Research of the Efficiency of a University Video Conferencing System Based on Open-Source Software: the Scalelite Balancer and the BigBlueButton Web Conferencing System

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Abstract

The need for synchronous online classes in video conferencing is associated with the transition of many universities to distance learning during the coronavirus infection. This problem has been solved by universities in different ways: some used internal video conferencing systems, some subscribed to third-party video conferencing systems, some used video conferencing systems on their own or rented servers. The increase in the number of video conferencing users during the pandemic led to technical failures in the operation of video conferencing systems. The expansion of communication channels and the increase in server capacity did not always lead to the desired result, since the software for the implementation of video conferencing has restrictions on the number of users. One of the ways out is to use a scheme with several video conferencing servers and a load balancer server. The article discusses the experience of the National Research University "BelSU" on the formation of a video conferencing system for providing synchronous online classes in the video conferencing classes based on the open software BigBlueButton and the Scalelite load balancer. This solution allows you to scale the number of simultaneous participants of synchronous online classes held in an educational organization in the video conference mode, due to the dynamic distribution of the load on several servers without changing the user's usual operating mode.

Keywords 1

distance learning, video conferencing, BigBlueButton, LMS Moodle, Scalelite, synchronous online classes

1. Introduction

In the spring of 2020, due to the spread of the coronavirus infection (COVID-19), a significant number of higher educational institutions made the transition to distance learning. At the same time, different approaches were used to organize distance learning. An asynchronous educational process within the framework of internal online courses of distance learning systems [1,2] and massive open online courses [3,4], the interaction of students and teachers through e-mail, social networks, and instant messengers [5-6], the use of video services for placement of video content [7,8], synchronous distance learning using video conferencing services [9,10] or a combination of various digital technologies. Studies have shown that both teachers and students during the period of distance communication lacked live communication [11,12]. Systems that provide training using video conferencing bring the remote educational process as close as possible to the real one. Classes with the use of videoconferencing are carried out synchronously with the audiovisual interaction of the participants in the educational process. Educators do not need to redesign the curriculum in the format of online courses or prepare additional

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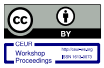

digital content. It is enough, as in the case of traditional education, to conduct classes on a schedule, but instead of a real audience, use the digital environment of the virtual classroom, which the videoconferencing system offers. And therefore, a significant part of universities implemented the distance educational process using videoconferencing services, including in combination with other distance educational technologies [1,13].

Universities used cloud services or their systems to implement the educational process using video conferencing. The use of external video conferencing services to ensure the interaction of a large number of students and teachers was associated with quite large financial costs. The universities had a choice either to spend the necessary funds on a subscription or to use the video conferencing systems in a free limited format.

Another way is to use video conferencing systems deployed on our own or leased facilities. As the analysis of the literature shows, some universities that relied on their systems to support distance learning were forced to hastily increase their server capacity and expand communication channels [14,15]. BigBlueButton software is a popular solution for implementing an internal video conferencing service [16]. One of the advantages of BigBlueButton is convenient integration with the Moodle distance learning system, which is relevant for universities that use LMS Moodle in the educational process. In LMS Moodle, you can install a standard plug-in for the BigBlueButton element, and then the work of the teacher and students on using the videoconferencing service will not differ from the work with another educational element. A separate authorization is not required to work in the video conferencing system.

One of the disadvantages of the BigBlueButton software is the presence of a limit on the maximum number of users simultaneously authorized on the server (about 1000 people). Exceeding the recommended number of users leads to an unstable operation of the video conferencing service. The solution is to use a cluster of BigBlueButton servers with a load balancer server. Based on that solution the Belgorod State National Research University has implemented a video conferencing system used in the educational process.

2. Purpose and Objectives of the Research

The purpose of this research is to study the performance of the video conferencing system implemented based on the BigBlueButton web conferencing software, distributed on several servers and the Scalelite load balancer server, integrated with the popular distance learning system (educational content management system) LMS Moodle. To achieve this purpose, the following objectives were set: a literary review of video conferencing systems used for conducting synchronous online classes in the video conferencing mode in educational institutions; selection of research methods; analysis of the integration schemes of the BigBlueButton video conferencing system and LMS Moodle, conducting an experiment to study the performance of the BigBlueButton system distributed on several servers using a load balancer; identifying recommendations for using the implemented video conferencing system.

