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Mobile Learning in Mobile Cloud Computing Environment

Stojan Kitanov [1] and Danco Davcev [2]

[1] University for Information Science and Technology "St. Paul the Apostle"
Ohrid, Macedonia
[2] "Ss Cyril and Methodius" University, Faculty for Computer Science and Engineering
Skopje, Macedonia
Email: stojan.kitanov@uist.edu.mk; danco.davcev@finki.ukim.mk

Abstract: This paper presents a new model of mobile distance learning system (MDL) in an extended Mobile Cloud Computing (MCC) by using High Performance Computing (HPC) Cluster Infrastructure, as well as some existing videoconferencing technologies enriched with mobile and wireless devices. This MCC model can be applied everywhere where there is need of fast and intensive computing and analysis of huge amount of data, such as modeling of 3D graphics visualization and animation in ecology, global climate solutions, financial risks, healthcare and medical learning, decoding genome projects, etc. After the MCC model presentation, the experimental system architecture will be provided, as well as its possibilities, with particular reference to mobile learning environment and its potential issues. In this architecture the mobile device may optionally use the open source e-learning course management system platform Moodle, to access the learning material and the relevant data that needs to be transferred to the HPC Cluster Infrastructure for further computing. In order to provide higher quality of presenting the learning material, the Cisco WebEx application will be used to test the distance learning in both fixed and mobile environment. Then, a Quality of Experience (QoE) evaluation of such mobile distance learning system will be provided. Finally, it will be concluded that this MCC model that incorporates HPC Cluster Infrastructure can be applied anywhere where there is need of fast and intensive computing and analysis of huge amount of data which cannot be performed by a conventional PC, Laptop or Mobile Device.

Keywords: cloud computing, distance learning, high performance computing cluster, mobile cloud computing, mobile distance learning.

1. Introduction

Together with the explosive and rapid growth of Internet, mobile networks, mobile applications, and cloud computing, mobile cloud computing is introduced as a potential technology for mobile devices. As mobile network infrastructures continuously improve, their data transmission becomes increasingly available and affordable, and thus they are becoming popular clients to consume any internet web-based applications. Cloud computing provides delivery of services, software and processing capacity over internet, reducing cost, increasing, automating systems, decoupling of service delivery from underlying technology, and providing flexibility and mobility of information. Mobile Cloud Computing (MCC) integrates the cloud computing into the mobile environment and overcomes the obstacles related to the performance (battery life, storage, and bandwidth), environment (heterogeneity, scalability and availability), and security (reliability and privacy) [1]. One future potential application of MCC is the Mobile Distance Learning (MDL), where the students can get the knowledge from centralized shared resources at any place and any time [1] [2].

This paper presents a new Model of Distance Learning System in Mobile Cloud Computing Environment, by using High Performance Computing (HPC) Cluster Infrastructure [3] [4] as well as some existing videoconferencing technologies enriched with mobile and wireless devices. This MCC model can be applied everywhere where there is need of fast and intensive computing analysis of huge amount of data, such as modeling of 3D graphics visualization and animation in ecology, global climate solutions, financial risks, healthcare and medical learning, decoding genome projects, etc. Then, the experimental system architecture of Mobile Distance Learning (MDL) system in Mobile Cloud Computing (MCC) environment will be presented. In this architecture the mobile device may optionally use the open source e-learning course management system platform Moodle [5] [6] to access the learning material and the relevant data that needs to be transferred to the HPC cluster infrastructure for further computing. In order to provide higher quality of presenting the learning material, this architecture uses Cisco WebEx application [7], as well as some existing videoconferencing technologies enriched with mobile and wireless devices such as smart phones, or tablets. The main contribution of the paper is the Quality of Experience (QoE) evaluation of such MDL system in MCC environment.

The paper is organized as follows. Section 2 summarizes the related work. Section 3 presents the new model of distance learning system in mobile cloud computing environment. Section 4 provides the system architecture of MDL in MCC environment. Section 5 gives an overview of the Quality of Experience (QoE) aspects of MDL in MCC environment. Section 6 presents the QoE evaluation scenarios, while Section 7 gives the comparison QoE evaluation results for MDL in MCC environment with respect to the Distance Learning (DL) in the conventional CC Environment. Finally, Section 8 concludes the paper and provides information about future work.

2. Related Work

Cloud computing in mobile platforms has invoked a new wave of evolution in the rapidly developing mobile world. Many mobile devices such as smart phones, PDAs, tablets, pockets PC have been added to the Mobile Cloud Computing (MCC) Environment. Today these mobile cloud applications on iPad and iPhone, etc. are already available [8].

