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QoE Measurement in E-learning Systems Based on a Videoconferencing Platform

Toni Malinovski, Tatjana Vasileva-Stojanovska, and Vladimir Trajkovik

Ss. Cyril and Methodius University, Faculty of Electrical Engineering and Information Technologies, Skopje, Macedonia

Abstract – E-learning educational systems are constantly being evaluated in a terms of performance, availability and their capacity to meet the end-users needs at the end. Technical behavior of the equipment, infrastructure-related parameters, overall QoS performance are lacking sufficient information about the end-users' experience. This paper explores videoconferencing implementation of an e-learning system, considering both necessary QoS controls (of the underlying videoconferencing infrastructure) and students' QoE perception (of the achieved learning). We propose basic and extended QoE measurement methods. In the basic model, we combine two different techniques based on surveys and cognitive interviews for students' evaluation in order to decrease the measurements errors and provide proper results. The extended approach based on ANFIS neuro-fuzzy model, is used to identify the causal relationship between input parameters of both objective and subjective nature, and the resulting QoE. The extended model uses the QoE estimation from the basic model as a subjective input variable to the system. To evaluate results of the basic model and support our claims, test experiment is conducted with videoconferencing application in two combined learning sessions, while gathered information is process through the proposed basic QoE measurement model.

Keywords – QoS, QoE measurement, Videoconferencing, E-learning educational systems, Neuro-fuzzy model, Evaluation

1. Introduction

Videoconferencing is a mature technology and is used heavily for different applications, since there are increasing reasons for people to meet in real time with one another, while reducing travel and associated costs. These applications cover collaborative sessions between two or more parties, distance-learning course delivery, internal/external corporate communication, general meetings etc. Videoconferencing session is a rich media experience that integrates audio, video and personal computer content and supports far greater interaction than is otherwise possible from many synchronous and asynchronous technologies.

Distance learning educational systems are becoming more popular in recent years while utilizing different forms of electronically supported learning and teaching. Videoconferencing provides collaborative sessions between two or more involved parties, so it is often utilized in the educational process while bringing the teacher as a source of information and the students, together in a 'same environment' for a learning session. Therefore an effective approach must be taken; proper factors must be evaluated, so the videoconferencing based e-learning systems can provide successful learning process at the end.

Videoconferencing has a close connection to the technological equipment and the underlying transport infrastructure. These factors influence the overall quality of the learning process during a videoconferencing sessions. But the distance learning models are not only dependent from the technological factors. They have close connection to students' engagement, students' technical background, motivation to learn, students' behavior and expectations from the learning process.

Therefore, our research focuses on the relation between the technical parameters and subjective students' perception, while providing preliminary analysis that can determine some of the factors that influence successful videoconferencing based learning process.

Videoconferencing basically creates two-way, interactive audio/video session, so its proper application depends from the performance of infrastructure within the system. When it is utilized in an educational system, correct teaching approach should be taken, while classroom equipment in a form of cameras, microphones and software/hardware, should be properly planed in the learning environment. Quality of Service (QoS) control must be present as set of requirements that needs to be met by the infrastructure, while transporting the data stream from the source to the destination. These provisioning methods have to include various aspects like Network-based QoS (NQoS), Application-based QoS (AQoS) and accordingly, overall QoS results as a summarization of those parameters.

Still, the evaluation of the technical aspects is lacking sufficient evidence of the user's quality perception and experience from the whole process.

ITU–T has proposed several subjective quality assessment methods for multimedia applications [12], [13]. Even more, ITU-T Recommendation G.1010 [2] has defined a model for multimedia Quality of Service (QoS) categories, which reflect end-user expectation for a range of multimedia applications, while defining eight distinct technological categories based on tolerance to information loss.

Recently using a fully user-oriented approach, researches have explored social element and students' subjective expectations, in terms of Quality of Experience (QoE) [1][8].

Even though there is extensive research in this field in the last years, only limited numbers of studies have produced information about the close relation between the technical parameters which are objective and measurable, and the subjective parameters in a form of end-user expectation and QoE.

In this paper, while focusing on videoconferencing based educational system, we analyze the necessary QoS controls that should be present to assure sufficient performance, which provides quality videoconferencing service, and their close relation with the students QoE. The presented basic QoE model encompasses survey based and cognitive interview based results, as a measurement of the students' learning experience in such environment. The extended approach based on ANFIS neuro-fuzzy model, identifies the relationship between input parameters of both objective and subjective nature, while using the QoE estimation from the basic model.

