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Implementation and evaluation of video conferencing system on public cloud

Vladimir M. Ciric, Oliver M. Vojinovic, Ivan Z. Milentijevic

***Abstract*— With constant growth of capacity and bandwidth of computer networks, resource demanding network applications that emerged as concepts a long time ago got their chance to gain a worldwide popularity and widespread usage. It is not the question anymore whether we can implement such applications, but rather how easy they are to implement, and how much their usage costs. In cloud-centric world of today this becomes the matter of the amount of required resources. The aim of this paper is to present the resource requirements of a video conferencing system based on open source BigBlueButton platform, while it is implemented on the Amazon AWS public cloud. The system will be implemented as the part of blended learning system. In order to determine the system limits and to give recommendations for implementation of similar systems, the results of the stress test will be given.**

***Index Terms*—Video conferencing, blended learning, cloud applications.**

I. INTRODUCTION

The roots of video telephone technology can be traced back to the late 1920s and can be found with the AT&T company Bell Labs and John Logie Baird, who experimented with video phones in 1927 [1]. Videotelephony was developed in parallel with voice telephone systems from the mid-to-late 20th century. A lot of effort was put in the field by Bell Labs during the 1950s and 1960s, which lead to AT&T's Picturephone. However, the market didn't respond well, and the service was withdrawn [2].

A lot of researches and companies continued development throughout the 1980s and 1990s, which led to a number of videoconferencing systems. The systems evolved from proprietary equipment to standard technologies that were available to the general public at reasonable cost. Early attempts have failed mainly due to the cost and the quality of both equipment and resources [2]. However, videotelephony become a practical technology for regular use with the introduction of powerful video codecs in the late 20th century, combined with high-speed Internet service [3].

The constant bandwidth growth resulted with a shift from transmission of a few low-quality images per second to high-definition real-time video conferencing [4]. The price of the video conference systems got significantly lower, resulting with an adoption of such systems in different applications. One of such applications is in education, namely blended learning [5]. In a nutshell, blended learning requires the presence of both a teacher and a student, where the student has control to a certain extent over time, place, and path [6].

In recent years blended learning is gaining a lot of attention due to the growing demand for distance learning and life-long leaning [6]. The popularity emerges from the fact that it combines online digital media with traditional classroom methods, elevating the learning experience. Blended learning, armed with video conferencing, exerts good sides of both traditional and distance learning. Video conferencing becomes a common classroom activity in the online learning stage of blended learning [7].

There are a lot of educational institutions that own blended learning platforms, and even more that don't. The era of cloud computing offers a possibility to institutions which don't own such platforms to utilize public cloud resources for courses delivery. Cloud providers offers different sets of resources in the form of virtual machines, called instances, starting with low price instances with modest resources at the cost of about $0.02 per hour, up to very powerful instances which can cost more than $10 per hour [8]. Observed on a monthly basis, the price may vary from $15-$20 per month, to a few hundreds, or even thousands of dollars. Speaking about the cost difference of up to 500 times, the choice of an appropriate instance for the particular application becomes an important question.

The aim of this paper is to present the resource requirements of a video conferencing system, regarding the number of users, based on open source BigBlueButton platform, while it is implemented on the Amazon AWS public cloud. The system will be implemented as the part of blended learning system. In order to determine the system limits and give recommendations for implementation of similar systems, the results of the stress test will be given. The measured parameters will include CPU, memory and network throughput. The system will be tested on three different AWS instance types, simulating up to 400 users. Recommended user number limits will be given for each of the tested instance types.

This paper is organized as follows. Section 2 presents the proposed implementation of blended learning system, based on video conferencing platform. Section 3 is devoted to the evaluation of the system. The concluding remarks are given in Section 4.

II. BLENDED LEARNING SUPPORT SYSTEM IMPLEMENTATION ON PUBLIC AWS CLOUD

In order to enable students to choose their learning path and create an environment where they can schedule the

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learning time on their own, blended learning support systems usually include several components [5,7]. These components should make learning material available online, should provide quizzes and tests, and not mandatory, but preferably enable two-way communication between teacher and students [5]. There are different approaches in the implementation of two-way teacher-students communication. E-mails are the oldest and the simplest solution. Nowadays, the most common asynchronous communication tools are discussion forums. Simple, but effective synchronous tool that can be found in such systems is chat. The most powerful two-way communication tool that is gaining more and more popularity is video conference [7]. Fig. 1 shows the common blended learning system components and their relation to teacher and students.

