

Using Script Command to Conquer the Narrowband Constraint in Synchronous Long-distance Teaching System

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Abstract: The applications of synchronous long-distance teaching (SLDT) are more and more valuable with the internet prevalence. One of the SLDT restrictions is the bandwidth consumption of the connection between teacher's side and students' sides. Even though most users use broadband network at present, there are still users using narrowband networks, such as dial-up and 3.5G network. It is very difficult to conduct SLDT in the narrowband network unless reducing the demands of network bandwidth consumption, especially while the teaching materials including video, audio, and so on. This paper proposes a novel scheme to reduce the network bandwidth requirement of SLDT efficiently. Original SLDT system transmits all teaching materials in full screen frames, so that it needs a great amount of network bandwidth. The proposed innovative technique encodes some of the teaching materials, including typing texts, messages on the electronic whiteboard, drawing pictures and timestamps into script commands. In this way, the encoded script commands are transmitted through the text channel of the multimedia streaming, while the audio and video channels carry the teacher's voice and images. When the students' sides receive the multimedia streaming, it is decoded back to the full screen frames. In this paper, the design of the encoder and decoder will be addressed in detail. The experimental results proved that our proposed scheme could reduce the demand of network bandwidth consumption efficaciously. Even at the dial-up and 3.5G network environment, students' sides could play the teaching frames very smoothly. That is, our implemented system could conquer the narrowband constraint and provide users to carry out SLDT in the narrowband network.

Keywords: Script Command, Streaming Technique, Long-Distance Teaching, Distributed-System, Media Encoder.

1 Introduction

In the traditional teaching setting, teaching and learning only could be performed in the classroom due to the limitations of time and space, which affected the flexibility of learning. With the prevalence of the Internet, the dissemination of knowledge can be very fast and can be done through diverse channels. Online learning has been emphasized and developed vigorously. Online teaching could impart knowledge to anytime,

anywhere, and it brings more flexibility, freedom and convenience than of the traditional learning setting. [1, 2].

One of the features of the SLDT is that the teacher and the learners can conduct classes by using communication channels in different locations, including the correspondence courses held a long time ago. For example, wireless broadcast began in this century, and television and

broadcast teaching started in the 1950s. The main problem of these Long-Distance Teaching (LDT) models is that they lacked a convenient two-way communication channel between the teacher and the students. The use of telephone, fax, e-mail, and BBS today also could not provide real-time interaction. For this reason, computers and the Internet were developed for LDT. According to learning scenarios, the LDT can be divided into two types: asynchronous and synchronous. Asynchronous Long-Distance Teaching (ASLDT) emphasizes the liveliness and diversity of website courses. Once the teacher establishes the courses on the ASLDT website, the students could learn through this long-distance learning platform with asynchronous in anytime. However, Synchronous Long-Distance Teaching (SLDT) emphasizes the real-time interactivity on the SLDT platform between the teacher and students. Like traditional teaching, the teacher and students can interact synchronously in the virtual classroom of SLDT platform [10]. Nowadays LDT websites as a teaching and learning aid are so popular and efficient, in which the lively simulated teaching sessions can influence the students' learning attitude and cognitive ability positively [4]. Therefore, the students' learning could be improved absolutely when the teacher provides instructions [4]. An effective learning aid can reduce the teacher's workload and provide more time for individualized instructions because of its independent learning and appropriate feedback to students. Not only the student's ability could be enhanced, but also their performance could be enriched [2] by using learning aids in teaching, especially in applying the information and communication techniques and in solving problems. The teaching aid could also offer an appropriate strategy to remedy students' learning [5].

In general, it must consist of learning materials including video, audio, picture, and text, which equates to a relatively high demand for network bandwidth in order to establish the best virtual classroom experience. Even now some of users still using narrowband networks, such as dial-up and 3.5G network. For narrowband network users, it seems very difficult to proceed with SLDT. Hence the primary key to implement LDT is to conquer the bandwidth restrictions on both the teacher's end and student's end [3]. Numerous papers emphasized on improving the learning effects by applying LDT platform in the teaching process at present [2, 4, 5], but rarely on improving the SLDT

network bandwidth consumption. It could be found from the results which the experimental systems proposed in the researches to exploring the researches related to the SLDT system, such as transmitting video and audio, and sharing pictures. A great quantity of network bandwidth and specific communication protocol are required, so that it could be restricted in using long distance through a Wide Area Network (WAN) with narrowband, flexibility and distance [6, 7, 8, 9].

