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A comparison of bandwidth consumption between proprietary web conference services and BigBlueButton, an open source webinar system

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Summary

The coronavirus disease 2019 (COVID-19) pandemic of 2020 had completely changed the lecture style in higher educational institutions. In Prefectural University of Hiroshima (PUH), all lectures in the first quarter were given online. One of the largest concerns for online lectures was the quality of the internet connection of students. In the Shobara campus of PUH, most of the students live alone and only have mobile connections, which are usually slow and restrictive in quantity. The companies providing web conference services (e.g. Zoom and Teams) disclose the estimates of network resource requirements, which however greatly fluctuate depending on the meeting style. Another concern is privacy. Both Zoom and Teams send the data to the cloud, process and distribute them to client termini. Although the companies claim that they respect privacy and provide safe data storage, the users are not able to either control how and where the data are stored or prevent the companies from using the data for marketing purposes. An on-site installation of an open source system is preferable. In this report I assessed the bandwidth consumption of two proprietary web conference services and BigBlueButton (BBB), an open source web conference and webinar system, installed on the Shobara campus, simulating the most common lecture style in Japanese universities. The total consumption was significantly smaller in BigBlueButton than in Zoom or Teams, especially when sharing videos. This advantage, together with other beneficial features including the low cost and small security concerns of BBB would render it a better option over the other proprietary services, in online lectures of higher educational institutions..

Keywords: Online lecture, Bandwidth consumption, BigBlueButton

Introduction

The COVID-19 pandemic has severely impacted many aspects of society. Among these, education is one of the most affected social activities that are indispensable in modern human life. To avoid expanding the contagion, teachers need to seek for a new lecture style without direct verbal communication. Online lecturing, in which teachers and students communicate through the internet, is probably the only option to be chosen.

Prefectural University of Hiroshima (PUH) has decided to switch all lectures in the first quarter (from

May to June) of 2020 to online. Initially, there has been some confusion in the Shobara campus of PUH on how to give lectures online, especially whether in real-time or in an on-demand style. On the principle of providing regular lectures with good quality even in the online format, the real-time style should have been chosen. However, most professors (35 out of 42) in the campus have carried out the lectures (excluding those given by multiple professors) in the on-demand style. In this style, teachers deposit the lecture materials (either lecture videos or presentation files or both) on cloud servers and students watch them at home. The Students basically study alone without real-time communication. Their accomplishments are usually evaluated by essays submitted after lectures. However, engaging students in learning activities by on-demand lectures is often difficult. Online live lectures are preferable.

However, the number of professors who have chosen the real-time lecture style has been much smaller (10 of 42; 3 have done both real-time and on-demand). The largest reason has been a concern about the quality and quantity of the internet connection of the students. Most of the students in the Shobara campus live alone without broadband connections, using the mobile network to access the internet. The mobile network providers in Japan offer the connection with a higher price than in many other countries (1), thus the students need to reduce the network usage in order to avoid an extremely slow connection (called “packet death”) after using up the allowance. To carry out the real-time online lectures smoothly, the professors have to seek for tools that are not very demanding in terms of the quality and quantity of the network.

The available web-conference tools that meet the criteria are Zoom (Zoom Video Communications) and Teams (Microsoft Corporation) (Table 1). Zoom is a new and growing web conference service with a high quality video and voice communication on broad or narrow networks. Teams composes the Microsoft Office suite together with other popular software and thus has an advantage on the smooth integration to the information technology environment already available in the university. Both Zoom and Teams require a subscription fee. PUH has paied for Teams already within the comprehensive contract with Microsoft, and Zoom has lifted up the 40 minutes limit of meeting duration for educational purposes even with the free license since the pandemic started.

Both Zoom and Teams disclose the required bandwidth on their websites. However, their simulation have not been performed in the typical online lecture format, namely that with a teacher talking in a video and showing presentation slides or movies to many students. Privacy issues have not been resolved either.