The Mobile Cloud Computing Forum defines MCC as follows [1] [9]:

"Mobile Cloud Computing at its simplest refers to an infrastructure where both the data storage and the data processing happen outside of the mobile device. Mobile cloud applications move the computing power and data storage away from mobile phones and into the cloud, bringing applications and mobile computing to not just smartphone users but a much broader range of mobile subscribers".

Mobile Cloud Computing will provide many benefits for cloud computing, mobile network operators, such as increased reach, reduced costs, and reduced reliance on hardware and software equipment. Mobile cloud computing has many advantages among the few listed below:

- Sharing information and applications without the need of complex and costly hardware and software since computations are run in the cloud [10];
- Enhanced features and functionalities of mobile devices through new cloud applications [10];
- Ease of access and development since the access point to mobile cloud computing is through a browser and not a mobile operating system [10];
- Cheaper for cloud computing vendors to build mobile cloud applications because of access to all mobile devices, i.e., one application can be shared and accessed by many mobile device users [10];
- Broader reach, since mobile cloud applications can be accessed through a browser, the cloud computing applications can be reached by all mobile device users, as long as the mobile device has an internet access [10];
- Extending battery lifetime for mobile devices [1] [11] [12] [13];

- Improved data storage capacity and processing power since MCC enable mobile users to store/access the large data on the cloud through wireless networks [1] [14] [15] [16] [17]; and
- Improved reliability since data and computer applications are stored and backed up on a number of computers [1] [18] [19].

However, there are still many obstacles for MCC, including service availability, mobility management, security, privacy, energy efficiency, etc. These problems must be carefully addressed before MCC could become completely operational.

Mobile Distance Learning is seen as one of the potential future applications of MCC [1] [2]. Mobile Learning (m-learning) is one of the applications that can be supported by MCC. Traditional m-learning applications have limitations in terms of high cost of devices and network, low network transmission rate, and limited educational resources [20] [21] [22]. Cloud-based mobile learning (m-learning) applications are introduced to solve these limitations. For example, utilizing a cloud with the large storage capacity and powerful processing ability, the applications provide learners with much richer services in terms of data (information) size, faster processing speed, and longer battery life.

One MCC model that is made up of complex network and relationships of and in between Infrastructure Providers, Application/Services Providers, End-Users and Developers all producing and/or consuming applications and/or services on internet is given in [23]. Of a particular interest in this model are the developers that offer their applications and services on the web via Software as a Service (SaaS) models running on other's hardware (HW) and software (SW) infrastructure providers. However since MCC can be applied in many areas, this model is too general and does not specify any details about MCC implementation.

Microsoft has proposed an HPC Server and Cloud Platform [24]. This platform uses Windows HPC Server 2008 Service Pack 1 that enables service oriented, HPC jobs to be executed as a service using Windows Azure datacenter. High Performance Computing (HPC) gives analysts, engineers, and scientists the computation resources they need to make better decisions, fuel product innovation, speed research and development, and accelerate time to market. Some examples of HPC usage include: decoding genomes, animating movies, analyzing financial risks, streamlining crash test simulations, modeling global climate solutions, computational fluid dynamics (CFD) and other highly complex problems. However this platform is specified only for Conventional Cloud Computing Environment.

Therefore, a new Mobile Cloud Computing Model for Mobile Distance Learning that uses HPC cluster Infrastructure is proposed in this paper. The advantage of the presence HPC cluster infrastructure in the MCC model is that it can be used in situations where the necessary computing cannot be performed by a mobile device, or a conventional PC, or laptop. This model is described in the next section.

3. Mobile Cloud Computing Model

The proposed Mobile Cloud Computing Model for Mobile Distance Learning is given on Figure 1. This Model incorporates High Performance Computing (HPC) Cluster Infrastructure. The communication between the end-user devices (terminals) and the HPC Center is in a cloud computing environment due to the various service requests.

The terminals can be connected to the HPC Cluster Infrastructure inside the University Local Area Network (LAN), or they can be connected on external network (internet). The University Moodle Platform Server (Moodle Course Management System) [5] [6] hosts educational resources and it is connected on the University LAN. The user may access the Moodle platform directly from the University LAN or through the Internet in order to collect the necessary data that needs to be computed by the HPC center. Alternatively, the data that needs to be computed can be collected by the HPC cluster infrastructure throughout the University LAN if the data is too large and cannot be collected by the mobile terminal. When the user wants some data to be computed by the HPC cluster

infrastructure it sends request to the HPC center. When the HPC acknowledges the request it receives the data directly from the user terminal or from the University Moodle Platform.