The aims of this paper are to modify the problem of network bandwidth constraint in constructing the best LDT virtual classroom, and to improve a new system design using Script Command (SC). It puts SC into the script command channel of multimedia streaming, then matches with the distributed network structure to overcome the problem of network bandwidth constraint and construct the best LDT virtual environment.

2 System Design

In order to simulate traditional teaching in the SLDT environment where would give learners the best learning through the better sensory stimulation, it must display the video, audio, and instruction content in the learners' end. These conditions of sensory stimulation to facilitate learning are called Teaching Elements (TEs). The TEs are all in the teaching screen of the system. Transmitting image in full-screen in the SLDT process will consume a great amount of the network bandwidth, and it would affect the performance in the narrowband network.

The basic structure of the proposed system is shown as Figure 2.1, which is composed of two major sub-structures, namely, the teacher's encoder end and the student's decoder end. In the teacher's end of the system, when the teacher conducts lessons, the encoder encodes the TEs to be displayed, and then transmits the information to the decoder in the student's end for decoding by the streaming. The student's decoder end will determine the displaying manner according to the data structure of the stream, and then present the teaching processes of the teacher's end correctly.



Figure 2.1: Basic system structure.

2.1 Teacher's Encoder End

In each stream, the multimedia information involves the compiled teaching video, audio, and the event-driven SC, and must provide at least three channels to store the multimedia information to make the stream carry this multimedia information.

Thus for this reason it must include three major objects, namely, header, data, and index in the data structure of the stream. The header object records the properties of streaming file, such as file properties, stream properties and SC properties, to describe the necessary decoding information for the student's decoder end when receiving the stream. The data object contains the data payload of three required channels including the teaching video, audio, and the SC. The index object is needed by playing the multimedia stream as the user wants.

In the data structure of the stream, the header object must record the timestamps of three multimedia channels, and then the student's end can synchronize the teaching process of the teacher's end with the timestamp information. The proposed data structure of the stream is shown in Figure 2.3.

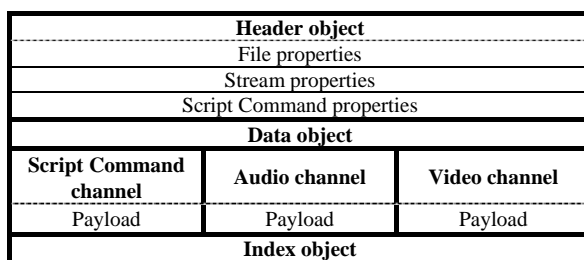


Figure 2.3: The model of the data structure of streaming file.

2.3 Student's Decoder End

In the system, the primary purpose in the student's decoder end is to receive the streaming from the teacher's end, and then decode based on the data structure of the stream. After that, it will display the decoded multimedia event information on the reactors of the TEs. The basic structure of the student's decoder end is shown as Figure 2.4.

After the stream is encoded in the teacher's end, it would be broadcasted to the student's end sequentially. After the streaming decoder of the student's end receives the encoded stream, it will decode. First of all, the streaming decoder determines the information of the header object, then separates the teaching video, audio, and SC, then transmits and executes them on the reactors respectively. First it determines the information on the timestamp field, then it will send the properties to their own reactors respectively and execute the carried payloads based on the information of time offset. If the separated information is the event of the teaching audio/video (A/V), it will be sent to the reactor of the teaching A/V and displayed on the student's end. If the separated information is the event of connecting URL, it will be sent to the reactor of the URL event and the connected teaching web page is opened. If the separated information is the event of operating mouse, it will be sent to the reactor of the mouse event and the starting and ending positions are determined, as well as all screen coordinates that they pass through, and then the marked line segments according to the setting of color information is drawn. If the separated information is the event of transmitting text message, it will be sent to the

