Enhancing User Experience for Networked Multimedia Systems

Mladen Georgievski, Nalin Sharda

School of Computer Science and Mathematics
Victoria University
PO Box 14428, Melbourne City, MC
Victoria 8001, Australia
Email(s): mladeng@csm.vu.edu.au, Nalin.Sharda@vu.edu.au

Abstract: As networked multimedia systems have evolved over the recent years, sophisticated multimedia applications have emerged. Through this, a revolution in the transmission of multimedia information over wired and wireless communication technologies has transpired. Society is now becoming more dependent on such technologies, and these are used in almost every aspect of our daily lives, including: communications, entertainment, education, marketing, research, health and medicine. To provide the user with effective experience in using these networked multimedia applications, it is imperative that optimum Quality of Service (QoS) is delivered. This requires innovative solutions for QoS management. These solutions need to employ better Human Computer Interaction (HCI) techniques and bridge the current gap between the user requirements and the system functionality. In our research, we have developed a Three Layer Quality of Service (TRAQS) model and defined a framework for QoS management of networked multimedia systems. A novel interface called the Quality Cost and Temporal Triangle (QCTT) has been implemented to provide the user with the ability to control the QoS in real-time. Furthermore, we have conducted a usability study in the application of the QCTT model for specifying and managing QoS. This paper articulates the need for developing novel QoS management models; presents the results of usability study carried out on one such model, i.e. the Quality Cost and Temporal Triangle; and discusses the benefits that can flow towards more effective deployment of networked multimedia applications.

1 Introduction

At the current rate of information communication technology (ICT) development, we can anticipate that there is a need to assimilate user requirements in developing user-oriented systems. With Networked Multimedia Systems being integrated in almost every aspect of our daily lives, we become more dependant on such systems to provide efficient and effective delivery of information. This calls for the introduction of a QoS management system that provides the facility to specify a desired service. Thus far, many research bodies have contributed to the development of communication protocols (such as: RSVP [Br97], ATM [Ha96]) and architectures (such as: QoS-A [CC97], in wireless networks UMTS [NN97]) that cater for QoS provision at the application and/or transmission perspective. Further research and development in static and dynamic QoS management [CS99] in mobile computing environments are being carried out. In this paper we present a usability study of static and dynamic QoS management based on a Three Layer QoS (TRAQS) model, QoS & Application taxonomy, and a Quality-Cost-Temporal-Triangle (QCTT) model [GS03a]. Section 2 presents an overview of Networked Multimedia Systems & QoS and section 3 presents QoS perspectives and the TRAQS model. Section 4 presents a usability study for Real-Time QoS management and section 5 presents a discussion and conclusions.

2 Networked Multimedia Systems & Quality of Service (QoS)

Effective multimedia communication requires that the delivered multimedia content be comprehended by all communicating parties. For this requirement to be satisfied, a QoS management system is required. In the following subsections we discuss the application of network multimedia systems and the necessity of Quality of Service (QoS) Management.

2.1 Applications of Network Multimedia Systems

Multimedia information includes text, images, audio video and/or combination of these. Real-time multimedia information necessitates stringent constraints on the synchronisation of the transmitted data, in order for the information to be fully comprehended. Synchronisation Accuracy Specification (SAS) factors involved in multimedia information networking include delay, jitter, skew and error rates [Sh99].

Applications of networked multimedia systems can be found in communications, entertainment, education, marketing, research, health and medicine. In most of these, a failure or misinterpretation of information could lead to even some dire consequence. For example, for a virtual organisation [Sa02] that heavily relies on video conferencing to maintain communications between offsite offices, a failure or inefficient transmission of information could paralyse communications, thus effecting the company’s operations. In order to maintain efficient communications and unambiguous multimedia information transmission, it is imperative to provide the ability to specify the required Quality of Service (QoS).