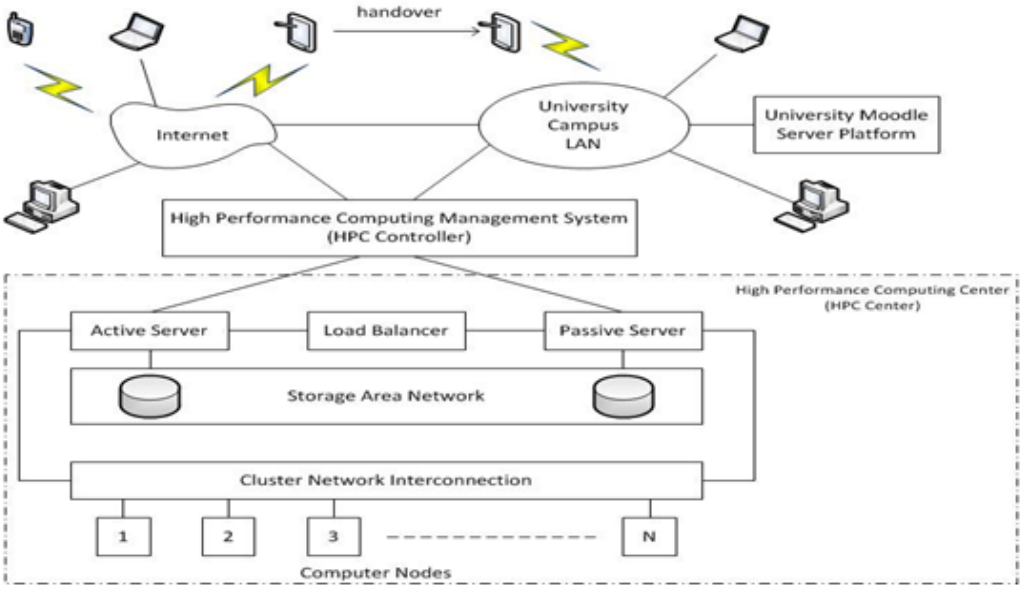

Figure 1. Mobile Cloud Computing (MCC) Model with High Performance Computing (HPC) for Mobile Distance Learning (MDL).

The user can access the HPC center either from University LAN, or directly from internet, through the HPC Management System (HPC Controller). The HPC Controller manages the authorized access to the HPC Center, and it is directly connected on both passive and active server. Like that a redundancy is provided in case the active server goes Out Of Service (OOS). The passive and the active servers are connected to the Load Balancer, which determines which server is active. The Load Balancer also determines which server needs to manage the load (either the active, or both), i.e., the incoming service request from the user.

Both active and passive servers are connected to the storage area network and the cluster network infrastructure. The server takes additional data from the storage area network that needs to be processed (computed), and then it forwards all the necessary data to the cluster network infrastructure for further computing. The cluster network infrastructure consists of N interconnected computer nodes. One of these nodes is the main node, or master node, and it determines which nodes should perform the computing of data. Like that parallel processing is enabled. Once the data computation is completed, the final information is sent back to the user. If the master node fails to operate normally, then another node becomes master node. Like that a redundancy among the nodes is achieved.

The advantage of this model is that it offers new services on mobile devices, as a special benefit from using the HPC center within the mobile cloud environment. HPC Cluster infrastructure is useful in situations where the necessary computing cannot be performed by a mobile device, or a conventional PC, or laptop. Another advantage of this model is that it provides service continuity, or seamless mobility as the user handovers from external network to the University Local Area Network.

The next section will present the Experimental System Architecture for mobile learning (m-learning) that supports Mobile Cloud Computing. In order to provide higher quality of presenting the learning material, the Cisco WebEx application will be used as an end-user application on the mobile devices.

4. Experimental System Architecture

The experimental system architecture for Mobile Distance Learning (MDL) that supports Mobile Cloud Computing (MCC) with High Performance Computing is given on Figure 2. According to this architecture the University classroom is connected to the University Moodle Server Platform, internet and HPC Platform. The University Classroom usually have the following equipment: PC, or laptop, microphone, speakers, tablet, webcam, projector, and a monitor, or screen. At the University Classroom the instructor presents and delivers the content of the learning material to the students present at the University in a classical manner, or via internet to the students that are at distant classroom, at home, at work, or simply they are mobile (on the road). The distance classroom is the classroom where the more students together are attending the course lecture, to attend the instructor's presentation over the internet. The distance classroom usually has the same equipment as the University instructor's classroom and the distant classroom usually may have the following equipment: PC or laptop, microphone, speakers, tablet, webcam, projector, and a monitor or screen. The students that are at home, or at work connect to the course by using their PC, or laptop using the high speed internet from their home, or their office. On the other hand, the mobile students (students on the road) use their mobile devices (mobile smartphones, or tablets) to connect to the course via their mobile and wireless networks (such as GPRS, UMTS, HSPA, WiFi, WiMAX, or LTE).

