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# THE TRANSFORMATION PROCESS FROM IN-CAMPUS CLASSES INTO ONLINE CLASSES DUE TO COVID-19 PANDEMIC SITUATION - THE CASE OF HIGHER EDUCATION INSTITUTIONS IN KOSOVO

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# The transformation process from in-campus classes into online classes due to COVID-19 pandemic situation - the case of Higher Education Institutions in Kosovo

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## ABSTRACT

The Covid-19 pandemic has caused many drastic changes in terms of traditional teaching. All the Universities of Kosovo have found the transition from teaching in class, to online classes quite challenging. Consequently, most Universities were not prepared for this adjustment and a lot of the universities before the pandemic stated that they never thought that this time would come and they would pause from classroom teaching. This study investigates the transformation of Higher Education Institution (HEI) of Kosovo from in-campus classes into online classes due to COVID-19 pandemic. Data collections were gathered from workshop and interview, resulting into qualitative data. Using 3C Lichtman approach we analyzed our data from the workshop and interview. Our analysis resulted in a new proposal of infrastructure model about 200k users in real time, regarding the sustainability aspect of this process, in order to provide a successful online teaching.



**Keywords:** infrastructure, COVID-19, online classes, traditional classes, concurrent users, video conferencing platforms.

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## GLOSSARY

HEI – Higher Education Institutions

P2P – Peer 2 Peer

SFU – Selective Forwarding Unit

MCU – Multipoint Control Unit

CPU – Control Process Unit

SLN – SUNY Learning Network

TCP – Transmission Control Protocol

UDP – User Datagram Protocol

SIP – Session Initiation Protocol

LMS – Learning Management System

BNC – Bayonet Neill Concelman

DMU – Decision Making Units

F2F – Face to Face

SWOC – Strengths Weaknesses Opportunities and Challenges

I/O – Input Output

IT – Information Technology

VR – Virtual Reality

AR – Argument Reality

SMU – System for the management of the universit

# 1. INTRODUCTION

Education is the key to a successful future, where we first learn how to read and write, and then gain knowledge about different areas. Through education our paths are opened, enabling us a happy and stable life and also making us self-dependent. Since the beginning of the millennium, we are witnessing a skyrocketing increase of Internet users worldwide. The incessant global spread of Internet backbone, the ceaseless boost of Internet speed and the continuous price reduction of Internet service resulted in Interned being used in almost every household in the world [1]. Technology has played a greater role in the today's world when it comes to Education system, the process of learning or acquisition of knowledge, skills, values, beliefs and habits [2]. Due to the COVID-19 pandemic, which bursted out this year, an entire education system was forced to make a switch from classrooms to World Wide Web. Consequently, online education took its place as a main type of education [1].

During the COVID-19 pandemic, lectures were held online, using various video conferencing platforms such as Google Meet, Zoom, BlueJeans, BigBlueButton and many others, which we will discuss in the following chapters. Video conferencing platforms enable online communication for audio meetings, video meetings, and seminars, with built-in features such as chat, screen sharing, and recording. E-Learning platforms have become very busy due to the increased number of requests to them. The fact is that not all universities used these systems 100% [3].

[1] After conducting the survey and interacting with several people we can say that a vast majority of people are facing the internet issue and lack the knowledge to use and resolve the problems related to technology, using the technology is also creating a void among the people, we all students and educational institutions need to work together to resolve the issues that are slowing us down in the development of academic life and find an absolute robust plan which help us endeavor.

This research paper is organized as follows (see Figure 1.1), Chapter 2 presents problem declaration. Chapter 3 presents literature review. Chapter 4 presents methodology. Chapter 5 presents empirical findings and a proposal of the new infrastructure model. Chapter 6 presents discussion.

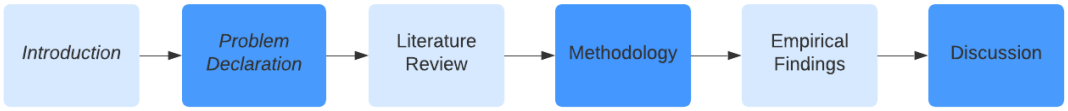


**Figure 1.1 Research Processes**

Problem declaration chapter indicates the purpose of the topic and its objectives, as well as the main problem that the topic examines. Literature Review chapter, examines online learning architecture, service providers and also related work. Methodology chapter examines data collection methods how we gathered data, data analysis using Litchmann 3C approach and also examines a case study about the transformation process from in campus to online classes due to COVID-19 pandemic, the case of higher education institutions of Kosovo. Empirical Findings chapter examines UBT faculty infrastructure they used during online learning, which results us into a proposal of the new infrastructure model for all the universities of Kosovo. Finally, discussion chapter concludes the article, shows how the new infrastructure proposal model will help all Kosovo universities.

## 2. PROBLEM DECLARATION

The spread of the COVID-19 pandemic worldwide led to profound changes in interaction and the organization of higher education institutions, where this sector felt these consequences directly in realizing the primary mission for providing the learning process to its students. Due to this situation the Universities in Kosovo, same as worldwide, were forced to switch to online classes since the country locked down. This process was organized ad-hoc, without any advanced planning, that's why many of them questioned the readiness of their institution to provide online learning by having in mind their current infrastructure.

### 2.1 The aim and objectives

The aim of this research is to identify the use of their network infrastructure and specific platforms from Universities in Kosovo for providing online teaching. Furthermore, based on the Universities experience a model will be proposed, when dealing with more than 200k users (students / professors) within the same time. Both the aim and objectives has been inherited from the project funded by Ministry of Education, Science and Technology, namely "The transformation process from in-campus classes into online classes due to COVID-19 pandemic situation - the case of Higher Education Institutions in Kosovo". The objectives of this thesis are as follows:

O1: Analysis of technological infrastructure and platforms used by Universities during COVID – 19 pandemic

O2: Analysis of technological infrastructure and platforms used in five Universities in Kosovo during COVID pandemic - 19

O3: Propose a new macro-based model on the whole Kosovo nation (for 200K students)

O4: Evaluate the performance of new proposed model in small scale – UBT Case

# 3. LITERATURE REVIEW

Today, due to COVID-19 situation, the Universities needed to switch to online classes 100% of their services. This chapter described the research that is investigated for a number of Universities worldwide and tried to grasp the knowledge in a context of the particular countries how these institutions have been affected during this pandemic, specifically on demands of IT services and how students and teachers are affected from this situation.

This chapter will give the fundamental concepts of tools that are used from Universities with focus to video conferencing tools as part of real-time online learning, especially the chosen architecture their topology.

## 3.1 Video conferencing as part of real-time online learning – online learning architectures

According to [4], video conferencing as part of real-time online learning allows two or more people to have real-time communication through voice and images. Real-time communication (synchronous communication) can be through audio, video, chat and many other opportunities that would help raise the level of interactivity between the participants. This way of communication can be accomplished by using network infrastructure.

In order to run successfully video conferences, it is enough for the end users to have the audio/video equipment (PC, headphones and listeners), and to determine the software they will use to perform such a service, for example: Skype, Viber, Facebook, to name a few.

However, if in this case we would like to realize video conferencing with a larger number of participants (such as in primary, or secondary classes or even Universities), then in addition to the end-user requirements mentioned above, analyzing from an organization perspective, such as the University itself, the infrastructure, and the selection of tools and platform are also important components. The latter is extremely important if we decide to provide such a service for the mass of users, such as the

University students. Depending on the number of participants that such a platform / software will support, the University need to determine the topology used as part of video conferencing, the architecture and infrastructure technical components.
In this thesis, the topology is defined as [5] network topologies are one major building block for data communication. They describe how network entities are directly interconnected with each other and thus define how information may flow. Such a structure of node relations can be built on different layers resulting in a physical or logical topology. The first will be constructed while connecting devices by a physical medium. On top of this structure data exchange can be arranged via the network and application layer creating a logical or overlay topology.

The network architecture refers to the way network devices and services are structured to serve the connectivity needs of client devices. The physical network infrastructure is required for a contemporary university network. University Management and IT manger may know exactly what kind of network they want to setup, upcoming plans, and expected growths is more complicated to understand [6].

The IT infrastructure [7] refers to the combined components needed for the operation and management of enterprise IT services and IT environments. If an IT infrastructure is flexible, reliable and secure, it can help an enterprise meet its goals and provide a competitive edge in the market. Alternatively, if an IT infrastructure isn't properly implemented, businesses can face connectivity, productivity and security issues—like system disruptions and breaches. Overall, having a properly implemented infrastructure can be a factor in whether a business is profitable or not. The components of IT infrastructure are made up of interdependent elements, and the two core groups of components are hardware and software. Hardware uses software—like an operating system—to work. And likewise, an operating system manages system resources and hardware. Operating systems also make connections between software applications and physical resources using networking components.

Currently, in video conferencing there are three different topological approaches that could be followed to deliver the services, Peer-2-Peer topology (hereafter P2P), Selective Forwarding Unit (hereinafter: SFU), and Multipoint Control Unit (hereinafter: MCU).

For the organizations, in order to determine which of the topology is good to follow, the number of their concurrent users in the video conference should be one of the defining criteria. As the number of concurrent users increases, so does the bandwidth which is required to transmit voice and real-time images to all participated users. Further, this increase in the number of participants would also affect the performance of the computer's CPU (hence their specifications) as real-time both voice and images must be encoded and decoded in convenient to be transmitted on one side, and adapted for the end user on the other side.

The P2P (mesh) topology could be used as a topology that would provide direct links between the users of the video conference, in which case each participant would be linked to each other (See Figure 3.1). But if we had an increase in the number of users the bandwidth load would increase, in which case any increase in users after the third participant would degrade the call quality exponentially. The main advantage [8] of P2P approach is scalability; each peer offers resources such as bandwidth, processor and memory to other nodes. Unfortunately, the bandwidth demand of video communications prevents these applications to form a multipoint (MP) video conferencing environment and limits them to only point-to-point video communications (Alhamza et al, 2012). This is mostly because of the fact that low bandwidth connections (e.g., ordinary modem over a phone line or wireless GPRS) that are barely enough for point-to-point video communications make more than one video connection infeasible. The main benefit [8] of implementing application layer multicast is overcoming the lack of large-scale IP multicast deployment at the network layer. Due to the benefit inherent in P2P systems, this paper presents a videoconferencing systems based on P2P Architecture.

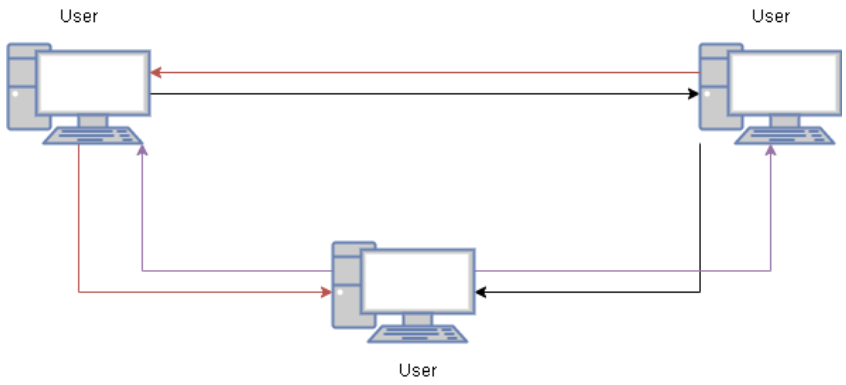


Figure 3.1 Peer to Peer Topology

In Figure 3.2, is depicted the SFU topology. The SFU topology receives audio and video transmissions streams from all users in a central device, and then the users receive through this center the streams separately from all other users. As the number of stream lines increases, the NSP topology in this case offers the possibility that users can determine which stream line they wish to have with higher bit rate, and this determination would result in the degradation of the traffic for the rest of the stream lines. In this case, the SFU would adapt to each participant's request, and would favor the quality of those participants stream line for which all other users were designated. That is to say, of all the users, the highest quality stream line would be dedicated to only one user. In this case it could be the professor line, which would utilize the greater capacities to deliver online teaching.

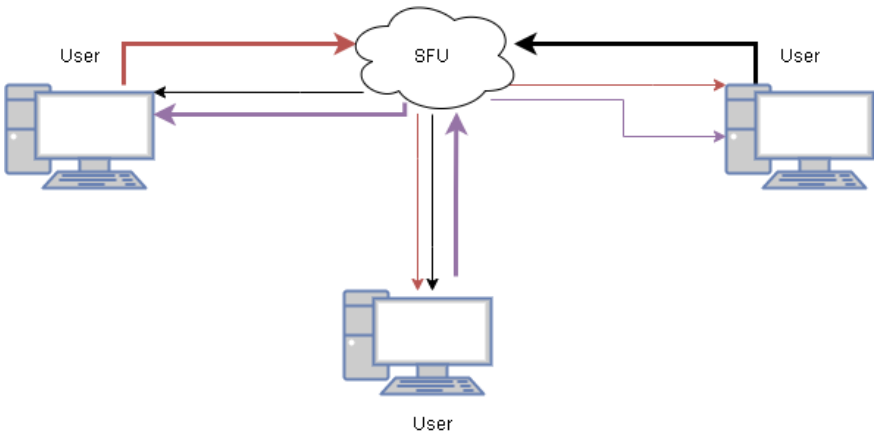


Figure 3.2 Selective Forwarding Unit Topology

Unlike the SFU, which receives and sends video and audio transmissions from the host participant to all other users, the MCU topology accepts all streams, encodes and decodes them, then combines all streams within one stream, and then sends the combined stream to all users through that shared channel (see Figure 3.3).