3. Methodology

The following methods were used to achieve the objectives: the analytical (the analysis of scientific literature and sources on the research topic, the analysis of the integration schemes of the BigBlueButton and LMS Moodle video conferencing systems), the interpretive (the complex and systematic study of the research object; the generalization of practical experience, etc.), the empirical (experimenting to study the performance of the BigBlueButton system distributed on several servers using a load balancer with diagnostics and identification of the experiment results).

Following the indicated research methods, the entire set of measures to study the operability of the videoconferencing system was carried out at the National Research University "BelSU" during the 2020-2021 academic year. The following was identified as the main areas of research: the analysis of problems related to the performance of the videoconferencing system in the spring of 2020 after the

full-scale transition of the National Research University "Belgorod State University" to a distance learning format; the selection of the necessary resources for the hardware and software complex of the video conferencing system based on the open BigBlueButton software and the Scalelite load balancer; the study of data on system objects (users, groups, rooms, organizations, messages, logs, etc.); the analysis of the health of the server and network infrastructure with the definition of restrictions on the use of the video conferencing system.

4. Literature Review

In modern literature, the sources of the video conferencing system are conventionally divided into two classes – hardware and software. Hardware systems are special MCU (multipoint control unit) devices for organizing multipoint video conferences and are often used in the corporate segment due to the high cost of equipment and limited application.

Software systems are less productive, but much more affordable, more flexible, and versatile [17]. Video sources can be very diverse, they can be mixed, and post-processing can be carried out. Most systems are fully functional when using only a browser and a webcam without additional software installation.

According to the communication technologies used, software solutions for video conferencing can be divided into three classes: using IP telephony tools; using Flash tools, and using standard browser tools.

Different video conferencing software solutions can differ in parameters: the number of people connected at the same time, the quality of audio and video stream transmission, the number of supported operating systems, and the availability of a separately installed mobile client. In addition to the basic parameters, most solutions have additional functions such as a calendar, chat, the ability to work with shared files, drawing tools, screen demonstration, informing by e-mail, recording the event, integration with other systems.

Table 1 shows a comparative analysis of frequently used video conferencing systems found in the works of domestic and foreign authors [17-21].

Table 1.
Comparative analysis of video conferencing systems

Video conferencing system	Software technologies	Availability of a plugin for integration with LMS	Free software	Maximum number of participants in 1 room	Availability of a mobile client	Screen demonstration	Availability of an online whiteboard
OpenMeetings	Red5, Java, Adobe Flash, HTML5	+	+	100	+	+	+
BigBlueButton	Red5, Java, Adobe Flash, HTML5, WebRTC, Redis	+	+	100	-	+	+
MConf	Red5, Java, Ruby, Adobe Flash, HTML5, WebRTC, Redis	-	+	100	+	+	+
Zoom	Java, WebRTC	+	-	100	+	+	-
Skype	MSNP24, WebRTC	-	-	50	+	+	-
Jitsi	Java, WebRTC	-	+	75	+	+	-

Zoom is the undisputed leader in use in the USA and Europe. It is advisable to use this service by educational organizations focused on the use of cloud technologies. A corporate plan with no

functionality restriction requires a paid subscription. In addition, Zoom is not a free software product, and if an educational organization is focused on forming a video conferencing system on its server facilities with integration with existing information systems, then in this case they should focus on open-source products. The video conferencing BigBlueButton meets the listed requirements to the greatest extent.

The BigBlueButton software tool, unlike other systems that implement video conferencing, was created as a training platform and is focused primarily on conducting synchronous online classes, and not on organizing remote meetings [16,17,22]. The fact that BigBlueButton was designed specifically for video lessons is reflected in the functionality of this system. In addition to the standard audiovisual interaction in the videoconferencing classroom, a virtual board has been implemented, on which not only presentations and documents are demonstrated, but students and teachers can work together using tools (text input, including in pencil mode, creating standard geometric shapes, filling shapes, etc.). Participants can show not only documents but also their desktop. To organize the interaction of participants in the BigBlueButton virtual audience there is a chat panel (public and private) and a notes panel. A teacher can manage the educational process (organization of group work, implementation of the "raised hand" functionality, control of the students' sound, etc.). Teachers can turn on the video and then use the recordings as a podcast.

