Adaptive Multimedia Learning Delivered in Mobile Cloud Computing Environment

Aleksandar Karadimce, Danco Davcev
Faculty of Computer Science and Engineering, University Ss Cyril and Methodius
Skopje, R. Macedonia
akaradimce@ieee.org, danco.davcev@finki.ukim.mk

***Abstract*— The process of integrating multimedia files, such as different types of learning objects (video, images, audio, animation, etc.) to m-learning systems requires more computational resources than mobile devices can provide. Considering mobile device limitations, such as storage, computing power and bandwidth, we propose a mobile cloud computing in order to deliver adaptive multimedia learning courses to students. In this paper, we propose a PaaS cloud-based framework, which offloads the process of dynamically adapting the multimedia content to the context-aware mobile learning environment. Hence, the student is provided with multimedia that is tailored to his or her cognitive style and the content is adapted according to context – aware network conditions.**

Keywords- mobile computing; cloud computing; adaptive multimedia learning; user profile; context-aware.

I. INTRODUCTION

Incorporation of mobile devices during m-learning is done in order to improve and increase the scalability, collaboration and availability of learners. Multimedia learning systems typically include different kinds of multimedia resources such as audio, video, images, text etc., since they provide an efficient learning environment. There are always newer multimedia functionalities available on mobile devices that need to be exploited during the process of m-learning.

Mobile language learning with multimedia using the image and audio-based training has opened the opportunity to develop mobile augmented and virtual reality spheres [1]. However, on the other hand, we can see the opportunities that mobile cloud computing architecture has provided for mlearning, with different cloud service models in university education, using a Software-as-a-Service (SaaS) cloud model, as in [2]. Similar related work has been done in [3], with the promotion of potential of m-learning using cloud computing for talent training in universities. In [4], X. Bai presented an application for interactive learning through mobile devices combined with the new technology of cloud computing where live lectures from the instructor's webcam are streamed to the cloud. Hence, the students interact with the lecturer and this increases the collaboration between them.

In [12], D. Kovachev et al. introduce the future prospects of web and mobile multimedia development for creating the next generation of mobile web applications and the new standards and protocols like HTML5 and XAML [16]. Similar to the research done in [8], we have also used the web browser that is an integral part of mobile devices to be used for accessing the adaptive multimedia learning system. The main contribution of this paper is exploiting the processing power of mobile cloud computing to adapt the multimedia content to the cognitive style and context – aware network conditions of the mobile user.

This paper is organized as follows: Section II presents our proposed architecture of the adaptive multimedia learning framework. Section III describes the data workflow for provisioning multimedia learning requests. Section IV presents the results from our experimental mobile multimedia learning system. Finally, Section V concludes the paper.

II. ARCHITECTURE OF ADAPTIVE MULTIMEDIA LEARNING SYSTEM

Existing m-learning systems typically include different kinds of multimedia resources because they help learners to be more interactive and interested for collaboration. Using the existing services on mobile devices, students are able to send their requests to be processed within the mobile cloud computing environment, in order to receive diverse multimedia learning resources. One of the first generic frameworks for mobile learning through cloud computing designed for education practitioners was presented by X. Bai [4]. They have adapted the course material for a mobile device in the form of learning content and developed a prototype of mobile-based assessment as a proof-of-concept for mobile learning. A similar framework could be found in [5]. That research has introduced an interactive mobile live video learning system in a cloud environment. Using a camera, the instructor's video presentation was captured and then was uploaded on a private cloud. Later, students using GPRS/WiFi connectivity on mobile devices are able to progressively download or replay the video [5].

The proposed adaptive multimedia learning framework (see Figure 1) in this research adopts the multimedia content to the cognitive style and context – aware network conditions of the mobile user. All of the requests from student's mobile device are sent to the mobile cloud and the response is appropriate multimedia content. The mobile cloud computing role is to offload and to reduce the workload of mobile devices by exploiting the remote multimedia processing resources in the cloud. That way, all the SQL queries that are sent from students and professors and the heavy-duty processing tasks will be executed in the mobile cloud.

Figure 1. Architecture of adaptive multimedia learning framework

Processing of the requests in the mobile cloud starts with gathering the context-aware information from the mobile user. Firstly, the mobile request is processed by the Request broker and scheduled for execution in the cloud. Next, Content adaptation component is analyzing the request and checks that the multimedia content is adapted to the context-aware conditions and user cognitive style. The proposed m-learning development environment is based on the Platform as Service (PaaS) cloud model that comes with integrated developer tools, a database management system and a web server. The web browser platform can work on different operating systems for mobile devices, and, in that manner, students and professors simultaneously can access the multi-tenant cloud-based platform from any location, at any time. The students can work on their application independently and efficiently without additional problems with software installation and compatibility issues.

