**QoE model for multimedia content delivery from mCloud to mobile devices**

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**Abstract**

Integration of mobile devices in the m-learning systems provides the learner with scaffolding outside the classroom, it allows them to easily store, record and deliver multimedia content in real-time. The process of delivering multimedia learning objects (rich text, video, images, audio, animation, etc.) from the m-learning systems to the users requires more computational resources than mobile devices can provide. Considering the existence of different kinds of mobile browsers, which have limited support for HTML plugins (Flash, Java and Silverlight), we face the challenge to deliver the adapted multimedia contents in the interactive m-learning system. Installation of add-ons to the mobile browsers is just a provisional solution that is not always possible on each mobile device. Generally, the m-learning systems presented on the mobile device that not provide rich multimedia information leads to a degraded learning experience. In order to provide users with multimedia content that is suitable for their mobile devices and according to their needs we introduce the mobile cloud computing environment as paradigm that is ideal to overcome these problems.

The proposed interactive mCloud system should provide high scale collaboration and interaction between the professor and students, in direction of increasing the quality of learning. The main focus is the delivery of multimedia learning objects to the users depending on the student’s cognitive style and adapting the content in accordance with the context-aware network conditions. The main task within this paper is to design a QoE model for estimating the multidimensional metric based on multimedia content adaptive features.

**Keywords**

Multimedia content, mobile cloud computing, user profile, QoE, QoL

**1. Introduction**

Throughout the traditional learning, educational process takes place in classroom, where professors and students are meeting face to face at the same time and in the same place. During the lectures professors present the learning material and interact with the students through sequence of questions and answers, which allows them to give rough assessment on level of achieved students’ knowledge. The learning materials are limited with certain multimedia objects that the professors have previously arranged and it is not possible to adapt that content to individual students learning requirements and cognitive style. Introduction of the mobile learning systems have provided a potential for introducing anytime and anywhere educational environment that supports the everyday student learning process and keep the continuity of life-long learning. Mobile devices as service platforms for distance learning are being considered as excellent educational tools for sharing multimedia learning content between learners and teachers.

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Particular benefits of mobile learning systems are easy portability, real-time learning, autonomy, interaction and collaboration in the process of m-learning [1]. However, mobile devices in order to provide these advantages are facing certain limitation, such as computational capacity and limited battery power, in the process of delivering secure multimedia based services to the learners. Existing mobile learning systems, which are based on traditional teaching and assessment principles, provide one and the same learning content to every student [2]. Certain progress can be observed with the introduction of the interactive mobile live video learning system in a cloud environment [3]. Here instructors video presentation was captured in private cloud and later students using GPRS/WiFi connectivity on mobile device where able to progressively download or play the video [3]. Existing m-learning environments still experience diverse technological and Quality of Service (QoS) problems in the process of delivering different kind of multimedia materials; adaptation of the learning material to individual student needs. Another important challenge is the real-time interaction between student and the environment that is difficult to achieve because of the context-aware bandwidth limitations.

The main advantages of the cloud computing in general are centralized storage, memory and data processing providing increased capacity for multimedia distribution. The existing intelligent multimedia delivery, based on cloud computing infrastructure called EVE (Elastic Video Endpoint), provides dynamic provisioning of multimedia content [4]. Similarly, there is positive improvement in m-learning systems with the emergence of EBTICs international iCampus (intelligent campus) initiative, which is delivering customized and adapted learning to individuals via mobile devices [6]. Its intelligent engine uses the Learning-Assessment-Communication-Analysis (LACA) model. The dynamic engine generates content based on the assessment of learners effectiveness and outcomes, rather than time spent on learning [6]. Benefit of delivery of multimedia content in cloud computing for the m-learning has already provided enhanced learning and more transparency, collaboration in the education [4], [7]. Important part of the research has been dedicated to the development of the model for estimating the students perception of Quality of Experience (QoE). This estimation model analyses the influence of cognitive style perception of different type of multimedia content, taking into consideration the multidimensional aspects of the QoE perception [8]. We have proposed conceptual QoE model for multimedia mCloud learning environment that uses the benefits of the cloud computing technology to deliver the learning materials.