2.2 Necessity of Quality of Service Management

Multimedia communications requires end-to-end service guarantees to ensure that the transmitted multimedia information is comprehended. From this, the concept of

Quality of Service (QoS) is defined where it enables specification of a set of parameters, which encapsulate the desired qualitative and quantitative requirements of a user. By providing QoS management ability, it enables the user to specify a desired service based on their auditory and visual perception. Current development and research of QoS in communication systems mainly function at the transmission perspective layer (TPL) [SG02]. QoS is monitored and negotiated at the TPL with minimal user interaction. In [BP04], research has been carried out to extend the seven-layer-OSI model to ten layers where three additional layers consider human factors in QoS. Further research has been carried out in the role of conceptual design in establishing users' mental representations of Internet services and their cost [BS01]. If a QoS specification methodology does not consider the user's needs, it cannot be guaranteed that the user will get the service they desire. Therefore, a mechanism for specifying QoS from a user's perspective is vital. As efficient and effective specification of QoS would be desired by most users, a usability study in QoS management is paramount.

3 QoS Perspectives and the Three Layer QoS (Model)

Transmission of multimedia information can be viewed from three perspectives, i.e. User Perspective, Application Perspective and Transmission Perspective. Based on these three perspectives we have defined a Three Layer QoS (TRAQS) model that defines the concept of QoS management for networked multimedia systems.

3.1 Three Layer QoS (TRAQS) Model

The TRAQS model forms a layered architecture of the three perspectives involved in multimedia communications, where each perspective is translated as a layer. The three layers that form the TRAQS model are: User Perspective Layer, Application Perspective Layer and Transmission Perspective Layer as shown in figure 1 [SG02]. Each Layer performs QoS for a set of parameters via three modules: Assess, Map and Negotiate. The main functions of the three perspective layers are:

- *User Perspective Layer (UPL)* interacts with the user and performs QoS negotiations with the user and the APL.
- *Application Perspective Layer (APL)* caters for the needs of the multimedia application.
- *Transmission Perspective Layer (TPL)* negotiates with the network to obtain appropriate communication services.

Our research is based in the User Perspective Layer where we conduct a usability study of various HCI methods for static[1] and dynamic[2] QoS management.

[1] Static QoS Management: Configure QoS in Non-Real-time
[2] Dynamic QoS Management: Monitor and Control QoS in Real-Time

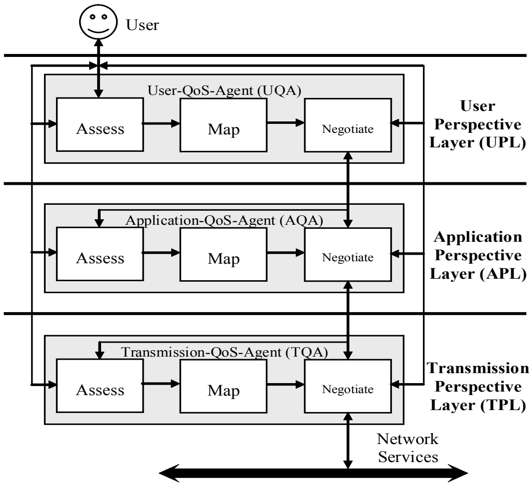


Figure 1: Three Layer QoS (TRAQS) Model

By the nature of its application, the TRAQS model can be implemented in a distributed networking environment. For running such applications as: Chat, Video-on-Demand, Online Education/Presentation, and Audio/Video Conference, we can identify three types of distributed architectures; Client—Server, Peer-to-Peer and Client-Server-Client architecture [GS03b].

3.2 QoS Taxonomy

We adopt a formal approach to categorise QoS parameters into five groups consisting of: two parameter categories – Independent and Dependent Parameters, and three profile types – User Profile, Application Profile and QoS Profile. These profiles allow specification of QoS by even non-technical users. Parameter categories and profile types defined in this taxonomy share three performance aspects: Temporal Facet, Quality Resolution, and Cost factor. The Quality, Cost, Temporal Triangle (QCTT) model embodies the inherent relationship between these performance aspects. We discuss the QCTT model in further detail in section 3.4. We define an Application Classification Model (ACM) [GS03a] that delineates spatial and temporal variations for multimedia applications into four classes of high and low frequencies. The ACM provides the ability for an application to determine the hard and soft requirements for a multimedia session in an attempt to provide effective QoS management.

