

Learning Styles for e-learning Systems over Virtual Desktop Infrastructure*

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Abstract—By introducing the technology of the virtual desktop infrastructure (VDI) to e-learning systems, the identical learning environment can be provided to the learner at any time, and at any place, and also even if the learner stops learning or working, he can restart it by different terminals including different operating systems. On the other hand, the quality of screen images on the desktop would be affected by the quality of service (QoS) of the network, since the screen images are transferred to the client from the server by their transfer protocol. In this paper, we discuss the influence of the QoS upon the learning styles caused by the usability over the VDI. By constructing the experimental network using network emulators, we evaluate and discuss the influence of the QoS such as a round trip delay time (DT) and a bandwidth (BW) upon learning style measured by the quality of experience (QoE). As a result, we clarify the relationships between the QoS of the network and the QoE of the e-learning styles.

Keywords— *e-learning; learning style; quality of service; quality of experience; virtual desktop infrastructure; DaaS*

I. INTRODUCTION

Recent developments of high speed networks and various kinds of computers have brought many changes in educational fields. Learning styles for e-learning systems have been widely extending especially by the progress of the cloud computing technology and the growth of video on demand (VoD) contents.

The virtual desktop infrastructure (VDI), which is realized by the cloud computing technology, has many advantages such as strengthened security, reduced management cost in computer network systems, not only for enterprises but for universities. Furthermore, the VDI for e-learning is able to provide the identical learning environment to the learner at any time and at any place. Even if the learner stops e-learning, he can always restart it by the different PC, smart-phones, or tablets, including the different operating systems. On the other hand, the quality of the screen images on the desktop would be affected by the quality of service (QoS) of the network, since the screen images are transferred to the client from the server by a screen transfer protocol. The influence of the QoS upon e-learning system has been examined by the previous researches

[1][2][3]. No research known to us, however, has discussed on the influence of the VDI.

In this paper, we discuss the influence of the QoS upon the learning styles caused by the usability over the VDI. Especially the learning style of e-learning systems for the students who live in overseas would be sensitive to the QoS of the network. By constructing the experimental network using network emulators, we evaluate and discuss the influence of the QoS such as a round trip delay time (DT), and a bandwidth (BW) upon learning style by the quality of experience (QoE). As a result, we clarify the relationships between the QoS of the network and the QoE of the e-learning styles from the viewpoint of both communication engineering and education engineering.

Throughout this paper, according to Table I, we use $[x]$, $x=I$ or II for the work, and (y) , $y=1, 2, \dots, 7$ for the basic operation to avoid the confusing construction.

II. E-LEARNING OVER THE VDI

A. Learning Styles for e-learning

Currently, the most usual e-learning style in universities is to learn with watching materials (e-learning contents) on PCs connected to the Internet, where the materials are stored in the server such as video on demand (VoD) or Web based training (WBT) contents. To evaluate the final score of each student, the grading by as reports, quizzes, midterm, final tests and so on are performed. In some cases, a class questionnaire is executed.

TABLE I. BASIC OPERATIONS IN e-LEARNING STYLES

Works	Basic operations
[I] Production works such as report, presentation contents	(1)Typing characters and sentences
	(2)Editing documents using MS Word
	(3)Drawing figures using PowerPoint
[II] Learning by e-learning contents	(4)Selecting radio buttons on the Web
	(5)Listening audio on the Web
	(6)Watching video on the Web
	(7)Learning the WBT contents

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The seven basic operations extracted from practical work in ordinary e-learning style are shown in Table I, and later they are used to evaluate the usability.

B. The VoD for e-learning

As stated in A, a class provides the e-learning contents from the content server via the Internet by the students' request. In other words, it enables the Just in Time learning at any place and at any time. When performing it over the VDI environment, it has the following advantages:

- If the learner quits out of his or her work, he or she can restart it with the same environment at all times.
- The learner can restart it at any terminals (including the OSs and their product versions).