Table 1. Three web conference / webinar systems examined

	Version	App size	Participants limit	Service form	Development	End-to-end encryption
BBB	2.2.19	- [a]	- [b]	on premises	open source	no
Zoom	5.1.0	9.8 MB	100 [c]	cloud	proprietary	no [d]
Teams	1.3.00.15561	87.4 MB	250	cloud	proprietary	no

a, no dedicated application, web browsers with the WebRTC support used
b, not limited, but more than 100 simultaneous participants not recommended
c, free and pro licenses
d, planned in future (2)

The users cannot control how and where the submitted data will be stored, and the possibility of misuse, e.g., for marketing purposes, cannot be excluded. Microsoft does not deny their intention to collect the user's data, even though they claim that the data will not be used for advertising purposes (3). Unlike other peer-to-peer communication services such as Skype (Microsoft Corporation), the end-to-end encryption is not usually deployed in web conference services involving many participants. Another problem is that both Zoom and Teams are proprietary software, preventing users from customizing it for a local environment. An on-site installation of an open-source conference system is ideal.

BigBlueButton (BBB) is a complete open source web conference or webinar system actively developed on GitHub, an open source software development platform. BBB does not require the users to install a dedicated application, using instead the internet browser's built-in capability for web real-time communication (WebRTC). In contrast to Zoom and Teams, which are principally developed as web meeting services where many-to-many communication is necessary, BBB is designed and optimized for a webinar format composed of a few speakers and many listeners.

The document of BBB describes the bandwidth required for communication very precisely (4). However, nobody has published data obtained in an actual online lecture format. Moreover, no direct comparison has been made between BBB and other proprietary cloud services. In this report, I will measure and compare the bandwidth consumption of Zoom, Teams, and BBB, simulating the one-to-many seminar style, which is still the most common lecture format in Japanese universities.

Materials and Methods

Installation of BBB

Ubuntu 16.04 64bit was installed on Dell Optiplex 390 (Dell Inc.) with Core i5-2400 3.10 GHz (Intel Corporation) and 8 GB RAM. The PC was connected to the commercial optical fiber network provided by NTT Communications Corp. The software BigBlueButton version 2.2.19 and its frontend Greenlight version 2.6.5 were installed according to the official instruction (5). I had been contributing to software development and debugging on GitHub. In PUH I also performed some local customizations, including the improvement of user interface, prevention of content downloading, and implementation of a video-less playback of the session records. The main communication component of BBB evaded these customizations and thus the bandwidth measurements in this study were not affected.

Network traffic measurement

The measurement was done on June 29, 2020. I simulated the webinar style lecture with two laptop PCs. Probook 650 G5 (Hewlett-Packard Company) with the Intel Core i7 (8^{th} generation) processor and 16 GB Random Access Memory (RAM), produced in 2020, was used for the teacher's side with the webcam and the built-in microphone on. For the student's side, I used an old laptop PC, CF-S10 (Panasonic) with the Intel Core i5 (2^{nd} generation) processor and 4 GB RAM, produced in 2011, with the webcam and microphone off. Both PCs were operated with Windows 10 (Microsoft Corporation) fully updated on June 2020. For Zoom and Teams, I installed the dedicated applications (not the web-based applications) provided by the manufacturers. To access the BBB server, I used the Chrome browser 83.0.4103.116 (Google LLC).

A PowerPoint (Microsoft Corporation) presentation was prepared with four slides (Figure 1). The first slide was composed only of texts. The second and fourth ones contained a full-screen image. In the third one a full-screen video was embedded.

The teacher's laptop was connected to the local area network of PUH, while the student's laptop was connected to the mobile 4G network (provided by NTT Communications) through a tethering function of the smartphone P10 lite (Huawei Technologies), equipped with the Kirin 658 octa-core processor and 32 GB memory.

The network packets were captured by the use of Wireshark (https://www.wireshark.org/) software version 3.2.4 installed on the student's laptop.

The presentation was performed as follows (also illustrated in Figure 1).

