stability.

Since the experiments are operated in office hours, the network is hugely used by users. By this situation, we can know how each system react to different bandwidths. When the bandwidth is enough, frame rate and throughput are in a high level; on the contrary, frame rate and throughput performance badly when the bandwidth is insufficient. Nevertheless, P2P LMS does not affected by the bandwidth for it will download the image in advance when the bandwidth is enough in order to respond to the bandwidth-insufficient situation.

Table 14. The Average Frame Rate of Each System in MAN

	P2PLMS	Co-Life	Marratech
Output	30		
Average	13	10	16
Maximum	13	12	19
Minimum	13	9	12
Biggest Difference	0	3	7
Standard Deviation	0	1.00	2.41

Unit：fps(frame per second)

Table 15. The Average Throughput of Each System in MAN

	P2PLMS	Co-Life	Marratech
Output	1000		
Average	979	461	258
Maximum	996	577	417
Minimum	961	364	77
Biggest Difference	35	213	340
Standard Deviation	12.06	61.53	147.31

Unit：Kbps (bit per second)

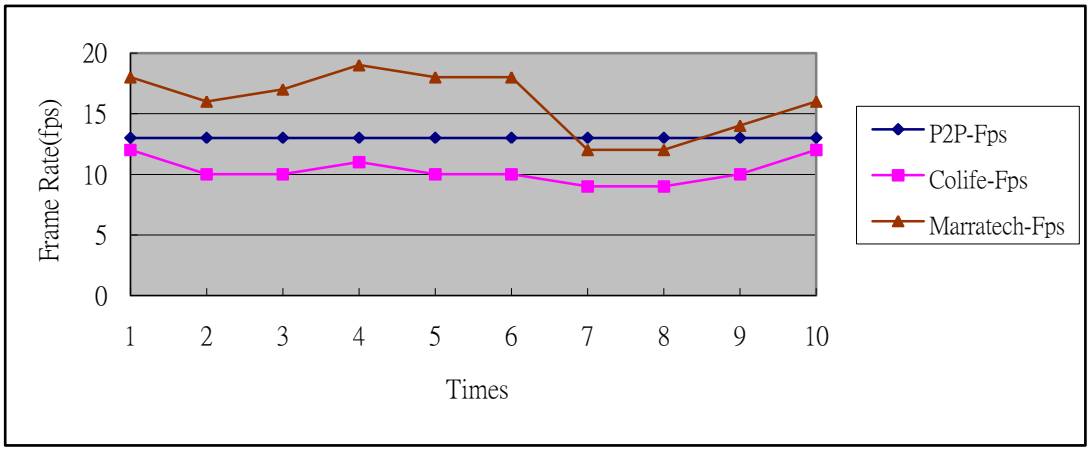

Figure 43. The Frame Rate Performance of Each System in MAN

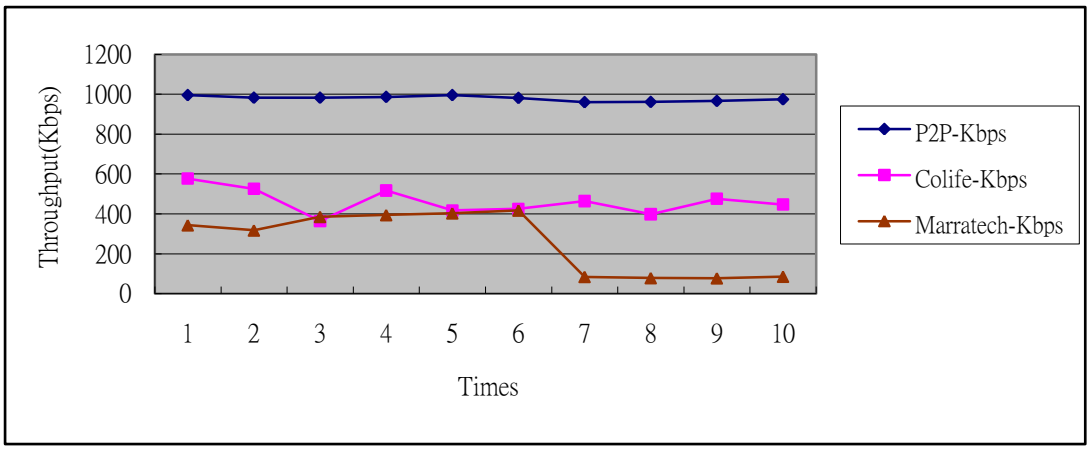

Figure 44. The Throughput Performance of Each System in MAN

Figure 45 is the accumulated chart of frame rate of three systems. We can see that all systems are quite stable, but P2P LMS is still the best one. Figure 46 is the accumulated chart of the throughput of three systems. Obviously, P2P LMS performs much better than Co-Life and Marratech.

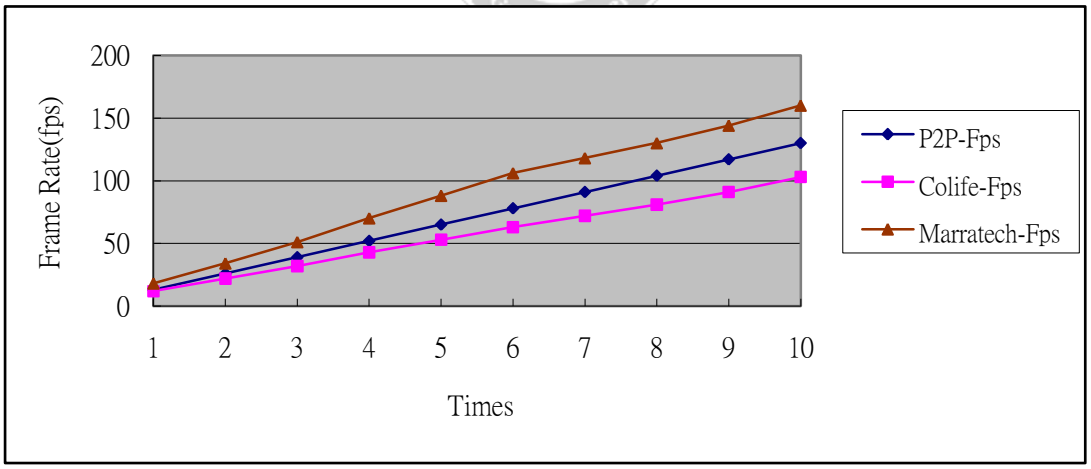

Figure 45. The Accumulated Chart of Frame Rate of Each System in MAN

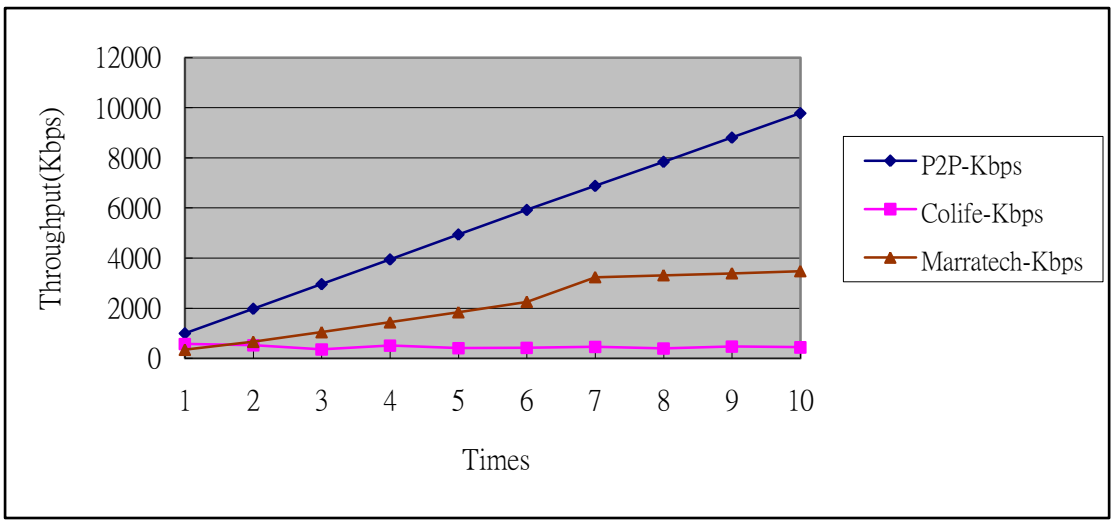

Figure 46. The Accumulated Chart of Throughput of Each System in MAN

(2) The Experiment Results of Stability in MAN

Figure 47 to 49 and Table 16 shows the frame rate performance of each system's single server. In single server's frame rate performance, P2P LMS still maintain good stability with a standard deviation of 0. Co-Life is the second with the standard deviation of 2.43, accompanying more frequent wave motions. Marratech has the most frequent wave motion with a standard deviation of 3.49.