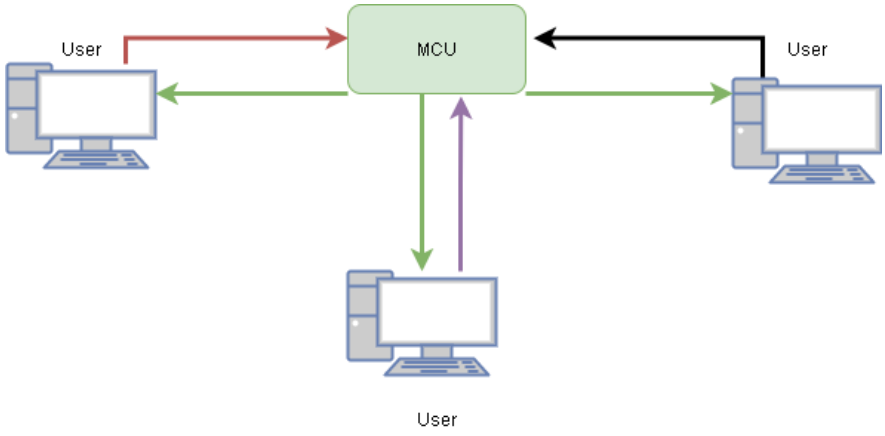


**Figure 3.3 Multipoint Control Unit Topology**

MCU, unlike other topologies is particularly favored when dealing with more than 10 video conferencing users, and moreover this topology can support signaling through SIP or H.323 protocols, the protocols used in networks to separate UDP traffic from that TCP, or more precisely, real-time traffic (which in this case is the voice that needs to be transmitted in real time), from that traffic that can be transmitted in non-real time, which means there is greater tolerance (for example, browsing a website). The MCU topology, unlike the SFU topology, has a very low latency, so it is very rare that the interruption of voice, voice mismatch, image freeze, etc. can occur.

## 3.2 Service Providers – online learning applications

Today, there a number of service providers that offer video conferencing services, however according to an online article [9] we will list only 5 of them, which are also used within the Universities in Kosovo.

Today, from one side, there are those providers that offer ready-made platforms and the institutions can only pay for their service, and from the other side, there are those

providers that offer their services as an open-source platform. The latter one offer their code for free, so the institutions can use, adapt or even further develop in the context of their institutions needs and requirements.

In Table 3.1, lists a number of commercial providers, but all of them also offer a limited free version.

**Table 3.1 Commercial video conferencing service providers**

| Providers | Meeting Duration | Users | With the same account | Address |
|---|---|---|---|---|
| **Zoom** | 40 min | 100 | Unlimited | https://zoom.us/ |
| **WebEx** | 40 min (unlimited during COVID-19 pandemic) | 50 (100 during COVID-19 pandemic) | 1 month (90 days during COVID-19 pandemic) | https://webex.com/ |
| **GoToMeeting** | 40 min | 250 | 14 days | https://gotomeeting.com/en-ie |
| **GoogleMeet** | Unlimited | 250 | G Suite users | https://meet.google.com/ |
| **BlueJeans** | 2 hours | 100 | Without needing to sign in or create an account | https://www.bluejeans.com/products/meetings |

Before accessing these platforms listed in Table 3.1, the users should have an open email, and then through this email the users can open an account to use the video conferencing services.

Through an account, the users can create unlimited number of video conferences, but their duration is limited to certain minutes (with respect to users of zoom.us is limited when we have 3-100 users, while unlimited for less), in addition to Google Meet which

offers unlimited video conferencing duration for up to 250 users, it also demands the Universities to be part of G Suite clients, in Kosovo context, most educational institutions are G Suite clients. Another feature where these providers vary is the number of users in that video conference. Discussing free versions, zoom and WebEx video conferencing services are open to 100 users, while GoToMeeting and Google Meet for 250 users each.

It is worth noting that with an email account, the free version is limited to one month on WebEx (90 days at the time of the COVID-19 pandemic), and 14 days on GoToMeeting, while other providers have no limit at all.

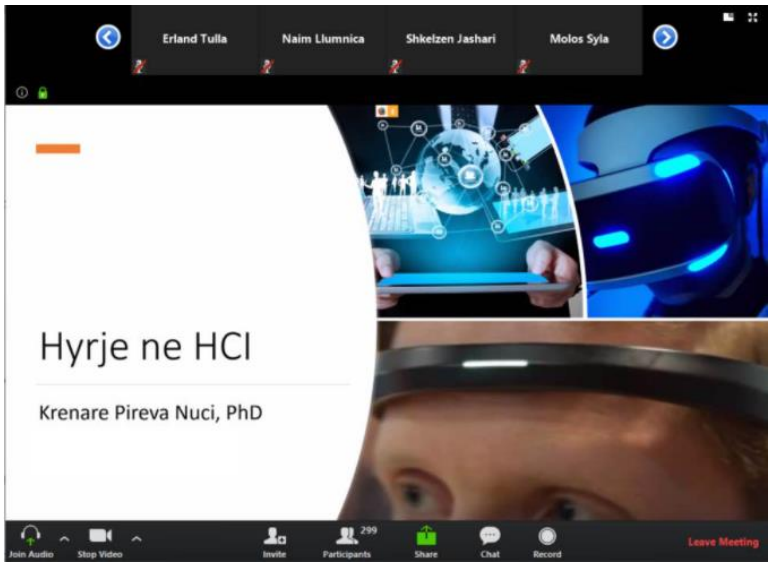


**Figure 3.4 Online teaching through Zoom.us**

However, if we think and plan that such a services can be provided to a larger number of users and for a longer time, then it is a very good opportunity to decide on the adaptation or further development of one of the providers listed in Table 3.2 that offer their platforms as open source.

Table 3.2 Providers of open source platforms for video conferencing services

| Providers | Technology | Topology | Users | Address |
|---|---|---|---|---|
| BigBlueButton | Java | MCU | 1-1000+ | https://bigbluebutton.org/ |
| Licode | C++ | MCU | 1-1000+ | https://lynckia.com/licode/ |
| Jitsi | Java, JavaScript | SFU | 1-1000+ | https://jitsi.org/ |
| Kurento | C, C++ | MCU | 1-1000+ | https://kurento.org/ |
| Jami | C,C++ | Distributed | 1-1000+ | https://jami.net/ |
| Linphone | C, Java, C#, Python | SIP | 1-1000+ | https://linphone.org/ |
| ezTalks Cloud Meeting | Asp.net | Star | 1-1000+ | https://eztalks.com/ |

All providers listed in Table 3.2, offer their free platforms (protected by open source licenses) with the possibility of their adaptation and further development for the institutions.


Figure 3.5 Online teaching through the Big Blue Button

However, to determine for one of these listed providers (see Table 3.2) it is good to set measurement criteria that would facilitate the decision-making process. For example, for the particular institution if the number of users in real time is very high then the

institution should have knowledge of which topology to determine as described in section 3.1, then with what technology it has been developed, what functions it offers (screen sharing, board writing, handshake by users, providing images through the camera, recording lectures, communication via chat) and so on.

Bigbluebutton [10] is an open source web conferencing system for online learning. This means you have full access to BigBlueButton's source code under an open source license. Web conferencing system, you get the core features you would expect from a commercial web conferencing system. These features include real-time sharing of audio, video, presentation and screen – along with collaboration tools such as whiteboard, shared notes, polling, and breakout rooms. BigBlueButton can record your sessions for later playback. BigBlueButton has built-in integrations with all the major learning management systems (LMS), including Canvas, Jenzabar, Moodle, Sakai, and Schoology (see Figure 3.5).

Licode [11] is an open source project that allows you to include real-time communications like streaming or video conference in your web application in a very easy and fast way.

Jisti [12] is a set of open-source project that allows you to easily build and deploy secure videoconferencing solutions. At the heart of Jitsi are Jitsi Videobridge and Jitsi Meet, which let you have conferences on the internet, while other projects in the community enable other features such as audio, dial-in, recording and simulcasting.

Kurento [13] is an open source software project providing a platform suitable for creating modular applications with advanced real-time communication capabilities. Kurento is a WebRTC media server and a set of client APIS making simple the development of advanced video applications for www and smartphone platforms. Kurento Media Server features include group communications, transcoding, recording, mixing, broadcasting and routing of audiovisual flows.

Jami (formerly GNU Ring and SFLphone) is an open source SIP-compatible softphone and SIP-based instant messenger for Linux, Microsoft Windows, Mac OS X and Android(a screenshot shown in Figure 3.6) [14]. With this software you can make calls,

create conferences with multiple participants, share media, send text messages during calls or out of calls. Features include: unlimited number of calls, instant messaging, scall recording, audio and video calls with multi-party audio and experimentally video conferencing.

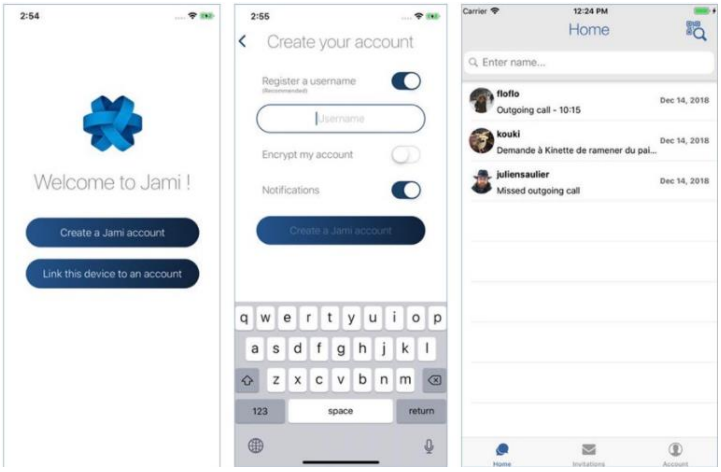


**Figure 3.6 Jami platform**

GNU (GPL) General Public Licensed - Linphone is a free voice over IP softphone widely used for Voice over IP, instant messaging, video conferencing. Initially, Linux was the base for developing Linphone, but now it also works on Microsoft Windows, Mac OS X, and mobile phones running Windows Phone, iOS, or Android. Linphone software (see Figure 3.7) offers an easy-to-use graphical interface. It provides advanced calling features like HD video calls with video preview, audio conference call, and call transfer & multi-call management (pause and resume). The software facilitates enhanced audio and video quality. It provides an enhanced instant messaging experience. It assures absolute security with audio and video encryption and end-to-end encryption for messaging.


**Figure 3.7 Linphone platform**

The cloud-based video conferencing system ezTalks (a screenshot in Figure 3.8) offers small & medium-sized businesses and large enterprises an exceptional platform to communicate as well as collaborate online. This best video conferencing software support Windows, Mac, Android, iPhone, and iPad applications. It facilitates HD video conferencing with different plans and packages. The ezTalks software provides free software hosting up to 100 users. The software incorporates HD video and audio, an innovative whiteboard, and a cross-platform chatting system. It supports playback, recording, and scheduling features to allow the users to share video and audio recordings and send them reminders about upcoming meetings or webinars.

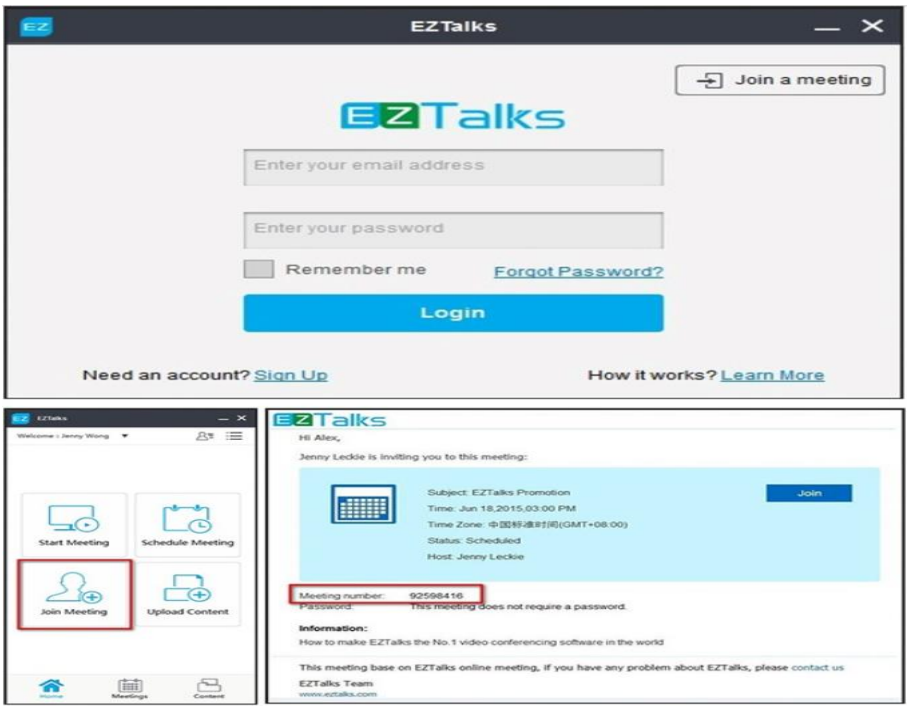


**Figure 3.8 Eztalks platform**

## 3.3 Related Work

Earlies in 2005, a research investigated the use of learning management system and other applications in Universities [15]. From this research resulted that only two institutions reported not currently using LMS, all other institutions have used at least one LMS (In total participated 111 Institutions). Seven institutions (37%) reported using only the institution-wide LMS, and did not use other systems. The OECD/CERI survey also asked to report about other IT applications than LMS. All sample institutions reported significant and ongoing investment in IT networks to support on-campus activity and/or distance learning, and many reported adequate functionality/bandwidth to support eLearning in the short-to-medium term. On campus, the standard model was Ethernet linked by fiber optic connections between buildings/campuses (typically one gigabit backbone, and around 100 megabit to the desktop) –with some institutions reporting plans to upgrade to one gigabit Ethernet

within buildings (see Figure 3.9). To give an indication of capacity, a number of institutions reported operation-wide multicast streaming functionality, or cited imminent upgrades to this effect. Some institutions reported examples of ongoing dependence on Bayonet Neill-Concelman BNC cables as well as Ethernet. Many institutions were connected to both the commodity Internet and dedicated, higher bandwidth academic networks.