During the research process, test experiment was performed, which provided information and results from two combined learning session that included videoconferencing between universities in two different countries. The test experiment's sessions produced different results, since the live technical behavior is always depended from the infrastructure. The students' perceived QoE also varied in each different session, so obtained information was used for analysis and evaluation of the proposed basic QoE model. The real time feed from the sensors' and the instruments' logs in the infrastructure, for the QoS performance, are compared to the QoE evaluation.

The paper is organized as follows: in section 2 the research methodology and objectives are presented; analyses, test results and findings are given in section 3, while section 4 concludes the paper.

2. Methodology and Objectives

Stakeholders of the institutions that deliver distance educational programs are always interested to determine factors that can increase the quality of the learning process.

Videoconferencing platforms are often deployed within such institutions, so different educational methodologies which are focused on collaboration can be developed. These challenging learning environments must be well defined with all of its building blocks, such as coding/decoding engines, centralized management, gatekeepers, cameras, microphones etc. The network infrastructure that provides transport over the distance must be properly positioned, so it can provide necessary service and performance. Still, those institutions that deliver distance educational programs and are able to understand importance of the successful students' learning experiences will be the leaders in the e-learning area.

So, the main objective of utilizing video conferencing infrastructure in the educational programs is to increase the quality of the learning process by providing factors for increased students QoE. Of course, these factors can be elaborated in wider scale, but we try to distinguish the important parts and develop QoE measurement model that provides proper results.

Therefore the paper contains brief Network-based IP Quality of Service (NQoS) analysis, which discusses networking facilities related to QoE, and Application-based QoS (AQoS) services which must be often present, so positive QoE is available from the videoconferencing sessions.

Test experimental was performed to provide preliminary results, evaluate the proposed models and explore the relationship between the technical performance of the system and the students' perceived QoE.

2.1. NQoS and AQoS Provisioning and Controls

Videoconferencing offers real-time collaborative and interactive communication, so the delivery and the performance of the equipment, influence the whole process, when utilized in the educational systems.

NQoS provisioning and controls must be present [4], [9], so the platform can provide predictive and stable behavior during each session. The large amount of data within the converged network may introduce bottlenecks at certain part of the infrastructure, so appropriate measures must be taken in advance, to avoid the problems that may occur and provide stable, efficient, cost-effective solutions. Thus each system should have a proper NQoS policy in place which can provide reliable delivery of multimedia data over the transport infrastructure. This policy should include classification and provisioning of the overall traffic through the infrastructure and proper controls to minimize the latency, jitter, and packet loss as possible. Context-aware NQoS approach provides even better results while introducing business intelligence built on the learning session needs.

AQoS in a systems focuses on the embedded mechanisms within an application, developed to preserve the quality of its intended use. Sometimes middleware are developed [10], [11], [14] to follow the predefined behavior of the applications and also produce results that are aligned to the dynamic requirements of the end-users while using the application by situation analysis.

In the videoconferencing based platforms, AQoS deals with dynamic bandwidth allocation, adaptive coding/decoding, proper call signaling, video error concealment etc. Services like media handling, end-point registration, call admission and capabilities exchange can be optimized with AQoS. When utilized in a learning session, even though students are not directly aware, the accuracy and reliability of these services directly affects students QoE.

Therefore, when properly deployed, NQoS and AQoS complement each other within the system, thus optimizing the performance features, which is reflected in better end-user experience at the end.

Following a path analyses methodology, through series of tests, we have produce results that emphasize the connection between the overall QoS as objective factor in a videoconferencing based system and the perceived students QoE as subjective. This paper contains analysis and test results from such test experiment scenario, which illustrates definite QoS/QoE connection.

2.2. QoE Measurement

Recently different systems and applications are constantly being evaluated from end-users point of view. QoE measurement refers to evaluation of the systems in a term of end-user experience and expectations of the systems' delivery, availability and performance. When videoconferencing is introduced in the learning environment, students QoE measurement can provide theoretical and practical significance.

Undoubtedly the QoE is influenced by different factors, like previously stated QoS/QoE connection, during a learning session. Still, since QoE measurement is subjective, proper models should be developed that can ideally produce transparent measurements, which are independent from the actual environment.

In our research methodology, we are employing two approaches for QoE evaluation. The basic model considers integration of the survey based evaluations and cognitive interviews after each learning session. The main objective in this approach is to decrease the measurements errors and provide proper results. In the extended model we construct a hybrid neuro-fuzzy inference controller that is able to predict the overall QoE in accordance to the objective parameters concerning video/audio quality and QoS, as well as the subjective parameters concerning the human perception of the service. The results obtained from the basic model will be reused as a subjective input parameter in the extended model. Our goal is to compare the results from the both approaches, and possibly provide a cost effective user oriented QoE solution for different education scenarios.