There are currently no cloud solutions for BigBlueButton. To use this video conferencing system, an educational institution must install the free server software on its server facilities. Therefore, on the one hand, this fact requires an educational institution to have a certain material and technical base and system administration, on the other hand, it will save on a monthly fee, which is typical for most cloud solutions in the case of tariffs without restrictions. Using BigBlueButton, an organization can independently control the video conferencing system, influence its performance characteristics and not depend on the quality of the cloud service. An additional advantage of BigBlueButton, in comparison with other video conferencing systems, is that you can specify additional options for integrating this software product and customization.

The undoubted advantage of BigBlueButton is integration with distance learning systems and CMS-systems LMS Moodle, Sakai, Drupal, WordPress, Bitrix, etc. For the educational content management systems Moodle and Sakai, both APIs and ready-made plugins for integration are used [16, 23]. The presence of the plugin allows you to create virtual BigBlueButton rooms in LMS online courses as normal course elements. Users of the online course go to the video conference via a direct link without additional registration on the BigBlueButton website.

5. Discussion

The BigBlueButton video conferencing system is used as a university video conferencing system at National Research University "Belgorod State University". The decision in favor of this software tool determined the openness of the program code (free use and the possibility of flexible configuration and change), convenient and simple integration with the Moodle distance learning system [24,25], the presence of its server infrastructure, and trained personnel. The integration scheme of the BigBlueButton system with LMS Moodle is shown in Figure 1.

Before switching to full distance learning in the spring of 2020, one BigBlueButton server was used at the National Research University "BelSU" to conduct classes in the video conferencing mode. The increase in the number of BigBlueButton users has led to problems related to the performance of the video conferencing system. When connecting a large number of users at the same time, about 1000-1200 people, the video conferencing server spat out an error. The number of teachers and students simultaneously participating in the synchronous online learning process was many times higher than the specified number.

In an emergency, additional servers were rented to normalize the performance of the video conferencing system. The following solution was implemented to divide the data streams into different servers: copies of plugins were created in the LMS Moodle, which the distance learning email perceived as different elements of the course; all Moodle online courses were evenly distributed among the BigBlueButton plugins by course id (the "pinning" of existing elements in the training courses for plugins was implemented using a script) (fig. 2).