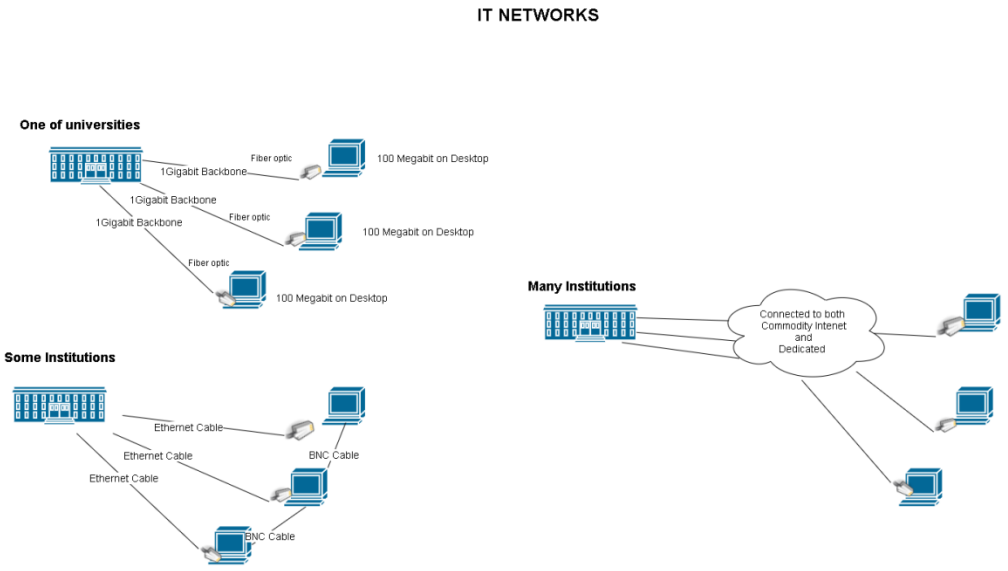


**Figure 3.9 Networks, Bandwidth of network, cables they used**

This gives enough argument to claim that universities have started to invest in infrastructure which was a plus once we started to experience the pandemic situation.

According to [16] a student's perspectives (the sample is 126 students from undergraduate and graduate studies)research study was conducted for Pakistani higher education students towards compulsory digital courses and distance learning in universities due to the Coronavirus pandemic (COVID-19). Undergraduate and postgraduate studies were surveyed to find out their perspectives on online education in Pakistan. The study findings highlighted that online learning may not produce the desired results in developing countries like Pakistan, where the vast majority of students are unable to access the internet due to technical and monetary issues. This study_[3] listed several problems that were highlighted by the students, such as:

- Lack of face-to-face interaction with the instructor,

- response time, and
- lack of traditional classroom socialization

In contrast to [3] which conducted the students perspective toward the online learning, the research paper [17] investigated the challenges for teaching successful online courses in Higher Education. A review of the literature using the COOPER framework was carried out to identify such issues. The cooper framework [18] involves six interrelated phases: Concepts and objectives, On structuring data, Operational models, a Performance comparison model, Evaluation and Results and deployment. Taking the first letter of each phase we obtain the COOPER- framework. In large and complicated datasets, a standard process could facilitate performance assessment and help to (1) translate the aim of the performance measurement to a series of small tasks, (2) select homogeneous DMUs and suggest an appropriate input/output selection, (3) detect a suitable model, (4) provide means for evaluating the effectiveness of the results, and (5) suggest a proper solution to improve the efficiency and productivity of entities (also called Decision Making Units, DMUs).

The three main categories of findings were identified under the categories of:

- issues related to online students,
- instructors and
- content development part.

According to [4], student issues included student expectations, readiness, identity, and participation in online courses. Instructor issues included changing faculty roles, face-to-face transition online, time management, and teaching styles. Content issues included the role of instructors in content development, the integration of multimedia into content, the role of guiding strategies in content development, and considerations for content development.

The authors in [19], investigates how coronavirus pandemic is forcing global experimentation with distance learning, by emphasizing the shift to virtual learning for future of higher education institutions. There are many indications that the pandemic

crisis will transform many aspects of life including education if distance learning proves to be successful. As this crisis-driven experiment begins, the research in [5] gathered data driven by three research questions about the business model of higher education and the possibility of achieving quality college education:

1. Do students really need a four-year residential experience?
2. What improvements are required in the IT infrastructure to make it more suitable for online education?
3. What training efforts are required by faculty and students to facilitate changes in manners and behaviors?

The paper [5] researched IT infrastructure and IT support staff in private and public universities and also to examine the costs students have to avoid if online learning is successful. The ongoing coronavirus pandemic has forced a global experiment that could highlight the differences between cost-benefit trade, the set of services offered by a residential university, and the ultra-low-cost education of an online education provider like Coursera. A few years ago, experts predicted that massive open online courses (MOOCs), such as Khan Academy, Coursera, Udacity and edX, would kill F2F college education - just as digital technologies were killing the work of telephone operators and agents of travel. So far, however, F2F college education has stood the test of time.

The paper [6] emphasizes in order for the Universities to prepare the students to be successful for the future they should provide a strong and flexible learning infrastructure, capable of supporting and providing ubiquitous access to technology tools that allow students to create, design and explore. Essential components of an infrastructure capable of supporting transformative learning experiences include:

- Ubiquitous connectivity,
- Powerful learning devices,
- High-quality digital learning content,
- Responsible use policies (RUPs).

According to [7] the COVID-19 pandemic challenged the education system worldwide and forced teachers to switch to an online overnight teaching mode. Many academic

institutions that were previously reluctant to change their traditional pedagogical approach had no choice but to switch entirely to online teaching-learning. The paper in [7] covers the importance of online learning and provided analysis of Strengths, Weaknesses, Opportunities and Challenges (SWOCs) of learning in times of crisis. This paper sheds light on the growth of EdTech Start-ups during times of pandemic and natural disasters and includes suggestions for academic institutions on how to address the challenges associated with online learning.

As strengths are identified the:

- Time flexibility,
- Location flexibility,
- Catering to wide audience,
- Wide availability of courses and content,
- Immediate feedback.

As part of weaknesses are identified:

- Technical Difficulties,
- Learner's capability and confidence level,
- Time management,
- Distraction,
- Frustrations,
- Anxiety and confusion,
- Lack of personal / physical attention.

Further the paper [7] as opportunities identified:

- Scope for innovation and digital development,
- Designing flexible programs,
- Strengthen skills: problem solving, critical thinking and adaptability,
- Users can be of any age,
- An innovative pedagogical approach.

Whereas as challenges are listed:

- Unequal Distribution of ICT infrastructure,
- Quality of education,
- Digital illiteracy,
- Digital Divide,
- Technology cost and Obsolescence.

The study [8] investigated from an abstract level the service quality, system quality, information quality, user satisfaction, system usage and the success of the e-learning portal. The output of the study is useful for policy makers of Malaysian universities such as senior management, ministry of higher education, union of Malaysian universities in designing policies and programs for the success of the eLearning portal in the country.

The authors in paper [20] evaluated the availability and effectiveness of administrative support for online teaching faculty. When administrators make decisions about the infrastructure needs of an actual online teaching program, these decisions are often based on the advice of outside experts. In this context, the online teaching faculty should be the best source of advice and information to see what fits and what does not fit to their need. Four main factors were the focus of this study (see Figure 3.10):

1. Faculty perceptions of what elements are important for developing a successful online teaching program
2. Perceptions of which of those elements were successfully implemented in the specific institution
3. Factors that serve to increase faculty participation in an online curriculum, and what factors hinder their involvement
4. Faculty perceptions of the expected clarity and effectiveness of the Matrix.

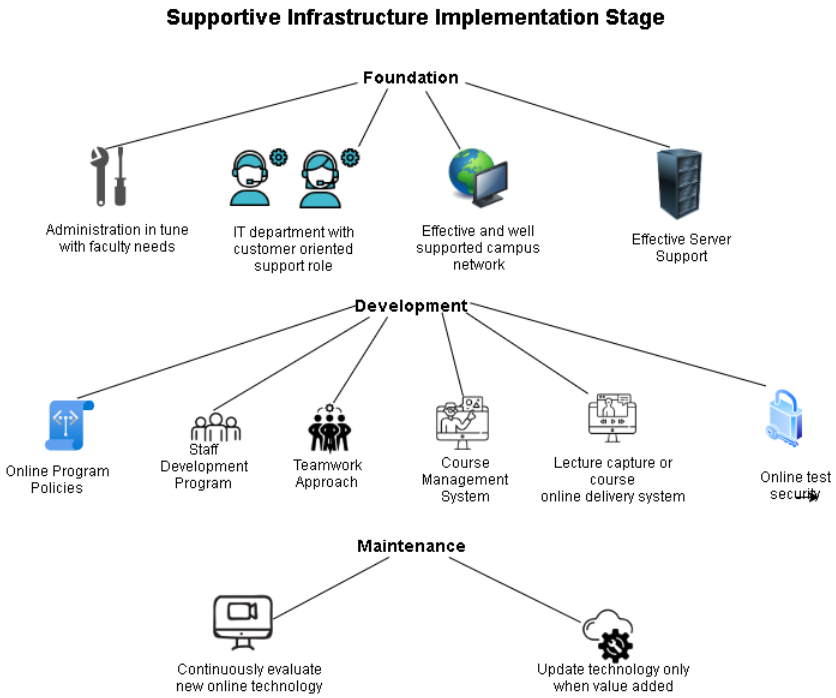


**Figure 3.10 Supportive infrastructure implementation stage**

Paper [10] addresses the possibility of further decision-making for the academic future during any type of disaster. The study emphasized the essential requirements of online teaching-learning in terms of education during the COVID-19 pandemic and show how the resources of educational institutions have effectively transformed formal education into online education through the help of virtual classrooms and other online equipment [10]. The research conducted treated three different aspects:

- Discover the different forms of online teaching-learning methods used during the COVID-19 pandemic.
- The perceptions of teachers and students on online teaching-learning during the COVID-19 pandemic.
- The challenges faced by teachers and students in adapting to the online teaching-learning process during the COVID-19 pandemic.

Further in [21], investigated how institutions in Pakistan run the online learning during COVID 19 situation, and the main focus was to explore the perception of teachers and students about the advantages, limitations and recommendations.

Reflections based on the existing literature and recent international datasets research paper using existing literature and evidence from the latest international data was conducted in [22]. The researchers gathered the articles from a number of online databases (Eurostat, PISA, ICILS, PIRLS, and TALIS) with respect to better understand how the COVID-19 crisis has affected students learning. The authors claimed that the students will not learn as much as they did before. Further, the authors claimed that COVID-19 will not affect all students equally, will adversely affect both cognitive and non-cognitive skills acquisition and may have long-term consequences other than short-term ones. Although online learning has a lot of potential, it is most effective when students and teachers have had time to prepare. The research conducted in School Education Gateway study[12], between April 9 and May 10, 2020, attracted 4,859 respondents from more than 40 countries, of (86% were teachers or school principals), indicating that, during COVID-19, most of teachers (66.9%) had taught online for the first time. Moreover, many teachers resulted to have had problems accessing technology (computers, software, reliable internet connections, etc.).

Paper [13] investigates the approach of offering online learning from technology and infrastructure in terms of hardware and software, namely the SUNY Learning Network SLN server infrastructure (see Figure 3.11). Further it investigates how much interaction was provided from students in the classroom and how much in the online classes. According to the interaction of students in online classes, the results shows that the interaction in the classroom compared to online learning resulted only 3% less.