For example, there is no need to store the reports under preparation in the terminal. By the widely use of packet communications and mobile terminals, it is possible to learn by smart-phones and tablet terminals as well as the PCs. This leads to so called the "mobile learning". The conceptual diagram of e-learning with the mobile terminals is shown in Figure 1.

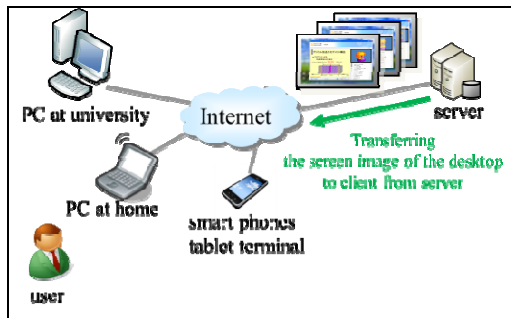


Fig. 1. The conceptual diagram of e-learning with the mobile terminals

However, some weaknesses are left to the VDI. As one of the important problems, the quality of the screen images on the desktop and operations at the terminal are greatly affected by the network environment, since the VDI uses the screen transfer protocol from the server to the client. As a result, the e-learning styles are strongly influenced by the QoS of the network. Later, we adopt the subjective evaluation (by 5 rated) to measure the usability of the learner.

III. PRELIMINARY

A. Current State of Quality of Mobile Network

Prior to our experiments, we investigated the current state of the network of the mobile phone in Japan. In order to discuss the learning styles including mobile learning, it is necessary to know the actual conditions. The distribution of the BW (bandwidth), and that of the DT (round-trip delay time) are shown in Figure 2, and in Figure 3, respectively. The distributions were measured for 3 weeks¹, by the FTP (file transfer protocol) for the BW, and by about 500 times of the 1000 [byte] ping packets for the DT. We found that the BW of

about 2/3 has a value of 0.25-2 [Mbps] from Figure 2, and the DT of about 3/4 has a value of 150-200 [ms] from Figure 3.

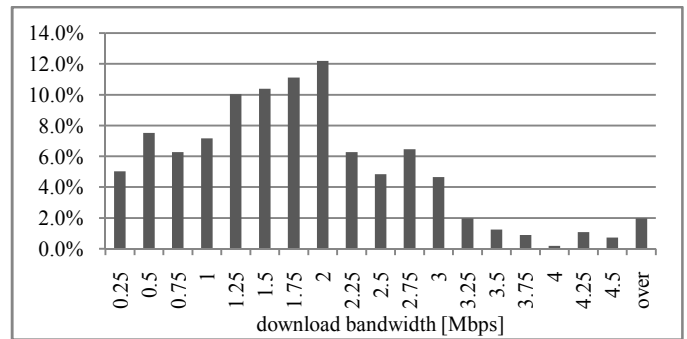


Fig. 2. The actual distribution of the BW (bandwidth) for Japanese mobile carriers

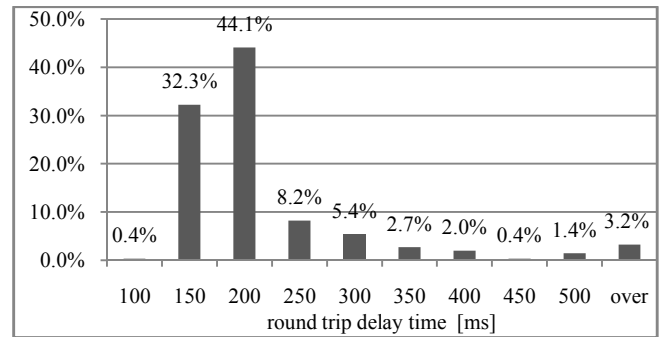


Fig. 3. The actual distribution of the DT (round-trip delay time) for Japanese mobile carriers

B. Usability of Mobile Terminal

To compare the user interface of the smart-phone and the tablet terminal with that of the PC, we evaluate it by an increase in working time for the same operation, where the DT is small (about 40 [ms]), and the BW is sufficiently large (about 2.2 [Mbps]). The case using the tablet terminal is shown in Figure 4, where some basic operations shown in Table I are used. Thus, by using the experimental results only obtained by the PC, it is possible to adjust the degradation in usability by the tablet terminal. We see from the figure that the operations of (3) Drawing figures such as extensions or compressions, and movements of the diagrams by the Power Point are significantly degraded.