Depending on the context-aware network conditions and the cognitive style estimation, the multimedia files are adapted and the request is sent to the Content delivery component to broadcast the appropriate information. The main advantage of the proposed architecture is that it offers a direct and flexible connection between the student and the mobile cloud environment. Different kinds of mobile devices (iPhone, HTC, Nokia etc.) using the diversity of access networks can connect to the Internet or telecommunication networks (using WiFi, WiMAX, UMTS, GPRS, HSDPA, 4G or LTE) and provide access to the needed service. The intention is to provide a set of mobile services that will allow mobile devices to communicate with the mobile cloud.

III. Data workflow for provisioning multimedia learning requests

The main focus of the proposed adaptive multimedia learning framework are the multimedia files. Initially, their delivery depends on context-aware network conditions and the type of mobile device that the students are using. Therefore, multimedia files need to be adapted according to the available bandwidth of the network connection and they should be encoded with the corresponding format and coding of the user's mobile device. Because of existing mobile device limitations, such as storage, computing power and bandwidth, we propose to use mobile cloud computing in order to deliver adaptive multimedia learning content. The results from our research have provided the data workflow diagram for provisioning multimedia learning requests in the adaptive multimedia learning framework.

The advantage of the proposed architecture is that all of the encoding and adaptation of the multimedia learning content is done in the mobile cloud and the ready multimedia data (MM data) is streamed back to the user. The top layer of the data workflow is dedicated to the mobile device. From there, the request is sent to the cloud. The collection station gathers all necessary context-aware information: type of mobile device, OS of mobile device and bandwidth settings of the network connection (see Figure 3).

Before users start using an application for the first time, cognitive style estimation will be conducted. We have used the Verbal-Visual Learning Style Rating (VVLSR) questionnaire, intended to tap the cognitive perception style [15]. The VVLSR questionnaire is an original one-item rating task used to estimate visualizer-verbalizer style dimension using a single question [15]. The question is: "In a learning situation sometimes information is presented verbally and sometimes information is presented visually. Please check mark indicating your learning preference" [15]. The answers rate the preference for visual versus verbal learning on a 7-point scale, as shown in Figure 2. The process of collecting of all VVLSR answers from the application users will fill the user profiles database that is stored in the mobile cloud. Verbalizers are users that have provided answers counted -3,-2,-1; visualizers are users with answers counted +3,+2,+1; and bimodal users provide count 0, which are saved in the user profiles database.

Hereafter, the user of mobile device can easily send his or her requests to be processed within the mobile cloud computing environment. After processing the received requests in the Analysis/Estimation engine we will have adapted multimedia content ready to be delivered to the user.

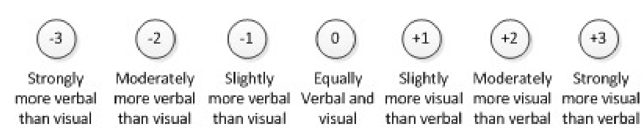

Figure 2. Verbal-Visual Learning Style Rating 7-point scale [15]

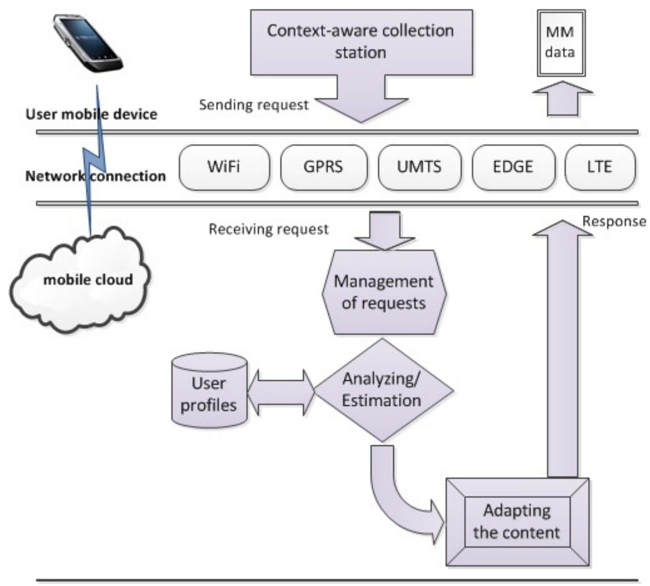

Figure 3. Data workflow for provisioning multimedia learning requests

Using the proposed cloud-based framework the CSE (computer science engineering) students have taken the role of main developers. They have created database objects, have written SQL request queries and have developed the web-based application. The proposed multi-tenant mobile cloud computing environment provides delivery of the distance learning environment where all of the participants are grouped by different roles. The professor has a supervisory role that allows him to be able to access the development environment. He can provide scaffolding and propose more efficient solutions or can interactively support error debugging in the application development progress. In the proposed data workflow, students and professors have independent access to the same development environment, while the end users have access only to the application level.