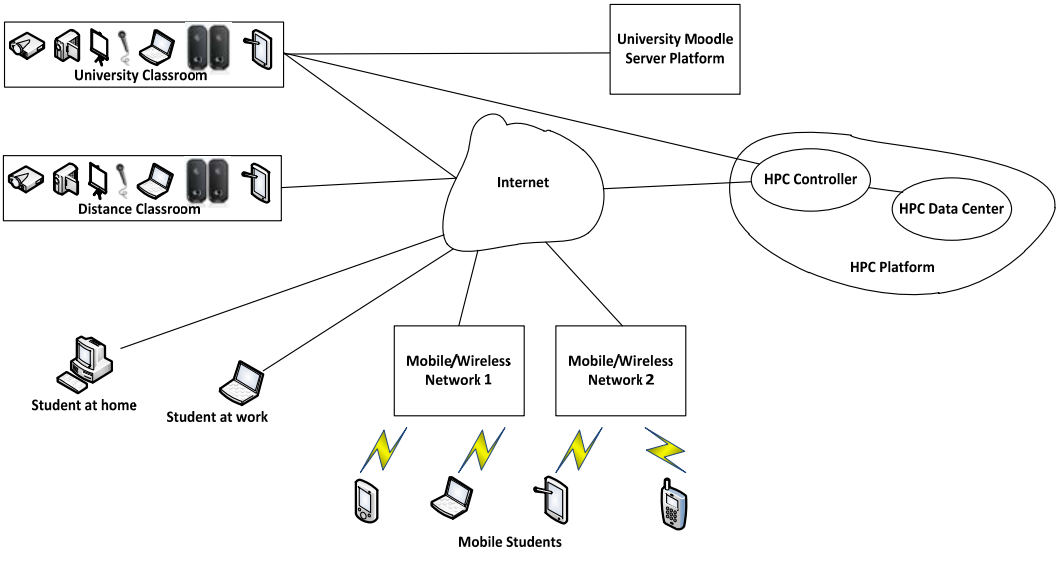

Figure 2. Mobile Cloud Computing (MCC) System Architecture with High Performance Computing (HPC) for Mobile Distance Learning (MDL).

The University Moodle Server Platform provides possibility to host the digital educational resources, which can be accessed by the instructor and all students either locally, or throughout internet connection. Additionally all students, as well as the instructor over the internet can access the University Moodle Server Platform to collect, or download the data that needs to be computed and to forward it to the HPC platform, for huge amount of data processing in a cloud computing environment. Alternatively, the HPC cluster infrastructure may download the necessary data from the University Moodle Platform, when it receives a request from the authorized user. In the HPC platform, the HPC controllers process the users' requests. The HPC Data center provides the hardware and software facility, as well as the infrastructure for cloud computing service providers. At the HPC Data centers, several servers are linked with high speed networks to provide services requested by users.

Particularly the overall theoretic performance of the HPC cluster in Macedonia is 9 TFlops, and achieved peak LINPACK performance is 7.776 TFlops, that is 86% efficiency. It consists of 84 computational blade servers with 2 Six core L5640 CPUs and 24 GB RAM. The 6 management servers have also 2 Six core L5640 CPUs and 24 GB RAM, four of which act as storage servers and are connected in a failover configuration to a Serial Attached Small Computer System Interface (SCSI) storage with 60x600 GB Dual channel Serial Attached SCSI (SAS) disks. The HPC cluster provides possibility for deployment of any needed library, or software pack for any research community.

One potential application that delivers the information (learning content) from the course lecturer to the distance student and vice versa with a very high presenting quality is the Cisco WebEx application. WebEx suite, compared to other tools, offers a broad range of Web conferencing, and content sharing [25]. No software download is required for participants, and WebEx will run on any Internet server, or mobile devices such as smart phones, or tablets. A summary of WebEx Key features is given in [26]. WebEx can be used for different educational scenarios. For example the WebEx Whiteboard is a suitable tool for teachers in distance learning sessions. Also there is a possibility of annotations of the browser's application while sharing a map. WebEx is also a suitable tool for sharing and highlighting medical images in Telemedicine. WebEx offers possibility for sharing a presentation, where either can be used the WebEx annotation tools, or better the Power point annotation tools that are available in the presenter mode.

5. Quality of Experience (QoE) of MDL in MCC Environment

Mobile Distance Learning in a Mobile Cloud Computing Environment can be evaluated on both QoS and QoE aspects. Below is provided a short description for each of these aspects.