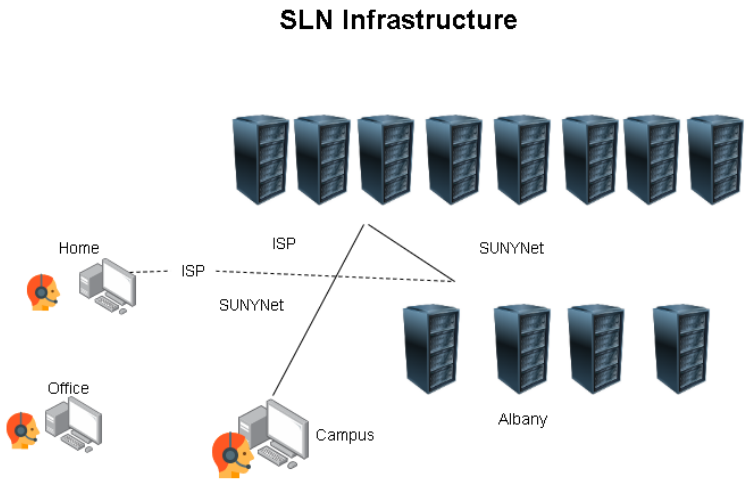


Figure 3.11 SLN infrastructure

According to [23] first experiment: The whole lecture was organized online due to COVID-19, and keeping the students engaged and more active virtually was challenging. Therefore, the first experiment targeted the engagement and interaction among professors and students in distance learning during the quarantine experience. Initially, the lecture started on a specific topic in HCI using the Zoom and BigBlueButton video conference platforms, and after covering the main learning objective of the specific topic, an in-lecture quiz using online quiz platforms was offered to the students to trigger their presence and keep them more engaged with the lecture. The in-lecture quiz was performed using different tools, where the control group used Google Form Quiz, and the experimental group used Kahoot!. Since the Kahoot! platform has more gamification components, the authors were curious to know whether these components, besides the usability approach, would contribute to increased engagement of the students in the learning process and interactivity among the professor and students.

The paper [24] investigated the challenges and problems associated with taking online classes in developing a country, such as Pakistan is today. The results claimed that students faced a number of problems while attending online lectures. Key problems include inadequate study environment, inequality in equipment availability, insufficient online study material, lack of internet access or slow internet speed, and reduced workload. In the context of this study, the authors recommended to reduce the length of online classes, and in order to encourage students and make effective online classes the institutions should

provide student training, easy availability of tools and cost-effective student online packages to be introduced

Latetly, the research paper [25] proposed a framework to guide an education how to respond to pandemic situation in order to support education decisions to establish and implement effective education. Research shows that education system leaders and organizations develop plans for continuing education through alternative modalities. They claimed that if an online educational strategy is not feasible, alternative distribution tools may be developed including television programming, if it is a partnership with television stations is feasible, podcasts, radio broadcasts, and instructional packages either in digital or paper form (same approached followed also by Kosovo Institutions for primary and secondary schools).

According to [26], to understand the issue of internet connectivity and how to use technology and the problem-solving skills they conducted a small survey upon a group of 160 people approx. to understand them more clearly. During the pandemic one the major issues faced was that when the schools & colleges started teaching online there was a lack of equipment in nearly about every household, out of 100 only 3.13 homes have personal computers & out of 100 people only 1.34 households have broadband connection [26].

The main indicators of ITIS that determine its quality are: availability, reliability, safety, confidentiality, integrity, maintainability [27]. In addition to availability, it can give us a precise information about the quality of the service, because in order to be of high quality, it must not only be available but have an acceptable level of response to customer requests [27]. In order to have quality assessment of IT IS by calculating quality indicators according to [27] it is necessary: To install appropriate software products that monitor the state of the systems and record the values of indicators such as: CPU usage; data pool, data volume and drives I/O operations per second, response time, capacity, Read/Write operations MB/s, cache usage, transfer size.

To investigate further the gap within the body of knowledge we listed the reviewed paper in Table 3.3, and emphasized the dimensions that have been analyzed from a number of researchers and presented in their respective papers with respect to online learning in pandemic situation.

Table 3.3 The general perspective online learning due to COVID 19

| | Student perspective | Teacher Perspective | Institution Perspective | IT perspective |
|---|---|---|---|---|
| Paper [1] | + | + | - | - |
| Paper [2] | + | + | - | - |
| Paper [3] | + | + | - | + |
| Paper [4] | - | - | - | + |
| Paper [5] | - | - | - | + |
| Paper [6] | - | - | - | + |
| Paper [7] | - | - | - | + |
| Paper [8] | - | - | + | + |
| Paper [9] | - | - | - | + |
| Paper[10] | - | - | - | + |
| Paper[11] | - | - | - | + |
| Paper[12] | - | - | - | + |
| Paper[13] | - | - | - | + |
| Paper[14] | - | - | - | + |
| Paper[15] | + | + | + | + |
| Paper[16] | + | - | - | - |
| Paper[17] | + | + | - | - |
| Paper[18] | - | - | - | - |
| Paper[19] | - | - | - | + |
| Paper[20] | - | - | - | + |
| Paper[21] | + | + | - | - |
| Paper[22] | + | + | + | - |
| Paper[23] | + | - | - | + |
| Paper[24] | + | - | - | - |
| Paper[25] | - | - | + | - |
| Paper[26] | + | + | - | - |
| Paper[27] | + | + | - | + |
| Paper[28] | - | - | - | - |

Referring Table 3.3, we see that only papers 3,4,5,6,7,8,9,10,11,12,13,14,15,19,20,23,27 treated the online learning from the IT perspective. Therefore, we extracted those papers from Table 3.3 and created Table 3.4, in order to investigate further the sub-dimensions of IT that have been investigated from the respective papers.

**Table 3.4 The IT perspective dimensions researched so far**

| | Infrastructure | Video Conferencing | Learning Management System | Online Learning Platforms |
|---|---|---|---|---|
| **Paper [3]** | + | + | - | + |
| **Paper[4]** | + | - | - | - |
| **Paper[5]** | + | - | - | - |
| **Paper[6]** | + | - | - | - |
| **Paper[7]** | + | - | - | - |
| **Paper[8]** | + | - | - | - |
| **Paper[9]** | - | + | - | + |
| **Paper[10]** | - | + | - | + |
| **Paper[11]** | - | + | - | + |
| **Paper[12]** | - | + | - | + |
| **Paper[13]** | - | + | - | + |
| **Paper[14]** | - | + | - | + |
| **Paper[15]** | + | - | + | - |
| **Paper[19]** | + | - | - | - |
| **Paper[20]** | + | - | - | - |
| **Paper[23]** | - | - | - | + |
| **Paper[27]** | + | + | + | + |

From Table 3.4 we see that papers 3,4,5,6,7,8,15,19,20 treated infrastructure, therefore the aim of this thesis, due to the result that came out of the Litchman 3C approach, it was necessary to focus on the infrastructure part as the most important part. This paper compared to the above works is differentiated based on infrastructure and video

conferencing information which were used by Kosovo universities during the COVID-19 pandemic.

# 4. METHODOLOGY

This chapter gives an overview regarding the methodology used and it describes how the data are collected and analyzed. Figure 4.1, describes the methods used for each phase of the research.

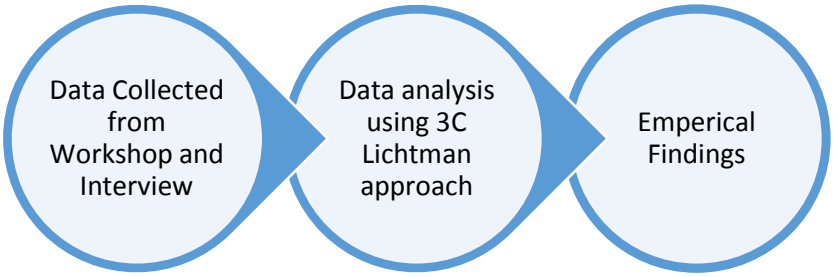


**Figure 4.1 Methodology Processes**

Each of the processes as part of the methodology is described further in the following sections.

## 4.1 Data Collection

Firstly, to create an understanding of online teaching and learning we have gone through a number of papers described in the literature review as well. There is defined a search strategy for collecting most relevant papers, such as combining keywords for online learning, University infrastructure, video conferencing, online platforms for learning.

Secondly, a workshop is organized 22$^{nd}$ of December 2020 with key stakeholders, the CTO of Universities in Kosovo, with the aim to address the readiness of the technology infrastructure of Universities within Kosovo to provide online teaching during the COVID-19 pandemic. The workshop is organized online due to COVID situation using the Big Blue Button and a screenshot is presented in Figure 4.2.

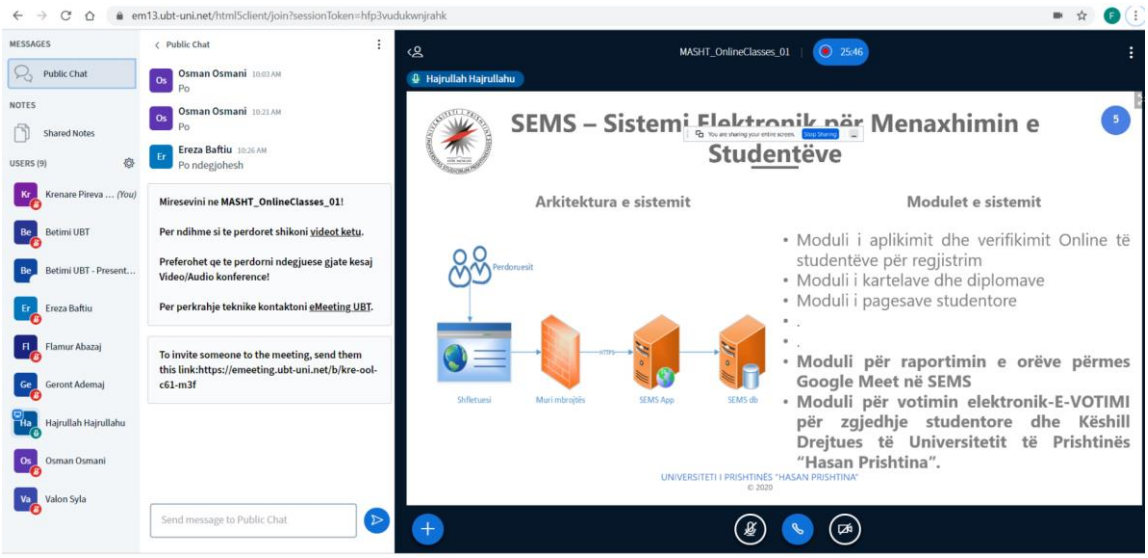


**Figure 4.2 A screenshot from the workshop**

This workshop is supported by a project funded by the Ministry of Education Science and Technology in Kosovo and led by my supervisor. This workshop aimed

. In this workshop participated chef technology officers from five different Universities:

- University for Business and Technology
- University of Pristina
- University of Prizren
- University of Gjilan
- IBCM Mitrovica

The discussion has been recorded, and the transcript was documented. One of the main leaders of this process were the IT offices of the participating Universities. For each CTO was allocated 15 minutes presentation which described the current University infrastructure, the platforms that are used for online learning, the challenges they experienced while supporting the switching process from in-campus classes into online classes. The workshop concluded with one hour discussion and exchanges of experiences among the participants (See Figure 4.3).

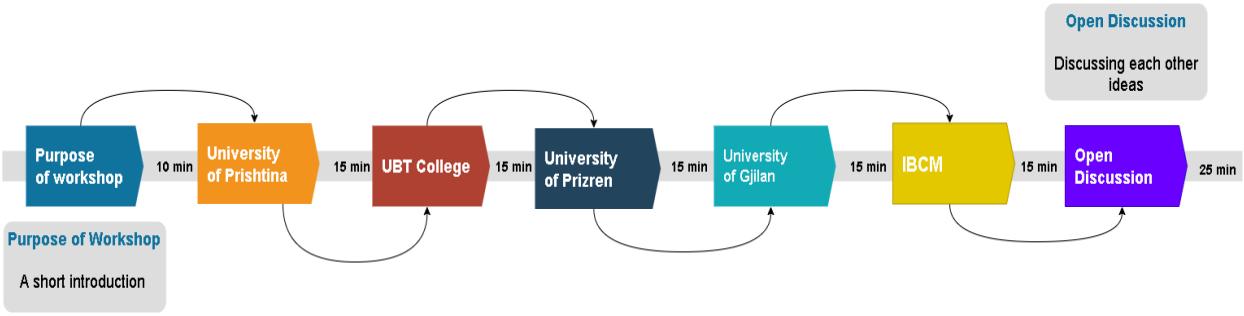


**Figure 4.3 Workshop workflow**

Finally, as part of this research we have conducted an interview with a key expert of IT and discussed our findings from the collected data.

## 4.2 Data Analysis

Having in mind that for data collection is used qualitative method, during this research we reviewed a number of data analysis methods and came up to Litchmann 3C approach [28], and similar to the approach followed in [23].

Since the data collection has used the qualitative method. The documented transcript is text based and using the Litchmann 3C approach [28] we resulted in six categories.
In Figure 4.4 presents the results of data analysis in three columns. The first columns lists the summary of most frequent discussion within the workshop, the second column lists the technologies derived from the summary of discussion in column 1, and the third column, extract the categories that the participants mostly discussed about.