(1) Preparation before the measurement

To the teacher's PC, I connected an external sub-display, on which the full-screen PowerPoint presentation was loaded in advance, but not broadcasted to the student's PC yet. The webcam and microphone of the teacher were on. The student joined the meeting with their webcam and microphone off, receiving the video and voice from the teacher.

(2) Start of the presentation

The timer started concomitantly with the start of packet capturing by Wireshark. Immediately after the measurement started, I loaded the presentation slides. On Zoom and Teams, the PowerPoint presentation displayed on the sub-screen was shared together with the PC's audio. Although Teams had an option to directly upload a PowerPoint slide, I did not use this function because the mouse pointer was not visible in the slides (see Table2). On BBB, the uploaded slides were converted into SVG (Scalable Vector Graphics) format and then distributed to the student's PC. This loading process took ~15 sec.

(3) Presentation

When the presentation was loaded, the slide and a small video of the teacher were displayed both on the teacher's screen and on the student's screen. I (as the teacher) stayed in front of the webcam but never spoke until I moved to the second slide at 30 sec. I shook the mouse pointer vigorously during the second slide was shown, but stayed silent. At 45 sec, I moved to the third slide, starting the video. On Zoom and Teams, the video in the PowerPoint slide was shown through the screen share function, which was the only way to smoothly start a video during the presentation. On BBB I used its unique function "direct external video sharing", by which the students directly watched the videos deposited in video sharing services such as YouTube (Google LLC). At 60 sec I paused the video and showed a still frame. At 70 sec, I moved to the