Table 16. The Frame Rate Performance of Single Server in MAN

	P2PLMS	Co-Life	Marratech
Average	13	10	20
Maximum	13	16	24
Minimum	13	7	7
Biggest Difference	0	9	17
Standard Deviation	0	2.43	3.49
Stability	Good	Medium	Medium

Unit：fps(frame per second)

Figure 50 to 52 and Table 17 show the throughput performance of each system's single server. In the throughput performance of single server, P2P LMS still stands out with an average of 989 Kbps. Co-life gets the second with 504 Kbps while Marratech falls behind with 323 Kbps.

Table 17. The Throughput Performance of Single Server in MAN

	P2PLMS	Co-Life	Marratech
Output	1000		
Average	989	504	323
Maximum	1074	1812	499
Minimum	919	127	182
Biggest Difference	70	1685	317
Standard Deviation	32.08	397.79	55.58
Stability	Good	Bad	Medium

Unit：Kbps (bit per second)

From two integrated charts, we can see that P2P LMS has lower probability of wave motion which means higher stability. It has less probability to cause motion blurs and sudden stops and lags. It is a better distance learning system.

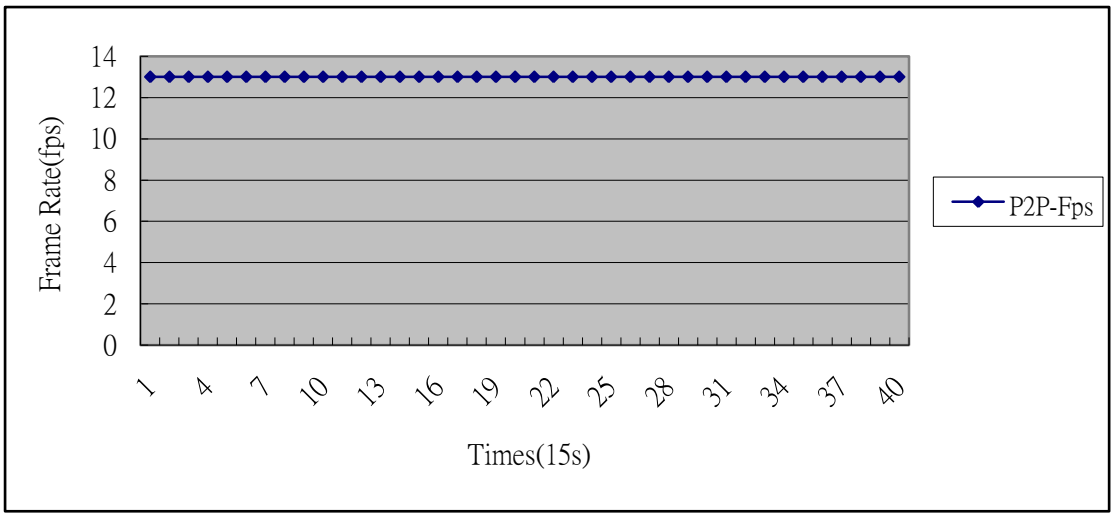

Figure 47. The Frame Rate of P2P LMS's Single Server in MAN

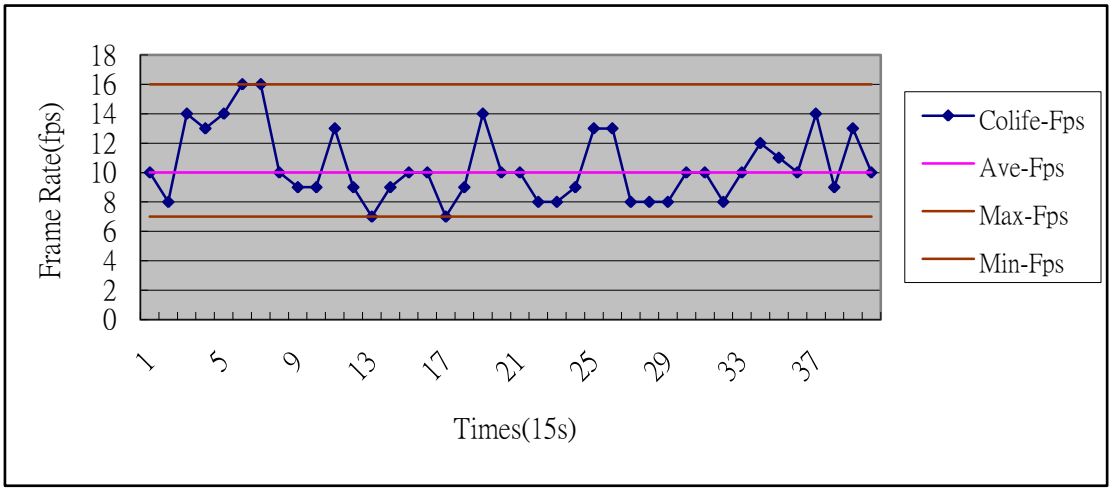

Figure 48. The Frame Rate of Co-Life's Single Server in MAN

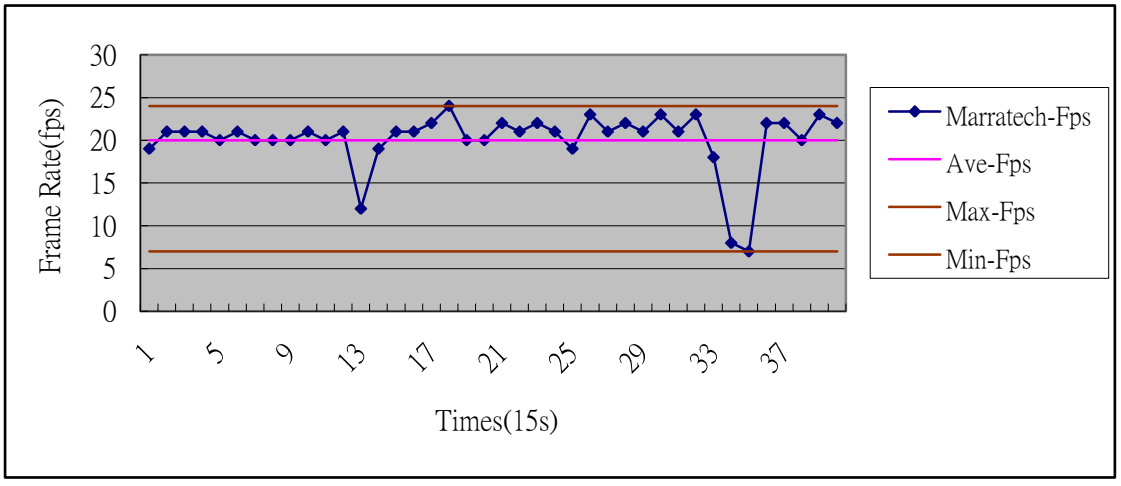

Figure 49. The Frame Rate of Marratech's Single Server in MAN

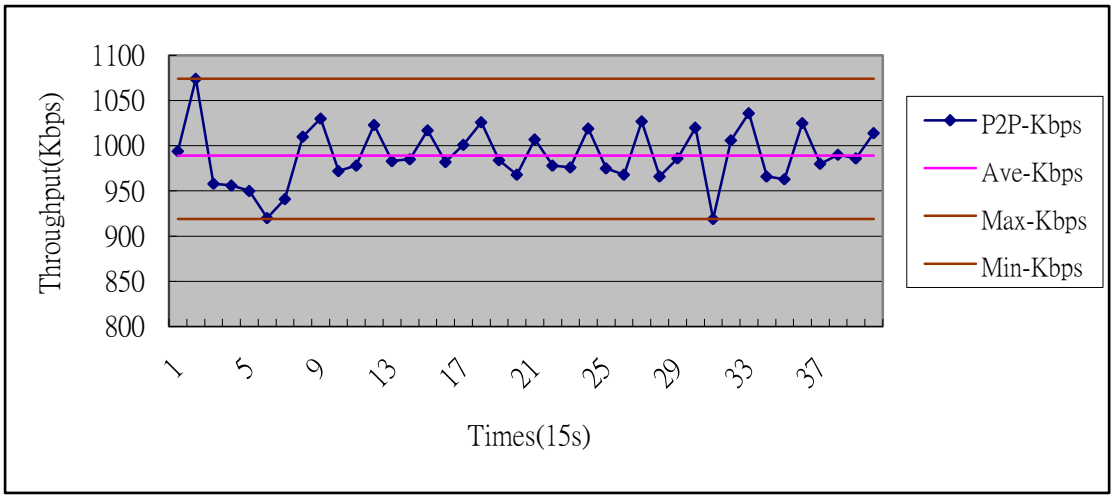

Figure 50. The Throughput of P2P LMS's Single Server in MAN

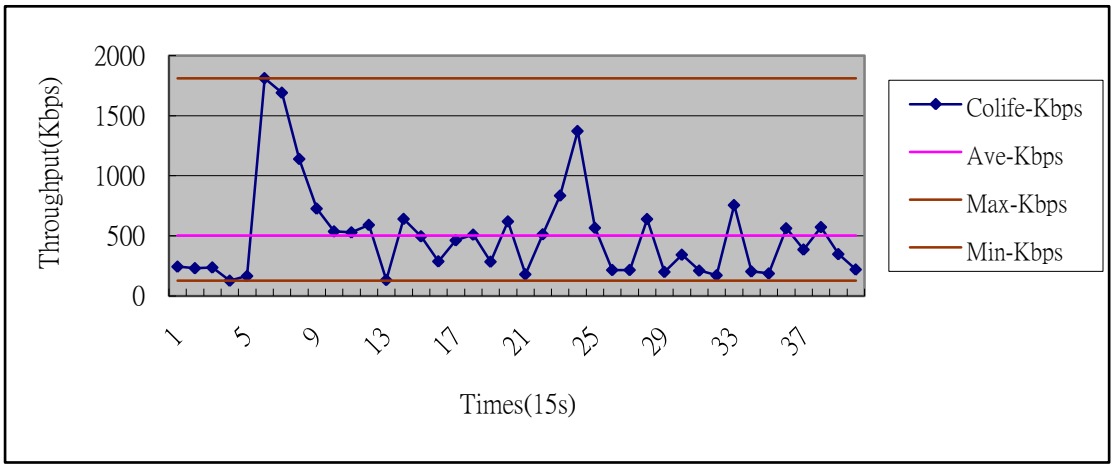

Figure 51. The Throughput of Co-Life's Single Server in MAN

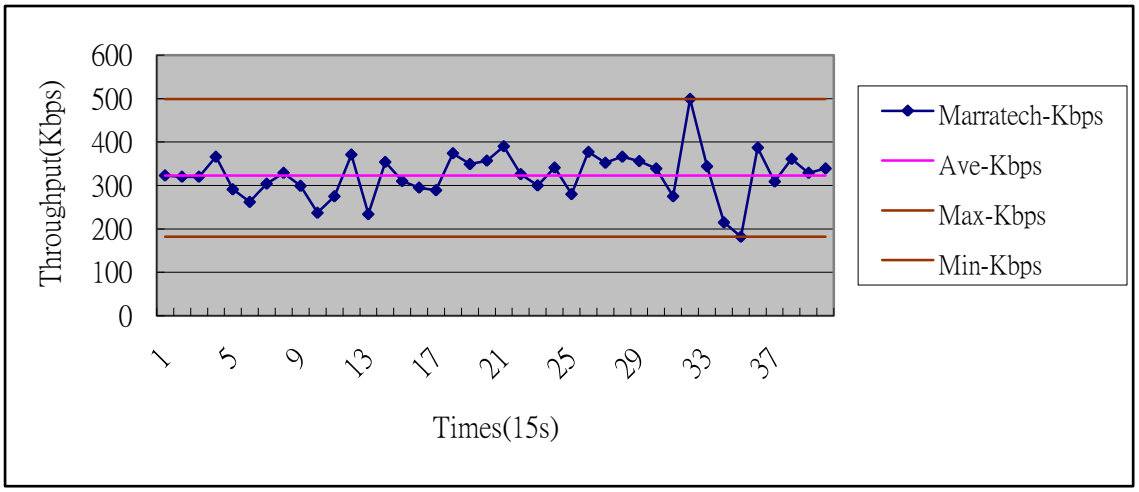

Figure 52. The Throughput of Marratech's Single server in MAN

5.2.4 The Experiment in WAN

There are three modes of broadband network in WAN:

1). ADSL (Asymmetric Digital Subscriber Line);

2). Cable Modem;

3). FTTH (Fiber To The Home).

ADSL(Asymmetric Digital Subscriber Line) is a new high speed broadband technique which provides the subscribers an unsymmetrical Upload/Download transmission rate by using the original telephone wire. The way ADSL connects to the internet is that the subscribers themselves connect to the ISP (Internet Service Provider) by using family telephone wire. Nowadays it is the most common way for internet access.