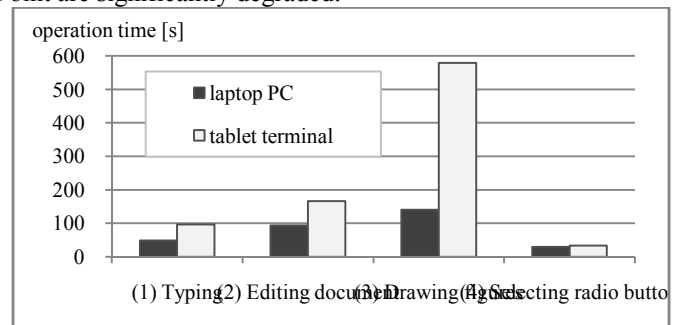


Fig. 4. Influence of usability of terminals for various operations²

² Typing represents the time to input Hiragana, and Chinese character input, the time to input 100 characters text requiring a Kanji conversion from Hiragana. The tablet terminal uses Apple's iPad2.

¹ Measure in July 2012.

IV. EXPERIMENTS BY USING NETWORK EMULATORS

First, as stated in III. A, we have clarified the quality of the mobile network to discuss mobile learning. Next, as shown in III. B, we have also clarified the differences between the usability of the PC and that of the mobile terminals (in the case of tablet terminals in Figure 4) to remove the cause of the usability of the mobile terminals. Consequently, we enable to evaluate hereafter by only the case of the PC.

A. Conditions of Experiment

As described before, the quality of the screen images at the desktop and the usability of the terminal are affected by the network environment. Therefore, we construct the experimental environment of the DVI by inserting the network emulator between the client PC and the Internet as shown Figure 5, where

- (1) Client Terminal: Notebook PC by Hewlet-Packerd Co.
 - Desktop: 15-inch (resolution: 1280 × 800)
 - Main Storage: 1 [GB]
 - HDD: 20 [GB]
- (2) Network Emulator: wlinee³
- (3) Screen Transfer Protocol: ICA⁴ by Citrix Systems Inc.
- (4) Virtualized Desktop Infrastructure (VDI) : XenServer⁵ and XenServer⁶
- (5) Subjects: Students of around 20 years old
- (6) Number of Subjects⁷: 10
- (7) Duration of Experiment: May-July 2012

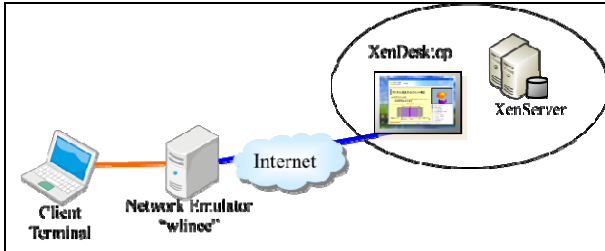


Fig. 5: Configuration of experimental environment

The typical QoS of the Internet is given by

Bandwidth (BW) : approximately 2.2 [Mbps]

Round-trip delay time (DT) : approximately 40 [ms]

and where the DT is estimated by ping (by the 1000-byte packet), and the BW, by the FTP throughput. As a result, the stable measurements throughout the experimental period are obtained such as 40 [ms] for the DT, and 2.2 [Mbps] for the BW. We use the total DT between the client and the server by the sum of the setting value of the DT of the network emulator and 40 [ms] in this paper. While we use the total BW by the

setting value of the BW of the network emulator which is smaller than the maximum bandwidth 2.2 [Mbps].

B. Experimental Methods and their Results

Let us show experimental methods of the seven basic operations illustrated in Table I. For the basic operations by the students, we decided that the average value of the actual operation time is used as the objective evaluation criteria, and also the average value of the usability for operations as the subjective evaluation criteria with 5 level rated⁸ shown by the mean opinion score (MOS). Based on this method, let us consider how the communication environment affects on the usability of the virtual desktop infrastructure.