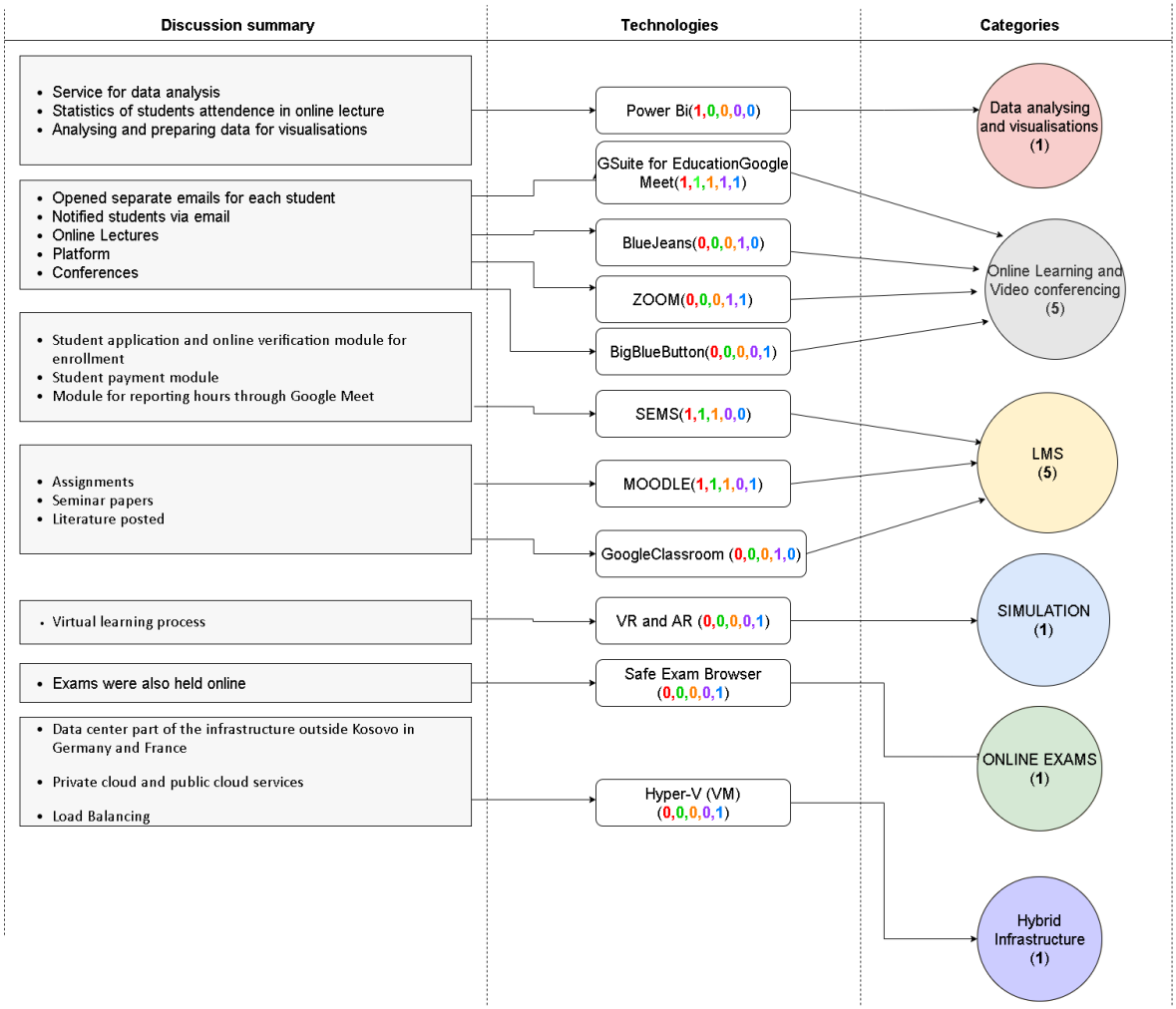


**Figure 4.4 Qualitative analysis of experts discussion**

Categories such as: Power Bi platform, which platform used University of Pristina to analyze and to prepare data for visualization. Using this platform they also generated statistics of students' attendance in online lecture.

Each of the five participants' universities has been using different platforms in order for online learning and video conferencing. Some of those platforms where G Suite for Education Google Meet which was used by all the universities. This platform helped opening emails for each student in order to take online classes. The Blue Jeans platform which is used only by IBCM. Big Blue Button platform is used by UBT College since they had their own infrastructure. Further, Zoom platform which is used by IBCM and

UBT College, all these generated the Online learning and Video Conferencing category (See Figure 4.4).

Learning Management System (LMS) category is created from all three platforms that universities declared that they are using in order to provide the learning materials, such platforms as SEMS, Moodle and Google Classroom. SEMS is developed by University of Pristina, and they shared it with University of Prizren and University of Gjilan. Moodle was used by all of the universities to publish learning materials for students online, for assignments and seminar papers, except for IBCM that they used Google Classroom platform.

As additional, UBT College declared that they have used virtual and augmented reality for simulation during online classes. The same platforms are used also for the online exams, except that UBT integrated also the Safe Exam Browser for avoiding potential misuse of exam time period.

# 5. EMPIRICAL FINDINGS AND ANALYSIS

This chapter presents the empirical findings from the data collect. The findings are presented in four different section and all of them related to the key categories that resulted from the data analysis.

## 5.1 Before COVID-19 phase

Since 2019 UBT made an agreement with EON Reality and they started to use the virtual and augmented reality services prior to the pandemic. They have also been prepared before the pandemic for online learning, since there have been cases where students have organized online learning, but of course this was not the same case as in pandemic when the UBT took the decision to switch to online classes 100%. Since 2010, the Moodle platform has been implemented and professors and students contributed with the learning materials, submission of seminars and assignments. After the implementation of Moodle, they extended their services with G suite for Education, by providing email account for all professors and students. Further, UBT developed various systems one of which is the Student Management Information System (SMIS) for additional administrative services. UBT has started researching various online platforms in the past in order to create the system for online training and certification. Same approach was followed also by University of Pristina, who created the SEMS system for administrative services, and they used G Suits for Education as well. The SEMS systems were offered also to the rest of public Universities, to University of Prizren (Ukshin Hoti University) and University of Gjilan (University Kadri Zeka).

University of Pristina claimed that they experienced to have online classes prior to COVID situation but very rare, and the same was also claimed by the University of Prizren, which emphasized some classes with Croatia and Bosnia Universities. However, they claimed that in two years, an average of six lectures per semester have been organized online, and due to this they created two conferencing rooms just for online learning. University Kadri Zeka, developed SMU for administrative issues and Moodle for sharing the learning materials. The International Business College

Mitrovica (IBCM) before the pandemic was mainly focused on the traditional setting where they held lectures physically together with students and professors.

As we can conclude from the previous discussion the situation of the pandemic caught the Universities in Kosovo almost unprepared for this situation in terms switching the in campus classes into online classes totally, 100%.

## 5.2 During COVID-19 pandemic

### 5.2.1 Data Analyzing and Visualizations

The University of Pristina has used the Power Bi service for data analysis. Through Power Bi it has displayed all the statistics of students who have participated in online lectures. Power BI is a secure service created by Microsoft that allows users to view the Power BI control panel, reports, and applications. Power BI allows a type of content that combines panel and related reports by using a web browser or through mobile applications for Windows, iOS and Android. Power BI has the ability to connect to multiple data sources such as: SQL database, directly from the web page, through API, Excel files, etc.

The University of Pristina has used Power BI Desktop for analyzing and preparing data for visualization, where Power BI Desktop is connected to Power BI Service which prepared the Dashboard and published the data. All together related to various media such as: email, website, smartphone, tablet, Laptop / PC, TV. Power BI Service has displayed all statistics files in SEMS, where SEMS has displayed the data to the user, and then sent the data to the SEMS database (see Figure 5.1). UBT College, student's attendance in lectures and exercises was reported through the BigBlueButton platform, as for other universities, for the exact purpose of data analyzing and visualizations of students attendance they used the features of the video conferencing platforms.

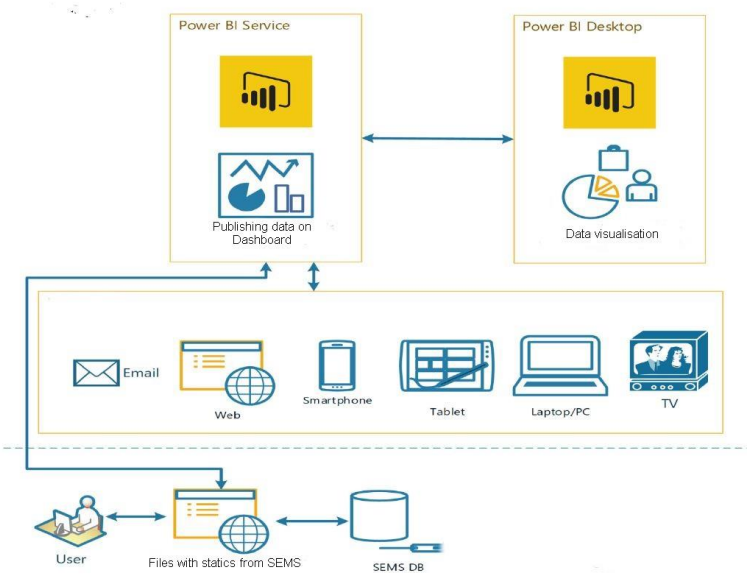


**Figure 5.1 Data Analysing and Visualisation using Power Bi**

### 5.2.2 Video Conferencing

Online learning at UBT was developed with the BigBlueButton platform which is an open source platform and was implemented by UBT during quarantine. UBT immediately started online learning through BigBlueButton having its first test week, where they tested the application on the academic staff and the students. After the first week ended, UBT started to hold online classes along with exercises for the students. The training of staff and students on using the BigBlueButton platform was done through different manuals and videos. Students have access to the BigBlueButton platform only through official UBT emails therefore students that aren't part of UBT do not have access to online lectures. This method has helped maintain the integrity of online learning and avoided dissatisfaction among lecturers. Student's attendance in lectures and exercises was reported through the BigBlueButton platform. The conferences have been held on live streaming through Facebook. The 2020 International Conference was held on Zoom, Google Meet and BigBlueButton.

University of Pristina, University of Prizren and University of Gjilan during COVID-19 pandemic, used Google Meet platform, where through its professors have given lectures in distance. University of Pristina also managed active users through Google Meet. During the pandemic over 2,000 teaching hours were held. There were 25,000 participants in online lectures and there were 1,500 academic staff. Since June 22nd, when the summer semester lectures ended there has been a decrease in Google Meet users due to the summer holidays. While from October 8th, with the holding of lectures the increase of users reached 20,013 users within the month (see Figure 5.2).

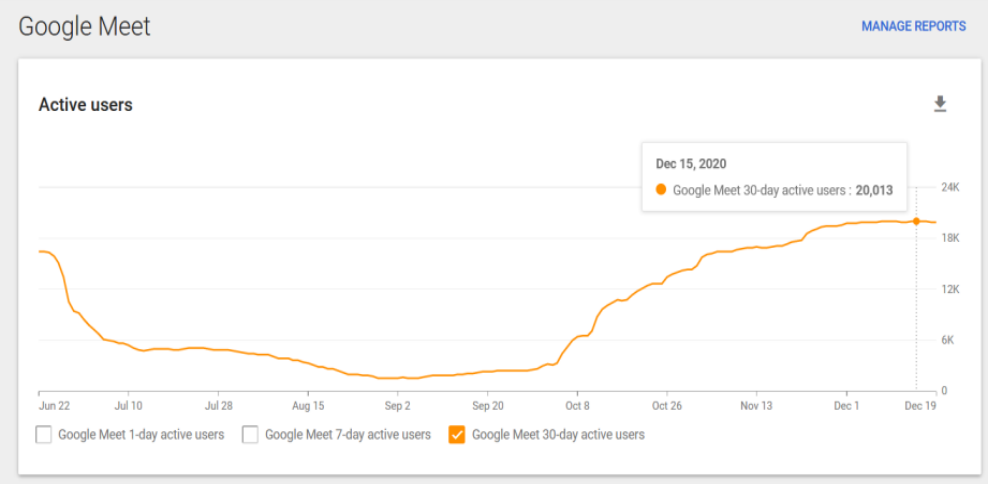


**Figure 5.2 Active users in lectures**

IBCM college during the pandemic have increased the possibilities of using software for enabling online learning. The BlueJeans application was used for video conferencing technology and the reason for selecting BlueJeans has been its automation for online learning education. Through BlueJeans they were offered very good opportunities to increase interactivity in lectures and they also used Zoom platform. The difficulty that IBCM has encountered during online lectures was problems with the internet and preventing direct access to students to help them with troubleshoot problems. Initially they only used BlueJeans for online lectures, but with the start of the new academic year they have switched to Google Meet. Since IBCM used G suits Education they had decided to use Google meet, meanwhile it's easier for integration and giving students easier access. Through official college emails they have maintained

the security of student access to the platforms knowing that the students who have accessed the lecture are IBCM students. The BlueJeans platform has continued to be used for various projects or meetings, while the Zoom platform has been phased out due to connection problems plus the servers have not been very stable during their use.

### 5.2.3 Learning Management Systems

UBT faculty implemented Moodle, professors and students contributed in literature, materials, submission of seminars and assignments over this platform. They also used the application of G suite for Education, where it has always been mandatory that every student who registers at UBT has the official email of UBT. Accessing the UBT system is done only through official email for security reasons so that students from different universities do not have the right to use and access. UBT has developed various systems one of which is the Student Management System (SMIS) which they use as learning management system, thereby through this system students have the opportunity to submit exams online, and receive other administrative services.