Cable Modem's development is expanded with the cable TV. Many families have equipped cable TV and cable TV is wiring by coaxial cable. Users only have to set up one modem at home and then they can connect to the internet through the contractor by using the coaxial cable. Cable modem has a wider bandwidth than ADSL; but it has to be shared with others so it is more instable.

FTTx is the so-called VDSL or VHDSL (Very High Bitrate Digital Subscriber Line). It mainly uses the fiber to replace the traditional telephone wire between the contactor and users. It makes the bandwidth faster and more stable. The bandwidth is from 10M/2M to 100M/5M. Table 18 shows the simple comparison of three different broadband services.

Table 18. The Simple Comparison of ADSL, Cable Modem and FTTx

Items	ADSL	Cable Modem	FTTx
Network Wire	Telephone Wire	Coaxial cable	Fiber
Download Speed	256K ~ 8M	384 ~ 12M	Up from 10M
Upload Speed	64K ~ 640K	64K ~ 1M	Up from 2M
Expenses	Medium	Medium	High
Subscribers	The Most	The Second	The Least
Network Quality	Excellent	Good	Excellent
Connection Mode	Needs Connection	Directly Use	Directly Use
Other Services	Few	Few	Many

Schools often hold activities like graduation, athletic meets and festal activities. Parents do not necessarily have time to participate in those activities. Sometimes students may not attend the events due to sickness as well. The absences are very regrettable for all parents and students. Fortunately, most companies and families have broadband network service and the bandwidth and speed are much improved than before. It is a good choice to participate in the activities by using the distance video.

Practically, our experiments may not encounter the activities. So this paper experiments the teachers' instruction and send it to the users of ADSL, Cable Modem and FTTx. We pick up one user from each broadband mode. The network distribution is shown as Figure 53.

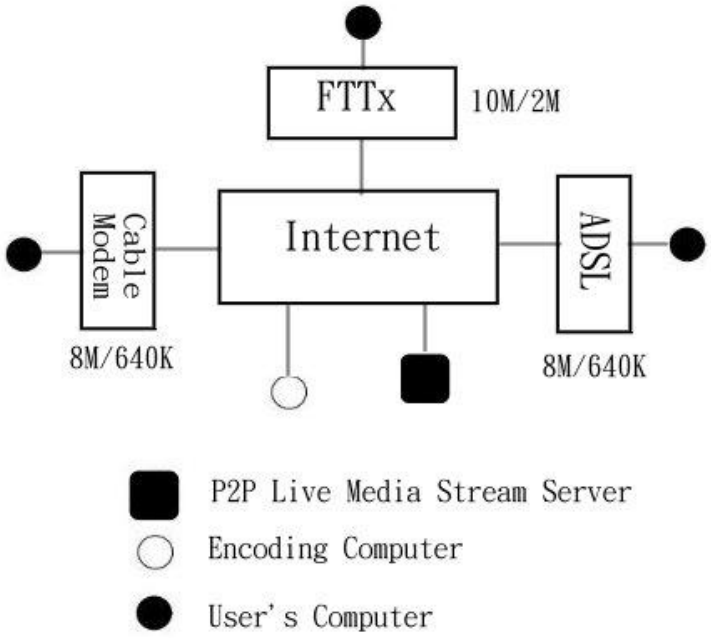

Figure 53. The Network Distribution of WAN

(1) The Experiment Results of Smoothness in WAN

For the convenience sake, we mainly take experiments in the weekends. Also, filming the situation of classrooms is our focus. The images contain fewer motions for they are filmed in the weekend. Furthermore, we pick up users whose bandwidth is more than 8M. Thus, we operate the experiment is a good network bandwidth. In this situation, we can know how each system works without obstructions.