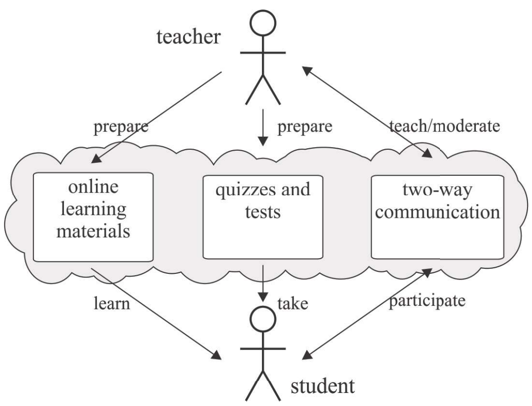

Fig. 1. The common components of blended learning systems

In order to support blended learning paradigm, the video conferencing system, if included, should provide multipoint conference, as well as video recording and streaming, with aim to enable students to schedule their learning time on their own. To provide the components from Fig. 1 two different platforms are required: distance learning platform, and video conferencing platform. Modern distance learning platforms always support both online learning materials delivery and testing of the students.

Both distance learning and video conferencing platforms are common in lecture delivery today, and there are a lot of available options for choosing the systems [9]. Seeking for a low-cost open-source and general solution, we chose the Moodle[1] as the primary learning management system, while for video conferencing we chose BigBlueButton[2] (BBB). The Moodle is chosen as the primary platform due to its ability to integrate BBB through its plug-in system, giving the students impression of accessing one platform only.

The BBB has the following features:

- it does not require any special software on the client side other than standard web-browser;
- good support and integration with Moodle;
- ability of sessions recording and streaming;
- up to 3 simultaneous videos, and 1 audio stream.

Video and audio streams that BBB can simultaneously have are: 1 video and 1 audio stream for the instructor's camera and microphone, 1 video stream for the presentation (PowerPoint, PDF, etc.), and 1 video stream for desktop share. Video stream for the presentation can be additionally used as a whiteboard. In addition, desktop sharing feature of BBB is available to create a live-stream of chosen desktop region to students.

Both Moodle and BBB systems are suitable for either private or public cloud implementation. The Amazon AWS provides a template that contains the software configuration (operating system, application server, and applications), called AMI, required to easily launch the instance with Moodle or BigBlueButton [10]. The chosen building blocks and their relations are shown in Fig. 2.

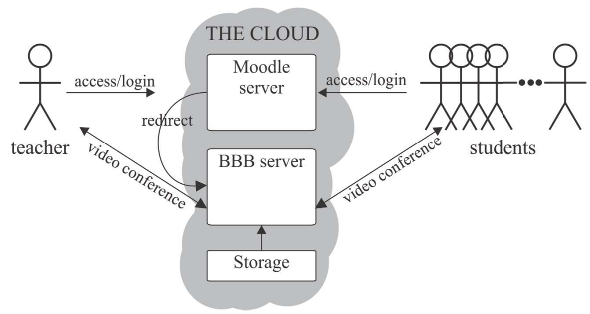

Fig. 2. The blended learning system building blocks

The Moodle can provide both online learning materials distribution, and testing the students' knowledge. Furthermore, it has tools for two-way communication with the students such as forums and chats. The BBB is an open-source project which can be easily included as a video conferencing extension of the Moodle, using available plugins for Moodle. Students are logged in using Moodle, and then, transparently, without additional login redirected to BBB video conferencing (Fig. 2). In order to store the video conference recordings additional storage is required (Fig. 2).

Fig. 3 shows the example of Moodle page prepared by the teacher. The figure shows sections in Moodle page, each devoted to one topic. In our implementation a section contains: learning objectives and learning materials, virtual classroom (given as a link to BBB Moodle plugin), additional learning materials, and online test.

Fig. 4 presents a screenshot of a web browser during a lecture in the virtual BBB classroom, which can be seen by following BBB links (the "b" icons on the Moodle page from Fig. 3). The left column of the screen contains the list of participants and the instructor video camera stream. The central part is devoted to the drawing canvas, while the right part of the screen contains the screen share showing the network simulator.

[1] Moodle is a free and open-source learning management system (LMS), originally developed by Martin Dougiamas, which is distributed under the GNU General Public License. URL: https://moodle.org/

[2] BigBlueButton is an open source video conferencing system, based on GNU/Linux operating system. URL: https://bigbluebutton.org/