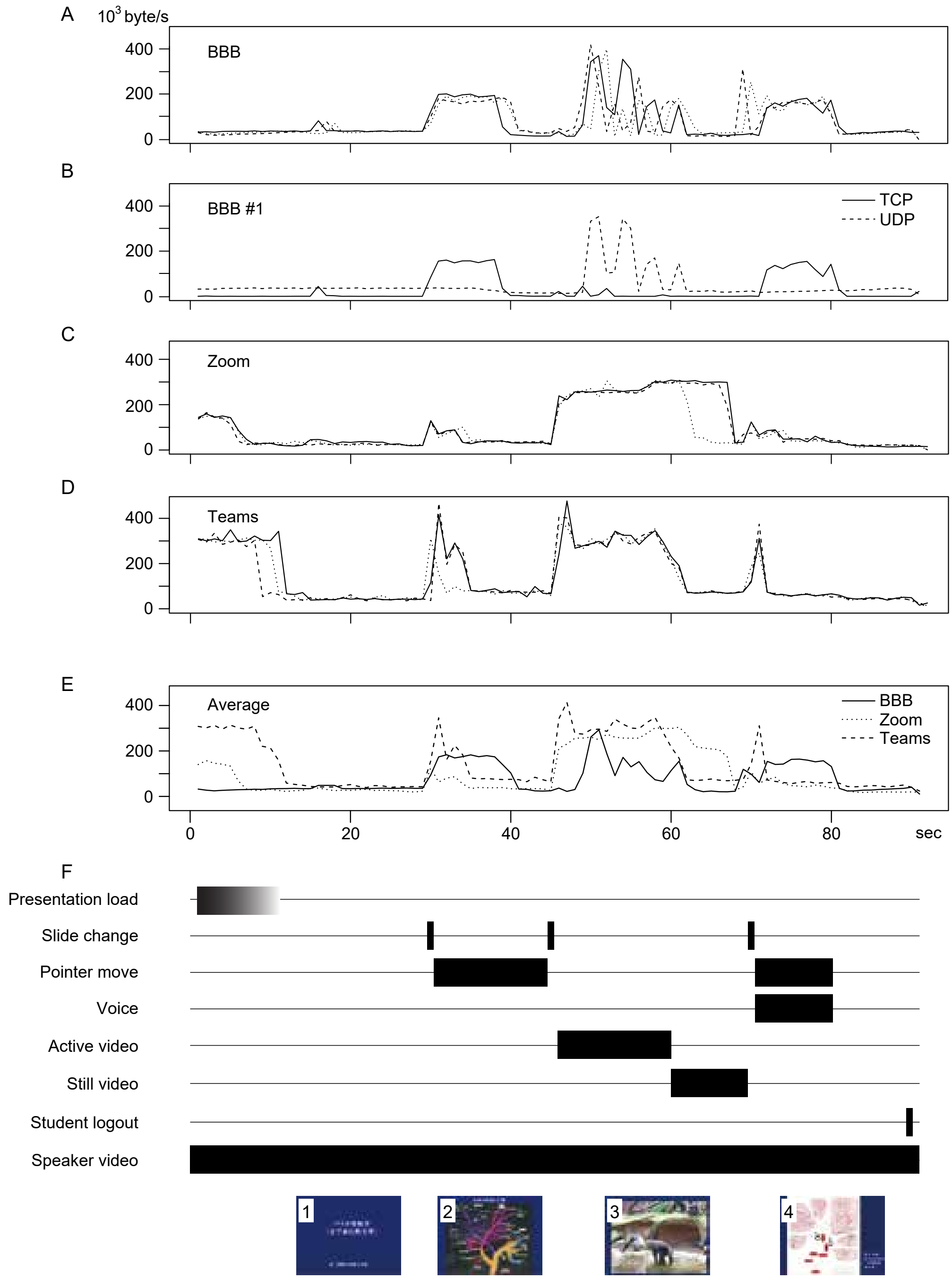

Figure 1 Measurement of bandwidth consumptions

The bandwidth consumptions were measured during a presentation for BBB (A and B), Zoom (C), and Teams (D). The measurements were done for three times (black, dotted, and dashed lines), and the averaged values were compared in (E). The data of the first measurement of BBB were separated to TCP and UDP traffics in (B). The presentation was composed of four slides (F). The moderator's operations are schematically shown by black boxes.

Table 2. Functions of three systems as webinar tools (until June 2020)

	BBB	Zoom	Teams
Presentation with uploaded slide	●		● [a]
Presentation by screen sharing	● [b]	●	●
File sharing	● [c]	●	●
Multi user whiteboard	●	●	● [d]
Polling	● [e]	● [f]	● [d]
Synchronized external video sharing	●		
Emoji communication	●	●	●
Raise hand	●	●	●
Chat	●	●	●
Break out rooms	●	●	● [g]
Shared meeting note	●		●
Recording	●	●	●
Downloading meeting records	[h]	●	●

a, mouse pointer invisible
b, incapable of sharing PC's audio
c, only files compatible for presentation such as PDF documents
d, by calling up another component
e, "quick polling" available only in BBB
f, only with "pro" license or more
g, by manually creating rooms in advance
h, possible with an experimental module

last slide and started to speak continuously, with the mouse pointer vigorously shaken. At 80 sec, I stopped moving the pointer and stayed silent.

(4) End of the measurement

At 90 sec, I logged out the meeting in the student's PC and stopped the packet capturing, without stopping the meeting itself. The captured data was processed with the statistic software R (https://www.r-project.org/).

Results

Functional comparison

A real world lecture is not only composed of a unidirectional presentation from a teacher. Questions will be asked by students and the teacher will answer them. To enable such teacher-students interaction online, a mean of bidirectional communication such as a chat system is required. In addition, a function to separate students into small groups is useful to engage them in intensive discussions. In order to facilitate effective learning on online lectures, such auxiliary functions are undoubtedly beneficial.

BBB, Zoom, and Teams are already equipped with such functions, either as built-in functions or as external software (Table 2). Among these, "quick polling" and "direct external video sharing" represent unique and useful features implemented in BBB (Figure 2).

With the quick polling feature, BBB reads the slide, captures itemized text, and automatically creates a dropdown to show a polling window on the student's screen. The poll result is published overlaid directly on the slide.