3.3 Quality, Cost, Temporal Triangle (QCTT) Model

The Quality, Cost Temporal (QCTT) model provides the ability to dynamically manage QoS whilst a multimedia session is in progress. The three performance aspects – quality resolution, cost factor and temporal facet – are bound by a triangular dependency that can be modelled as a triangular relationship shown in Figure 2 [GS03c]. Similar concepts have been applied before in Multimedia Project Management [EF99]. We have developed a user interface based on the QCTT model that provides a novel approach to specifying the desired quality. A user would like to obtain the best quality with least delay and the lowest cost, practically this is not possible. The QCTT model embodies this stringency between the three performance aspects. In providing the desired QoS it is only possible to achieve 'more desirable' parameter values for two aspects, while the third is forced to be 'less desirable'. This leads to three connotations:

1. HQR & LTF → HCF, **2.** HQR & LCF → HTF, **3.** LCF & LTF → LQR
Where High = H, Low = L,
Cost Factor = CR, Temporal Facet = TF, Quality Resolution = QR

The first predicate states that if a user selects High Quality Resolution and Low Temporal Facet, then the Cost Factor will be High.

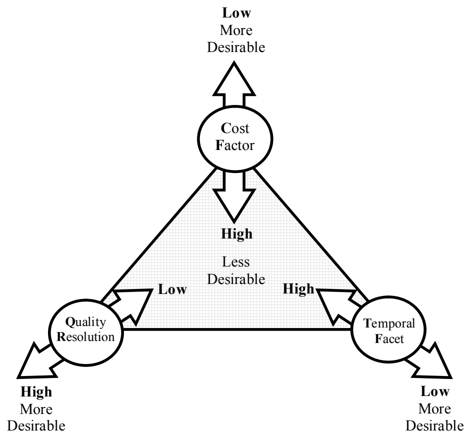


Figure 2: Quality, Cost, Temporal Triangle (QCTT) Model

4 Usability Studies for Real-Time QoS Management

In this research, we investigate the usability of Human Computer Interaction (HCI) methods developed for static and dynamic QoS management based on TRAQS, QPA, ACM, and QCTT models. Our aim is to enhance the user experience and bridge the gap between the user requirements and the system functionality. Various methods of HCI were investigated by using combinations of Physical User Interface (PUI) devices used with various Graphical User Interface (GUI) elements. Nielsen states that testing five users would reveal an average of 85% of the usability problems. To include users with diverse backgrounds we decided to use 10 participants for this usability study. Each participant was required to perform a scenario of tasks. For each experiment we collected user feedback via questionnaires.

Post Experiment Questionnaires were used to determine the participants' attitude towards the system, their knowledge of the system, and their level of satisfaction. We defined a set of criteria to evaluate various aspects of the usability for these experiments. User Task Performance Evaluation was used to determine the participants' efficiency in performing each task. Video monitoring was used to record the participant task completion time and task error logging. An error was recorded whenever a user performed an action not specified in the scenario of tasks, even if it was due to some misunderstanding. In our trial experiments we discovered that the traditional usability testing process [GS04] proved to be inadequate and posed many limitations for testing real-time systems. To overcome this obstacle we developed a new usability testing process and reconfigured our usability laboratory. From this enhancement were able to perform our usability study with improved efficiency. In the following subsections we present a usability study of static QoS management and dynamic QoS management respectively.

4.1 Usability Analysis of Static QoS Management

In this segment of our usability study, we initially conducted two fundamental HCI experiments.