University of Pristina as well as University of Prizren and University of Gjilan, they used SEMS as a learning management system (LMS), which they created. During COVID-19 pandemic they improved SEMS by adding more modules. One of the main modules was semester registration and payments. SEMS was also used by professors and management in order to carry out all administrative procedures in parallel. University of Gjilan also used Google Classroom and Moodle, so professors can publish literature for students and also students can submit their seminar papers and assignments through those platforms.

Lecture reporting was done through Google Meet on SEMS. The student service offices have done student registrations, where the IT offices have downloaded the lists of students in Excel. As well as creating emails in Google for each student. The IT office downloaded the held hours and the uploading of hours held. The students made their choices of subjects after accessing SEMS, in case they had chosen the subject they were

not allowed access to in the lecture in Google Meet. The professor after accessing SEMS has downloaded the student lists and created the schedule in Google Calendar and the professor has assigned the holding of the lecture or exercises. At the end of the hour, the calculation has gone into an automatic form, thus generating the full report for the hours held (see Figure 5.3).

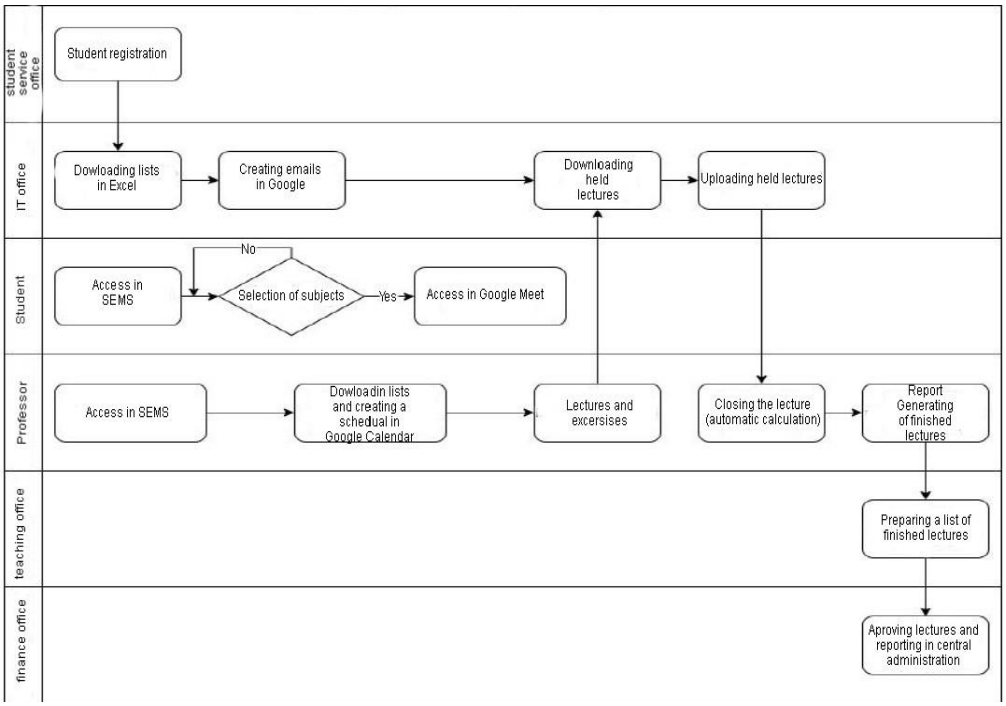


**Figure 5.3 Sequence Diagram - Lectures reporting using Google Meet in SEMS**

As for the IBCM college platform as Learning Management System they have used during online lectures is Google Suite for Education, Google Classroom. Through Google Classroom, students published their assignments.

### 5.2.4 Simulation

Since 2019 UBT College made an agreement with EON Reality where they applied VR and AR prior to the pandemic, and where through them they implemented the learning process. During the pandemic they used VR for the virtual learning process.

Online learning during the pandemic was also developed through 'EON Reality' in various faculties such as dentistry, nursing, mechatronics, etc. UBT is upgrading the

AR and VR platform (see Figure 5.4) in order for them to be used by all faculties in 2021. Below you can see one of the cases that were used.

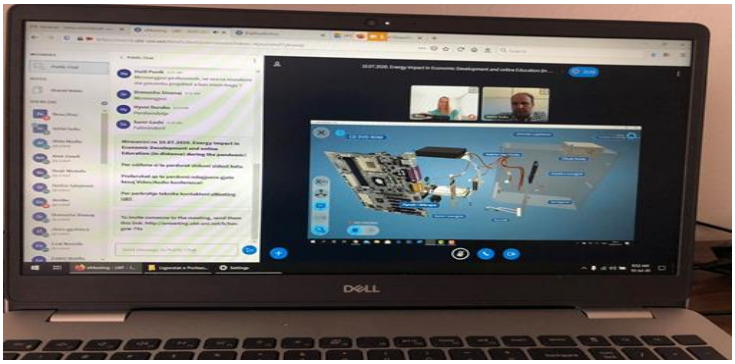

**Figure 5.4 Using AR and VR Platforms**

### 5.2.5 Online Exams

Exams at UBT during April were also held online. The attempt to stop or prevent plagiarism was done through Safe Exam Browser which does not allow the use of other applications during a specific exam. While the monitoring of students was done through Google Meet until the exam ended and students had submitted their exams. Students have also received a manual with all the necessary information and rules for holding the exams online in order to not have any misunderstanding. The requirements that UBT has seen necessary to improve in 2021 are: greater security during online exams (where so far they have used Safe Browser), and Copy sessions along with the IP address in order to make the online exams as secure as possible so that they avoid scams. As for other universities of Kosovo, they held exams physically respecting the protection measures against COVID-19 pandemic.

## 5.3 Infrastructure

### 5.3.1 University for Business and Technology

UBT has developed its infrastructure based on good foundation and premise. In the Lipjan campus near capital city of Kosovo there is a server room where they have a number of servers located physically and a number of internet connection from various internet services providers due to inconsistency of the internet connection that we have here in Kosovo. UBT claimed that part of their infrastructure is located outside of Kosovo, using a datacenter partially in Germany and France through Cloud Technology. This due to back-up data, as well as in case they are holding an online class and fall from one point to utilize the other point. UBT uses private cloud and public cloud services as well for a number of services that they provide to their staff and students. It all ended up in a hybrid infrastructure solution depicted illustratively in Figure 5.5.

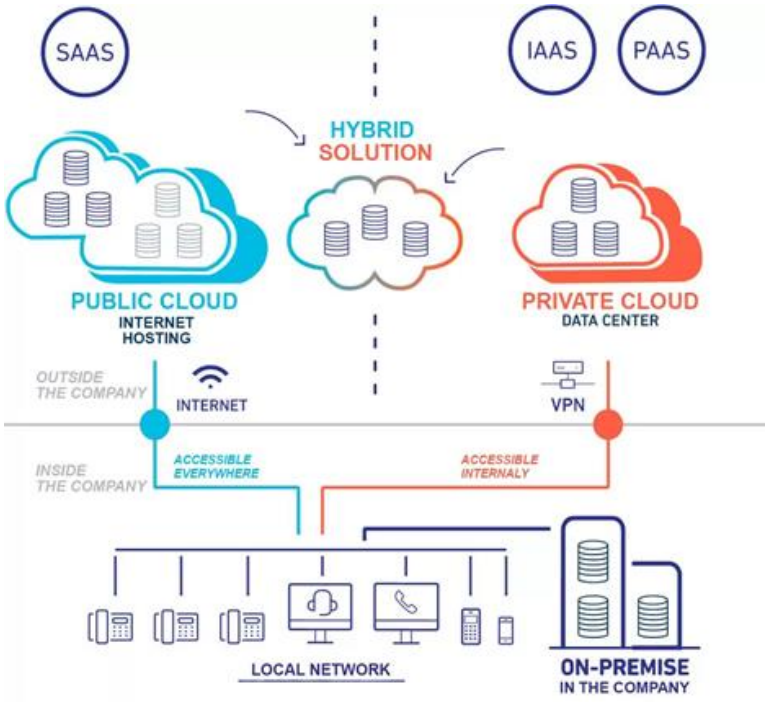


Figure 5.5 UBT Hybrid Infrastructure

Speaking in numbers, UBT has a total of eight servers. In terms of specification performance, 32 cores, 64 threads, 256 GB RAM with a sustainable power station. In addition to the main servers, UBT has used virtualization hosting services over 70 Virtual Machines. Some of them are located inside Kosovo while some others are in a private cloud and in some cases in a public cloud as mentioned previously.

During the pandemic, UBT experienced around 8,000 clicks concurrently, so they created a Clustered Database System, where data is located in several VMs. Due to high number of concurrent users, UBT included load balancing, so they managed to balance the usage once experiencing high usage of services, concurrent wise.

The infrastructure capacity of the platform supported concurrently more than 6,000 students in online lectures, where the BigBlueButton platform has been able to scale through Load Balancer in order to deal with such large mass. Even that the infrastructure supported simultaneously such high number of students, the session created for a single lecture limited the number of users, in our case the number of students for that particular session not more than 300.

During the pandemics, UBT implemented a strategy to record the lectures and provide the videos through the LMS Moodle to the end users, so they can revisit the lectures in case they didn't have the chance to be part of them. Therefore, currently UBT reached up to 2.5 TB of recorded lecture space, which are accessed by students only through the Moodle platform at any time.

### 5.3.2 University of Pristina

The University of Pristina (UP) used the services of G Suite for Education, where most of the information is stored in Google Cloud. For the development of online learning UP has:

- twenty servers of the type Dell PowerEdge R410,
- two servers of the type Dell PowerEdge R530,
- six servers of the type Fujitsu Primergy RX2540 M1,
- while the switch has two of the type CISCO SG200-25,

- one switch of the type ZyXel The GS 1900-24, which has 1Gb / s bandwidth and
- a D-Link Gigabit Switch DGS - 1024D,
- two CICSO 2800 Series routers and one CISCO 3800 router.

The University of Pristina has developed an electronic system for student management namely "Sistemi Elektronik për Menaxhimin e Studenteve" (SEMS). The SEMS system during the pandemic evolved with a number of additional modules in order to comply with the pandemic rules, thus attempting to increase the number of services that the students can obtain online. The University of Pristina divided the system into several modules:

1. Student application and online verification module for enrollment,
2. Cards and diplomas module,
3. Student payment module.

During the pandemic they made the addition of modules:

4. Module for reporting hours through Google Meet in SEMS,
5. E-Voting module for student elections and Steering Council of the University of Pristina.

In Figure 5.6 is provided the architecture followed by University of Pristina, in order to offer the services to the staff and students. So, the users (staff and students) accesses the browser, accesses the website, but in case of accessing sensitive modules it needs to pass a firewall for filtering purposes, so only authorized users had the ability to access the system.


**Figure 5.6 System architecture of the University of Prishtina**

### 5.3.3 University of Prizren

Switching to online classes has had difficulties in implementing some subjects, some of which were: music, art and math. In these subjects the interactivity of the student is needed. The other challenge during the pandemic was the equipment of the academic staff and students, which didn't support the proper performance and lack of applications. As well as the lack of hardware resources to students and professors often presented problems where they couldn't access the system. The rest of the infrastructure has all been in the hands of Google. Another significant problem that has caused an obstacle in online learning regarding the connection of the professor / student with the system has been the network service companies that have had their own problems. Along with the damaged network equipment, where the IT staff had to intervene in the staff in order to convince them that the problems have not always been at their terminal equipment or systems.

### 5.3.4 University of Gjilan "Kadri Zeka"

The infrastructure implemented in the University of Gjilan contains two servers. One of them is located in the University of Pristina, so it is managed by UP. Meanwhile the other server is located in the University of Gjilan where Moodle is hosted. This

infrastructure offers services for around 3,000 active students of the University of Gjilan and about 200 other academic staff. For the rest of services they decided to go through the Cloud Technology, such services as Google for Education provides. University of Gjilan organized the online lectures using Google Meet. To conclude, University of Gjilan using the current in campus infrastructure and Google Cloud Infrastructure dedicated for Education offered the ability to organize 3,600 hours online per day, 50 lectures, by providing services for around 3,000 active students along with 97 teachers. During the ten-week period throughout the pandemic there were a total of 100,000 online connections and 1,500 daily connections. Compared to other universities, University of Gjilan implemented a strategy to allow students either with the official email address to enter the online classes or with their personal accounts, with the intention no to miss the classes. In Figure 5.7 is stated the number of students who accessed the lecture by unofficial email versus to others who accessed through university official emails.


**Figure 5.7 Students access formal and informal email addresses.**

During the pandemic the Student Management platform used by the university was advanced by adding extra modules for online learning. Through SMU, professors noted the participation list of the students and automatically the students are notified by email for the start of the lecture along with the link of the class. Professors have found it easier to issue reports to participants in online lectures through the SMU. Through Moodle professors posted the learning materials. The students had access to Moodle all

the time and through the Moodle platform they submitted the seminar papers, assignments, etc. As students and professors have become more familiar with Moodle they have not used the Google Classroom as much, but depending on the professor they have been free to use either of them.