With the direct external video sharing function, BBB automatically picks up the URL of video sharing services such as YouTube written in the slide, offering the presenter a dropdown to play it. The playback is moderately synchronized on the terminus of each participant. Unlike Zoom and Teams, on which the movie will be "broadcasted" from the teacher's computer through the screen sharing function, BBB lets each client connect directly to the services. The video sharing services usually distribute the data via many servers and optimize the video quality depending on the user's network. Therefore, BBB is able to show

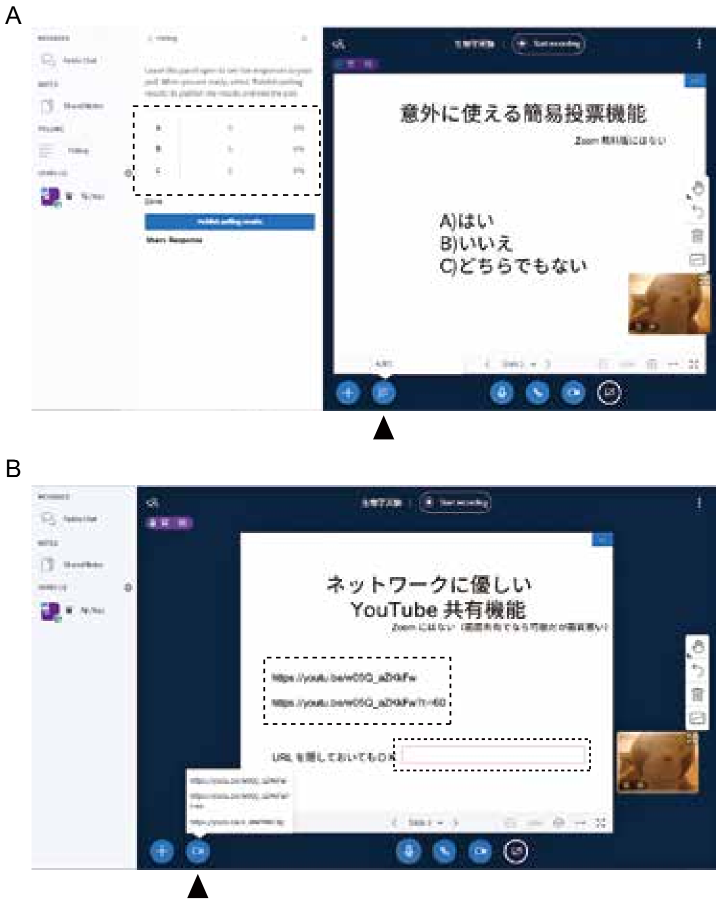

Figure 2 Features unique to BBB
(A) Quick polling. An itemized text written in the slide is sought by the application, which displays a button (arrowhead) to immediately start polling (upper dashed box). (B) Quick external video sharing. When a URL of video sharing services such as YouTube is written in the slide (upper dashed box), BBB recognizes them and displays a button (arrowhead) to share the video within the BBB window. The URL can be hidden from the students (lower dashed box).

videos in higher quality than the other services (data not shown).

Another helpful feature of BBB is the “fail-safe” recording. On BBB, all meetings are recorded by default, and only the portion where the recording button has been on will be processed for publication. Therefore, the teacher can recover the meeting record afterwards, even if the record button has been left unclicked. On the other hand, the tested version of BBB does not offer the function of downloading the meeting record as a single video file; the data of teacher’s video, slide images, and pointer coordinates are stored in different files. This feature prevents users from sharing the record by uploading it to external video sharing services, while it allows BBB to flexibly arrange the meeting records on the playback screen. The development community of BBB has already recognized this issue and a couple of solutions have been proposed (6).

Comparison of bandwidth consumption

The measurement was done for three times (Figure 1). With the start of the screen share, Teams showed a high bandwidth consumption for ~10 sec. Zoom also showed a similar heap, which was however much smaller than that of Teams. In contrast, BBB used almost no network resource until the slide distribution started (indicated as small peaks at 16 - 18 sec).