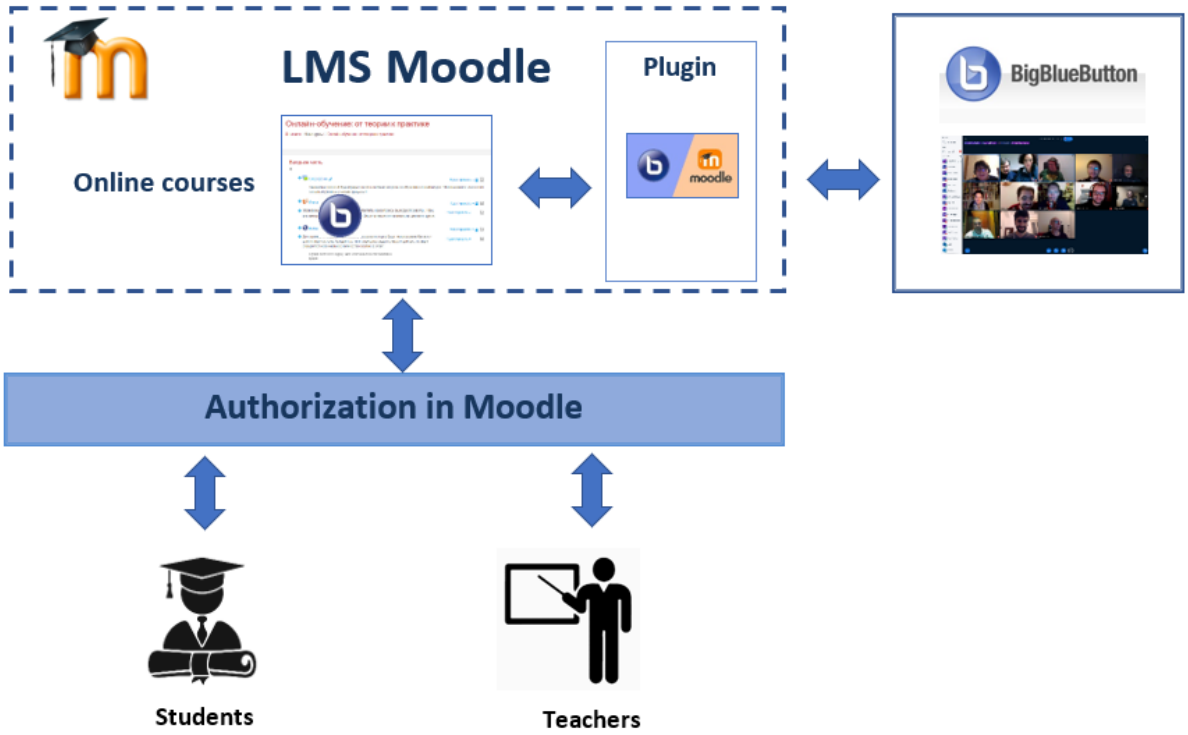

Figure 1: Integration scheme of the BigBlueButton system with LMS Moodle

Participation in the virtual learning process was no different from the usual scheme with a single plugin and a BigBlueButton server. Users in the online course simply selected the video conferencing element and entered the video conferencing room on the corresponding BigBlueButton server associated with the plugin with which this element was created.

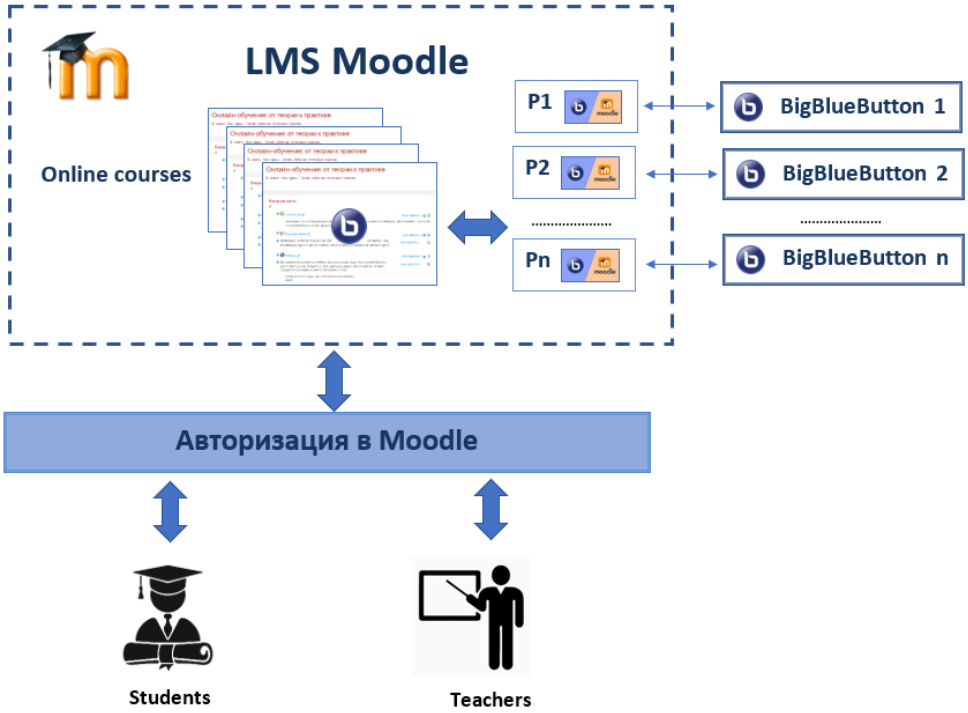

Figure 2: Scheme of integration of the BigBlueButton system with LMS Moodle with several plugins and video conferencing servers (VIDEO CONFERENCING)

This solution was transitional since it did not fully determine the need for load balancing between video conferencing servers. First, the load was distributed uncontrollably in real-time because some

Moodle courses tied to a particular BigBlueButton plugin were used more heavily than others. Secondly, after assigning videoconferencing course elements to plugins, teachers created BigBlueButton elements in the online course using different plugins, which eventually led to a static imbalance in the server load.