This paper is organized as follows. Section II describes the proposed conceptual QoE model for multimedia learning in cloud computing environment. Section III presents QoE as multidimensional quality metrics. Section IV describes experienced quality evaluation and finally Section V concludes the paper.

2. CONCEPTUAL QoE MODEL FOR MULTIMEDIA LEARNING IN CLOUD COMPUTING ENVIRONMENT

Delivery of multimedia content is highly dynamic and innovative mobile technologies that are introduced every day provide increased capabilities. When new media content is offered by the teacher than it leads user’s preferences to change overtime, making a feedback loop. In order to have an efficient learning system, which increases the Quality of Learning (QoL), it is necessary continuously to receive feedback from the students in order to apply appropriate learning techniques. This feedback loop in our proposed QoE model for multimedia learning should provide collaboration between the participants using the social network interaction.

In order to increase the quality of delivering multimedia content current systems try to improve the network parameters such as delay, jitter, packet loss, which are definitely important
parameters to be considered using the Quality of Service (QoS). However, they are mainly measuring the accuracy of networked data delivery that is not sufficient to describe the actual experience of the user. Quality of Experience means overall acceptability of an application or service, as perceived subjectively by the end-user and represents multidimensional subjective concept that is not easy to evaluate [9]. The relationship between QoE and QoS is non-trivial and we have investigated and analysed what additional factors are influencing the user’s perception of quality for delivery of multimedia content in cloud computing environment.

Taking in consideration and analysing all of the factors and parameters that affect the QoE, we are proposing this conceptual model for immersive learning in cloud computing environment (Figure 1). Input parameters in this model are network parameters, measured by the QoS and the cognitive learning styles of the users, measured by the Quality of perception. Quality of perception (QoP) is a novel term which includes not only users’ enjoyment and satisfaction with a multimedia presentation, but also their ability for content perception [10]. The proposed model considers the user cognitive skills that are be used for modelling the knowledge and cognition in a given domain, as a set of metrics connected to the appropriate education rules. The QoE model is developed in order to integrate the learning process and user cognitive domain.

![Figure 1. QoE model for multimedia learning in cloud computing environment](image)

The Quality of Interaction (QoI) is defined as relation between User Interaction (UI), as a feedback loop created by the Multimedia interaction (collaboration) model and the Domain knowledge model, returned by the Quality of Feedback (QoF). The Quality of Interaction in the m-learning has proven that is an important dimension in evaluating the quality of e-learning [11]. Perceived QoP and QoI by the end user are very important parameters that form the User Experience (UX) model, measured by Quality of User Experience (QoUX). The UX model deals with studying, designing and evaluating the experiences that people are experiencing through the use of a system [12].

According to Mayer [5], the user experience is divided into four parts: perception measures, rendering quality, physiological measures, and psychological measures. His research is limited for cognitive style, learning preference, and cognitive ability for estimating the individual differences along the visualizer–verbalizer dimension within a multimedia learning environment [13]. This QoE model for multimedia learning is designed to integrate the user experience (UX), user’s personal cognitive skills and technical (QoS) parameters together. In our proposed model content adaptability will be performed by serving the user with preferable multimedia content i.e. any combination of text, graphics, audio, video or animation that best suites individual’s cognitive perception.
This way the Domain knowledge model will provide increased Quality of Learning (QoL) that participates in delivering appropriate multimedia content (MM content) in the learning process.

3. QoE AS MULTIDIMENSIONAL QUALITY METRICS

Delivery of mobile multimedia services is difficult and challenging since in the mobile environment; bandwidth and processing resources are limited. Audio-visual content is present in on demand multimedia service that will meet user expectation of perceived audio visual quality, which can differentiate the speech and non-speech contents. End-user quality expectation is influenced by a number of factors including mutual compensation effects between audio and video, content, encoding, and network settings as well as transmission conditions. Moreover, audio and video are not only mixed in the multimedia stream, but there is even a synergy of audio-visual media (audio and video).