Figure 54 and Table 19 are the average frame rates of each system. Due to the high and stable bandwidth, the frame rates are all stable without wave motion. Among them, Marratech has an outstanding average of 24 fps; meanwhile, Co-Life has the average of 16 fps and P2P LMS get 14 fps. We can conclude that three systems are very stable for the standard deviations are all 0.But when we take a look at Figure 55 and Table 20, the throughput of each system in WAN shows totally different results. As mentioned in the experiments in WLAN, Marratech will turn down the throughput to the bottom in order to get the best performance in frame rate when the motions are

fewer. Thus, the images will be displayed in a lower quality for the throughput has been abandoned. The situation is not what this research wants to see. At the same time, P2P LMS still have the same outstanding quality, having an average of 1000 Kbps which is better than Co-Life' 402 Kbps and Marratech's 82 Kbps. P2P LMS is the best distance learning system for it displays the best image quality. From the perspective of standard deviation, P2P LMS still leads at 1.83 while Marratech and Co-life's standard deviations are 4.01 and 36.48.

Table 19. The Average frame Rate of Each System in WAN

	P2PLMS	Co-Life	Marratech
Output	30		
Average	14	16	24
Maximum	14	16	24
Minimum	14	16	24
Biggest Difference	0	0	0
Standard Deviation	0	0	0

Unit：fps(frame per second)

Table 20. The Average Throughput of Each System in WAN

	P2PLMS	Co-Life	Marratech
Output	1000		
Average	1000	402	82
Maximum	1004	467	91
Minimum	998	346	75
Biggest Difference	6	121	16
Standard Deviation	1.83	36.48	4.01

Unit：Kbps (bit per second)

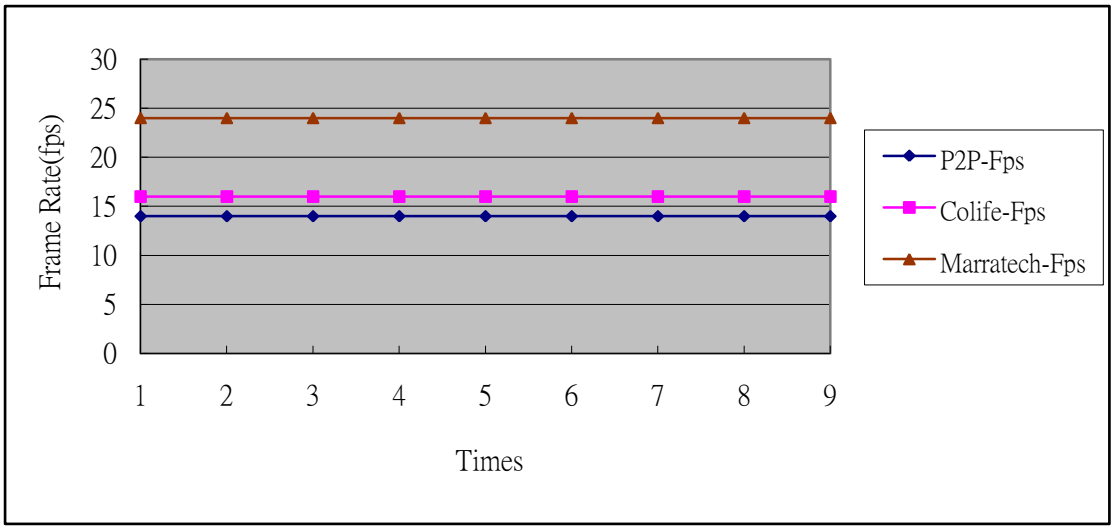

Figure 54. The Frame Rate Performance of Each System in WAN

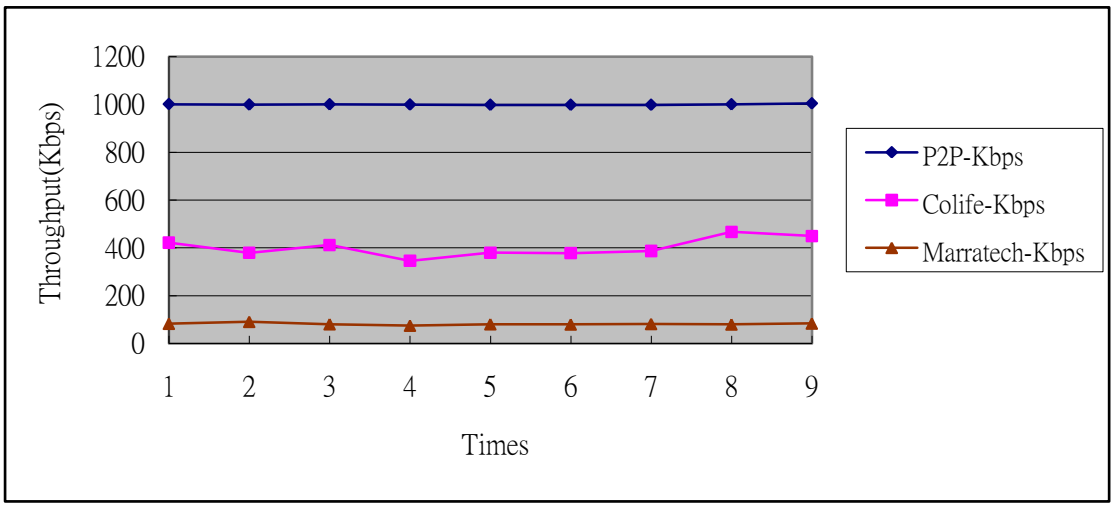

Figure 55. The Throughput Performance of Each System in WAN

Figure 56 is the frame rate accumulated chart of these three systems. We can see that all systems are very stable because of the bandwidth. Figure 57 is the throughput accumulated chart of these three systems. Obviously P2P LMS performs much better than Co-Life and Marratech.