1. *Fundamental Control* aimed to determine the most suitable PUI device for basic control of various GUI elements. Various PUI devices, namely: Mouse & Keyboard, Joystick, Game Pad, Steering Wheel with Pedals, and Touchpad & Pen; were interfaced with GUI elements: Menu Item, Slide-bar, Radio Buttons, Check Box, List Box, Combo Box, Push Button, Scrollbar, and Tab Control. For each task, participants were required to perform a series of actions that required clicking on objects and navigating a GUI interface. After conducting this experiment, participants showed an overall preference towards the Touchpad & Pen PUI device, with a task completion time of 32.3 seconds and a medium error count of 15 for interacting with each GUI element.

2. *Fundamental Response* aimed to determine the most suitable GUI device for basic system feedback response. Various GUI elements, namely: Audio Alert, Three Colour Traffic Light Alert (with & without Audio), Four Colour Traffic Light Alert (with & without Audio), and Pop-up (with & without Audio), to provide three random responses, namely; Critical, Informative and Advisory. We evaluated the accuracy of perception for each combination, and the participants overall preference. The final results for this experiment indicated that the Three Colour Traffic Light Alert (with Audio), Four Colour Traffic Light Alert (with Audio), and Pop-up (with Audio) provided adequate level of recognition, and the Three Colour Traffic Light Alert (without Audio) was the overall preferred GUI response element. The outcome of these experiments facilitated in designing the following QoS Management experiments.

4.1.1 Static QoS Specification

Static QoS specification implies that a user is able to specify a desired QoS prior to initiating a multimedia communication session. We developed GUI interfaces based on the QoS Parameter, and Application Taxonomy that enables a user to specify QoS using three different methods: 1.Profile Only, 2.Profile with Example, and 3.Walkthrough Wizard. Figure 3 shows an example user interface for the Walkthrough Wizard method. Feedback of the specified QoS is given by a sample video clip which can be viewed only when using the specification methods Example and Walkthrough Wizard. For this usability study, ten participants performed a scenario of nine tasks and specified QoS using the three methods as a beginner, intermediate and advanced user. We evaluated via questionnaires; the Ease of Use, Ease of Learning, Usefulness, Effectiveness, Efficiency, Satisfaction, Stress Factor and Ease of Comprehension; and via onsite monitoring the task completion time and error count.

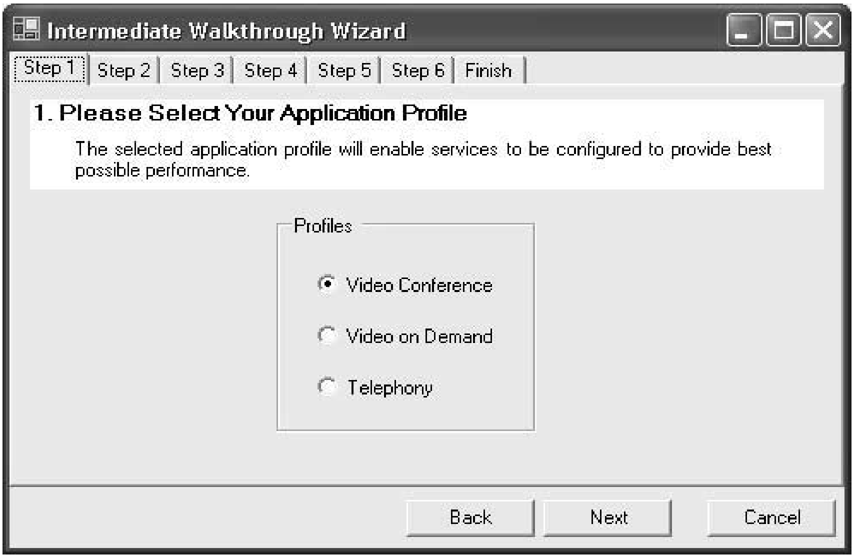
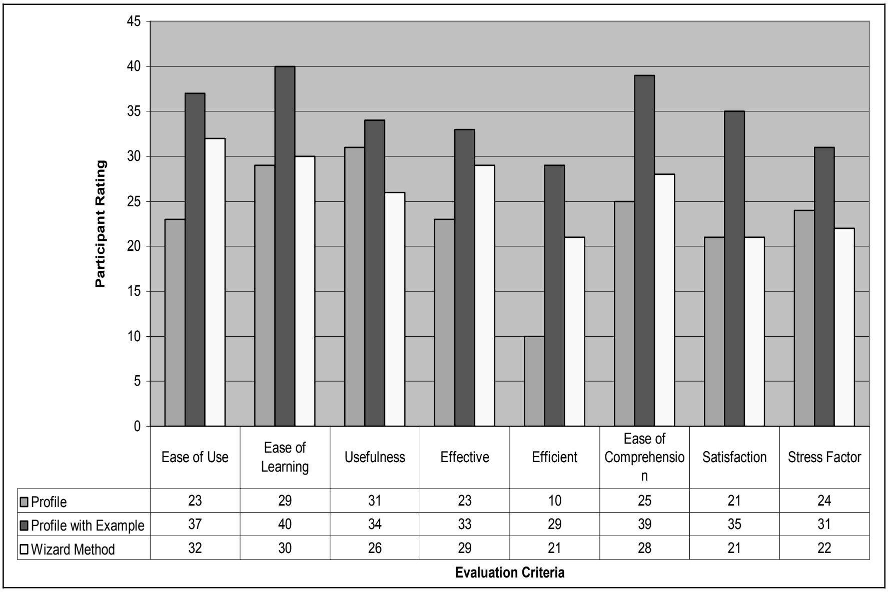