BBB sends the slides as SVG format data to students, thus the quality of slide image is very high and the bandwidth consumption is expected to be zero as long as the slide remains the same. Indeed, BBB made almost no traffic for the first 30 seconds (Figure 1A). It was however surprising that both Zoom and Teams did not consume large bandwidth either, as they were supposed to send the slides as video data (Figure 1C and D). Both systems were obviously equipped with good video codecs (computer programs that encode or decode digital data stream) either within the application or on the cloud.

When I moved to the second slide at 30 sec, the consumption graph showed a heap in all systems. In Teams the consumption was particularly larger than the other two. Teams also showed a similar peak at 70 sec when the presentation was moved to the fourth slide. BBB showed a continuous consumption of 150 - 200 Kbytes / sec during the mouse pointer shaking. A similar pattern was observed from 70 sec to 80 sec, where the mouse was also shaken vigorously. Only TCP (Transmission Control Protocol) traffic accounted for this consumption (Figure 1B), indicating that BBB uses a relatively large network resource to faithfully reproduce the pointer movement. Contrary, the peaks of Zoom and Teams were composed almost exclusively of UDP (User Datagram Protocol) traffic (data not shown), consistent with the assumption that both systems encode the pointer movement together with the video of the shared screen. This also implies that Zoom and Teams sacrifice the detailed information of the pointer movements to save the bandwidth used for presentations.

On the video sharing, BBB showed a significantly small consumption compared to the other systems. On BBB, the students receive the video data directly from video sharing services, which deploy a high-quality video codec. Indeed, the quality of the video was much better than the other two systems (data not shown).

The bumpy pattern of the graph may reflect the intermittent data loading from the service provider to avoid interruption of the video playback. Interestingly, Zoom sometimes continued a heavy use of the network after the video was paused (Figure 1C, 60 - 70 sec). It seemed that Zoom needed some time to recognize that the video was not played anymore.

In contrast to the video sharing, the audio transmission did not require much network resource on any of the three systems, as indicated by the similar bandwidth consumption observed from 30 sec to 45 sec, where I kept silence, with that from 70 sec to 80 sec, where I spoke continuously.

The averaged data constantly showed smaller bandwidth consumption on BBB than the other two systems, as long as the mouse pointer was not moved much (Figure 1E). In contrast, Teams consumed the largest network resource all through the presentation. It was however unexpected that the video of the speaker did not consume much bandwidth in any system during the presentation. The data transmission seemed to be minimized by squeezing the teacher’s video during the presentation. The total consumption was significantly smaller in BBB than in Zoom and Teams, confirming the advantage of BBB for the general lecture purpose (Figure 3A).

For students who are not able to follow real-time online lectures due to, for example, a network failure, the teachers are expected to record the session and publish it for the on-demand playback. It is thus important that the size of the record stays reasonably small. Although the session is recorded as a single movie file by Zoom and Teams, the tested version of BBB does not officially offer such function. Therefore, in order to estimate the bandwidth consumption of the record playback on BBB, I summed the file size of the slides and the teacher’s video that were stored in the server. The data of shared external video was not