QoS refers to the technical aspects. It is defined as the ability of the network to provide a service at an assured service level. QoS encompasses all functions, mechanisms and procedures in the network and the terminal that ensure the provision of the negotiated service quality between the User Equipment (UE) and the Core Network (CN). QoS is measured, expressed and understood in terms of networks and network elements, which usually has little meaning to a user. The reliability in service concerns throughput, delay, jitter and loss in data during transmission of data; service availability, security in terms of authentication as well as authorization, coverage area, and service setup time of the related bearer service; service retain ability, in general characterizes connection losses [27].

QoE refers to the perception of the user about the quality of a particular service, or network, i.e., it depends on customer satisfaction in terms of usability, accessibility, retain ability and integrity of the service. QoE means overall acceptability of an application, or service, as perceived subjectively by the end-user. Quality of Experience includes the complete end-to-end system effects (client, terminal, network, services infrastructure, multimedia learning content, etc.). Overall acceptability may be influenced by user expectations and context.

However, the overall QoE (user perception) is influenced by both technical performance of the network (QoS aspects) and the non-technical aspects of the service. This is illustrated on Figure 3. QoE refers to the personal feelings of the customer about the quality of a service, and it expresses using perceptive words like 'good', 'excellent', 'poor' [28].

Since High Speed reliable and secured internet access is used at the University Campus Network it can be assumed that the network has excellent technical performances, i.e., no QoS technical issues are present. Therefore the main focus in this paper is directed towards the non-technical aspects of QoE evaluation of the mobile distance learning system in MCC environment, and its comparison to the conventional distance learning system in CC environment.

The QoE will be evaluated through answering the survey questions by the participants after the completion of the distance learning course. The survey contains the following questions:

- What is the user's satisfaction in using the system from quality of presentation of learning documents?
- Is it easy to understand the presented concept?
- Did the user focus very easy to the presentation?

- How interactive is the system for communication with the presenter, asking the questions, etc.?
- Did the user find the Human Computer Interaction (HCI) friendly for himself/herself?
- How available is the learning system to the user?
- Did you find the usage of High Performance Computing (HPC) Center useful?

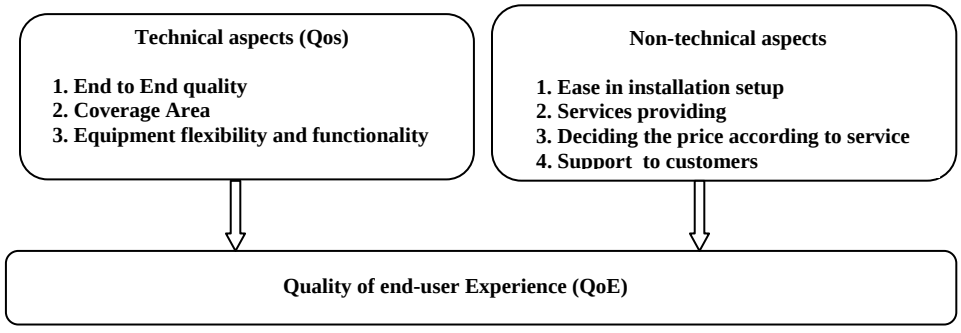

Figure 3. Relation between QoS and QoE [27].

6. QoE Evaluation Scenarios

In order to provide the QoE evaluation results (Section 7), the system has been tested in the following two environments: the Distance Learning (DL) system in the conventional Cloud Computing (CC) environment and MDL system in MCC environment. These two scenarios are described in subsections 6.1 and 6.2.

6.1 Evaluation of DL System in a Conventional CC Environment

The test of WebEx Communication System for the DL system in the Conventional CC Environment was performed in the following two distance learning conference scenarios: Local Conference and International Conference. This corresponds to the scenario Student at Home, Student at the Office, or Student in a Distant Classroom, described in Figure 2. The test was performed in the following two conference scenarios: the local scenario and the international scenario.

The local distance learning conference was performed locally, in order to verify whether the WebEx can be used for distance learning, as well as to discover the possibilities and features of WebEx.

The international distance learning conference was performed on an international level. A screenshot from this test is given on Figure 4. Since high and reliable internet connection existed throughout this conference students were able easily to follow the presentation, to ask questions, or to exchange some ideas using the WebEx features. Both scenarios were several times performed and were successfully completed.

6.2 QoE Evaluation of MDL System in MCC Environment

After the successful tests in subsection 6.1, the WebEx Application was tested in a MDL System. This scenario corresponds to the mobile students' category (a situation when the students are on the road), described in Figure 2. In order to perform the tests of this scenario one user used the following mobile devices: Motorola Milestone, HTC Sensation, iPhone 4 and iPad. The tests were successfully performed. Screenshots from these tests are given on Figures 5, 6 and 7.