Further searches for a solution to the problem of building a video conferencing system based on the BigBlueButton system with several servers led to a scheme with dynamic load balancing using the Scalelite balancer server [26,27]. Scalelite is open-source software that acts as a load balancer for information systems [28]. In particular, it can be used to scale the use of the BigBlueButton video conferencing system by distributing the load on several servers. The diagram shown in Figure 3 uses one BigBlueButton and LMS Moodle integration plugin. Requests from the BigBlueButton element of the Moodle online course do not go directly to the videoconferencing server, but the load balancer server. The balancer processes the request and sends it to one of the BigBlueButton servers, which is currently the least loaded. The Scalelite balancer constantly audits the server load (the number of connected users) BigBlueButton to determine the least loaded video conferencing server. Thus, the BigBlueButton servers are evenly loaded in real-time.

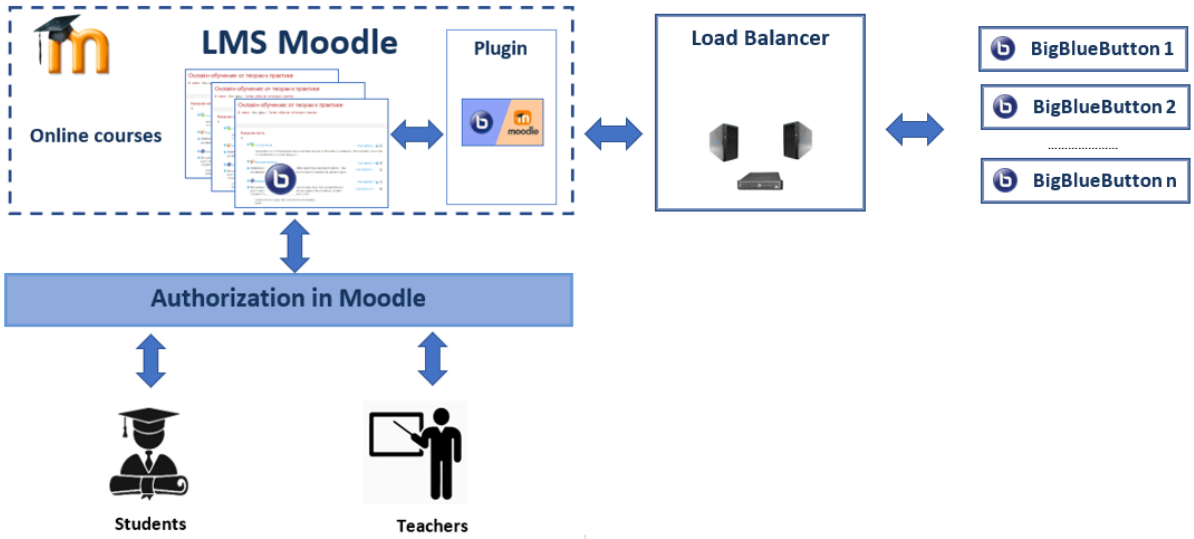

Figure 3: Scheme of integration of the BigBlueButton with LMS Moodle system with a load

After implementing a pool of video conferencing servers with a load balancer, one of the tasks was to configure the indexing of video conferencing session records to correctly display links for recording in Moodle courses. To solve the problem of managing records in the case of using a cluster of BigBlueButton servers with a load balancer, a common directory of records was used. The shared directory is mounted via a network file system from records stored on video conference servers. Each BigBlueButton server has its record naming system that does not overlap with others, so the names of records in the shared directory are not duplicated. The shared directory itself is stored on the load balancer server. Through the BigBlueButton plugin in the Moodle system, the conference record is associated with a specific element, a specific online course, and can be accessed by users.