Figure 3: Static QoS Wizard Specification User Interface

Figure 4 shows aggregated results obtained by adding all the participant ratings. It can be clearly seen that participants placed first preference for the Profile with Example method, followed by second and third preference for the Walkthrough Wizard and Profile Only QoS Specification methods, respectively.



	Ease of Use	Ease of Learning	Usefulness	Effective	Efficient	Ease of Comprehension	Satisfaction	Stress Factor
Profile	23	29	31	23	10	25	21	24
Profile with Example	37	40	34	33	29	39	35	31
Wizard Method	32	30	26	29	21	28	21	22

Figure 4: Preferred Participant Rating for Three QoS Specification Methods

The Profile with Example method recorded the lowest task completion time with an average of 116 seconds, and a total error count of 10. The Walkthrough Wizard method recorded a second lowest task completion time of 65.1 seconds with a total error count of 5. The Profile method recorded the highest task completion time of 70.4 seconds with a total error count of 12. It can be concluded that the Profile with Example method is the most efficient and preferred method for static QoS specification.

4.1.2 Static QoS Negotiation

We developed an innovative QoS negotiation GUI (Figure 5) and a new QoS negotiation process for negotiating static QoS prior to initiating a multimedia communication session. Using this method participants are able to specify their desired QoS profile, and then interactively negotiate with the system; a feasible Cost and QoS via intuitive GUI elements (Four Stage Traffic, and System/User Status Response Signalling Systems). These GUI elements provide assistance and helpful system feedback to the user. Ten participants performed a scenario of six tasks in this investigation.