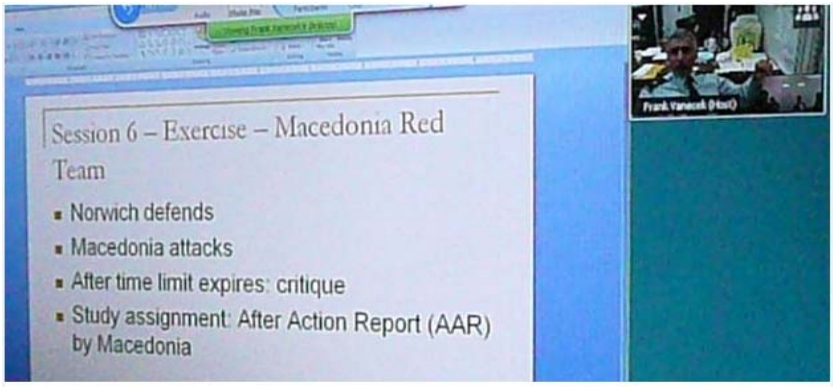

Figure 4. A screenshot from the Testing of WebEx on International Distance Learning Conference.

Figure 5. HTC Sensation as a Part of the Learning System.

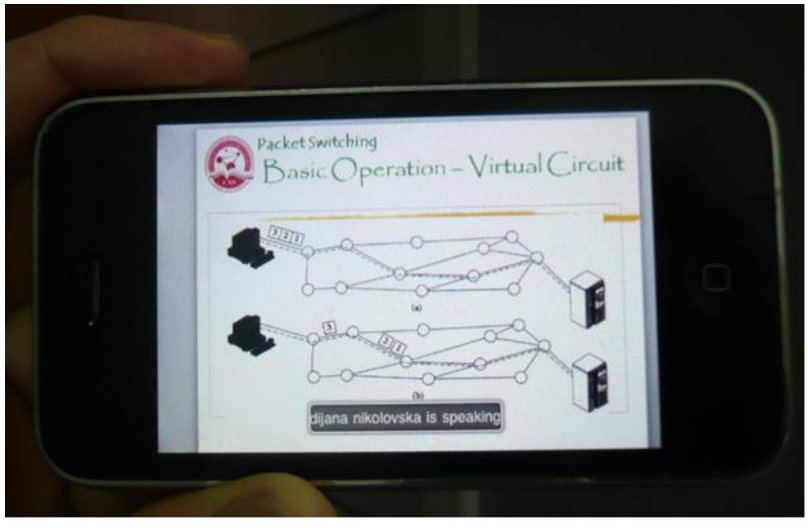

Figure 6. iPhone4 as a Part of the Learning System.

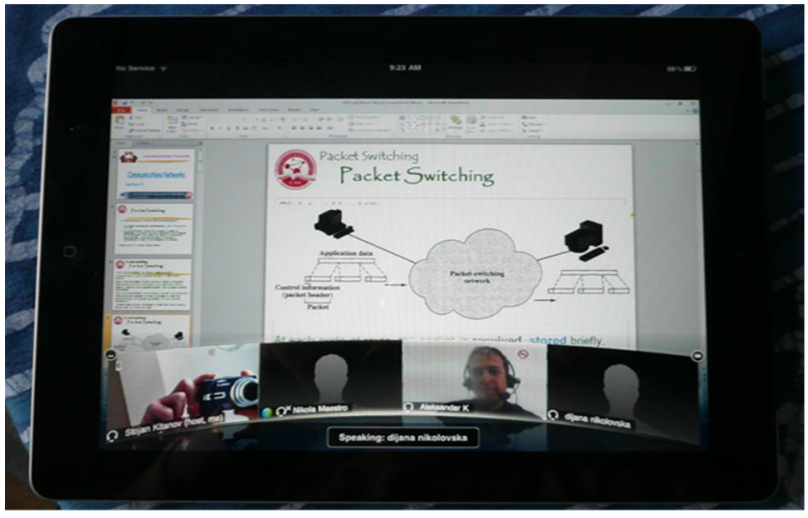

Figure 7. iPad as a Part of the Learning System.

7. Comparison of QoE Evaluation Results

The survey questions were answered by 30 students that participated in the distance learning sessions of both CC and MCC environment. They answered the questions after their participation in the distance learning course. For simplicity the answers have two options: 'good' or 'bad', i.e., 'yes', or 'no'. Each student's vote for each question has a weight of 10/3 by 30 participants. A summary of the QoE evaluation results is given in Figure 8. The following things can be concluded.