The main benefit of this proposed architecture is that no software download is required for CSE students to start development on any mobile device with its own web browser that is integral part of the device. The Web service reference is based on a Web Services Description Language (WSDL) document that describes the target Web service. When you create a Web service reference using a wizard, first it analyses the WSDL and collects all the necessary information to create a valid SOAP (the Simple Object Access Protocol) message. Using web-based mobile services, users of mobile devices easily send their requests to be processed within the mobile cloud computing environment. The received HTTP requests can then be managed and scheduled for processing in the mobile cloud.

Using the context – aware network conditions, presented by QoS and the user profile database, which takes into consideration the user cognitive perception style measured by QoE, we have the mapping settings given in Table 1.

TABLE I. MAPPING BETWEEN QOS AND QOE METRICS

QoS Bandwidth	QoE- cognitive perception style	
	Visual perception	Verbal perception
High	HQ images, audio and video	3D graphics, text and audio
Low	Icons and images	Text and audio

The mobile cloud is the development platform that contains the user profile database and the bandwidth network QoS estimator. The mobile devices provide information for current bandwidth. If that bandwidth is above the QoS threshold (1000 KB/s) than the user is in high bandwidth region; otherwise, below the QoS threshold, the user is considered to be in low QoS bandwidth region.

Depending on the available QoS factors, the framework can adapt to low or high bandwidth scenarios. The proposed mapping, given in Table 1, considers at the same time the user cognitive perception style. For better network conditions, in high bandwidth, the system can deliver more dynamic and high quality information. However, in low bandwidth conditions we have estimated that more static media is delivered (icons, images, text and audio). Therefore, according to the context –aware preferences, the system is providing adaptive change of the multimedia type [6]. In the last step, the requested multimedia learning content is streamed back to the mobile device. The mobile user receives dynamically adapted multimedia content to the given context compatible with its mobile device.

IV. EXPERIMENTAL MOBILE MULTIMEDIA LEARNING SYSTEM

Cloud computing is a real benefit for young and developing universities that do not have diverse computer laboratory facilities. With the integration of cloud computing technology for the courses, such as Distributed Database systems, requirements for dedicated development platform and intensive computational resources are inevitable. There already have been different related studies for cloud service models in the university, using a Software-as-a-Service (SaaS) cloud model, as in [2]. Similar related work has been done in [3], with the promotion of the potential for m-learning using the cloud computing, and the stress is put on virtualization, using the Infrastructure-as-a-Service (IaaS) cloud model.

We have proposed an experimental mobile multimedia learning system that is based on the Platform as Service (PaaS) cloud model, and it will extend the potential for developing web applications that require database background. The Oracle APEX [13] platform is a comprehensive web-based SQL and application development environment that delivers platform for fast, reliable development and running on web applications [7].

The Oracle APEX web-based platform in a mobile cloud environment allows us to write our custom SQL query and generate reports according our needs directly from the mobile device, see Figure 4.

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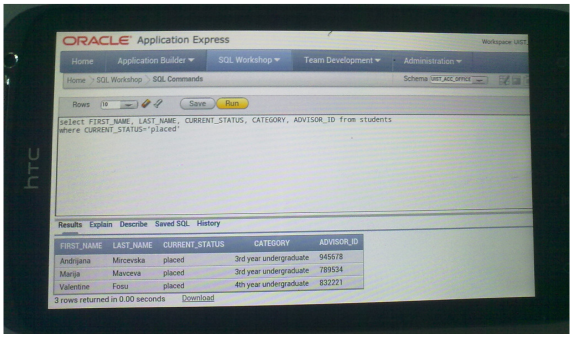

Figure 4. Running SQL query on Oracle APEX using HTC.

After we have compiled the configuration of the application, we have run experiments with three most used mobile devices: iPhone, HTC, Sony Ericsson and Nokia, which can access the Oracle APEX framework. Using the APEX platform, university students have used a simple use case web-based application for online shopping. The database system consisted of 3 tables: Customers, Products and Orders.