6. Results

The video conferencing system implemented at the Belgorod State National Research University is a hardware and software complex that includes 7 servers with the BigBlueButton server software installed, a Scalelite balancer server. Servers with the following characteristics are used as BigBlueButton servers:

- CPU: Intel Gold 4x4, 3 GHz
- Memory: 32 GB
- HDD: 500 GB

The load balancer server has the following characteristics

- CPU: Intel(R) Xeon(R) 2x4, 3,3 GHz
- Memory: 12 GB
- HDD: 700 GB

As a tool for analyzing the health of the server and network infrastructure, a freely distributed system for monitoring and tracking the statuses of network equipment and Zabbix servers was used [29]. More than 2000 users were involved in the study of the operability of the hardware and software complex of the video conferencing system, which includes seven BigBlueButton servers and a Scalelite load balancer. Trainees and curators used virtual rooms for the curatorial hour. In total, 2,136 users were simultaneously recorded on the BigBlueButton's servers (157 using video cameras).

During the test load of the video conferencing system, the load on the server equipment (processor and RAM) was 20-25% (Fig. 4). Thus, it is possible to predict the maximum critical number of users per server of about 1200 people. The permissible number of users for the load of the server equipment at the level of 80% is about 1000 people.

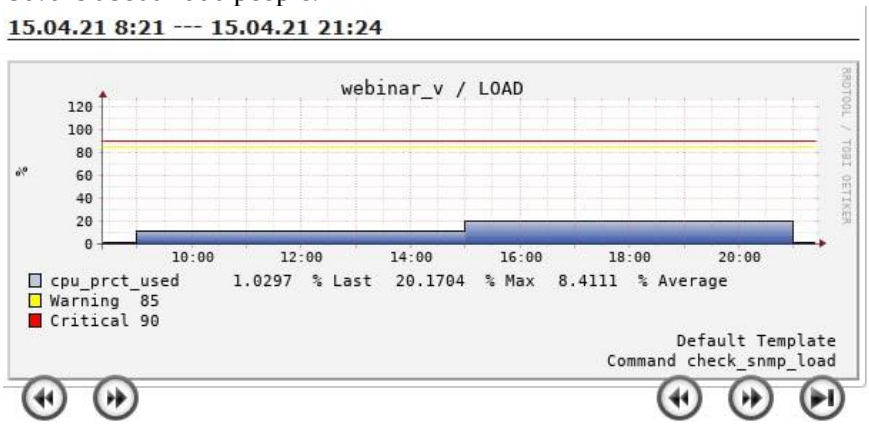

Figure 4: Loading the BigBlueButton server during the test load

To study the operability of the videoconferencing hardware and software complex in the case of a large number of video streams in one virtual room, additional tests were carried out. Users sequentially included webcams in the web conference, and the equipment load was recorded on the BigBlueButton server. When the number of video streams in one room is more than 30, problems were observed in the performance of user computers with insufficiently high characteristics. Figure 5 shows that at the moment when 36 participants in the video meeting simultaneously turned on their webcams, the processor load (Celeron with a clock frequency of 2.7 GHz) of one of the user's computers was 100% and the user was unable to participate in the web conference. At the same time, the load on the processor and RAM of the BigBlueButton server was 35-40% (Fig. 6).