2.2.1. The Basic QoE Estimation Model

The standardized survey based questions can cover larger scope for evaluation, but may introduce some level of inaccuracy due to misunderstanding of the questions or lack of motivation to fully participate, from the students' point of view. Conducting flexible interviews with larger audience is more difficult to implement, but can provide different measurements, since students will be able to understand the purpose of the questions as the survey designers intended.

Furthermore, since we have chosen a path analyses model that uses both techniques, a survey non-response adjustments [3] is also needed to produce more accurate results. Therefore incomplete survey's data (some students may decide not to answer all the questions) is corrected during the calculations.

QoE has subjective nature, so questions have to be prepared in advance and presented to the students for evaluation. In the survey based approach, these questions are distributed to the students, while in the interview based they are read and briefly explained by a moderator.

Let *N* represent the number of a survey based questions, x_i the value of variable *x* for unit *i*, while $i=1 \dots N$, and let

$$X = \sum_{i=1}^{N} x_i / N \tag{1}$$

represent mean value of *x*, which represents the positive answers in the survey based questions.

Following the same example, when *M* represents the number of questions asked during the interview based evaluations, y_j the value of variable *y* for unit *j*, while $j=1 \dots M$, we get the mean value of *y* through similar equation

$$Y = \sum_{y=1}^{M} y_i / M \tag{2}$$

In our proposed model, we summarize the positive answers of both survey techniques, so we can reach a final QoE measurement (represented as *Q)*, with non-response adjustment through the following equation

$$Q = (X*X_r + Y*Y_r)/2 \tag{3}$$

where X_r represent response rate for survey based questions and Y_r response rate for the interview based approach. We have decided to give equal weight to *X* and *Y*, even though through series of test, *Y* can be emphasized through ponder, since moderator's explanation and guidance might introduce more accurate results, than the survey based approach.

When the QoE measurement in (3) is applied in the e-learning system based on a videoconferencing platform, we can evaluate the systems capabilities to meet the students' requirements. Therefore, if such system is subjected to simulations and tests before it is utilized in the learning process, while using the proposed QoE measurement, we can predict how the system will behave when implemented in the learning environment.

2.2.2. The Hybrid Neuro-fuzzy QoE Model

In the extended approach we are employing an ANFIS (Adaptive Neuro Fuzzy Inference System) controller that operates in two phases: learning and application phase. The main objective in conceptualization of this approach was to identify the causal relationship between the parameters that affect the QoE and the overall perceived QoE. To meet our objective, we need to employ a mathematical model capable of human knowledge representation to address the subjective nature of QoE, having in mind that the traditional machine learning techniques do not offer the flexibility of knowledge representation. ANFIS is a hybrid neuro-fuzzy inference system that possesses ability to learn from sample data, as well as structured knowledge representation [15], [16].

In our ANFIS based model for QoE estimation, a five layered network structure is proposed, each layer containing nodes of different structures and connections. The input signals for every node come from the output signals from the previous level.

In the learning phase we employ a specialized learning method to minimize the system error by back propagating the error signals, i.e. to update system parameters as to reduce the system error $e_x(k)$ which is the difference between the system output $x(k)$ and the desired output $x_d(k)$. The rule base consists of first order Sugeno type rules.

The learning cycle is a two-pass, a forward pass and a backward pass. In the forward pass, an automatic Right Hand Side (RHS) tuning of the rules by using Least Square Error (LSE) algorithm (off-line learning) is done. In the backward pass, the Left Hand Side (LHS) tuning of the rules is done by using back-propagation algorithm.

In the application phase, the neuro-fuzzy model obtained in the learning phase is used to generate control actions, i.e. to tune the system parameters in order to obtain the desired QoE in the given setup of the system.

To define the extended system, three major steps should be done:

1. Identification of the input variables
2. Identification of the output variable

3. Rule base definition

2.2.2.1.Input variables identification

In the process of identification of the input variables we were guided by the researches that define the parameters that mostly affect the QoE [17]. The input variables are classified as objective and subjective.