Figure 5 provides a comparison overview of the Products table which contains multimedia content, presented on iPhone, HTC and Nokia mobile devices. Using this overview, we cannot distinguish any significant difference when presenting the multimedia content between the three types of mobile devices.

We have done similar comparisons for the Customers and Orders database tables. There was also no difference in the display of information between the three mobile devices. Significant dissimilarity between the mobile devices was noticed in the Reports in Figure 6, where a web-based OLAP report is executed. Here, Nokia and iPhone mobile devices did not provide the expected multimedia graphs for the Report of Sales by Category/Month. The Sony Ericsson mobile device that uses Android mobile OS, on the other hand created a colorful histogram for the Report of Sales by Category/Month, as seen in Figure 6.

We noticed from our research that there was also a different adaptation of the multimedia content for different interfaces, depending on the web browser used by the mobile device because they displayed the same code page differently. Adapted multimedia content is usually compressed using compression algorithms or codecs in order to achieve smaller file size for faster transmission or more efficient storage [12]. The results from the experiments have shown that using different mobile devices to access a single cloud computing platform, in this case Oracle APEX, produces different user experiences.

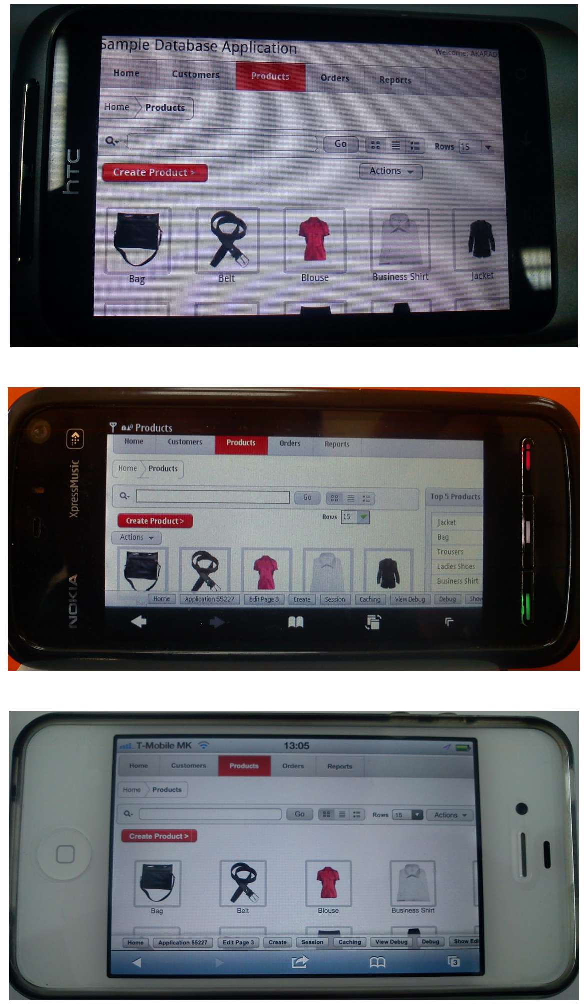

Figure 5. Comparison of database tables for Oracle APEX with HTC (top), Nokia (middle) and iPhone (bottom).

We have used OPNET for our simulations. It provides a comprehensive development environment with a full set of tools including model design, simulation, data collection, data analysis and support on the modeling of communication networks [14]. This simulator provides a way to model the network behaviors by calculating the interactions between modeling devices. We have used the Discrete Event Simulation (DES) because it enables modeling in a more accurate and realistic approach. It creates an extremely detailed, packet-by-packet model for predicting the activities of the network. The simulation models of individual mobile device were developed using the OPNET network simulation software that provides a virtual network communication environment.

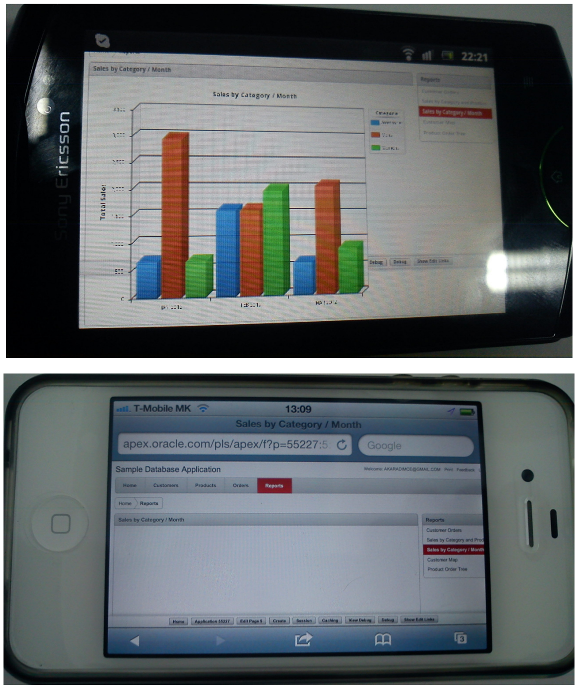

Figure 6. Comparison of reports for Oracle APEX with Sony Ericsson (top) and iPhone (bottom).