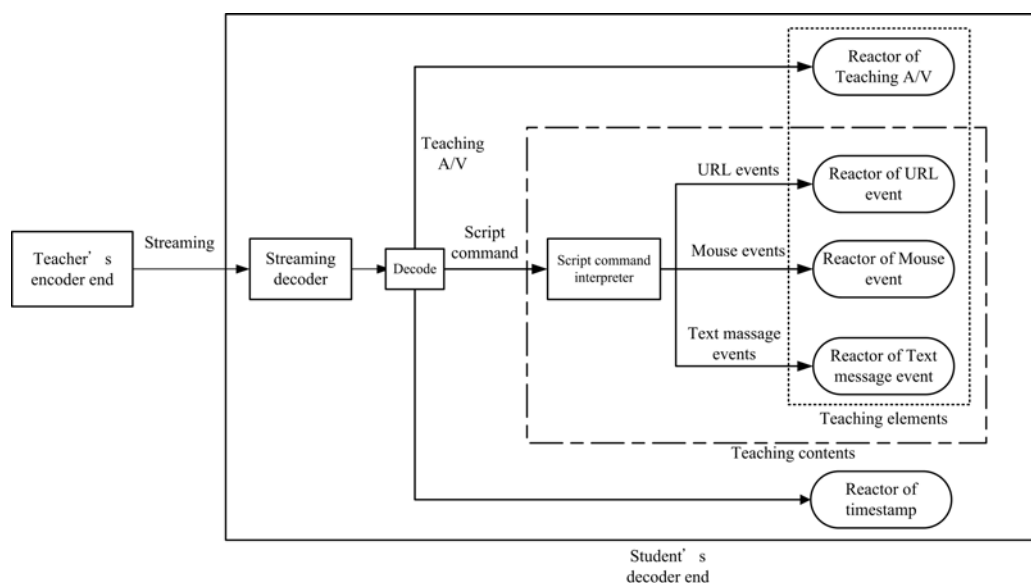


Figure 2.4: Basic structure of student's decoder end.

reactor of the text message event and the remarks sent from the teacher's end will be shown on the student's end.

3 System Implementation

3.1 Operation Interface of the System

It mentioned that the TEs of the teaching video, audio, and instruction content must be provided to the learners to build the best sensory stimulation for learners in the learning setting in the previous section of System Design. In order to conduct the SLDT more conveniently, we use the design method that embeds the ActiveX component into the web page to develop the web-based SLDT interface, providing a more friendly and simpler installation and operation process. Using the SC technique as the core of the system design can not only reduce the network bandwidth consumption, but also provide the accessibility to users in the narrowband network.

The teaching images were analyzed to transmit during the SLDT and they could be divided into four regions including the material-display region, the teacher's A/V region, the electronic-painting region, and the text-message region [1]. These TEs can be configured by the users themselves under different situations. It would be illustrated to operate interface of this SLDT system in detail in this paper as follows:

3.1.1 Operation Interface of the System from the Teacher's end

In order to build the best sensory stimulation for learners, the operation interface of the system in the teacher's end provides four regions including the material-display region, the teacher's A/V region, the electronic-painting region, and the text-message region. The operation interface of the system in the teacher's end is web-based, which is different from other application programs. The functions of the four regions of the system interface are embedded into the web page with the ActiveX control components, which are then taken as the catchers of events. When the teacher conducts the SLDT, he/she just needs to link to the URL of the system for the teacher through the web browser. Upon connecting for the first time, the ActiveX control components will be installed in the teacher's end automatically, which does not require any complicated installation procedures. Thus this method can make the operation more convenient for the teacher.

The operation interface of the system on the teacher's end is shown as Figure 3.1. The function of the material-display region is similar to a web browser container, which can open the required teaching materials in web page style. The teacher's A/V region embeds the media player component into the web page, through which the teacher can record and preview the teaching A/V. The electronic-painting region, that embeds the ActiveX control component developed by Microsoft Foundation Classes (MFC), possesses the function of electronic whiteboard, in which the teacher can set the line color and mark the key points to improve sensory stimulation while teaching. The text-message region embeds the ActiveX control component developed by ATL (Active Template Libraries), through which the teacher can transmit texts, such as the message, the assigned homework, and other key points in this region while teaching.

3.1.2 Operation Interface of the System on the Students' End

The operation interface of the system on the students' end is also web-based, which embeds the required TEs into the web page by the ActiveX control components and will be taken as the reactors of the events. Similarly, students just link to the URL of the system through a web browser to study how to use the SLDT.

The sensory stimulation provided the student's end which includes three TEs of the teaching video, audio, and instruction content. The design of the TEs on the students' end plays the passive role of information receiving. Thus, when students study how to use SLDT, they could see the displayed materials and the marked key points in the material-display region; they also could see the teacher's video and hear the teacher's explanations in the teacher's A/V region; and they can see the transmitted messages and other remarks from the teacher in the text-message region. Since the students' end is the information receiver, they do not need the electronic-painting region to mark key points. The operation interface of the system in the students' end is shown as Fig.3.2.