The following objective input variables are identified:
- Visual quality
- Audio-video synchronization
- Network QoS
- User Synchronization

as well as the subjective input variables:
- User perception
- Material quality

Once we have identified the input variables, we need to define the corresponding term sets. The term set for each input variable in our system consists of the terms {poor, sufficient, good}. The membership functions are of bell-shaped type, i.e. expressed as

$$\mu(x) = bell(x;a,b,c) = \frac{1}{1+\left|\frac{x-c}{a}\right|^{2b}} \qquad (4)$$

Where the parameter *c* defines the center of the membership function (MF), parameter *a* defines the width of the MF, and the parameter *b* defines the slopes at the crossover points, i.e. the points at which the membership function gets value of 0.5.

The parameters a_i,b_i,c_i for each membership function in this level are called premise parameters. The total number of premise parameters is calculated as a product $k*n*p$ where k is the number of parameters in the bell function; n is the number of input variables; and p is the number of values in the term set of each input variable. In our model we have $k=3$, $n=6$, $p=3$; thus having a total of $3\cdot6\cdot3= 54$ premise parameters.

Graphical representation of the bell-shaped function is given in Figure 1:

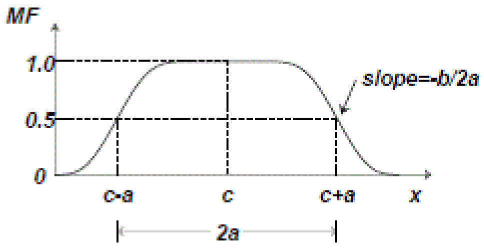

Figure 1. Bell-shaped function.

The crisp values for the objective variables are taken from the technical values for a concrete setup of the system.

The crisp values for the subjective input variable “User perception” in the extended model are used from the results for the QoE estimation in the basic model.

In a similar manner the values for the other subjective variable “Material quality” will be obtained through a survey given to the participants.

2.2.2.2.Output variable identification

A single output variable QoE is identified at the output. The QoE is subjective and measured with the Mean Opinion Score (MOS) scale. MOS is recommended by ITU-T P.800 as a subjective appraisal of a test panel with values from 1 to 5, where 5 = excellent, 4 = good, 3 = fair, 2 = poor, 1= bad [17]. The minimum threshold for acceptable quality is 3.5. Therefore, our objective is to keep the MOS value for QoE above the value of 3.5.

2.2.2.3.Rule base definition

In the first-order Sugeno fuzzy model with six input variables and one output variable, consists of rules of the following type:

Rule i: if x_1 is A_i and x_2 is B_i and x_3 is C_i and x_4 is D_i and x_5 is E_i and x_6 is F_i then $f_i=p_ix_1+q_ix_2+l_ix_3+m_ix_4+n_ix_5+s_ix_6+r_i$

In the ANFIS model the rules are “learned” from the given sample input-output data pairs in the learning cycle. The parameters p_i, q_i, l_i, m_i, n_i, s_i, r_i are the coefficients of the linear function f_i that are to be determined and tuned during the forward pass of the learning cycle. They represent the relationship between the input pattern and the output from the *i*-th rule.

2.2.2.4.The system layers

The ANFIS based structure consists of five layers, each layer containing nodes of different structures and connections. The input signals for every node come from the output signals from the previous level. The output from the *i*-th node in *k*-th layer is noted as $O_{k,i}$.

The graphical representation of the system is given in Figure 2:

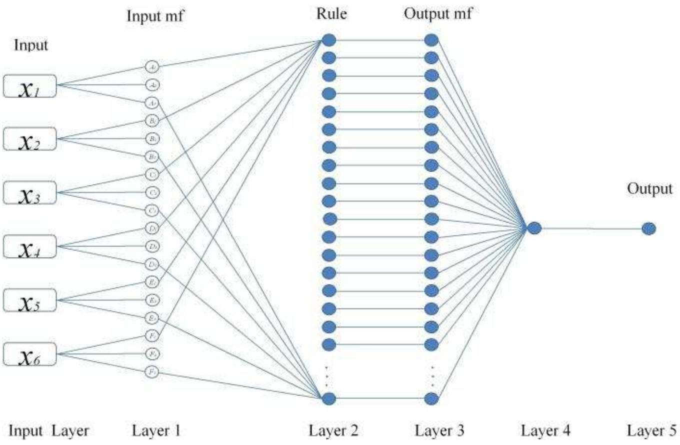

Figure 2. The graphical representation of ANFIS system with six input and one output variable.

Layer **0**: input variables layer

Layer **1-** Fuzzification layer: In this layer the membership functions and the term sets of each variable from the previous layer are defined. Each value from the term sets of the input variables represents a node in this layer.

The Output of this layer is the membership value of the input from the previous layer.