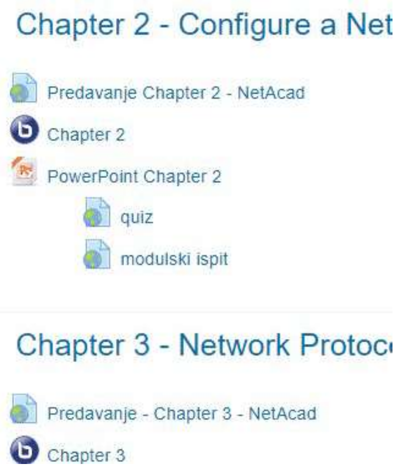

Fig. 3. The example of Moodle page prepared by the teacher

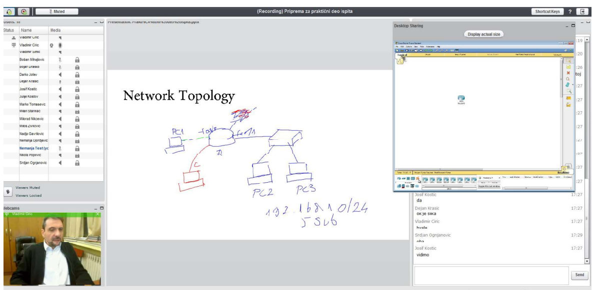

Fig. 4. Screenshot of a web browser showing virtual BBB classroom

III. THE RESULTS OF THE SYSTEM STRESS TEST

The system from Fig. 2 is implemented on Amazon AWS cloud. The resources for learning materials distribution are not critical, thus the Moodle is implemented using *t2.small* instance (1 vCPU, 2 GB RAM). In order to observe the system scaling capabilities and determine limits for different instance types regarding the number of users, we tested video conferencing part of the system using three different instances: *t2.small*, *t2.medium* (2 vCPUs, 4 GB RAM), and *t2.large* (2 vCPUs, 8 GB RAM). Linux CentOS 7 is installed with Moodle v3.2 and Ubuntu 16.04 with BigBlueButton v1.1. Each instance was created with 25 GB of EBS disk reserved for operating system and applications. AWS S3 is used as associated storage (Fig. 2).

In order to perform the stress test, we connected the teacher with one audio stream, one video stream sharing teacher's camera in low resolution (320x240px), and one video stream for the presentation. We used 80 physical PCs to simulate students' connections. Students were viewers only. The connection rate was one new connection per 10 - 20 seconds. We created 5 - 10 connections per PC. During the test we observed the system behavior and user experience, and we measured objective system parameters of BBB server.

For each tested instance we recorded three events: the first time when the system unexpectedly disconnected some of already connected users due to the system load (event "D"); the time needed for establishing a new connection is significantly slowed down (event "S"); the system limit (event "L"). It is interesting to notice that when the limit is reached the system doesn't fail. It rather disconnects some (or more) of already connected users in order to connect the new ones. Moreover, connected users don't experience quality degradation. Table 1 gives the number of users for which events "D", "S", and "L" were recorded.

TABLE I
THE OCCURRENCES OF SIGNIFICANT EVENTS FOR DIFFERENT INSTANCE TYPES DURING THE SYSTEM STRESS TEST

Event \ Inst.type	*t2.small*	*t2.medium*	*t2.large*
"D"	80	200	290
"S"	140	300	300
"L"	415	371	400

The parameters measured during the stress test are given in Fig. 5. We were measuring the following: CPU utilization (Fig. 5a – Fig 5c); memory consumption (Fig. 5d – Fig. 5h); and network throughput (Fig. 5i). The parameters were measured using Linux commands *free*, *uptime*, and *vmstat*.

Figs. 5a – 5c show CPU utilization. Regarding the CPU, we were measuring the time that CPU spends in idle (Fig. 5a), the number of interrupts per second (Fig. 5b), and the number of context switches per second (Fig. 5c). All three parameters give a good insight how the CPU performs with the increase of the number of users. The official BBB documentation recommends the CPU load below 80% for system stability. This is aligned with our findings: the event "D" for *t2.small* instance appeared with 80 users (53% of time CPU spent on idle, Fig 5b), and the event "S" started with 140 users (24% of CPU idle time). We were able to connect more than 400 users (Table 1), but we don't recommend this instance type for more than 120 - 140 users due to the frequent connection losses. This can be noticed in inability for the CPU to increase the number of interrupts and context switches (Figs. 5b and 5c). This instance type was stable for up to 70 - 80 users, when the first disconnections appeared ("D", Table 1). The instance *t2.medium* with its 2 vCPUs performed much better, as expected (Table 1 and Figs. 5a – 5c).

Figs. 5d – 5h show the memory parameters. From Fig. 5e it can be seen that used memory is the same regardless the instance type, which is expected (between 1.1 and 1.6 GB). Instances *t2.*medium and *t2.large* have more available memory (Fig. 5d), which they can spend for kernel disk caches and buffers (Fig. 5h), but this didn't influence the user experiences significantly in our test. Thus, we can conclude that the memory is not a limiting factor.

Due to the completeness of the results, let us briefly mention the storage requirements, disregarding the fact that it is not a limiting factor. For hard disk capacity we chose 25GB for the Linux operating system. The requirements of the storage from Fig. 2 are as follows. The instructor's audio stream with the presentation or drawing canvas requires 110 MB per recorded hour (Mbph) for RAW recorded materials, or 10 MBph for post-processed materials. If the instructor's video camera is added, 130 MBph are required for unprocessed and 50 MBph are required for post-processed materials. When all three streams are used simultaneously, they require 240 MBph and 75 MBph for RAW and post-processed materials, respectively.