(i) Evaluation for the effect of the BW (bandwidth)

We measure the subjective evaluation for the BW by the fixed DT, where the DT is fixed to 40 [ms] which is the typical QoS of the Internet (DaaS⁹ 40m[s] in Figure 6 [I] and [II]).

(ii) Evaluation for the effect of the DT (round-trip delay time)

Similar to (i), we measure the subjective evaluation for the DT by the fixed BW, where the BW is fixed to enough larger than 2.2 [Mbps] which is the typical QoS of the Internet (DaaS 2.2M[bps] in Figure 6 [I] and [II]).

First, we consider the operations related to production works such as documentation which is important and indispensable to reports submission.

(1) Typing characters and sentences

The average input speed of the Hiragana¹⁰ by typing software in the number of characters/minute over the VDI is measured (objective evaluation), then we have the first column of Figure 6 [I], where each student types twice Roman characters to Hiragana character conversion. The average value of all subjects is used.

(2) Editing documents using MS Word

The speed of the Japanese text using the MS Word in the number of characters/minute is measured (objective evaluation), then we have the second upper column of Figure 6 [I], where the text was selected from the article in the Journal of Information Processing of Japan, September 2011 which includes sentences easy to convert Hiragana to Chinese characters and those except for special characters. The each student edits twice it in the same communication environment. In addition, for the same operations, each student gives 5 rated usability to their operations as shown in the second lower column of Figure 6 [I].

³ <http://hata.cc/docs/wlinee/1.html>

⁴ Independent Computing Architecture

⁵ <http://www.citrix.co.jp/products/xsendesktop>

⁶ <http://www.citrix.co.jp/products/xsenser>

⁷ Based on ITU-T P.800 [4].

⁸ 1 to 5, i.e., the lowest point 1 to the highest point 5. Based on ITU-T P.800, the average (MOS: Mean Opinion Score) is used [4][5].

⁹ DaaS (Desktop as a Service) is a part of the VDI.

¹⁰ One of Japanese phonogram.

(3) Drawing figures using Power Point

The documentation is carried out by the operations of the keyboard, while the drawing, by operation of the mouse. Using the MS Power Point 2007, students draw the 12 squares at a specified location along the grid lines. The vertical axis illustrates in the number of drawing the squares /second (objective evaluation). The result is shown in the third column of Figure 6 [I].