### 5.3.4 IBCM

During the pandemic, lectures were physically altered by shifting to online lectures. The advantage of IBCM compared to other universities has been that they work with smaller groups of students. It has been the easiest way to manage the system in their case. IT staff have had enough space to approach the needs of students and professors, communicating with them more simply. As the others universities IBCM didn't implemented their infrastructure, they used G suite for education, and used their platforms, along with BlueJeans and Zoom platforms.

# 6. CASE STUDY - UBT

Since, UBT claimed that they used a hybrid approach of infrastructure, by using the in-campus infrastructure and cloud infrastructure (see Section 5.3), then the intention was to have UBT as a case study and see their actual system from a broader view, so we can conclude if the same approach could be followed in larger scale.

The infrastructure owned by UBT is HybridCloud. There are servers inside the institution and servers used outside Kosovo using the Cloud Technology. The servers that are inside the campus in UBT are called On-premise servers, the servers that they use outside Kosovo are Private Public Cloud, through which a number of services are used for our students, and Google services are one of them. The UBT infrastructure has 3 physical servers, where they use server virtualization via Hyper-V, VMWare or Proxmox, to extract a kind of data virtualization. Two of the servers have performance 256 GB RAM 32 CPU cores 64 threads (see Table 6.1). Their capacity is provided for 5500 students, who can access the system at the same time. Internet access on physical servers located in Germany in Frankfurt and France in Roubaix was initially 1Gbps, but due to Ddos attacks that UBT experienced very offend during the pandemic time, and also the increase usage for upload and backup, the internet link increased to 10Gbps per server.

This infrastructure is not only used for online learning but also for other services like Moodle. The concurrent number of users for a server is 250, so when virtualization is used, different instances of the VM are created, in order to come up with services for 5500 concurrent users. With a simple math, when dividing 5500 concurrent students (users) with 250 users for each VM, we come up to have at least 22 virtual machines up and running in order to offer appropriate services (see Table 6.2).

Table 6.1 Server performance

| Physical Servers | RAM | CPU | Threads |
|---|---|---|---|
| Server 1 | 256 GB | 32 cores | 64 threads |
| Server 2 | 256 GB | 32 cores | 64 threads |
| Server 3 | 256 GB | 32 cores | 64 threads |

Table 6.2 Concurrent users

| Physical Servers | Virtual Machines | Users per VM | Total users per server |
|---|---|---|---|
| Server 1 | 22 | 250 | 5500 |
| Server 2 | 22 | 250 | 5500 |
| Server 3 | 22 | 250 | 5500 |

Load balancing is done by creating a separate virtual server through Linux. Once the VM is created it uses an algorithm, which loads the less loaded server. The type of load balancer is HA proxy, while the type of algorithm they use is Roundrobin and LeastCon. Through LeastCon algorithm, the server which has the least connection is loaded. When creating a balanced infrastructure it is best that all servers have a common service where they store all lecture records. UBT uses the NFS service, which they use to store the recorded lectures. Since March 2020 this service has 3TB records. During March, if the professor recorded a lecture, the system slowed down, but there was always room for more optimization. This problem has occurred because when a server has been recording the lecture, it created another format which took space on that server, at the moment when a recording ends the encoding (recording processing) of the lecture in a format begins that took less space (for example in MP4 format). During the time when the recordings are processed they take up a lot of computer resources, using a lot of CPU. As a solution to this problem, the encoding in the part of processing

records is done at night when there is no load, from 21:00 to 08:00 in the morning, in this form the load is removed from the servers. Every lecture that is recorded today, the next day is ready to publish in Moodle course pages. Due to media stream, in case of using Wi-Fi, a 5GHz band was preferable compared to 2.4GHz. In the other cases the optimal is to connect the device directly to the Ethernet Cable. In order not to overload the servers, their location is preferably to be closer, for example in the case when the students are in Europe and the servers are in America the network delay causes problems, in this form interruptions occur. This triggered us to have four local servers on campus in Lipjan, which are used for internal services, and the rest of the online learning takes place through servers located outside Kosovo. The reason for this solution is due to the stability of the network, power and hardware that these servers possess.

When switching to online classes, started from March 2020 UBT had only one physical server, through which online learning was developed. Physical servers that virtualize through them (Hyper V or VMWare) are counted as hosts. These current servers are not 100% utilized, but each server utilizes capacities of about 60% or 70%, if its load increases (the number of competing students increases) new VMs created. The basic configuration that each of the servers must have is done through several scripts, which perform the installation faster. When the VM is created, the script is activated, completing the installation and increasing its capacity. Each VM that is added is ensured to have space for 250 students. If the capacity of the student's increases, the time needed to create another VM is a maximum of 2 hours, maybe even less than that.

One of the physical servers with higher storage capacities, around 25 TB disk, use a Hyper-V feature called Hyper-V replica. Each VM found backs up the entries to the other host, in case of failure to launch other server. In VM the most important data that are located are the recordings of lectures, the records are stored in another server. Whatever happens to the VM, if one or the other stops doesn't matter as the load balancer always knows who is active and who is not, so there is no need to pay attention to the back-up.

The reasons for causing downtime is the unsustainability that Kosovo is experiencing with power failure (if the servers are located in a place where there are power problems), another problem could be the internet or hardware problems. The latter problems can occur very rarely. The most challenging problem that UBT has encountered in the downtime part has been the Ddos attacks that occurred during October 2020. These attacks could not get data but only attacked the network and loaded the network link, which caused downtime. To protect our services from these attacks UBT increased the network link to 10Gbps and the server located in France used for protection purposes, as that server has provided more efficient Ddos protection.

The worst scenario that UBT has ever experienced so for with downtime could be rounded into max 17 minutes. In case of a system failure we needed to enter the second host. The VM data located with one host is copied to the other host, when one host enters the other host and reverses the replica, it starts sending the data to the other host. This method needs to be done in the Moodle part or in the web part, but in the learning system it is not necessary to make manual intervention case the load balancer does it automatically, it detects which server is down and sends the new requests to the other VM links which are up and running. The reason why there are four physical servers in Campus and the others in France and Germany is to have large distances between each other, in order to avoid the signal point of failure, where the probability of falling of all servers is very small. Other solutions are to allocate resources to different points and replicate all the data in another location, where each server inherits the data to the other (see Figure 6.1).

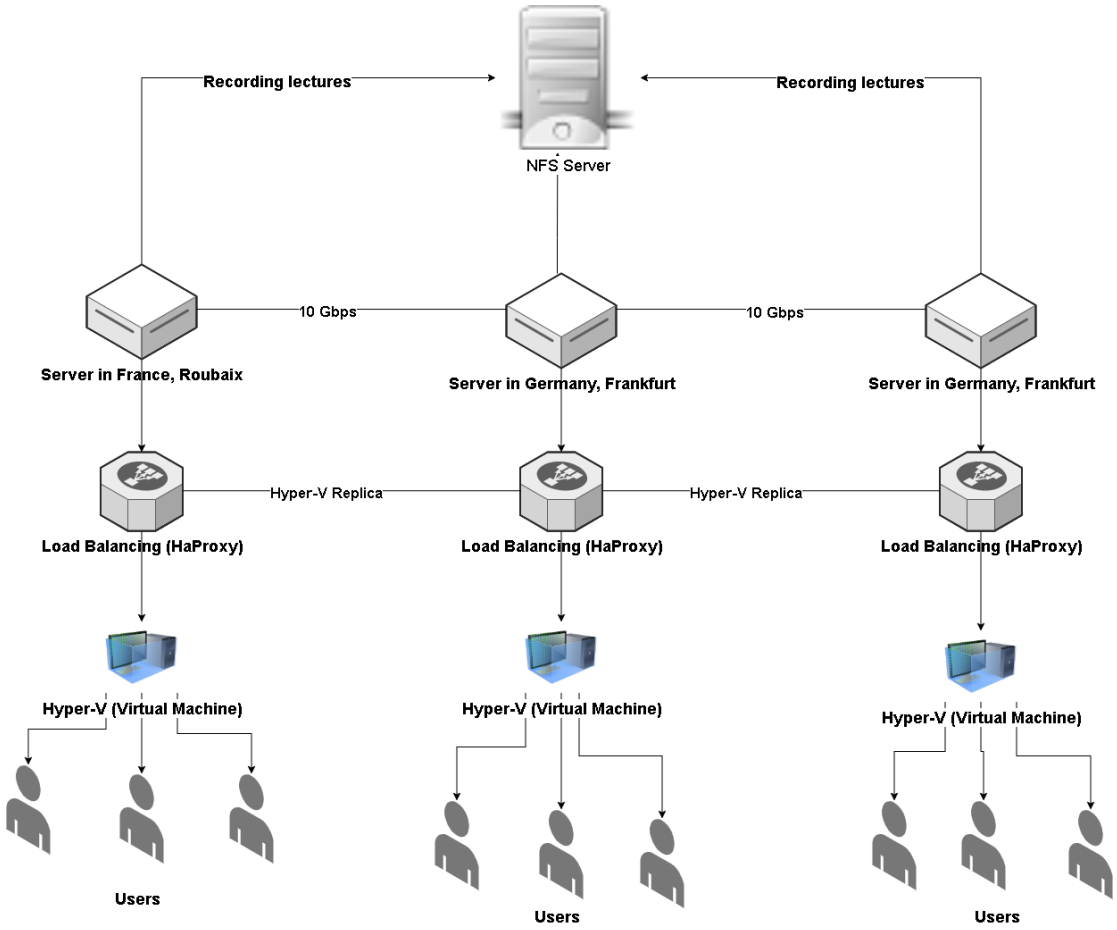


**Figure 6.1 Server Infrastructure using Load Balancer**

At UBT it has never happened that a student outside the UBT faculty enters physical lectures, all students are identified by name, surname and email. If any external service is used (Google Meet, Zoom, etc.) there is always the risk of someone unknown entering and abusing the lecture. Through a platform that hosts its own data, there is greater security, and the privacy concerns are related to the institution politics. This was one additional reason why UBT implemented the self-hosted platform.

In the future, UBT aims to establish the infrastructure in Kosovo, in order to decrease the distance among the server that provides the services, and the students that use our services. During the pandemic the internet line happened to have loads, there were cases that even other platforms such as Zoom and Google meet had problems. Uploading the international link is done by different services, when the services are more hosted the network performance is degraded. If the infrastructure is located in the

country where you are located you don't have the weakness of the international link. Providers are within the state, they communicate with each other with fiber optics, in these cases the delay is very low and the quality increases, but even if there are loads of international internet links, providers within the state are not dependent on them and do not pose a problem.

**Scenario: Threshold positioning as far as the number of competing students, the infrastructure you possess maintains high quality and where is the performance curve starting to fall?**

There are currently 22 active VMs available at all times. 22VM x 250 students for each a total of 5500 competing students. The scenario with the lower performance or quality level is in cases when the total number of students within a lesson is greater than 180 for one session.

An online class to have the best quality level is preferably not to have more than 180 students, when this number is exceeded the performance starts to fall. In order not to drop the quality level, they have decided to increase the VM in which the BigBlueButton system is located, through which online learning is held.

UBT vary rare experience to have 5500 competing students, as the classes are held at different times. In order to be more prepared if the load increases, we have decided to support the capacity of 5500 competing students, even when we experience to have only actually 2000-3000 competing students, this way the server distribution is better and the servers are not loaded, also the performance is optimal.

Because of the social responsibility, UBT initiated a discussion to offer the whole system for all schools in Kosovo, and in the next section we are going to model such a system that could support around 20k number of students concurrently around Kosovo.

# 7. PROPOSE AN ONLINE SYSTEM FROM UBT TO OUR KOSOVO NATION

Based on the literature review, on the data collected from the workshop and the discussion with the CTO of UBT, through this section is presented an online system infrastructure model that supports 200,000 concurrent users. This model with a good will from all stakeholders can be concretized for our Kosovo Nation, from UBT with heart!

For 200,000 concurrent users, we need twenty-seven physical servers (hosts), some of the hosts should be located in EU, such as in Germany and in France. It is preferable for hosts to be distanced from each other's to keep a good performance. Twenty-seven of the hosts should have performance of 256 GB RAM 32 CPU cores 64 threads and its operating system is Microsoft Windows Server 2019 – Data Center Edition. To separate users into hosts we have to install Virtual Machines (guests) using Hyper-V or you can choose another virtual machine depending on our preference. Each host will store 7,500 concurrent users per host. Keeping a good performance and quality, each host needs to load 30 Virtual Machines. Every VM will contain BigBlueButton platform. Every Virtual Machine that is created must have 16GB RAM 8CPU cores that can handle 250 users per VM. Through the Linux operating system, you will install the NFS server. All the recorded lectures should be located into NFS storage. Each lecture should have enough space, 150MB per each recorded lecture (session). So you need to start with a storage starter, where in the future it continues to grow depending on its need. Using RAID5, we get 10 HDDs where each of them contains 16TB. Starting storage in this case will be 144TB. Each recorded lecture (session) occupies 150MB of space, according to the starting storage on the server it will be possible to record 960,000 lectures. The other advantage of this infrastructure is the use of Logical Volume Manager LVM which is a device mapper framework that provides logical volume management for the Linux kernel. After creating disk partitions, if this amount of recorded lectures is reached, LVM allows us to add new disks in order to increase the current space. To allow VM's to be created if we have a higher number of concurrent

users we should use load balancing, as well as to bring less problems in terms of load. Twenty-seven physical servers that you will have to rent and pay for them monthly will contact with each other using 10Gbps internet link, to prevent cyberattacks. Each host will use a load balancer which is called Scalelite, to scale Virtual Machines so each VM can hold 250 concurrent users (see Figure 7.1).