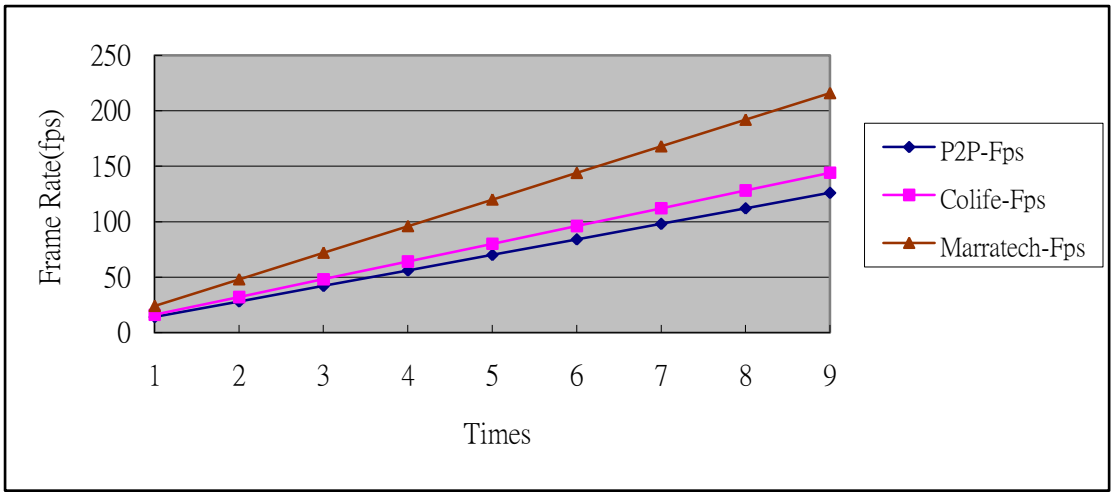

Figure 56. The Frame Rate Accumulated Chart of Each System in WAN

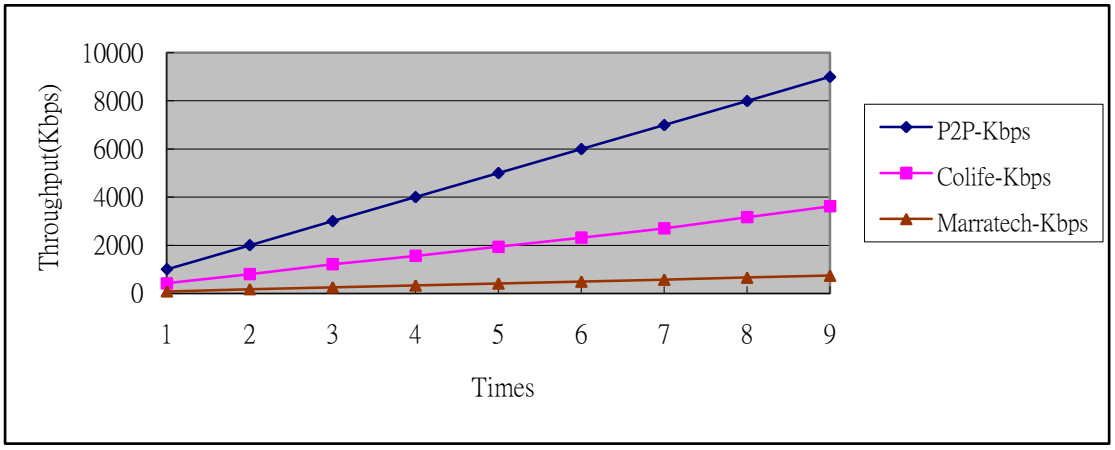

Figure 57. The Throughput Accumulated Chart of Each System in WAN

(2) The Experiment Results of Stability in WAN

Figure 58 to 60 and Table 21 show the frame rate performance of each system's single server. Due to the fine bandwidth, all systems show good stability on the frame rate of single server. P2P LMS again leads with the standard deviation of 0. At one time, Marratech's standard deviation is 0.72 and Co-life's 0.73. All of them are lower than 1 so the wave motions are unapparent.

Table 21. The Frame Rate of Single Server in WAN

	P2PLMS	Co-Life	Marratech
Average	14	16	24
Maximum	14	17	25
Minimum	14	14	22
Biggest Difference	0	3	3
Standard Deviation	0	0.73	0.72
Stability	Good	Good	Good

Unit：fps(frame per second)

Figure 61 to 63 and Table 22 show the throughput performance of each single system. P2P LMS still works the best in throughput with a standard deviation of 14.1. The standard deviations of Marratech and Co-Life are 9.81 and 274.01. But the throughput of Marratech is too low so it has no referential value. We can see in the two integrated charts that P2P LMS has fewer wave motions and good stability which causes less motion blur, sudden stop and lag. It is a better distance learning system.

Table 22. The Throughput Performance of Single Server in WAN

	P2PLMS	Co-Life	Marratech
Average	997	407	81
Maximum	1066	843	130
Minimum	991	130	65
Biggest Difference	75	713	65
Standard Deviation	14.1	274.01	9.81
Stability	Good	Bad	Medium

Unit：Kbps (bit per second)