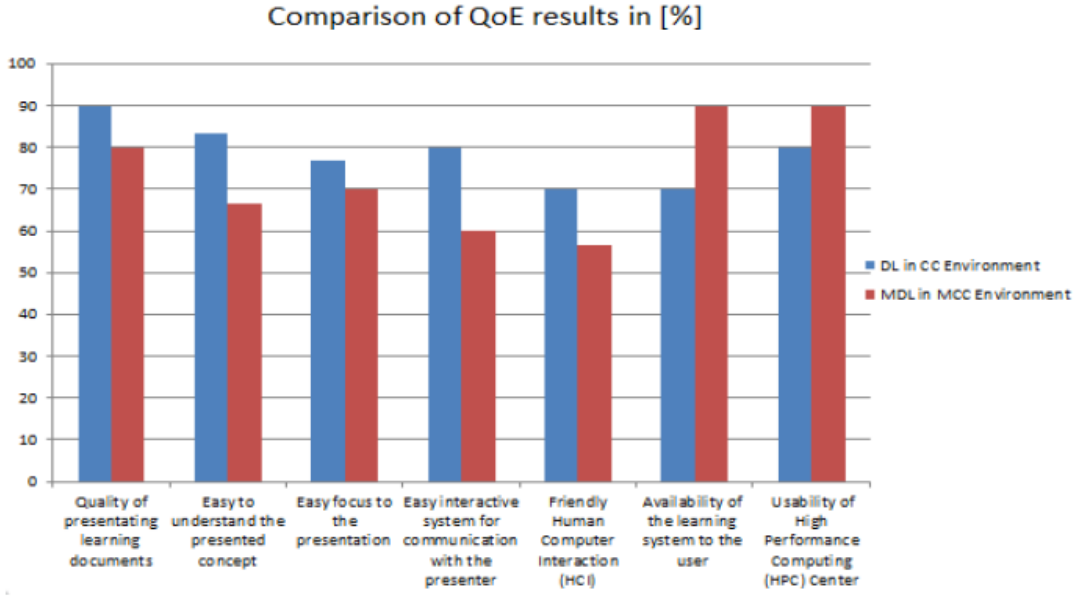

Figure 8. Comparison of QoE Evaluation Results.

The mobile devices provide higher and easier availability of the MDL system in MCC environment, since the conventional DL system in CC environment cannot provide the learning content for the mobile students. Additionally the usage of High Performance Computing (HPC)

Center is more useful for MDL system in MCC environment, rather than DL in CC environment. HPC Cluster infrastructure is useful in situations where the necessary computing cannot be performed by a mobile device, or a conventional PC, or laptop. This MCC model can be applied everywhere where there is need of fast and intensive computing and analysis of huge amount of data, such as modeling of 3D graphics visualization and animation in ecology, global climate solutions, financial risks, healthcare and medical learning, decoding genome projects, etc.

Additionally, the mobile devices have limited capabilities compared to conventional Laptop, or PC. Laptop, or PC can provide audio and video conversation, chat, and data sharing option. The tablet (iPad) supports audio and video conversation, and chat. The mobile phone supports audio conversation and chat. Currently data sharing (content sharing) from the mobile devices is not supported. A summary of the WebEx features that can be supported by the PC, and the mobile devices is given on Table 1.

Table 1. Comparison of WebEx Features Supported by PC, Laptop, Tablet or Smartphone.

WebEx Feature	Device		
	PC or Laptop	Tablet (iPad)	Mobile Phone (Smartphone)
1. Audio Conference	Yes	Yes	Yes
2. Video Conference	Yes	Yes	Currently not supported by WebEx
3. Chat	Yes	Yes	Yes
4. Content Sharing to be viewed (Data, Whiteboard, Presentation)	Yes	Yes	Yes
5. Content Sharing to be initiated (Data, Whiteboard, Presentation)	Yes	Currently not supported by WebEx	Currently not supported by WebEx

These constraints are due to the capabilities of the mobile devices as well as the features that are supported by the application (in this case the current WebEx version). However, the smart phone and the tablet (iPad) can only view the data (content) that is shared from a PC or Laptop. This is sufficient for mobile students (students on the road) to listen, to view and follow the lecture, since it not expected from them to make any presentation.

Additionally, the following was concluded. For the DL system in CC environment was noticed a perfect communication, without any delay, or noise interference, since a high speed secured reliable internet access was used. For the MDL system in MCC environment the network may not have good performances if the user uses the network on a high speed train.