Layer **2**: Every node in layer 2 represents the firing strength of each rule using the product (or soft-min) of all incoming signals as an output signal.

$$O_{2,i}=w_i=\mu_{Ai}(x_1)\cdot \mu_{Bi}(x_2)\cdot \mu_{Ci}(x_3)\cdot \mu_{Di}(x_4)\cdot \mu_{Ei}(x_5)\cdot \mu_{Fi}(x_6)$$

Layer **3**: This layer is called a *normalization layer*, having in mind that every node represents the ratio of the node's firing strength to the sum of all rules's firing strengths. Outputs of the nodes are called normalized firing strengths.

$$O_{3,i}=\overline{w_i}=\frac{w_i}{w_1+w_2+w_3+w_4+w_5+w_6}$$

Layer **4**: The $O_{3,i}$ from the previous layer weighs the result of its linear regression $f_i=p_ix_1+q_ix_2+l_ix_3+m_ix_4+n_ix_5+s_ix_6+r_i$ in the fourth layer called the *function layer*, generating the rule output

$$O_{4,i}=\overline{w_i}f_i=\overline{w_i}(p_ix_1+q_ix_2+l_ix_3+m_ix_4+n_ix_5+s_ix_6+r_i)$$

Layer **5**: Output parameter is the overall output as sum of all incoming signals from layer 4, i.e.

$$O_{5,i}=\sum_i \overline{w_i}f_i=\frac{\sum_i w_i f_i}{\sum_i w_i}$$

2.3. Test Experiment

Following the methodology and the objective presented in this paper, test experiment was conducted, so the proposed claims can be evaluated. This test experiment evaluates overall aspects of QoS implementation, the close QoS/QoE connection and subjective QoE measurement following the proposed method.

Videoconferencing platform that connects several universities through live transport infrastructure was used as videoconferencing solutions, to enhance a learning session between two classrooms in different locations. This platform has a central location, which houses the Media control unit (MCU), gateways, gatekeepers, central management center, and several conferencing rooms connected through the central site. The management center consists of interconnect bridge, which can interconnect the videoconferencing platform with remote stations, that might or might not be a part of a closed user-group, via playing the role of a gatekeeper utilizing the standard signal protocols such as H.323. For the video encoding/decoding, the platform utilizes standard H.264 protocol and vendor proprietary Siren22 as an audio protocol. The test experiment was conduct with high quality video at 1920 kbps call rate for optimal user experience. A video recording and streaming equipment is also present at the central location, so each learning session can be recorded, edited and deployed to wider audience as content available to students at any time after the session.

Figure 3 illustrates the architecture and the components of the videoconferencing platform used in the text experiment.

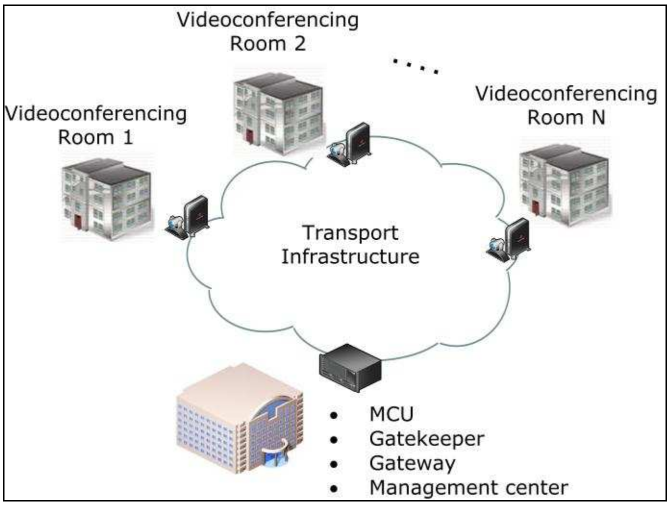

Figure 3. The architecture of the videoconferencing platform used in the test experiment.

Overall QoS policy was design to meet the experiment objectives while providing proper treatment of the videoconferencing traffic through the infrastructure. The sophisticated networking equipment was aligned according to this policy, so the infrastructure itself was tailored in a context-aware NQoS approach for optimal performance.

AQoS mechanisms were also prepared and tested in advance, so they can be fully utilized during the test experiment. Video error concealment, error correction and dynamic bandwidth allocation were implemented through the videoconferencing platform, so the delivery of rich media can be optimized towards the different videoconferencing nodes situated at different geographical locations. AQoS was also implemented to optimize the processing delay and limit the latency of signaling, while improving signaling reliability.