QoE is a subjective metric that quantifies the perceived quality of a service by the viewers. As such, QoE needs to correlate numerous parameters that affect the perceived quality such as the encoding, transport, content, type of terminal, as well as the user’s expectations [14]. It defines user expected quality and satisfaction from the multimedia learning content, efficient interaction with the multimedia content provider, usability and effectiveness of the system as multimedia content provider from the user point of view. The QoE is dynamic and adaptable measure is based on a multidimensional concept that is affected by five major dimensions [8]:

- Effectiveness
- Usability
- Efficiency
- Expectations
- Context

Considering all of the above factors that the end user is expressing and the level of interaction measured by the Quality of Interaction (QoI), we have proposed the dependence formula (1). Based on the proposed conceptual model, on Figure 1, the QoI is defined as relation between the User Interaction (UI), as a feedback loop created by the multimedia interaction (collaboration) model and the domain knowledge model, returned by the Quality of Feedback (QoF), weighted by the coefficient \( m \) \((0<m<1)\). The Quality of Interaction in the e-learning has proven that is an important dimension in evaluating the quality of e-learning systems [15].

\[
QoI = m(QoF) + UI......(1)
\]

\[
QoUX = g(QoP) + u(QoI)......(2)
\]

\[
QoUX = g(QoP) + u[m(QoF) + UI]......(3)
\]

\[
QoE = f(QoS) + e(QoUX)......(4)
\]

\[
QoE = f(QoS) + e\{g(QoP) + u[m(QoF) + UI]\}......(5)
\]

Quality of User Experience, given with formula (2), is influenced by level of user’s interaction with mCloud, measured by QoI weighted by the coefficient \( u \) \((0<u<1)\), and user’s content perception QoP, weighted by the coefficient \( g \) \((0<g<1)\). If we merge formula (1) and formula (2) we will discover the 3 dimensional dependencies in UX model given with the formula (3).

From the QoE model for multimedia learning in cloud computing environment proposed in Figure 1, we can conclude that QoE, formula (4), is related with network characteristics for
delivery of multimedia content measured by QoS, with functionally relation weight \( f(0<f<1) \), and the degree of Quality of User Experience (QoUX), weighted by the coefficient \( e \ (0<e<1) \).

We can conclude from formula (5) that the QoE is multidimensional construct depending from 4 different characteristics: User Interaction (UI), Quality of Perception (QoP), Quality of Feedback (QoF) and Quality of Service (QoS). This leads to conclusion that in order to measure the QoE, users need to have efficient interaction level with the mCloud that will be achieved using the social network communication, which will provide quality feedback and will provide estimate for the perception level.

4. EXPERIENCED QUALITY EVALUATION

This paper focuses on the real-time interaction that provides collaborative and adaptive learning environment for the students, which takes into account context-aware conditions and their different cognitive perception for the multimedia content. Mayer [13] has described multimedia learning as a field which has matured over the past decade, it proposes that m-learning courses should be based on a cognitive theory. For the proposed model there exists one major open issue how to measure the cognitive dimension to the individual student, in order to deliver multimedia m-learning material which corresponds to the face-to-face knowledge communication. User Interaction (UI) between the participants is achieved by using the social network interaction forum. We propose to use questionnaires in order to estimate the cognitive dimension for the end user, measured by Quality of Perception (QoP), we have adopted Learning Scenario Questionnaire [13] for our research area of Database systems. Taking into consideration the proposed QoE model for multimedia learning in mCloud environment and the QoE as multidimensional construct given with formula (5) we have created the derived QoE dependence model, given on Figure 2.

![Figure 2. The derived QoE dependence model](image)

The proposed QoE model for estimating the multidimensional metric has been demonstrated to the students using the university distance learning web 2.0 mCloud portal. Students have been enrolled in order to learn the course Database Systems, which covers the Entity Relations (ER) and SQL query data manipulation class, see Figure 3.
After completing the course Database Systems the group of 30 students, which participated in the m-learning process, have been given Learning Scenario Questionnaire (LSQ), see Figure 4, in order to conduct estimation of user’s preferences in five learning situations for database systems.