3.2 Operation of the System

For the server versions recommended in this paper, the operating system of the content server is set up by using Windows Server 2000, and the media server is set up by using Windows Server 2003. The SLDT streaming platform utilizes Windows Media Service 9 based on the operating

system of Windows Server 2003. As for the development of the system encoding components, the researchers utilize Windows Media Encoder 9 Series SDK as the tool, and the library of ActiveX Template Library (ATL) as the program bank. In addition, this paper used Microsoft Internet Explorer (IE) as the application program platform, and developed ActiveX control components by JavaScript language.

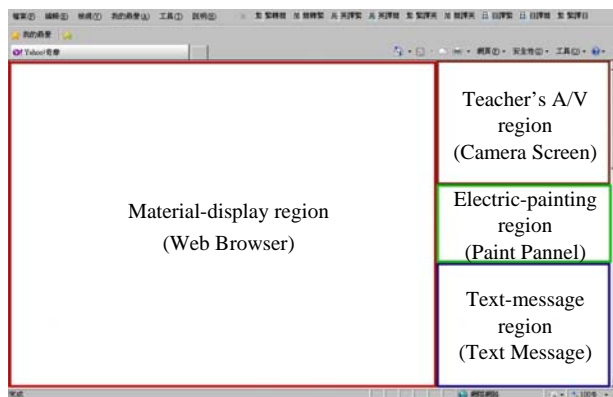


Figure 3.1: Teacher's system interface.

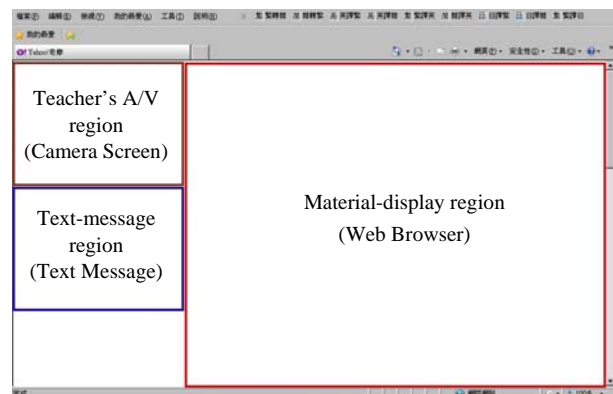


Figure 3.2: Student's system interface.

The system operation connects with each operation component of the system in the SLDT system through the network structure of the distributed-system. The operation components in this system involve the media sever, the content server, the teacher's end, and students' end, in which the content server is like a web server and the content server and student's end can have multiple nodes. The system component of the media server is a transmitting relay station, which is mainly used to receive and transmit the multimedia streaming, as well as store the multimedia stream in the media server. Thus the media server can possess both functions for SLDT and ASLDT. The content server is the source of the teaching materials, which is used to store the teaching materials in web page style.

The operation model of the implemented system is shown in Figure 3.3. The complete operation procedures in the SLDT processes are explained in the following steps.

Step 1-1: When the teacher operates the teacher's interface of the system in the SLDT process, the ActiveX control components will catch the teaching information in the teacher's end and then convert the teaching information to SCs by the designed generator. Then the media encoder embedded in the teacher's end will encode the teaching A/V and SCs into the stream at the same timestamp by using the dynamic compression algorithm. The SCs involve the URL events of the web browser for displaying the teaching media, the painting events including Pen Color, Mouse Action, and Mouse pointer coordinates for the whiteboard effect, and the text events of the message object for transmitting teaching information.

Step 1-2: When the teacher executes the URL events to the content server for displaying the teaching media, the teaching media screens will be returned to the web browser in the teacher's end immediately.

Step 2: After encoding the stream, the encoder will broadcast it to the media server.

Step 3-1, 3-2: When the media server receives the stream from the encoder, it will not

Step 4-1: When students use the learning interface of the system in the SLDT process, the student's end will request the streaming connection to the media server. When the students' end receive the stream, the media player, which is the streaming decoder in the system will separate SCs from the teaching A/V, and then the interpreter will transmit the events in the SCs to their ActiveX control components for execution according to different timestamps, including the URL events, the painting events, and the text events. In this way, the teaching A/V and the actions of these components will be displayed synchronously.