The NQoS and AQoS controls complemented each other during the test experiment, thus optimizing the performance features in order to improve the students' perceived QoE. Real-time feed from the sensors and the equipment in the videoconferencing platform was gathered, so proper correlation can be made with the students' subjective impressions during the learning sessions.

For the test experiment purposes, videoconferencing was used in a combined learning session which included students from the University of (F) and students from the University of (S). Total number of students was 45, which had different cultural backgrounds (they came from two different countries), different nationalities (five different nationalities in total) and were attending different fields of study (two different curricula were engaged).

Within this experiment, we conducted two video conferencing learning sessions, with the same participants, which following educational methodology which promoted collaboration among students. The first session delivered lecture from (S) to (F), and the second one was dedicated for giving lecture from (F) to (S).

To properly evaluate the videoconferencing educational system in the test experiment, each learning session was designed to start with 30 minutes of presentation from the remote lecturer through videoconferencing, which followed 30 minutes of presentation from a local lecturer at each site. It gave the students opportunity to follow hybrid course in an e-learning and face-to-face environment, so they can properly evaluate the distance learning presentation on similar topic compared to the local one.

Following our methodological approach, for both learning sessions, we have prepared survey questions and interview based evaluations.

Table 1 lists the survey based questions, that were analyzed through the (1) equation.

Table 1. Survey based questions

x variable	Question
x1	Did you think audio quality was good?
x2	Did you think video quality was good?
x3	Did you find the quality of the presentation over videoconferencing sufficient?
x4	Was the videoconferencing response time adequate to promote students participation?
x5	Were the technical directions for the videoconferencing session sufficient?

The interview based questions, listed in Table 2 were conducted by the moderator, and were later analyzed through the (2) equation.

The moderator was able to briefly introduce the evaluations, its purpose and explain each question if necessary. The interview was performed to the whole group and the students' positive answers to the questions were noted and evaluated through the research findings.

Table 2. Interview based questions

y variable	Question
y1	Were you able to maintain the attention level?
y2	Was it easy to concentrate during the learning session?
y3	Were you able to follow teacher's explanation?
y4	Did you find it easy to ask questions and get required answers?
y5	Were you able to interact with the remote site?
y6	Did you observe educational advantages in the use of this methodology?

Both learning session followed similar pedagogical methodology, while the participating students had similar technical background. The students were not aware of the technical measures in the form of QoS provisioning and controls, or the proposed QoS/QoE relation that was subjected for evaluation. They were simply participating in a learning session and were positively motivated to experience the videoconferencing integration in the learning process. The instructors did not influence student's response to the questions.

3. Research Results and Findings

QoE is conceived as a multidimensional concept [7] that is not so easy to evaluate. Since it is consisted of both objective (e.g. infrastructure-related parameters, technical behavior of the equipment, etc.) and subjective (e.g. user-related, teaching methodology, contextual) aspects, it is difficult to represent QoE with one single measurement.

Through the test experiment, overall QoS and QoE following the proposed method in (3) were evaluated, so our claims can be confirmed through practical implementation.

Since both learning sessions produced different results for the performance of the videoconferencing platform and transport infrastructure from one side, and the students subjective experience from the other, they provided valuable input in our analysis and research finding.

After each learning session, monitoring information from the infrastructure through the management center (placed at site (S)) was collected and analyzed. Table 3 represents the statistics for the technical behavior, regarding the overall QoS performance, during the learning sessions:

Table 3. Overall QoS performance during the learning sessions

	Maximum Latency (Rx/Tx) msec	Maximum Jitter (Rx/Tx) msec	Maximum Percent Packets Loss (Rx/Tx)
VC from (S) to (F)	156/180	26/45	0.5/2.4
VC from (F) to (S)	75/65	18/10	0.9/0.2

The results show that the system was behaving differently during each session, but still within the expected performance. The average results correlate to the maximum numbers for both sessions. Since both NQoS and AQoS mechanism were in place, unexpected behavior was avoided and the provided service was acceptable. Even though the system was aligned to the same overall QoS policy, the videoconferencing platform and the service from the live transport infrastructure provided different results. This was expected, so the monitoring information from the different learning session could be compared to the students QoE.

After each learning session, interview based evaluation was performed according to Table 2, which produced values for *y1* to *y6* used in (2). At the end, web link with survey questions listed in Table 1, was provided to the students, which produced values for *x1* to *x5* used in (1). The x_i values produced information about user perception for the technical behavior of the videoconferencing platform and the y_i values information about the pedagogical approach and students' experience during the learning session in general.