8. Conclusion and Future Work

This paper provided a new Model of Distance Learning System in Mobile Cloud Computing environment, by using High Performance Computing (HPC) Cluster infrastructure, as well as some existing videoconferencing technologies enriched with mobile and wireless devices. After the introduction and the related work, the new MCC model was presented. Then new system architecture was proposed for the Mobile Distance Learning System in Mobile Cloud Computing Environment that uses the Internet Access. Then some QoE aspects of such distance learning system were addressed. Finally QoE evaluation was performed by comparing the MDL system in MCC environment with respect to the DL system in CC environment. It was concluded that mobile devices provide higher and easier availability of MDL system in MCC environment, since the conventional DL system with CC environment cannot provide the learning content for the mobile students. The smart phone and the tablet (iPad) can only view the data (content) that is shared from a PC, or

Laptop, which is sufficient for the mobile students (students on the road). They have to listen, to view and to follow the lecture, since it is not expected from them to make any presentation. Additionally, the usage of High Performance Computing (HPC) Center is more useful for the MDL system in MCC environment, rather than for the DL system in CC environment. HPC Cluster Infrastructure is useful in situations where the necessary computing cannot be performed by a mobile device, or a conventional PC, or laptop. This MCC model can be applied everywhere where there is need of fast and intensive computing and analysis of huge amount of data, such as modeling of 3D graphics visualization and animation in ecology, global climate solutions, financial risks, healthcare and medical learning, decoding genome projects, etc.

In future, the following issues for the MCC are planned to be addressed: Low Bandwidth, that could be solved with 4G (5G) and/or Femtocells, Network Access Management, QoS (from technical point of view such as network delay by using cloudlets, clonecloud, etc.), billing and standardization of the interface. However the main interest will be focused in providing more services on Software as a Service (SaaS) basis for mobile learners and/or more efficient MDL by using HPC center. Additionally, services based on simulation, or experiments performed by the HPC center on behalf of mobile users, particularly in healthcare and medical education and learning, where extremely is necessary to perform quick data analysis of 3D medical images also are planned to be included.

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Authors

Stojan Kitanov received Bachelor's Degree in Electrical Engineering majoring in Electronics and Telecommunications at Ss Cyril and Methodius University, Faculty of Electrical Engineering in Skopje in 2003. He obtained a Master of Science Degree in Telecommunication and Information Systems in the area of 4G Mobile Networks, at the University of Essex, Electronic Systems Engineering Department in Colchester, UK. Currently he is enrolled as a PhD student at the Ss. Cyril and Methodius University, Faculty of Electrical Engineering and Information Technologies in Skopje, Macedonia. From October, 2005 to August, 2010 he was Systems Support Engineer in Motorola. He provided technical support for GSM and WiMAX networks to the 2nd Mobile Operator in Macedonia, ONE. He also participated in the deployment of many GSM Base Stations, GSM EDGE Deployment, WiMAX Deployment as well as software upgrade of GSM and WiMAX Live Networks. During his employment he completed many trainings at the Motorola Training Centre in Swindon, UK and he obtained many qualifications from GSM and WiMAX networks and quality control, among them Motorola Professional Certificate in Wireless and Mobile Networks – BSS Optimization Engineer Networks 2nd Level Intermediate and he obtained yellow badge for quality control. In November 2010 he obtained the professional certificate in Java SE, from the Oracle University. Currently he works as a teaching and research Assistant at the University for Information Technology and Science in Ohrid, Macedonia, since December 2010. His research interests include Next Generation Mobile and Wireless Networks, Future Optical Networks, Distributed systems, GRID network, Cloud computing, Multimedia Networks and Services and Architecture of Future Internet.

Danco Davcev obtained the degree of Engineer in Electronics and Computer Science from the Faculty of Electrical Engineering at the University of Belgrade (YU) in 1972. He received his "Doctor – Ingenieur" degree in Computer Science from the University of ORSAY (Paris, France) in 1975 and Ph.D. degree in Informatics from the University of Belgrade (YU) in 1981. From 1984 - 1985 he was a Fulbright postdoctoral research scientist at the University of California, San Diego (USA). In 2001/2002 he was a Visiting Fulbright Research Professor at several Universities in USA, where he was working on Distance Education projects, cross-cultural educational programs, Augmented Reality systems and Multi-agent systems. He participated on several International conferences and gave several invited lectures and seminars. He is currently a professor in Computer Science and Engineering at "Ss Cyril and Methodius" University in Skopje, Macedonia. He has more than 250 research papers presented on International Conferences or published in International Journals in Computer Science and Informatics. His research interests include Multimedia Databases and Educational Systems, Spatio-temporal data and 3D objects, Intelligent Information Systems and data fusion, Distributed Systems, Cloud computing, Wireless sensor systems, mobile computing etc. He is a Senior member of ACM and a Senior Member of IEEE.