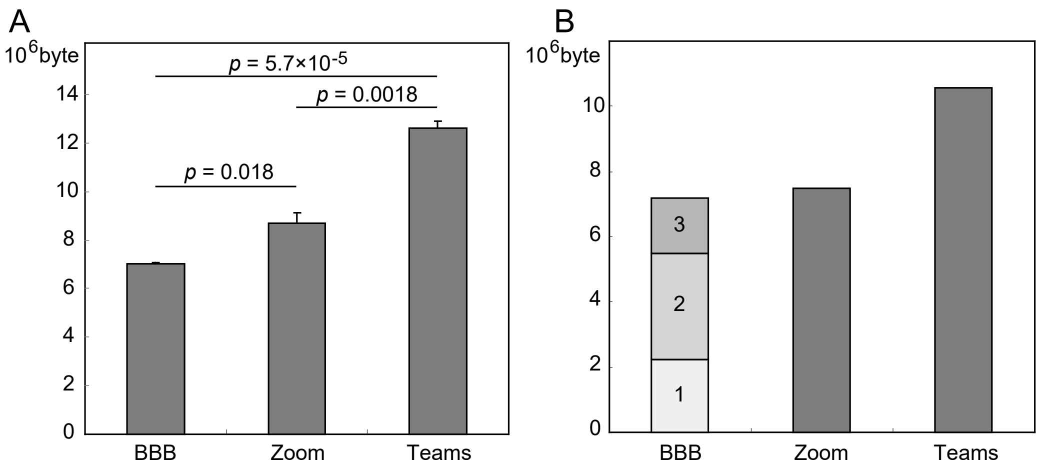

Figure 3 Total bandwidth consumptions

(A) The total bandwidth consumptions were averaged for three measurements and shown with error bars (SE). The statistical significances of the difference were established by Student’s t-test (p-values shown). (B) The sizes of the session records that would be used for on-demand playback. For BBB, the estimation was done by summing the file size of the slides (1) and the teacher’s video (2) with the expected bandwidth consumption (3) during the external video sharing calculated from Figure 1A.

stored in the server, thus I estimated the traffic of the external video sharing by subtracting the base-line traffic (32.9×10^3 bytes/sec; calculated by averaging the 1 sec – 15 sec and 19 sec – 29 sec traffic in Figure 1A) from the averaged traffic and totaling it from 46 sec to 70 sec, where the external video was played. The file generated by Zoom was much smaller than that by Teams, and the estimated network consumption of playback on BBB was comparative to Zoom (Figure 3B), consistent with the live measurements done in Figure 1.

Discussion

As online lecture tools, the spectrum of functions deployed in BBB, Zoom, and Teams does not differ too much. However, the smaller bandwidth consumption of BBB represents a significant advantage over the others, especially for the students with poor internet connections (7). The only caution would be to minimize "brandishing" the pointer (similarly in the real world lectures) because BBB tries to reproduce it very faithfully.

It is still possible that the simulation in this report does not reflect the reality. The tested three systems are all equipped with a function to adjust the broadcast quality automatically depending on the user's network. Although I simulated the situation where the majority of students in Japanese universities would take online lectures, further tests should be performed in various network conditions before the final conclusion (8).

Not only the small network resource that BBB consumes, but also the low cost of setup, the large room for customization, the small security concern, and the exclusively dedicated server (unlike other cloud services, on which the service quality can be severely affected by users from other organizations) would make BBB a good option to be chosen for an online lecture platform in higher educational institutions.

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I thank Toshiki Yagi and Kenji Suguri (PUH), for helping me to set up the BBB server in the university.

要　旨

新型コロナウイルス感染症（COVID-19）は高等教育機関における講義の在り方を一変させた。県立広島大学では、第一クォーターの全ての講義がオンラインで行われた。オンライン講義を行う上で最も大きな懸念の一つは、学生のネットワーク環境である。特に庄原キャンパスではほとんどの学生が一人暮らしで、インターネットへの接続を、遅く、通信量も限定されたモバイルネットワークに依存している。Zoom や Teams などのウェブ会議システムを提供している企業は、ネットワークの使用量データを公開しているが、それらは大学での講義を想定したものではない。加

えて、これらのシステムにはプライバシーの問題もあり、キャンパス内で完結したシステムの方が望ましいことは明らかである。本稿では、Zoom、Teamsに加えBigBlueButton（BBB）というオープンソースのウェブ会議システムのネットワーク使用量を測定し、互いに比較した。測定の際は実際の大学での講義スタイルをできるだけ再現するよう留意した。その結果、BBBのネットワーク使用量は他の2者と比較して有意に小さいことが明らかとなった。BBBには、ネットワーク負荷の低さの他、学内でシステムが完結する安全性、導入コストの低さ、また大学での講義の形式に最適化された諸機能の存在など多くの利点があり、大学においてオンライン講義を実施する上で、有力な選択肢の一つであると言える。

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