In the end, we can conclude that for system stability

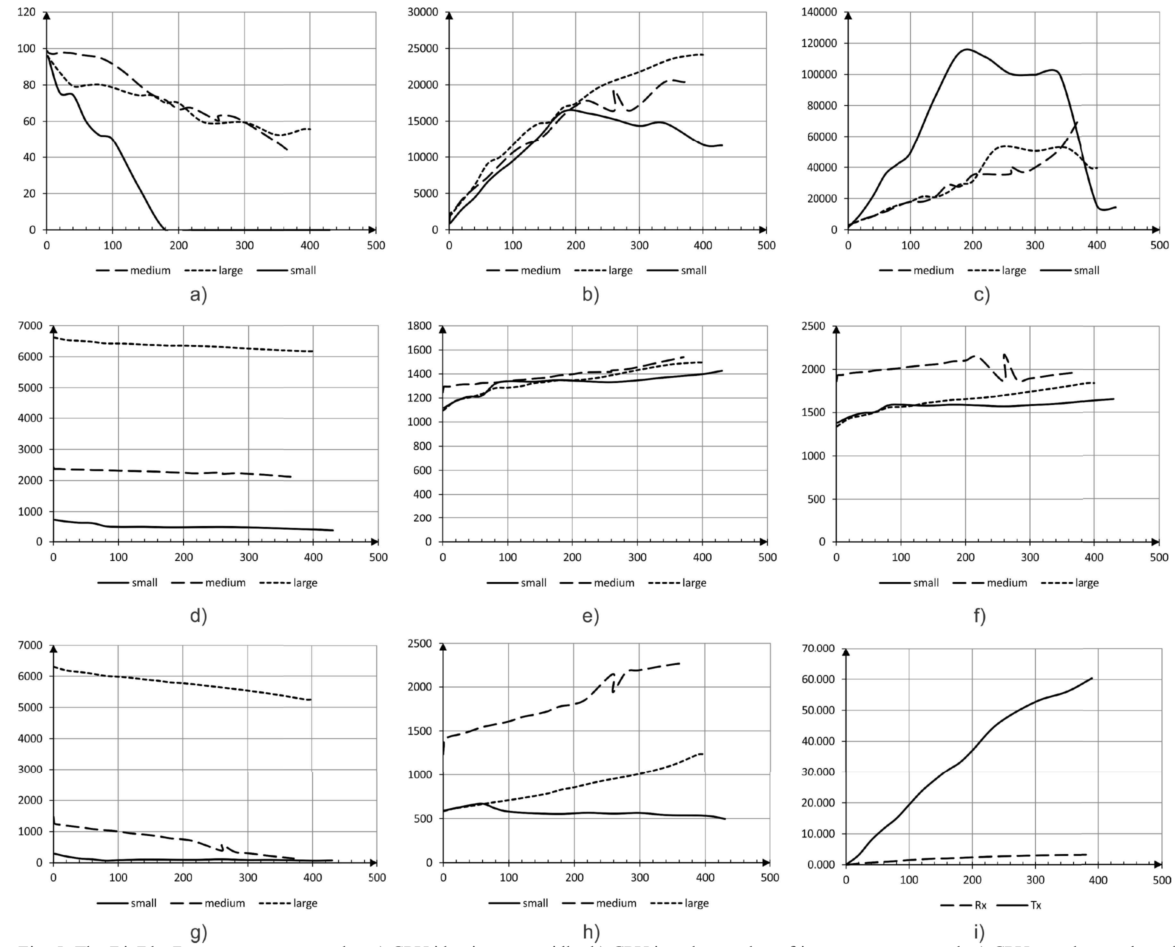

Fig. 5. The BigBlueButton stress test results: a) CPU.id - time spent idle, b) CPU.in - the number of interrupts per second, c) CPU.cs - the number of context switches per second, d) memory - available, e) memory - used, f) memory – active, g) memory – free, h) memory – kernel buffers and caches, i) network throughput

t2.small instance should be used for up to 70 users, while *t2.medium* is sufficient for up to 150 - 200 users. There was no significant gain with *t2.large* instance type.

IV. Conclusion

In this paper the resource requirements of a video conferencing system, based on open source BigBlueButton platform and implemented on the Amazon AWS public cloud, are presented. The system was implemented as the central part of blended learning system. In order to determine the system limits and give the recommendations for implementation of similar systems, the results of the stress test are given. The given parameters include CPU, memory and network throughput. The system was tested on three different AWS instance types, simulating up to 400 simultaneous users. For tested instances the recommended number of users were given.

Acknowledgment

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