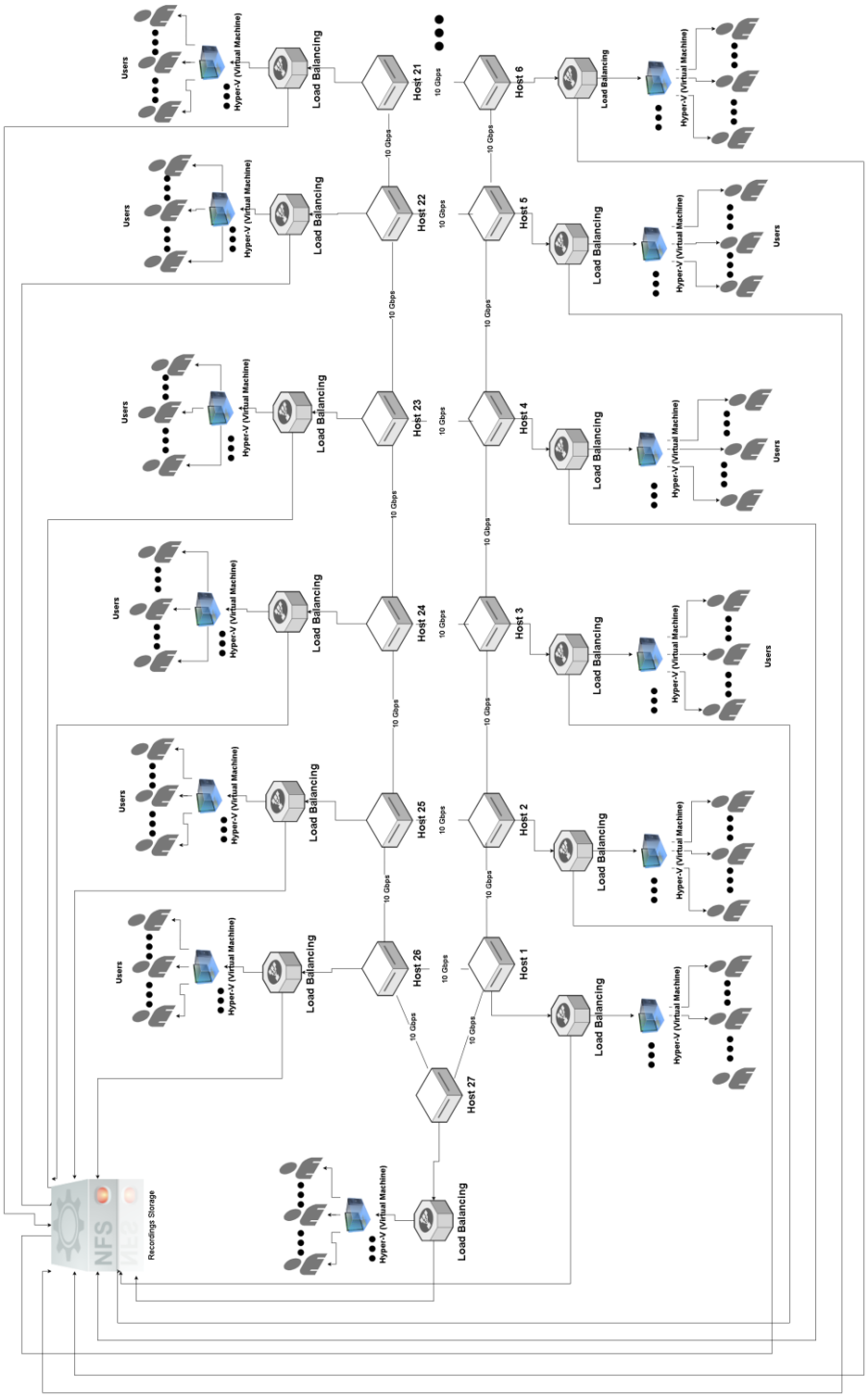


**Figure 7.1 Infrastructure model proposal for 200k concurrent users**

Operating system of each host is Microsoft Windows Server 2019 – Data Center Edition as we mentioned before. This operating system has a service called Microsoft

Hyper V service. Hyper V replica is a feature of Microsoft Hyper V. Load balancer is always active and it will notice if one of configured hosts is down, as Figure 7.2 shows, for example Host 1 goes down, using Hyper V Replica, Host 2 will duplicate all Virtual Machines of Host 1.

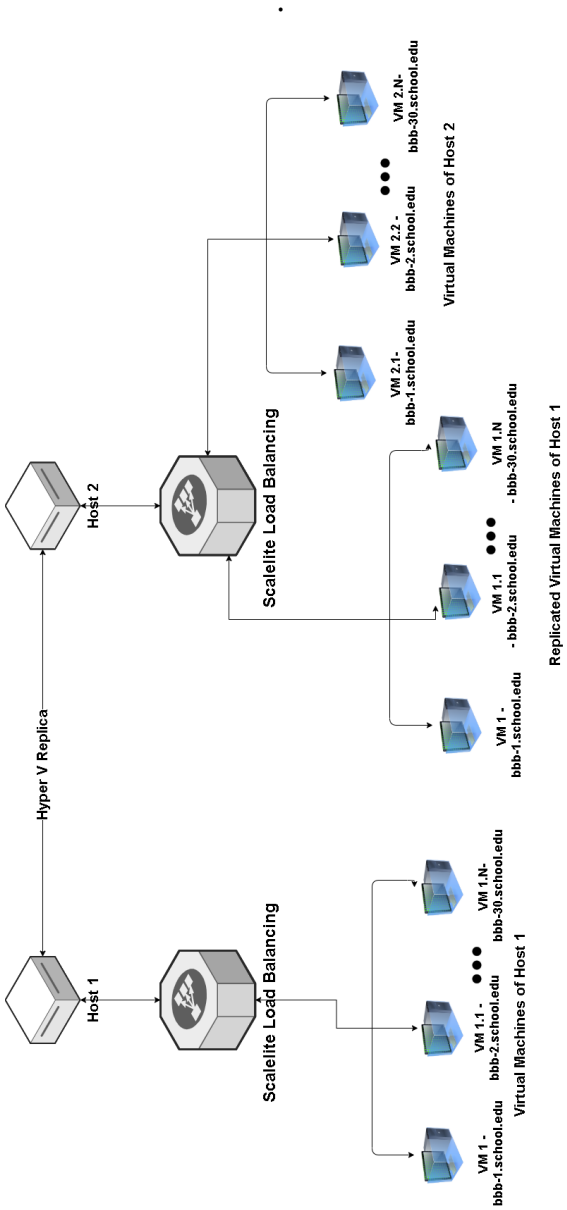


**Figure 7.2 Hyper V Replica**

In Figure 7.3, the Load Balancer does scaling of virtual machines, where BigBlueButton is located on each virtual machine (VM). The moment a session is

created, Load Balancer sends us to the VM which has less space. Initially the VM processes the lecture recordings locally within its own space in order to occupy as little space as possible and to be playable. After processing, it sends the recordings to NFS storage via a script. It is preferable that the recordings be processed during the time when the system is used less, for example in the evening. Load Balancer also uses both Postgres and Redis databases to know where is a recording in storage. In case you want to watch the recorded lectures, Load Balancer accesses the NFS, where it finds the lecture through a certain path. Load Balancer also communicates with Moodle via API calls.

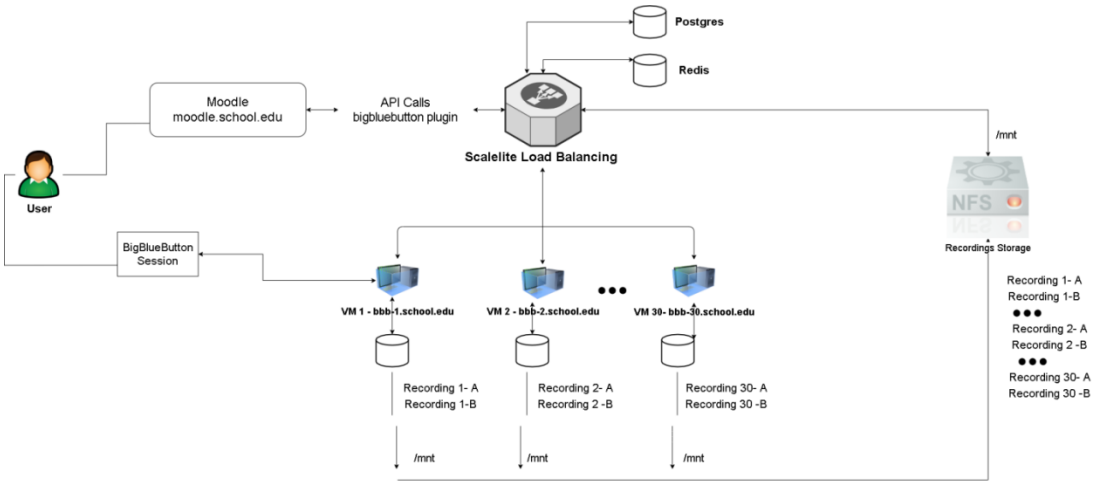


**Figure 7.3 Load Balancer Scaling Virtual Machines**

Another solution to the model you might want to try in case you want easier management and less stress, is the implementation of infrastructure in a public cloud such as Amazon Services, Microsoft Azure or Google cloud, but this requires a good budget to realize this model. The good thing about this model is that most problems, such as cyber-attacks or server crashes, will handle the competent company depending which one you choose. You will have to pay about their service depending on how many concurrent users you need. They have a model pay as you use. Since this is very costly for 200,000 concurrent users it could be a good approach to keep as a plan B in case a failure of plan A as discussed above (cyber-attacks, power problems, hardware problems,internet connection problems).

## 8. DISCUSSION

The results indicate the processes that have been followed to move from traditional learning to online learning in higher education institutions (HEI) in Kosovo. The research presents the identification of the network infrastructure to provide online teaching at the partner universities within this project. Further, the main purpose of this research was to identify the criteria that have pushed HEI's to the definition of platforms to provide online teaching. While previous research has focused on students and teachers perspective, how they were affected by online learning, these results demonstrate network infrastructure and video conferencing platforms during COVID-19 pandemic in Kosovo's HEI.

At the beginning of the COVID-19 pandemic, no one would have thought that traditional learning would be completely replaced by online learning. Kosovo's higher education institutions (HEI) haven't been prepared for online learning in terms of infrastructure. After two weeks of being in a lockdown, universities have come up to different solutions. Most universities used the cloud based infrastructure, while the UBT faculty was the only university in Kosovo, which had infrastructure for about 5000 users in real time.

Data collection was gathered from a workshop, we interviewed five participating universities. The interview of the universities of Kosovo as well as the interview of the UBT faculty, resulted in a new proposal of infrastructure model about 200k users in real time, regarding the sustainability aspect of this process, in order to provide a successful online teaching. This proposed model will help all universities to improve teaching within Kosovo, resulting in plan B in case a failure of plan A. Plan A, by purchasing servers in Germany and France, avoids technical problems, such as power outages, internet and hardware problems, enabling universities to have teaching with better performance. Increasing internet link to 10Gbps will avoid cyber-attacks, so it won't cause downtime of the system. This infrastructure will support recording lectures, so students can re-watch them anytime they want. Another advantage of this infrastructure,

to prevent downtime of the system which will cause the decline of lectures, is the replication of virtual machines from one server to another.

The use of the BigBlueButton platform preserves the confidentiality of the university, not allowing access into lectures of students who don't belong to the university in question. The good thing about this infrastructure is the increase of server capacity, in case the number of concurrent users increases, by adding virtual machines to support all the lectures. Given that each university has different teaching hours, using this infrastructure, downtime of the system won't be a problem, because the capacity of this infrastructure is calculated very carefully. In case a failure of Plan A, we have the plan B, which is very costly for 200K concurrent users. Plan B is the implementation of infrastructure in a public cloud such as Amazon Services.

## 9. CONCLUSION

To sum up everything that has been previously stated, this thesis aimed to gather the right information about the transformation of universities during the COVID-19 pandemic phase, from traditional learning to online learning. Collecting data from other research papers that investigated a number of Universities worlwide and tried to grasp the knowledge in a context of the particulate countries how these institutions have been affected during this pandemic, specifically on demands of IT services and how students and teachers are affected from this situation. Seeing that the research of IT perspective during COVID-19 was small, we examined the key components in terms of technology to provide a successful online teaching, for a number of over 200k students in real time. The methodology used in this thesis was the perfect one to gather and to understand the infrastructure of all the Universities of Kosovo. Collecting data from the Workshop with five participants of Universities of Kosovo and also interviewing CTO of UBT College.

Based on qualitative data and data analysis through Litchman 3C approach we came into a proposle new macro-based model on the whole Kosovo nation (for 200K students). This thesis also aimed to analyze technological infrastructure and platforms used in five Universities during COVID-19 pandemic.

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