Step 4-2: After the SCs are separated, the URL events will be executed by the ActiveX control component of the web browser, and then the teaching media screens from the connected content servers will be displayed.

Step 5-1, 5-2: When the content server receives the request of the URL event from the students' end, that is to display the teaching materials, the teaching media screens will be returned to the students' web browser immediately.

4 System Testing

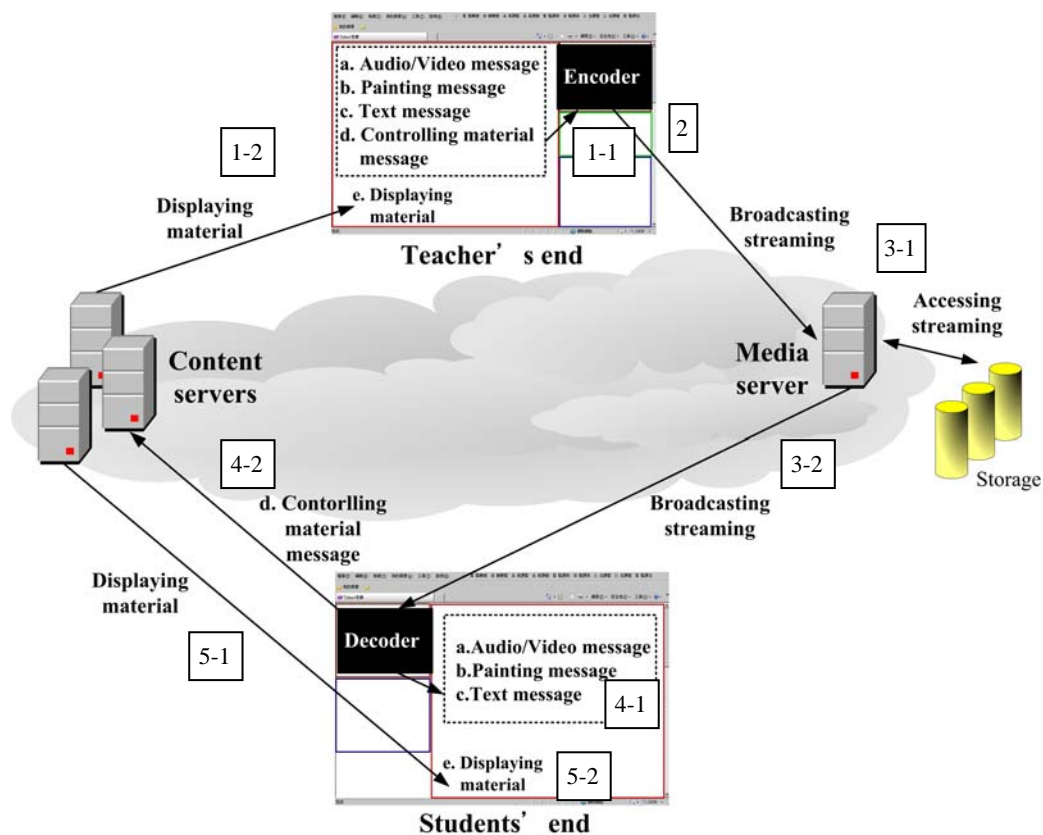


Figure 3.3: Operation model of the implemented system.

The researchers could discover that the process of transmitting the stream affects the timely delivery between the teacher's end and the student's end from the system design and operating model. However, the condition of the network is also a factor to be considered for the time needed to transmit the stream. Thus this section will test the initial delay time in different network bandwidths, and discuss the experimental subjects on the performance evaluation.

4.1 Initial delay time versus network bandwidth

For the original SLDT system, it transmits the whole screen image by using point-to-point method during teaching regardless of the type of teaching material. The proposed system in this paper utilizes an innovative technique that converts some of the teaching elements into the SC which is a string type, such as texts and drawings on the electronic whiteboard, etc. Its file size can be reduced to within 10^2 bytes. Assume an SLDT environment wherein the teacher uses a webcam with 300×10^3 pixels for catching the teaching video, and conducts the SLDT in one minute. After comparing the transmission size in the process with the original

SLDT system, with a full-color image resolution of 1024×768 pixels, we find that the transmission size can be substantially reduced around 13.64 times.