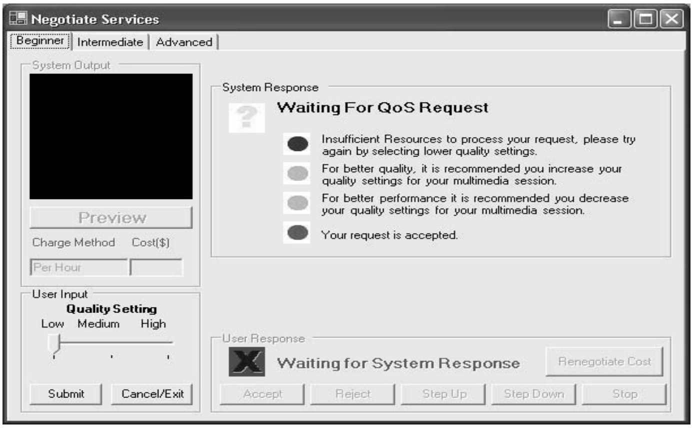


Figure 5: Static QoS Negotiation User Interface

For each task participants were required to: 1.Specify a desired QoS, 2.Negotiate a feasible QoS, and 3.Negotiate a cost that satisfies the budget restriction given. QoS feedback via a sample video was not given in this interface, as the focus was more on the negotiation process and user interface elements for providing negotiation control and response. We evaluated via questionnaires; the Ease of Use, Ease of Learning, Usefulness, Effective, Efficient, Ease of Comprehension, Satisfaction, Stress Factor, and Ease of Response Perception; and via onsite monitoring the task completion time and error count. Figure 6 indicates that participants provided a positive rating in Ease of Use, Ease of Learning, Effectiveness, Ease of Comprehension, Stress Factor and Ease of Perception. A negative rating was given for Efficiency and Satisfaction. For this experiment an average task completion time of 90.7 seconds and a total error count of 16 were recorded.

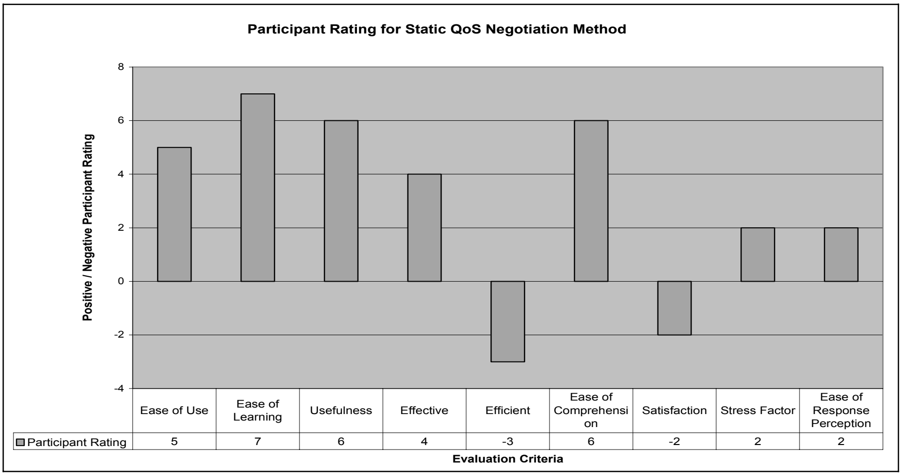


Figure 6: Participant Rating for Static QoS Negotiation

From this usability study, we can deduce that there is a need for such mechanisms for QoS management as the majority of participants have provided positive feedback. This research has shown the direction in further research to be carried out.

4.2 Usability Analysis of Dynamic QoS Management

Our analysis in Dynamic QoS management was carried out by initially conducting a usability study in Fundamental Control for a GUI interface we developed based on the QCTT model. We aimed to determine the most suitable PUI device and GUI element for basic control of the QCTT model implemented as a GUI using the Triangular Fractal System (TFS). A combination of various PUI devices namely; Mouse & Keyboard, Joystick, Game Pad, Steering Wheel with Pedals, and Touchpad & Pen; and GUI elements; Three Sliders Control, Three Numeric Buttons Control and Pivot Point Control were used in this experiment. For each task, participants were required to perform a series of actions that required controlling and repositioning the Pivot-Point in various locations in the QCTT GUI. In this study, participants showed an overall preference towards the Touchpad & Pen PUI device to interact with the GUI interface. Participants preferred to control the pivot-point using direct Pivot-Point Control, Three Slider Control for making minor adjustments and the three numeric buttons for making fine adjustments.