The network simulator was configured to run one hour of multimedia learning content, and the comparison of the results is presented in Figure 7. The dark blue line measures the performance from laptop using a classical web-based application without any mobile cloud environment, which takes most of the performance load. The red line measures the HTC mobile device, the green line measures the Nokia mobile device and light blue line measures the iPhone mobile device. For all mobile devices we have used the mobile cloud environment to show the decreased performance load. The simulation results from the multimedia performance load analysis clearly show that mobile devices using applications in a mobile cloud environment have a decreased performance load compared to the classical web-based application.

A. Manjunatha et al.[16] are exploring the data intensive calculations for mobile and cloud computing landscape. Similarly, S. Wang et al.[17] are addressing the adaptive mobile cloud computing techniques for graphic rendering. The integration of mobile and cloud is used for adaptive display virtualization [18]. Similarly, R. S. Khune et al.[19] proposed a cloud-based intrusion detection system for Android mobile devices that provides continuous in-depth forensic analysis to detect any misbehavior in network. In our case study mobile devices with Android mobile OS have presented the complete report with multimedia information. On the other hand, mobile devices that have Symbian and Apple mobile OS have not displayed completely the needed multimedia content. The multimedia content is usually compressed using compression algorithms or codecs, in order to achieve smaller file sizes for faster transmission or more efficient storage [12].

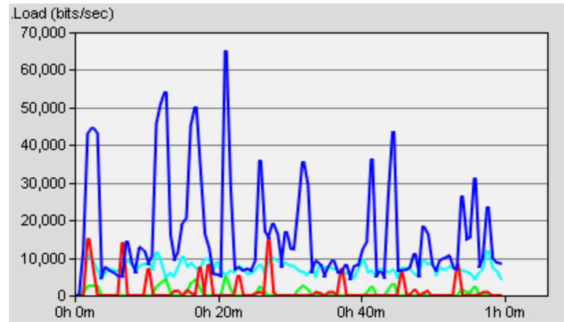

Figure 7. Comparison of performance load in OPNET simulator.

TABLE II. COMPARISON OF DIFFERENT MOBILE DEVICE MEDIA PLATFORMS

Type of media format and codecs support	**Android 3.0 [9]**	**Symbian S60 [10]**	**Apple mobile OS [11]**
Audio	AAC, MP3, MIDI, OGG (vorbis), WAV	MP3, OGG (vorbis), AAC, WMA	AAC, HE-AAC, MP3, MP3 VBR, AIFF, WAV
Image	JPEG, GIF, PNG, BMP	JPEG, GIF, PNG, BMP, MBM	JPG, TIFF, GIF
Video	H.263, H.264 AVC, MPEG-4, VP8	WMV, FLV, MP4, OGG, 3GP	H.264, MPEG-4, Motion JPEG

In Table 2, a comparison of the different mobile device media platforms is based on different formats and coding protocols for Apple, Android and Symbian mobile OS [9-11]. This represents another major challenge that m-learning faces, to adapt multimedia contents in order to be compatible with different mobile devices. Future mobile cloud computing applications should be able to provide conversion of media types to a compatible media format and codecs support for present mobile devices.

V. CONCLUSION

Mobile multimedia learning systems provide an intuitive and collaborative environment where users can experience the advantages of flexibility, portability and scalability. Mobile cloud computing can reduce the workload of mobile devices by exploiting the remote multimedia processing resources in the cloud. Therefore, all the services need to be designed in order to put less workload on the mobile device and allow heavy-duty processing tasks to be done in the cloud.

We have developed a framework for mobile adaptive multimedia learning systems that is delivered using a mobile cloud computing environment. This kind of environment provides users with the appropriate mapping settings between the type of context – aware network conditions presented by QoS and user profile estimation, which takes into consideration the user's cognitive perception style stated

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by QoE. The experiments done using three different types of mobile devices have heightened the importance of choosing the appropriate device to be used in mobile multimedia learning systems.

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