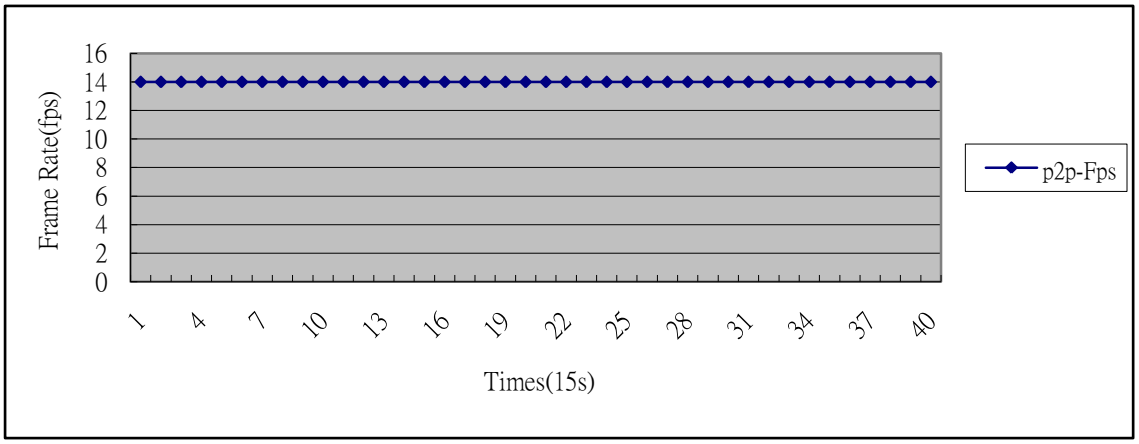

Figure 58. The Frame Rate of P2P LMS's Single Server on WAN

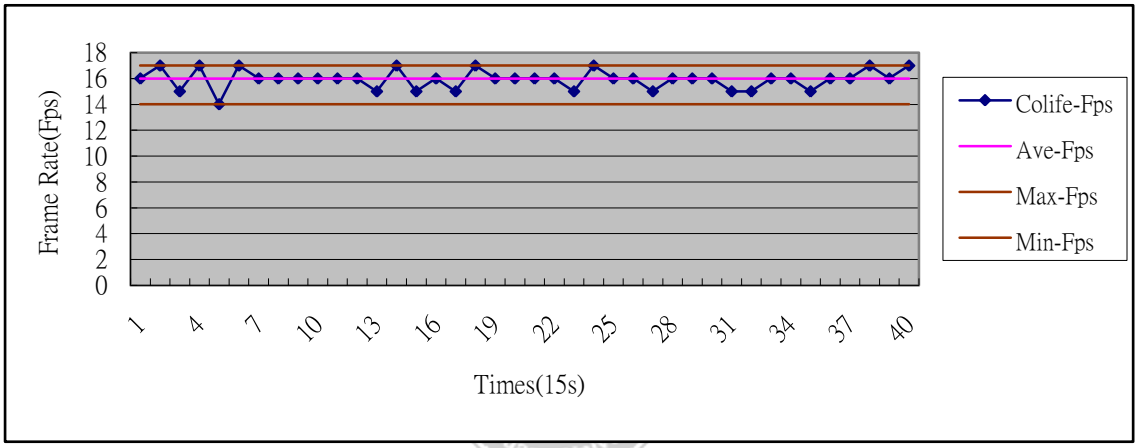

Figure 59. The Frame Rate of Co-Life's Single Server in WAN

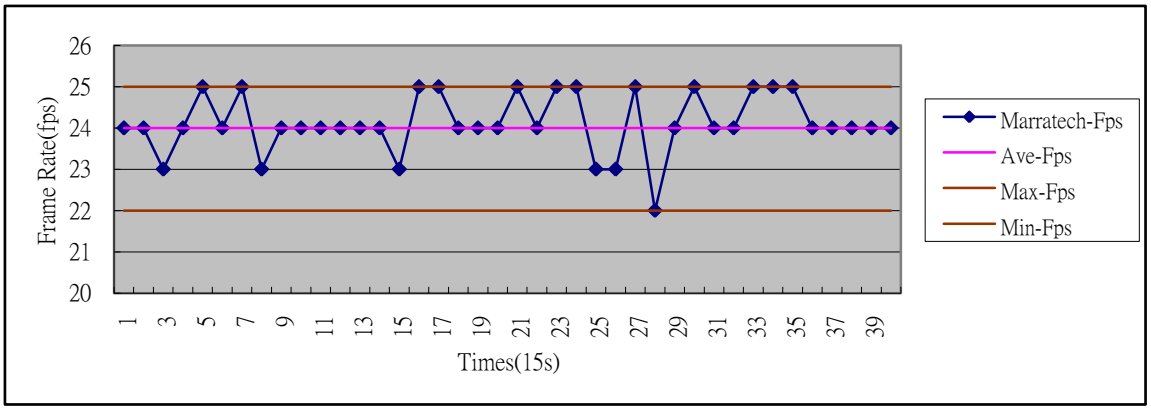

Figure 60. The Frame Rate of Marratech's Single Server in WAN

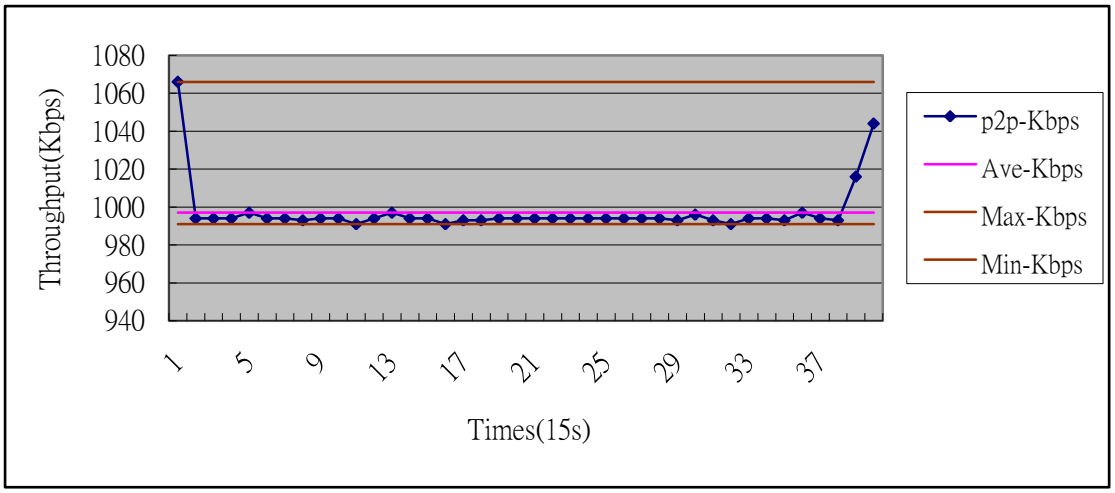

Figure 61. The Throughput of P2P LMS's Single Server in WAN

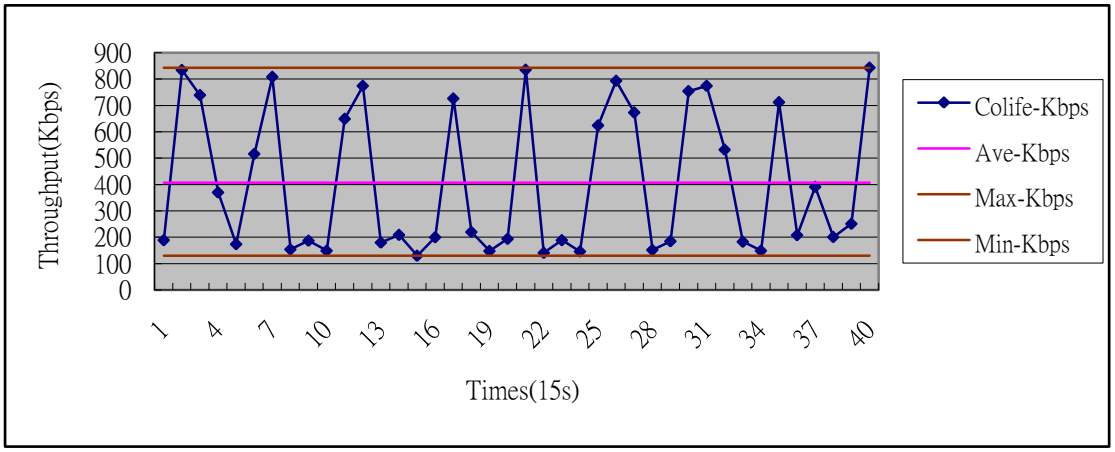

Figure 62. The Throughout of Co-Life's Single Server in WAN

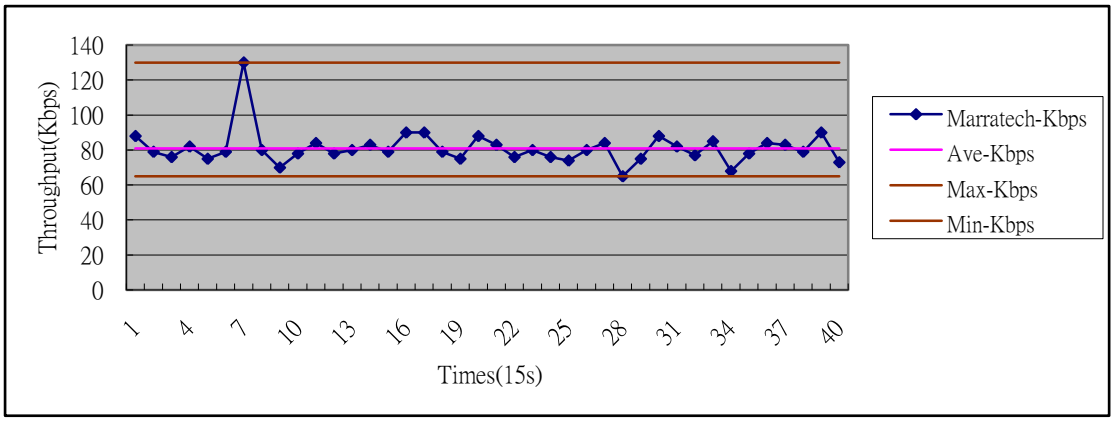

Figure 63. The Throughput of Marratech's Single Server in WAN

Nevertheless, we cannot say that Marratech has worse video qualities in motionless situations for it has lower throughput value. It is caused by how Marratech encodes the videos. Maybe the video encoding mode of Marratech is more suitable in filming environments with less motion and better video qualities would be produced in these situations

5.3 The Situation of Connection Recovery

In the experiments of connection recovery, this paper sets the situation of network disconnection from the user-ends. The time of disconnection is from three and ten seconds. We aim to figure out the situations of connection recovery of each three system.

5.3.1 The Experiment Results of Connection Recovery

The connection recovery of P2P LMS works outstandingly because of buffer function. The user-end will save some images in buffer area in advance in order to respond to the problems occur during transmission. We can see in Figure 64 that although the network is disconnected from the third second to the fifth second, the video keeps playing. On the other hand, we can see obvious image lags in Figure 66 and 68.

In the comparison of Figure 65, 67 and 69, we can know that the throughput of P2P LMS hugely increases after the connection recovery. It is because that it has to download the images which have not been downloaded during the disconnection of network. In Figure 67 and 69, we can see that Co-Life and Marratech are both unable to receive the images after the disconnection of network. The only common point is that these three systems all have to reconnect to the server for replaying the video when the disconnection takes too long.

One interesting situation is found when experimenting on P2P LMS. When the playing starts, there is a time difference of nine seconds between the playing time and actual time. It is much longer than the time differences of Co-Life and Marratech which are both lower than one second. As the playing time extends, the time difference will extend to about 28 seconds. Though the time difference is nearly half minute, the video can keep playing after 10 second disconnection of network. It can be seen as a good function for we have enough time to respond to the problems which occur during transmission. The only thing that can be debated about is the playing time is far from the actual time. Nevertheless, it is not a defect; on the contrary, it is an advantage. The integrated comparisons are shown in Table 23, 24 and 25.