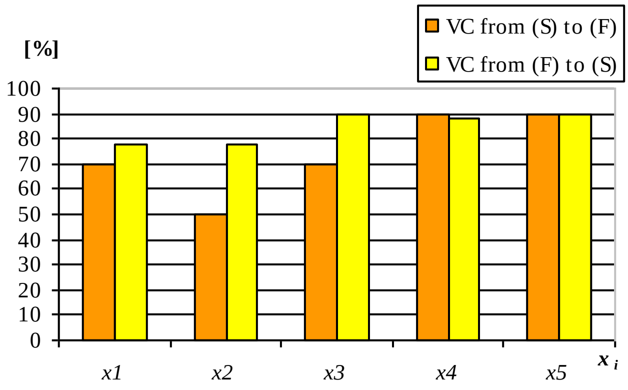

Figure 4. Students' provided values for x_i.

Figure 4 and Figure 5 illustrate the values provided by the students as positive answers to each question.

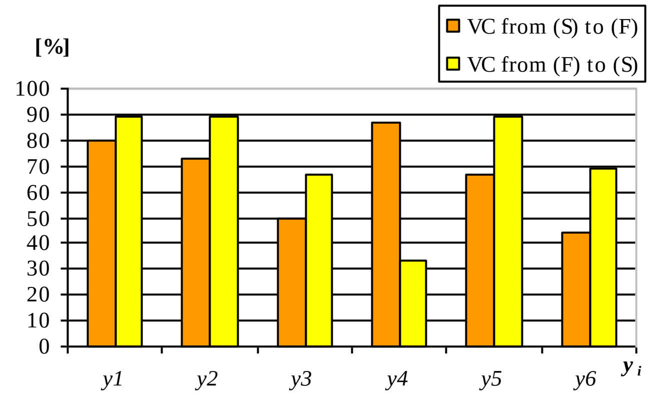

Figure 5. Students' provided values for y_i.

Table 4 lists summary of the findings for the students' perceived QoE, represented as a QoE measurement derived from the students' evaluation, calculated through the (1), (2), (3) equations (with non-response rate included).

Table 4. Students' perceived QoE during the learning sessions

	X value in (1)	*Y* value in (2)	*Q* value in (3)
VC from (S) to (F)	74%	66%	(74*0.95 + 66*1.00)/2 = 68%
VC from (F) to (S)	84%	72%	(84*0.90 + 72*1.00)/2 = 73%

The test experiment was conducted to evaluate the QoS/QoE relation in an actual scenario, while putting in practices the proposed mathematical model for basic QoE measurement. In this example, the percentage of positive answers to the elaborated questions was calculated through the equations. This approach could be extended while introducing scale of grades for each question, but we believe that this simplified approach gives also accurate results, which are sufficient for the basic QoE estimation. The students were simply expressing their positive or negative experience during the test experiment for the asked questions, without worrying of the grading scale that should be applied for each question.

The results listed it Table 4 show that second learning session produced higher level of QoE among the students. The students perceived quality and performance of the technical equipment, combined with overall experience during the learning session reached higher level of positive answers during the second session.

The test experiment has confirmed the close relationship between the QoS controls, technical performance of the system and the students perceived subjective QoE. Both learning sessions followed similar pedagogical methodology, but the difference in performance of during the first learning session, resulted in lower level of QoE. The proposed basic QoE measurement method produced results that were closely correlated to the overall QoS performance. They have shown that we have chosen proper input parameters, which are used in the ANFIS extended model for QoE estimation.

In [5] a methodology of video-stream output at the receiver for enhancing QoE is proposed, while QoE is assessed in terms of the psychological scale. In [6] authors use statistical modeling technique which correlates QoS parameters with estimates of QoE perceptions while identifying the degree of influence of each QoS parameters on the user perception. In [8] authors have explored models that can be used to predict user satisfaction according to the system performance in multimedia streaming.

The research in this paper focuses on the necessary QoS controls and provisioning that are needed in a videoconferencing based e-learning system. The proposed basic model of QoE measurement represents early stage developed model for evaluation, which will be extended in the future with the neuro-fuzzy model. The results obtained from the basic model will be reused as values for a subjective input parameter in the extended model. Together with the measurable objective parameters obtained from the visual quality metric, audio/video synchronization, network QoS and the estimated parameter for the educational material quality, we will extend the model of QoE estimation by training and testing a hybrid neuro-fuzzy system with the most relevant parameters that affect the QoE.