<table>
<thead>
<tr>
<th>Learning Scenario Questionnaire</th>
</tr>
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<tbody>
<tr>
<td><strong>A.</strong> Which format do you prefer a scientific description of a Database System?</td>
</tr>
<tr>
<td>1) a paragraph describing each part</td>
</tr>
<tr>
<td>2) a label diagram showing each part</td>
</tr>
<tr>
<td><strong>B.</strong> Which format do you prefer in learning scientific explanation of how executing SQL query works?</td>
</tr>
<tr>
<td>1) an essay describing what happens with each command of SQL query statement</td>
</tr>
<tr>
<td>2) a series of labeled diagram swong the status of each part of execution scenario of SQL query</td>
</tr>
<tr>
<td><strong>C.</strong> Which format do you prefer for following directions for how to draw an ER diagram?</td>
</tr>
<tr>
<td>1) verbal direction including telling you that you have to draw first entities, attributes and relations, respectively</td>
</tr>
<tr>
<td>2) a map showing how to draw the entities, attributes, and how are they connected with relations</td>
</tr>
<tr>
<td><strong>D.</strong> Which format do you prefer for following instructions for how to aggregate data using SQL statement?</td>
</tr>
<tr>
<td>1) a list of steps in words</td>
</tr>
<tr>
<td>2) a labeled diagram showing the steps</td>
</tr>
<tr>
<td><strong>E.</strong> Which format do you prefer for describing the results of the executed SQL queries?</td>
</tr>
<tr>
<td>1) a list of results in table</td>
</tr>
<tr>
<td>2) a graphical report with chart, diagram or pie.</td>
</tr>
</tbody>
</table>

Figure 4. The Learning Scenario Questionnaire (LSQ)
Using the proposed QoE model for multimedia learning we received feedback from students via the LSQ, which offers interactive collaboration between the participants. This experience quality evaluation has been conducted using the course discussion forum, which allowed each user independently to answer the questions from the Learning Scenario Questionnaire. The mCloud learning portal is consisted of social network forum that provides interactive communication that was used to conduct experience quality evaluation and receive feedback from the students, see Figure 5.

Figure 5. The University web 2.0 mCloud social network forum

After analysis of these results we have gained one more metric, the Quality of Feedback (QoF) in our proposed conceptual QoE model for multimedia mCloud learning environment. Complete review of the results from the completed Learning Scenario Questionnaire is given in Figure 6.

Figure 6. The derived QoE dependence model

These results confirm that majority of the students are video learners – verbalizers, they prefer to receive graphical/image learning objects. The peak is emphasized in question B from the Learning Scenario Questionnaire that highlights the use of labelled diagram for on the question “how executing SQL query works”. However, in the question C from the Learning Scenario
Questionnaire the audio learners – verbalizers prefer to receive textual instructions in form of learning objects, have shown increased interest. This QoE model for estimating the multidimensional metric that is proposed in this research evidently provides increased student satisfaction and advantage of the used methodology of learning.

5. CONCLUSIONS

The proposed QoE model for multimedia mCloud learning environment uses the benefits of the cloud computing technology to deliver the learning materials. It enables the students to learn their topics of interest transparently and immediately using various devices whenever and wherever they want. In this paper we have proposed a QoE model for estimating the multidimensional metric based on audio and video multimedia content adaptive features. Results from the research have concluded that the QoE metrics as multidimensional construct is dependent from 4 different characteristics: User Interaction (UI), Quality of Perception (QoP), Quality of Feedback (QoF) and Quality of Service (QoS). These factors directly influence the user satisfaction with the system used, resulting to increased knowledge that has impact to the learning process in general. We can conclude that cognitive style and user interaction, with hands on practice, provides increased educational benefit, measured by increased Quality of Learning (QoL).

REFERENCES


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