This proposed SLDT system utilizes the multimedia streaming to transmit the teaching A/V and the SC, thus it does not wait until all teaching files are downloaded to play. The streaming delay in displaying the teaching situation between the teacher's end and the students' end will only occur at the starting moment of receiving the streaming in the students' end, hence we test the initial delay time of the streaming in different network environments from the students' end under four experimental network environments including Internet dial-up, 3.5G, Asymmetric Digital Subscriber Line (ADSL), and Local Area Network (LAN), all of which makes use of LAN as the teacher's operating environment. The streaming delay time occurring in the experiment includes the streaming recording time and the streaming transmission time.

In addition, the experiment uses two different long-distance teaching scenarios to test the streaming delay circumstance affected by the A/V in the said four network environments. One is an

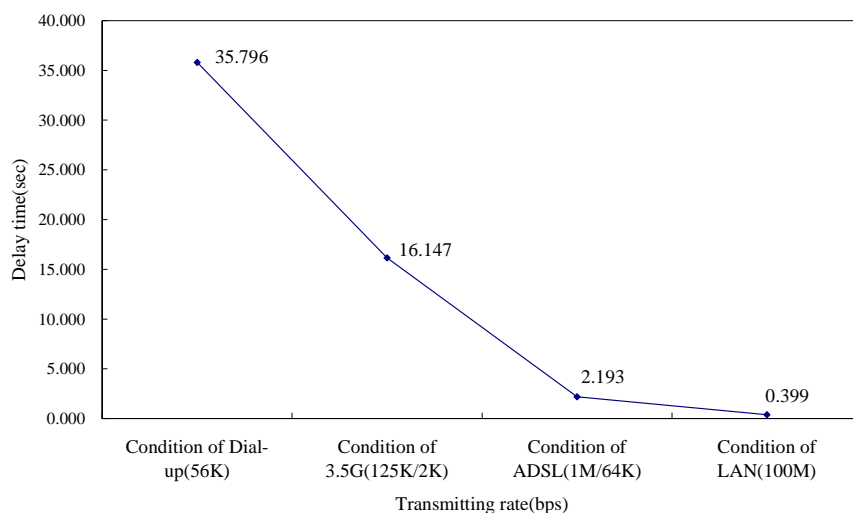


Figure 4.1: Comparison of the initial delay time of the different network condition in experiment I.

SLDT situation involving four teaching elements: video, audio, electronic whiteboard, and message transmission, while the other situation only contains the pure TEs designed by the SC; that is to say the teaching video are removed but the audio, electronic whiteboard, and message transmission are retained.

The results of the initial delay time between the two different teaching situations measured in four network environments are shown in Table 4.1. According to the results of the first experimental scenario, the network environment of the 56Kbps dial-up has the worst transmission performance, which produces a delay time of 35.796 seconds. The network environment of 3.5G of 125K/2Kbps has a delay time of around 16.147 seconds. But in an ADSL network environment of 1M/64Kbps, the delay time was substantially reduced to 2.193 seconds. However, the delay time was only 0.399 seconds in a LAN environment with 100Mbps, which is considered to have the best performance among the testing network environments. The data from the first experimental results are presented using a line chart, which clearly exhibits the degree of difference in the initial delay in streaming between the four testing network environments shown as Figure 4.1.

In the second experimental scenario, the video element is removed and the initial delay time in streaming was tested. According to the results of the second experimental scenario, there is hardly difference in the initial delay time among the different network environments, and it is in a reasonable and acceptable degree. This result

indicates that the SLDT process can be conducted smoothly.

Initial delay time (sec)	Condition of Dial-up (56K)	Condition of 3.5G (125K/2K)	Condition of ADSL (1M/64K)	Condition of LAN (100M)
Experiment I	35.796	16.147	2.193	0.399
Experiment II	0.674	0.304	0.041	0.008

Table 4.1: Initial delay time of different network environments.

The above experiment results indicate that the teaching video has a significant influence on the initial delay time in streaming in the SLDT process. Fortunately, we can forego the teaching video to some extent under the condition that it does not affect the teaching performance to reduce the initial delay. The teaching scenario at this time that includes the teaching audio, the teaching content, and the marked teaching points is sufficient to meet the requirements of the SLDT.

Thus the experiment proved that the SLDT system adopts the innovative design concepts of the SC, distributed-system network structure could reduce the network bandwidth consumption efficaciously, and could enable the learners using a narrowband network with the SLDT smoothly in the class.