The test experiment has shown the close relation of QoS/QoE. Those institutions that understand the need for constant evaluation and improvement of the student perceived QoE will be the leaders in the distance learning field in the future. The QoE measurement models can be used to evaluate students QoE, which can provide preliminary results and guide institutions for future positioning and development.

4. Conclusion

This paper focuses on user oriented approach when videoconferencing system is utilized in the e-learning process. We proposed two approaches for QoE as measurement for students' experience that should be taken into consideration when e-learning systems are being evaluated.

The proposed basic QoE measurement model combines integrated survey based evaluations and cognitive interviews, evaluated through a test bed scenario. In addition to the basic model, we propose an extended ANFIS based model for QoE estimation, operating in two phases: learning and application phase. In the learning phase we use the results from the basic model and extend it with the variables affecting the overall QoE.

This paper also contains NQoS analysis, which discusses networking facilities related to QoE, and AQoS services which must be often present, so positive QoE is available for voice/video sessions.

In our future work, we plan to further extend the QoE measurement model and test its behavior while utilizing already implemented videoconferencing platform. We will continue to use the proposed models to retrieve results that will help us in the development of QoS-to-QoE mapping algorithm and QoE estimations, which can considerably improve governance and management of the e-learning systems. This can help institutions that deliver distance educational programs, in proper positioning towards the objective/subjective factors and their future development for successful educational process.

References

[1] A. Takahashi, D. Hands, and V. Barriac, "Standardization activities in the ITU for a QoE assessment of IPTV", Communications Magazine, IEEE, vol. 46, iss. 2, pp. 78-84, 2008.

[2] ITU-T Recommendation G.1010, "End-user multimedia QoS categories", 2001.

[3] R.J.A. Little, "Survey nonresponse adjustments", International statistical review, 1986.

[4] S. Bhatti, S. Sorensen, P. Clark, and J. Crowcroft, "Network QoS for grid systems", The International Journal of High Performance Computing Applications, 17(3), 2003.

[5] S. Tasaka, and H. Yoshimi, "Enhancement of QoE in audio-video IP transmission by utilizing tradeoff between spatial and temporal quality for video packet loss", Conf. Rec. IEEE GLOBECOM2008, 2008.

[6] F. Agboma, and A. Liotta, “QoE-aware QoS management”, 6th Int. Conf. on Advances in Mobile computing and Multimedia, pp. 24-26, 2008.

[7] K. Kilkki, “Quality of experience in communications ecosystem,” Journal of Universal Computer Science, vol. 14, no. 5, pp. 615–624, 2008.

[8] V. Menkovski, A. Oredope, A. Liotta, and A. Cuadra Sánchez, “Predicting Quality of Experience in multimedia streaming,” Proceedings of the 7th International Conference on Advances in Mobile Computing and Multimedia, Kuala Lumpur, Malaysia: pp. 52-59, 2009.

[9] C. E. Rothenberg, and A. Roos, "A review of policy-based resource and admission control functions in evolving access and next generation networks", Journal of Network and Systems Management, vol. 16, iss. 1, pp. 14-45, 2008.

[10] Q. Liang, H. C. Lau, and X. Wu, "Robust application-level QoS management in service-oriented systems," pp.239-246, 2008 IEEE International Conference on e-Business Engineering, 2008.

[11] P. Xiong, Y. Fan, and M. Zhou, "QoS-aware web service configuration", Systems, Man and Cybernetics, Part A: Systems and humans, IEEE Transactions on, 2008.

[12] ITU-T Recommendation P.910, Subjective video quality assessment methods for multimedia applications”, September 1999.

[13] ITU-T Recommendation P.911, “Subjective audiovisual quality assessment methods for multimedia applications”, December 1998.

[14] R.B. Halima, K. Drira, and M. Jmaiel, "A QoS-oriented reconfigurable Middleware for self-healing web services," 2008 IEEE International Conference on Web Services, pp.104-111, 2008.

[15] J.S.R Jang, C.T. Sun, and E. Mizutani, "Neuro-fuzzy and soft computing-A computational approach to learning and machine intelligence", Prentice Hall inc, 1997.

[16] J.S.R Jang, and C.T Sun, "Neuro-fuzzy modeling and control", in: Proceedings of the IEEE Issue Date: Mar 1995, pp. 378-406.

[17] F. Kuipers, R. K. D. de Vleeschauwer and K. Brunnström, "Techniques for measuring Quality of Experience", in WIRED/WIRELESS INTERNET COMMUNICATIONS, Lecture Notes in Computer Science, 2010, Volume 6074/2010, 216-227.