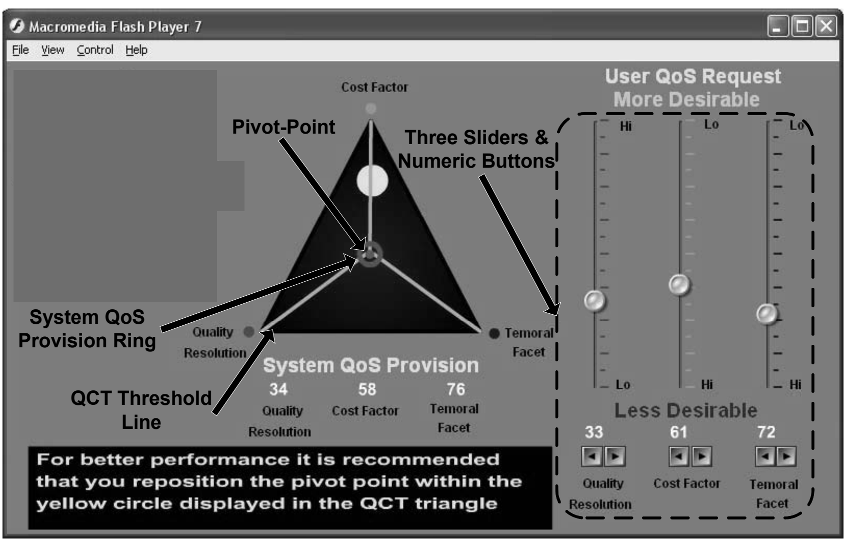


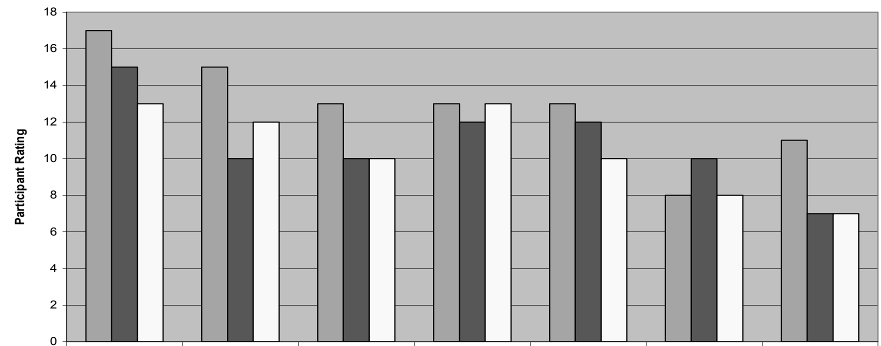
Figure 7: Dynamic QoS Management User Interface

4.2.1 Dynamic QoS Specification

We developed an innovative QoS management GUI (Figure 7) to provide an efficacious HCI method for specifying/adjusting QoS in real-time while a communication session is taking place. With the assistance of three new GUI control elements: Three Sliders Control, Three Numeric Buttons Control and Pivot Point Control; and system feedback GUI elements; System QoS Provision Ring Point, System QoS Provision Values, and QCT Threshold Line. Nine participants performed a scenario of three tasks to specify and manage QoS in real-time.

In Task-1, participants were required to specify QoS by solely repositioning the pivot-point in the QCTT GUI. In Task-2; participants were required to specify QoS and take into consideration system feedback given by the *QCT Threshold Line,* which uses a three traffic light colouring system to display system feedback of desirable and non-desirable values for each aspect in the QCTT. In Task-3, participants were required to specify QoS and take into consideration system feedback given by the *System QoS Provision Ring Point,* which displays the current QoS the system is providing. As this experiment was focused on understanding the HCI aspects of the QCTT and using it for QoS management, output of the selected QoS was not fed back into the video clip. For each task, we monitored task completion times & error counts, and Ease of Use, Ease of Learning, Usefulness, Effectiveness, Efficiency, Satisfaction, and Stress Factor were measured via questionnaires.

Figure 8 indicates that participants provided an overall high rating for specifying QoS based on the method and GUI elements used in Task-1. Participants rated Task-2 as their second preference for dynamic QoS specification, and Task-3 as the least preferred method. The average rating for this study shows our QoS specification methods are (in ascending order of participant preference): 1.Easy to use, 2. Effective, 3.Easy to learn, 4.Efficient, 5.Useful, 6.Moderatly Satisfying, and 7.Moderatly stress impacting. Task-3 recorded the lowest task completion time of 101.5 seconds, Task-2 158.4 seconds, and Task-1 183.8 seconds. Task-1 and Task-2 recorded a total error count of 3 each, and Task-3 recorded an error count of 5.