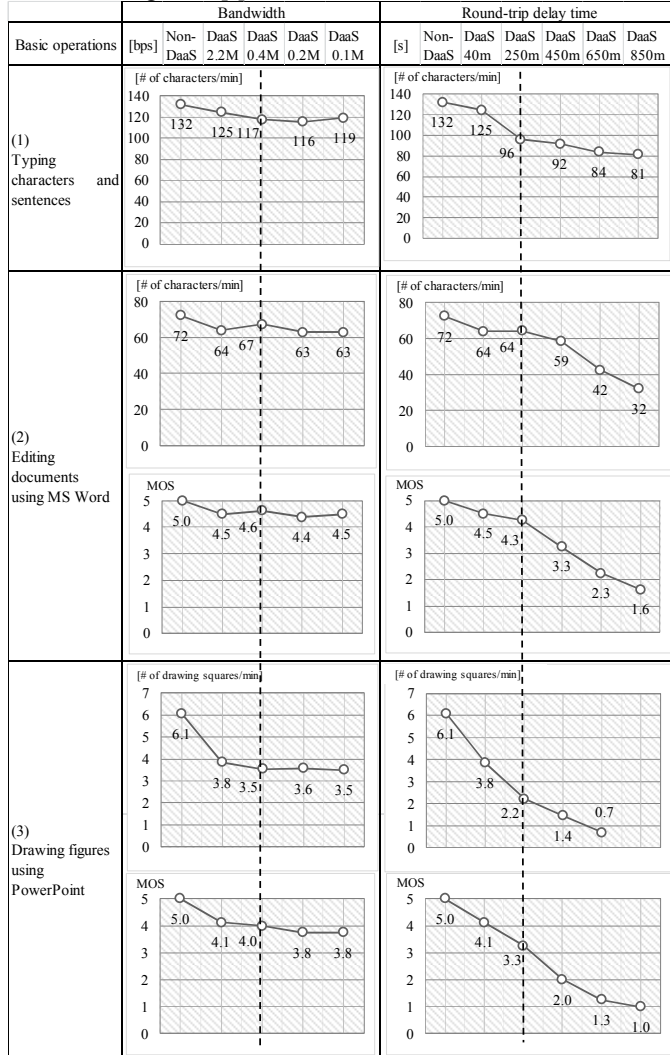


Fig. 6 [I]: Evaluations for [I] production works such as report, presentation contents

The evaluation results (1)-(3) described above are assumed to produce documents such as reports over the VDI by students. Next, we perform experiments on the operations in the browser, assuming that students watch the teaching materials on the desktop, where they are usually given by the VoD and the WBT contents in e-learning.

(4) Selecting radio buttons on the Web

Suppose that students work the item choice problem for the quiz or test of the WBT executed by selecting the radio buttons on the Web. We then prepare for 12 sets of radio buttons where the student selects 1 among 5 buttons for each

set, and measure the working time required for selecting buttons for the 12 sets (objective evaluation). The student tries it by twice for every communication environment. The first column of Figure 6 [II] shows the result in the averaged value.

(5) Listening audio on the Web

Suppose that students watch e-learning contents such as the VoD which contains audio and video. We then measure the QoE of the reproduced audio signal using the site¹¹ of the NHK radio news (subjective evaluation). The second column of Figure 6 [II] shows the result in the averaged value for all subjects.

(6) Watching video on the Web

Using the site of YouTube¹² and TBS Newsi¹³, we measure the QoE of the reproduced video signal (subjective evaluation). In the case where the DT becomes larger, it is impossible to measure the QoE. We only show the result on the BW in the third column of Figure 6 [II].

(7) Learning the WBT contents on the Web

We measure the QoE for the case where students work on learning using real WBT contents over the VDI (subjective evaluation). The fourth column of Figure 6 [II] shows a result by Web learning plaza¹⁴ provided by JST (Japan Science and Technology Agency), where the teaching materials on this site are consisted of Flash-based voice and slide animation, and the selective self-diagnostic test is implemented.

V. DISCUSSIONS

A. Discussions for the Experiments

At first, let us consider on the influence of the documentation work over the VDI given in Section IV [6][7].

(1) Typing characters and sentences

From the first column of Figure 6 [I], we see that the narrow bandwidth does not bring the degradation in the QoE, even if the BW is around 0.4 [Mbps]. On the other hand, the increase of the DT brings the degradation of the input speed in the number of characters/minute, and the decrease of the QoE, since increasing the DT directly affects to responsibility, i.e., quick indicating the inputted character is required on the desktop. In the case of Hiragana input, however, some degradation in responsibility is permissible, since the key buffer can receive before indicate the inputted character on the desktop.

(2) Editing documents using MS Word

From the second column of Figure 6 [I], we see that the influence of the BW is small similar to Hiragana input. The reason would be that it is possible to reduce significantly the

¹¹ <http://www.nhk.or.jp/r-news/>

¹² <http://www.youtube.com/>

¹³ <http://news.tbs.co.jp/>

¹⁴ <http://jst.go.jp/>

bandwidth consumption by the ICA¹⁵ protocol, which transfers information using the differential information on the screen for an input work of Japanese characters, since the input work gives small changes on the screen on the desktop. Comparing with the BW in this figure, however, the influence of the DT is large. Since the operation of selecting the candidate characters or words with the Kana-kanji conversion is necessary, the real-time interactivity is strongly required in the case of an input work of Chinese characters. Then the work of editing documents has a strong influence on the DT due to large amount of Kanji input. In particular, when the communication environment such that the DT exceeds 650 [ms] which can occur even in the 3G network for mobile phones, the usability would be considerably deteriorated, hence it can be easily understood that learning styles are significantly affected by the DT in this case.