4.2 Operation testing

In the functional testing of the system, it focuses on the following tests on the teacher's end and the student's end to test the functional correctness of

the system operations, including the URL event of displaying the teaching material, the painting event of the electronic whiteboard, the message event of the transmitted message, and the playing result of the teaching A/V.



Figure 4.2: Teacher's system interface.

The test is done with the teacher connecting the URL of the teacher's system interface with the content servers from the teacher's end first, and then entering the web-based system interface to conduct the SLDT afterwards. The experiment tests such functions as connecting the URL of the teaching material, using the mouse to mark the point on the electronic whiteboard, transmitting the teaching message, and displaying the teaching A/V. The testing results revealed that the above tested functions could be displayed on the system interface of the students' end completely and correctly. The testing result of the teacher's end is shown as Figure 4.2, and the testing result on the students' end is shown as Figure 4.3.



Figure 4.3: Students' system interface.

4.3 Other Considerations

The following explanation will focus on the system installation method, the system structure, the LDT model, and the operation of system interface. They are described in detail as follows:

a. The installation method of the SLDT system embeds the ActiveX control components into the web page. When users browse the web-based system interface via IE, the ActiveX control components will be downloaded and installed. The installation procedure is only done once when connecting for the first time, which can simplify the problems that are faced by the users during the system installation procedure, providing a user-friendly SLDT operation interface to users.

b. The SLDT system adopts the distributed-system network structure to connect the system components. By separating the media server from the content server, it technically disperses the network bandwidth in the SLDT process, so that the SLDT performance is more efficient in the narrowband network.

c. The SLDT system can provide the SLDT and ASLDT models, which is available to real-time teaching and review lessons after class.

d. The SLDT system utilizes the SC to realize the functions of the TEs. The combined teaching scenario can get the same performance as watching the video.

Some issues were discovered in the experiment. The great variability of the network packet transmission and the properties of the streaming transmission make the network connection disrupted when using ADSL to upload the stream. It would not be a big problem since it is merely for the streaming of the teaching A/V. In the event that the network connection is disrupted, the user just click the play button of the A/V to display the teaching A/V again, then it would not influence the operation of the system greatly.

If the network connection is disrupted in the proposed SLDT system and then the streaming is displayed again, it still won't affect the teaching A/V that much. It would cause the inconsistent operation between the teacher's end and the student's end for some components that need the SC to execute the actions because the SC is added into the streaming. For example, the teacher might have already browsed the next web page, but the students have not linked the same web page yet because they lose the SC of this segment. For this problem, the researchers provided a solution after the experimental verification. A timer was designed to embed it into the web page. The attribute data of the component would be transmitted to the encoder component at every fixed interval and the receiver would determine whether to update the state

according to the current state. It overcomes the synchronization problem with the SC.

5 Conclusion

This paper proposed the new SLDT system which adopted the innovative design concept of the SC and the distributed-system network structure. The experiment proved that the transmission size could be substantially reduced around 13.64 times. We can forego the teaching video under the condition that affected the teaching performance to reduce the initial delay. The teaching scenario which includes the teaching audio, the teaching content, and the marked teaching was sufficient to meet the requirements of the SLDT. The experimental results indicated that the initial delay time in the streaming was only 0.674 seconds in the worst network environment which uses the dial-up, which was reasonable and acceptable in the SLDT process. Thus the experimental result proved that the proposed SLDT system could overcome the narrowband constraint and allow users to conduct SLDT in the narrowband network smoothly.

The proposed SLDT system could not only reduce the network bandwidth consumption efficaciously, but also provide a web-based operation interface that embeds the ActiveX control component. Therefore, the users enable to operate the system easily and more convenient. Moreover, it also provides the SLDT and ASLDT models which are available for real-time teaching, and the students could review lessons after class.

For the further development of SLDT, the researchers will continue to construct the media database of the teaching material in the content server. It could provide the teachers who use the system to conduct the SLDT and the asynchronous revision after the session. The questionnaire survey method and experimental evaluation method are utilized to evaluate the efficacy of this system as a teaching aid. The researchers could realize the teacher's satisfaction level regarding the instructional proficiency, and the student's satisfaction in operating the system and on the LDT by the results of the survey and experimental evaluation. As for improving the initial delay time in streaming, the hardware of the media server and the content server can be upgraded, and improved the generation and interpretation methods of the SC, so as to accelerate the streaming encoding and data processing time, allowing the system to perform better.

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