	Ease of Use	Ease of Learning	Usefulness	Effective	Efficient	Satisfaction	Stress Factor
Task 1	17	15	13	13	13	8	11
Task 2	15	10	10	12	12	10	7
Task 3	13	12	10	13	10	8	7

Evaluation Criteria

Figure 8: Participant Rating for Dynamic QoS Specification

4.2.2 Dynamic QoS Management

We enhanced the QoS Management GUI (Figure 7) to provide an efficacious HCI method for adjusting/managing QoS in real-time using advisory feedback given by the application. This interface comprises a QoS Recommendation Assistant that helps the user in making QoS adjustments when fluctuation occurs in the QoS provision. In this experiment, ten participants performed a scenario of a task where they were required to respond to several system feedbacks in real-time while carrying out a Video on Demand presentation. Once again, selected QoS parameter values were not fed back to effect changes in the video clip. We evaluated Ease of Use, Ease of Learning, Usefulness, Effectiveness, Efficiency, Satisfaction, and Stress Factor. Using our innovative method for dynamic QoS management, participants provided a positive rating for Ease of Learning, Ease of Perception, Stress Factor, and Ease of Comprehension. Ease of Use, Usefulness, Effectiveness, and Efficiency were given highest ratings, while satisfaction got a moderate rating.

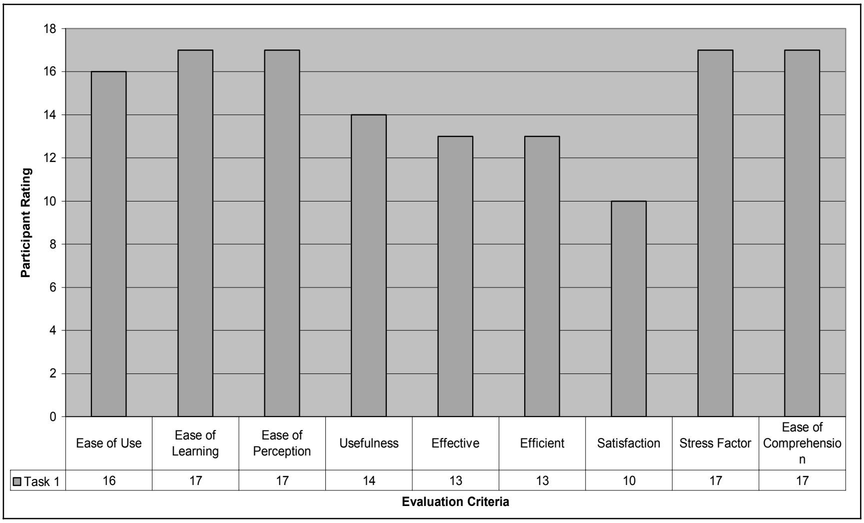


Figure 9: Participant Rating for Dynamic QoS Management

5 Discussion and Conclusions

We have presented a usability study of user interfaces designed for enhancing user experience of networked multimedia systems. The proposed QoS management system is based on a Three Layer QoS (TRAQS) model, QoS & Application Taxonomy, and the Quality Cost Temporal Triangle (QCTT) model. Initial tests pointed to the need for developing such a system for real-time QoS management Furthermore, it demonstrated the need for developing various Graphical User Interfaces and test them with different Physical User Interface devices. Based on these interfaces we carried out usability investigations for dynamic and static QoS management. This study demonstrated that the novel interfaces developed for QoS management can provide the desired functionality required for enhancing the user experience with networked multimedia applications. Further research is in motion where a QoS management user interface, based on the QCTT model, is being developed for use on Personal Digital Assistants (PDAs) and mobile phones. This user interface will incorporate QoS feedback given in the streaming video.

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