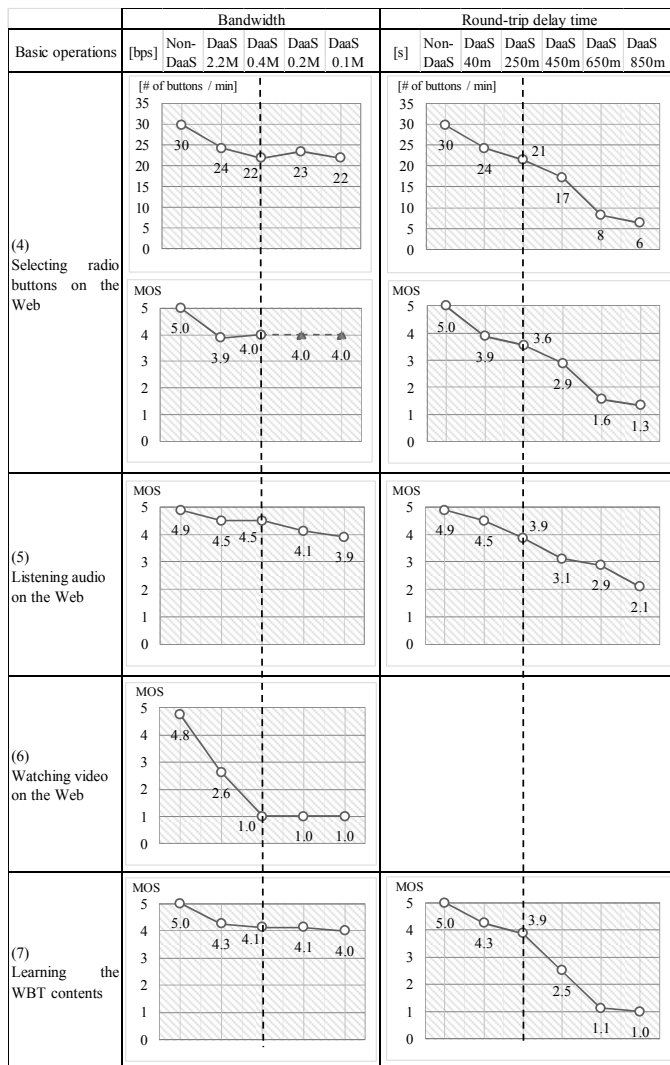


Fig.6 [II]: Evaluations for [II] learning by e-learning contents such as VoD and WBT

(3) Drawing figures using Power Point

From the third column of Figure 6 [I], the BW for drawing figures is not significantly affected, which is the same as the case of the character input operation discussed in (1). It can be seen, on the other hand, that it would be more strongly affected on the DT than the character input operation, which is also seen in the objective evaluation in the number of characters/minute shown in the upper figure. This can be understood from the fact that the effects already appear for the DT at 250 [ms], while it does not appear too much at 250 [ms] in the case of the character input operation. The operation which requires fine cursor positioning such as drawing, the tracking of the pointer is important, hence it is considered to be more sensitive to the DT.

Next, we discuss the case where the students work a quiz or test of WBT, and watch the e-learning contents.

(4) Selecting radio buttons on the Web

From the first column of Figure 6 [II], we see that the BW does not influence the speed of the input operation so much. As described in the mouse operation of (3), however, the BW influences it much more, since the operation of the pointer requires to follow in real time even for the case of relatively simple in the mouse operation like the choice of the radio buttons. Therefore, the operation takes nearly twice times compared to the case of non-DaaS, even when the DT is around 450 [ms]. As a result, the work which requires the mouse operation is not suitable for the case of the QoS exceeding 400 [ms].