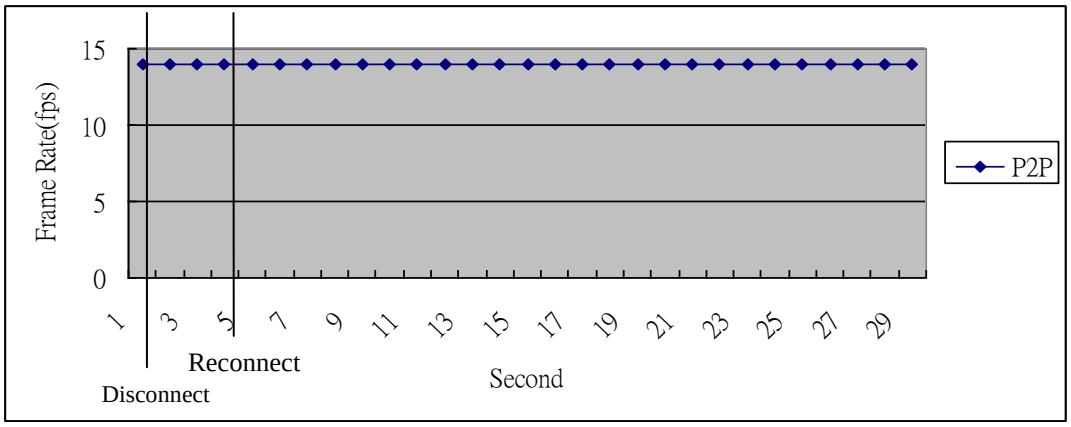

Figure 64. The Frame Rate of P2P LMS When Facing Disconnection of 3 Seconds

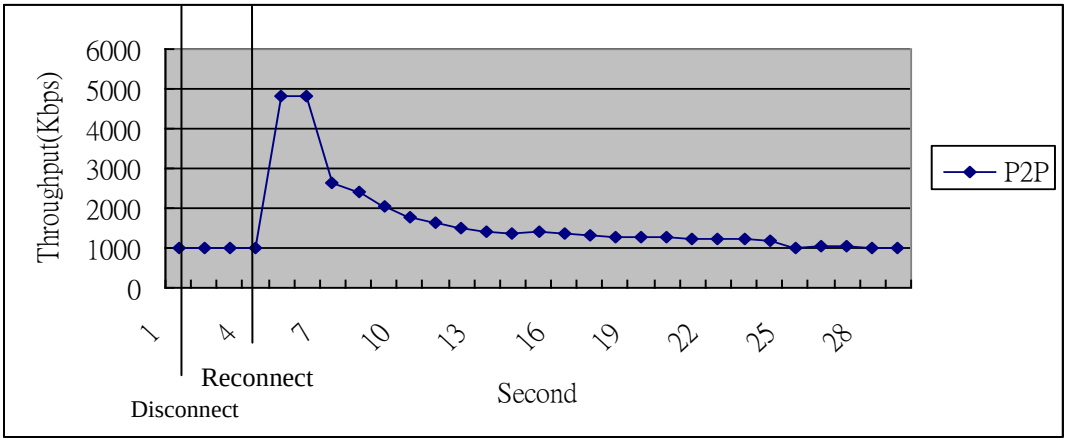

Figure 65. The Throughput of P2PLMSWhen Facing Disconnection of 3 Seconds

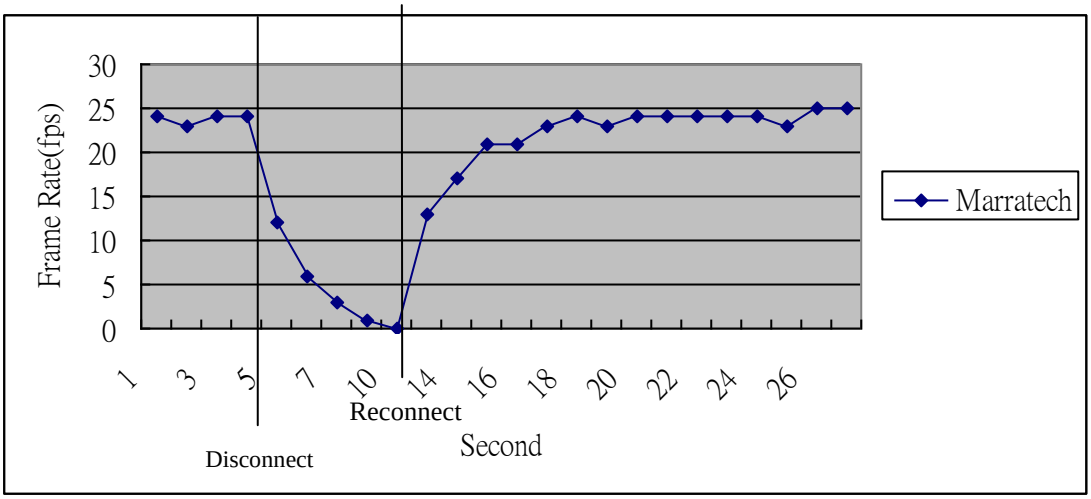

Figure 66. The frame Rate of Marratech When Facing Disconnection of 3 Seconds

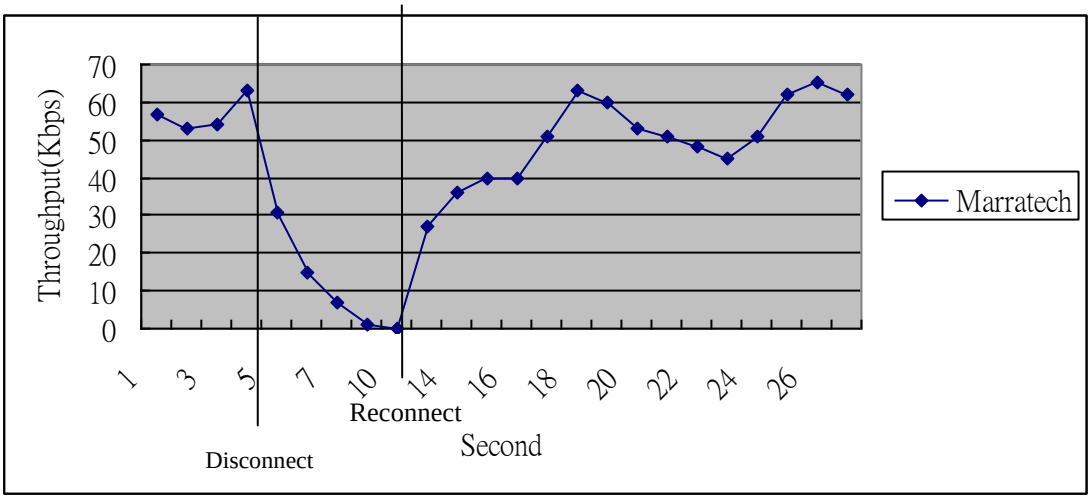

Figure 67.The Throughput of Marratech When Facing Disconnection of 3 Seconds

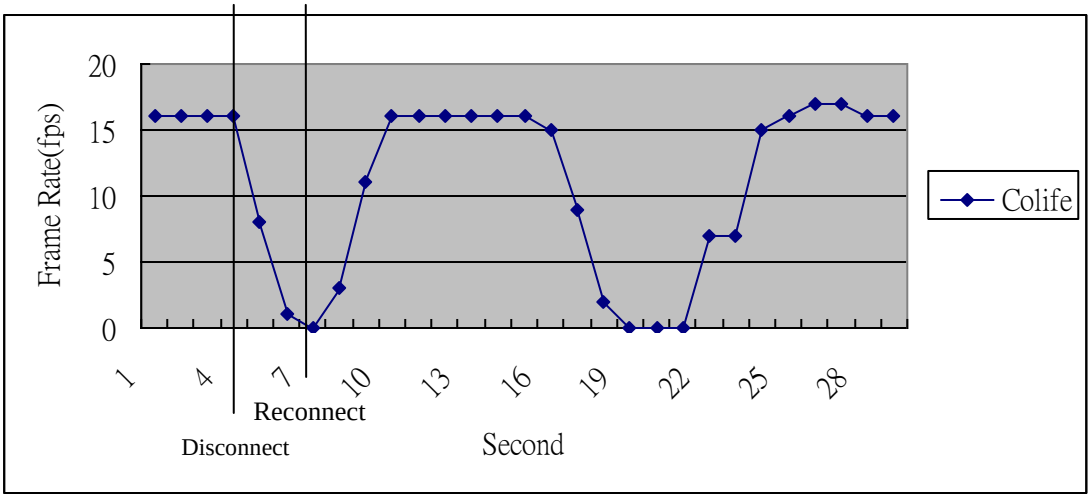

Figure 68. The Frame Rate of Co-Life When Facing Disconnection of 3 Seconds

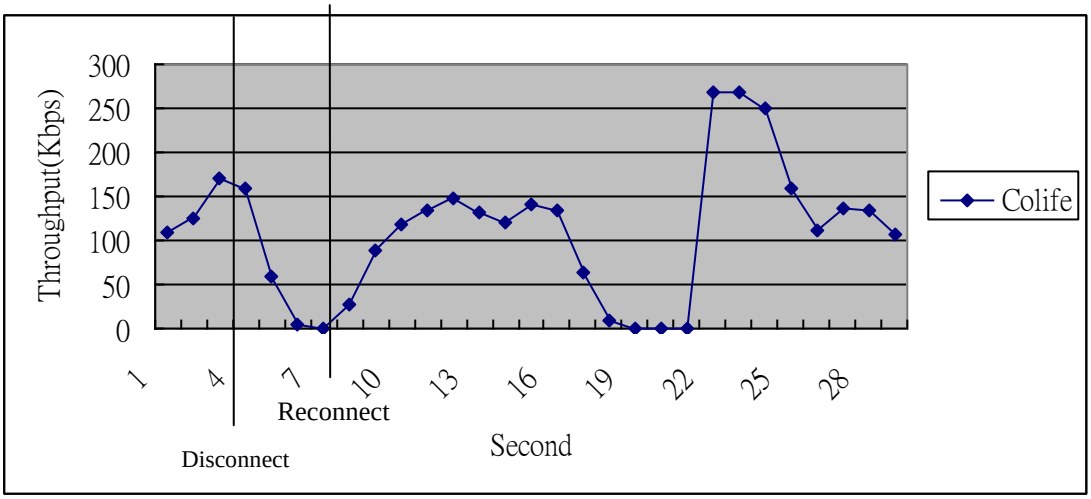

Figure 69. The Throughput of Co-Life When Facing Disconnection of 3 Seconds

Table 23. The Frame Rates of the Three Systems in Network Disconnection

	P2PLMS	Marratech	Co-Life
Disconnection of 3 Seconds	Changeless	Reset to Zero and Recover	Reset to Zero and Recover
Disconnection of 10 Seconds	Changeless	Disconnect and Reset to Zero	Temporarily Recover and Reset to Zero
Disconnection of a Long Time	Disconnect and Reset to Zero	Disconnect and Reset to Zero	Temporarily Recover and Reset to Zero

Table 24.The Throughput of the Three Systems in Network Disconnection

	P2PLMS	Co-Life	Marratech
In Disconnection	Changeless	Reset to Zero	Reset to Zero
After Reconnection	Hugely Increase for Downloading the Images have not been Downloaded in Disconnection	Recover to the Original Level	Recover to the Original Level
Long Time Disconnection	Reset to Zero	Reset to Zero	Reset to Zero

Table 25. The Playing Situation of the Three Systems in Network Disconnection

	P2PLMS	Co-Life	Marratech
In Disconnection	Keep Playing	Video Pauses	Video Pauses
After Reconnection	Keep Playing	New Images	New Images
Continuity	Continuous Playing	Inconsistent Images	Inconsistent Images

From Table 23, 24 and 25, we can easily see that P2P LMS has better abilities to handle the emergencies. As shown in Figure 65, the video keeps playing in network disconnection and will re-download the missing images after reconnection which causes the huge increase of throughput. Co-Life and Marratech performance worse in this part for the video immediately pauses when the network disconnects. After the recovery of network, they are unable to play the images during the disconnection; instead, they directly play the coming images. Some important information may be lost in this situation.

5.4 Overall Comparison

The performance of P2P LMS in each network connection is arranged in Table 26 and 27. We can see that P2P LMS has stable frame rate, keeping around 14 fps in live broadcasting. Also, the throughput maintains in almost the highest output about 1000 Kbps. It is very stable and huge wave motions seldom happen.

Table 26. The Overall Comparison of P2P LMS's Frame Rate

	LAN-video	LAN-live	WLAN	MAN	WAN
Average	30	14	14	13	14
Maximum	30	14	14	13	14
Minimum	30	14	14	13	14
Biggest Difference	0	0	0	0	0
Standard Deviation	0	0	0	0	0
Stability	High	High	High	High	High

Table 27. The Overall Comparison of P2P LMS's Throughput

	LAN-video	LAN-live	WLAN	MAN	WAN
Average	1125	997	1000	979	1000
Maximum	1176	1125	1004	996	1004
Minimum	1058	829	997	961	998
Biggest Difference	118	296	7	35	6
Standard Deviation	1.47	9.32	2.2	12.06	1.83
Stability	High	High	High	High	High

The overall performance of Co-Life in each network connection is arranged in Table 28 and 29. We can see that the wave motion of frame rate is a bit huge but still remains about 10 to 20, a not bad performance. But the huge wave motions indicate that some stops and motion blurs may occur during playing. The performance of throughput is also good for it maintains above 400 Kbps and maximum to 700 Kbps average. It is a good result to image quality especially when the video is played in full-screen mode. Nevertheless, it is worse than P2P LMS's 1000 Kbps.

Table 28. The Overall Comparison of Co-Life's Frame Rate

	LAN	WLAN	MAN	WAN
Average	15	12	10	16
Maximum	17	14	12	16
Minimum	10	10	9	16