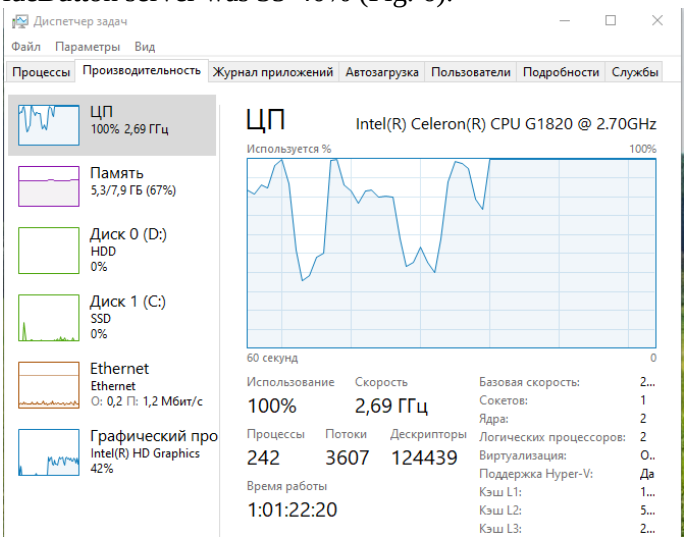

Figure 5: CPU load of the user computer

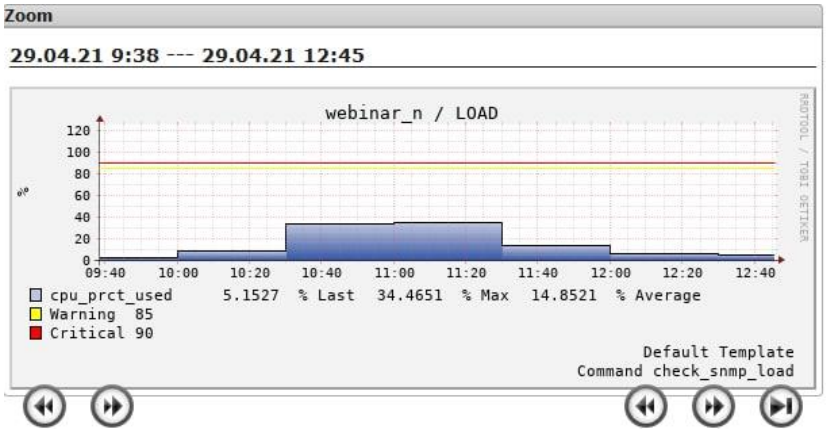

Figure 6: The BigBlueButton server load

Thus, the results of the conducted research determined the limitations on the use of the video conferencing system and allowed us to form recommendations for conducting various types of classes in virtual rooms.

Lectures. In the case of online lectures, a lecturer uses an audio-visual device and can demonstrate presentations, documents, and their desktop. Students are recommended to participate in a video conference without using a microphone and a video camera. Students can ask questions in the chat, and in the case of a discussion, participants can connect sound and camera. The recommended number of participants in one room is not more than 100-150 people.

Practical classes (seminars). This type of training involves the active interaction of participants in the educational process. Without audio-visual interaction communication of participants in the educational process will be difficult. However, it is advisable not to exceed the number of simultaneous video streams in the online room by more than 30. Exceeding this number can negatively affect the performance of participants' computers and can significantly increase the load of data transmission channels and server equipment.

Exams (tests). In the case of an interim certification, it is recommended to divide the video conference space into 2 rooms for group work. In one room, organize a waiting room, where students wait for their turn to "enter" the room for passing the exam (test). Students are present in the waiting room without using sound and a camera. When transferring to the room for passing the exam (test), the examinees are required to turn on the sound and camera. The recommended maximum number of simultaneous students in the exam hall is 5-7 people. This will ensure a normal monitoring mode for students and will not lead to an overload of communication channels, server equipment, and the computers of participants.

7. Conclusion

The conducted studies have shown that it is advisable to use the BigBlueButton system to implement the university video conferencing system used in conjunction with LMS Moodle for distance learning if the organization has its own or leased server capacities and trained personnel. BigBlueButton was originally designed as a system for conducting classes in the video conference mode, so it has excellent integration with distance learning systems. The openness of the code allows you to additionally change and configure the system "for yourself".

If the number of simultaneous users in an educational organization can exceed 1000 people, it is recommended to increase the number of servers. To implement a distributed video conferencing system, it is advisable to use a BigBlueButton server cluster with a load balancer. In this case, good integration with a distance learning system, for example, Moodle, is provided, due to the use of a standard plugin, the load on the servers is distributed evenly in real-time.

When organizing the educational process, you should take into account the restrictions: the number of simultaneous users should not exceed 1000 users per BigBlueButton server, it should be justified to use video communication in virtual conferences, the maximum number of simultaneous video streams

per server should not exceed 100. In one video conference, it is advisable not to connect more than 30 video streams at the same time, since this can lead to a maximum load of users' equipment.

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