(5) Listening audio on the Web

From the second column of Figure 6 (2), we see that the audio signal can be comfortably reproduced only in the BW of 0.4 [Mbps]. We can permit relatively large DT, since the audio signal reproduction does not need to quick response.

(6) Watching video on the Web

For the reproduction of the video contents with large data size, it can be clearly seen from the third column of Figure 6 [II]. The video signal reproduction is dominated by the BW in contrast to other operations, i.e., watching the video contents is intolerable even the condition of the BW around 2.2 [Mbps]. If the resolution is small, for instance, in the VoD contents only a portrait of a lecturer with small size video images (e.g., 20 frames/second, and 240x400 pixels) is displayed, it may be improved. When a lecturer wishes to use large video images, however, it should be carefully design the contents to adopt communication environment.

(7) Learning the WBT contents on the Web

Finally, let us consider the case of learning the WBT contents over the VDI. Since the site of "Web learning plaza" does not include video images such as the portrait of a lecturer, the QoE is not influenced by the BW not so much as showed in the fourth column of Figure 6 [II]. Although the contents include animation, the BW assumption is small, since the

¹⁵ The ICA stands for Independent Computing Architecture. The XenDesktop, and XenServer of Citrix Inc. adopt the IPA.

animation does not require a large BW. The QoE, however, is decreased for the DT exceeding 450 [ms] due to degradation in usability of the mouse operation, not to the reproduction of the audio and animation. It should be carefully investigated to learning styles for the case restricted by the poor QoS such as mobile learning.

B. Remarks for the experiments

Constructing the environment by the network emulator, we have collected data used for evaluation of learning style for e-learning. As a result, the followings become clear:

- Except for the case of watching video, the influence of the BW is small. Although the audio signal reproduction has no deterioration, the video signal reproduction has, even if the case of the DT around 2.2 [Mbps]. There are still a few effects on works of drawing figures by the Power Point.
- When interactive communication to servers is necessary, the influence of the DT is large. It affects to learning styles such as producing the presentation documents or reports, and learning by the WBT contents, even if the case of the DT around 300 [ms].
- There is a possibility that the objective evaluation in application layer is fairly good estimation of the subjective evaluation (MOS) as partially shown in Figure 6 [I] and [II].

Although details are omitted here, the following are obtained by additional experiments:

- It is almost possible to evaluate by assuming that the BW and the DT are mutually independent [8].
- If the packet loss rate is less than 15 [%], there is no large influence, and the influence of the jitter is still small [9].
- The video signal reproduction is affected by the BW, but it is possible to improve by letting the ratio of the bit rate of the video signal to the BW be about 1/2. The influence of a packet delay and the packet loss is small [9].

As a conclusion, it can be noted that almost all learning styles except for watching video are acceptable assuming the $BW > 0.4$ [Mbps], and the $DT < 250$ [ms] which can be applicable to the domestic network environment such that the server is located in Japan, and the client uses the ADSL.

VI. CONCLUDING REMARKS

We have evaluated from a viewpoint of how much must be the QoS of the network to achieve the required QoE for the e-learning styles based on seven basic operations. As a result, we have for the mobile learning:

[I] As working for such as producing the reports;

- The editing work can be practically tolerable by using the 3G line environment.
- There are still many problems from the stand point of the usability to operate application software for the MS Windows by tablet type terminals.

[II] As learning by the environment of the e-learning class;

- The works which require the real-time responsiveness such as the character input or the mouse operation are affected by the DT, but even the quality of the 3G lines is acceptable.
- There is no large problem on narrow BW except for the video signal reproduction.
- It should be avoided to use the streaming of the video signal for the mobile terminals under the present conditions.

As future works, we have:

- In addition to seven basic operations of e-learning which discussed in this paper, we try to perform experiments of the other operations such as for collaborative learning and active learning.
- We clarify the guideline of the contents design methods for the applications programs which can automatically choose screen images for PCs or those for mobile terminals.
- Additional experiments are necessary for the coming networks, e.g., the 4G lines, the LTE, and the Wi-Fi spot.

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