Biggest Difference	7	4	3	0
Standard Deviation	0.46	1.00	1.00	0
Stability	High	Medium	Medium	High

Table 29. The Overall Comparison of Co-Life's Throughput

	LAN	WLAN	MAN	WAN
Average	666	701	461	402
Maximum	1448	923	577	467
Minimum	169	532	364	346
Biggest Difference	1279	390	213	121
Standard Deviation	42.78	134.93	61.53	36.48
Stability	Low	Low	Low	Medium

We arrange the performance of Marratech in all network connections in Table 30 and 31. We can conclude that Marratech has larger variation in frame rate, from 13 fps to 24 fps. Still, it is a pretty good performance. But we see in the experiments that the Marratech has lower frame rate toward moving objects; meanwhile, Marratech has higher frame rate toward motionless objects. But in distance learning, we mainly film the moving objects and it is impossible to film only motionless objects. Concerning filming moving objects in WLAN and MAN (the server of LAN is set in the campus so the network quality is very good; in WAN, filming focuses on motionless objects), the frame rate of Marratech is similar to P2P LMS's. Especially, Marratech has a huge

advantage – the server is set in the County Academic Network which is much nearer than the servers of Co-Life and P2P LMS which are put in the NCHC. However, the performance is almost on a par with Co-Life and P2P LMS. So we can conclude that the Marratech system may not be as good as Co-Life and P2P LMS.

Regarding the performance of throughput, Marratech only has highest value of 471 Kbps when the server is set inside the campus. The throughput is down to an average of 82 Kbps when filming motionless objects. Compared to P2P LMS, the throughput is always around 1000 Kbps in any situation. So, Marratech system evidently falls behind to P2P LMS.

Table 30. The Overall Caparison of Marratech's Frame Rate

	LAN	WLAN	MAN	WAN
Average	21	13	16	24
Maximum	25	13	19	24
Minimum	9	12	12	24
Biggest Difference	16	1	7	0
Standard Deviation	1.10	1.08	2.41	0
Stability	Medium	Medium	Low	High

Table 31. The Overall Comparison of Marratech's Throughput

	LAN	WLAN	MAN	WAN
Average	471	329	258	82
Maximum	765	423	417	91
Minimum	115	277	77	75
Biggest Difference	650	146	340	16
Standard Deviation	62.67	38.38	147.31	4.01
Stability	Low	Medium	Low	High

Chapter 6 – Conclusion and Future Works

We can conclude the advantages of P2P LMS from Table 32:

(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.

Table 32. The Overall Comparison of Each System

		P2PLMS -video	P2PLMS -live	Co-Life	Marratech -inside	Marratech -outside
LAN	Frame rate	Excellent	Normal	Normal	Good	
	Throughput	Excellent	Excellent	Good	Normal	
	Stability	Excellent	Excellent	Good	Normal	
WLAN	Frame rate		Normal	Normal	Good	Normal
	Throughput		Excellent	Good	Normal	Normal
	Stability		Excellent	Normal	Normal	Normal
MAN	Frame rate		Good	Normal	Good	
	Throughput		Excellent	Good	Normal	
	Stability		Excellent	Normal	Good	
WAN	Frame rate		Normal	Normal	Good	
	Throughput		Excellent	Good	Normal	
	Stability		Excellent	Normal	Normal	
Connection Recovery			Excellent	Normal	Good	

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.

This paper did not have ideal results when operating the pressure experiments so we did not put them into the research results. The main reason is that the network bandwidths in elementary schools are not as sufficient as we thought so we faced too many problems during the experiments. If the bandwidth problem can be overcome and user-ends can be more wide-spread in network environment, better results can be expected. In addition, experiment results in WLAN may be a little bit different from the actual situations of using P2P in WLAN. This paper uses only two notebooks so the results are quite good. However, a great deal of network collision could happen to reduce the network efficiency when it is put into a massive implementation. As for the ideal limit of connection number, it may need experiments to figure it out.

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