A STUDY ON THE IMPACT OF QUALITY OF SERVICE ON THE QUALITY OF EXPERIENCE IN MULTIMEDIA ENVIRONMENTS

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Abstract: Providing a guarantee for the customer satisfaction is essential nowadays in multiple domains. A user-centric approach has become a necessity since user satisfaction represents a key performance indicator for the providers; a metric, providers can use in order to improve their business. In multimedia environments, users are sensitive to factors as noise, echo or delay; it is a matter of seconds to quit using a service. To this purpose, QoS (Quality of Service) plays a crucial role. This paper focus is to provide insights on how QoS impacts the QoE (Quality of Experience) perceived by the end-user of multimedia networks. The literature review, the practical approaches and the experiments described in this paper aim at providing a better understanding of the QoS-QoE relationship when dealing with multimedia traffic.

JEL classification: C88

Key words: QoS; QoE; user; multimedia; traffic; voice; video; data.

1. INTRODUCTION

Customer satisfaction is a key performance indicator for the providers. It represents a metric, product and services suppliers can use to improve their business, therefore special attention must be paid to meeting customer expectations. A user-centric approach is a necessity in several fields, and a clear understanding the ratio between the expected satisfaction and the achieved satisfaction is recommended. In multimedia environments, user satisfaction is described by how clear they can hear their interlocutor when using voice services or how qualitative a video stream is. People are sensitive to noise, echo or delay; it is a matter of seconds to quit using a service. In this perspective, QoS (Quality of Service) plays a crucial role. This paper focus is to provide insights on how QoS impacts the QoE (Quality of Experience) perceived by the end-user of multimedia networks.

Multimedia traffic like video, voice and data requires very often to be supported by a broadband ISDN network. These types of traffic exhibit different behavior and ask for special treatment. This is where QoS tools come into play. Performance evaluation and analysis of multimedia networks is essential because test bed experiments facilitate a better understanding of QoS. QoS represents the service level at the provider side; at the user side, the measure is QoE. The paper focus alternates from QoS, which must be guaranteed at the provider's side to QoE, the guarantee of quality at end-user's side. QoS and QoE are studied with respect to multimedia traffic. Multimedia networks are environments able to service multiple types of traffic concurrently.

The paper begins with a classification of the traffic traversing multimedia network; traffic is classified according to multiple criteria. Of greatest importance we state triple play traffic: video, audio and data, which is further classified according to the bit rate into: Constant Bit Rate (CBR) and Variable Bit Rate (VBR). In the experiments referenced in this paper, QoS is analyzed at congestion time (traffic entering the network is greater than the network capacity) deploying various scenarios which combine CBR and VBR traffic with different queuing policies: FIFO, Priority Queuing (PQ) and Weighted-Fair Queuing (WFQ) and resource reservation protocols. Experiments are presented in Section 5. This represents the provider's side, which most of the time is invisible to the end-user. On the other hand, practice reveals that no matter how high the service quality, the user side is the blind spot for the provider and it represents the greatest weakness service providers need to overcome. The paper presents insights from QoE practical case studies in Section 4. Anyhow, in order to translate QoS and QoE into measurable entities, a parametric description of both is needed. In Section 3, we identify QoS parameters and QoE parameters. While QoS can be described in terms of tangible, well-defined parameters as jitter, delay or packet-loss, QoE is based very much on the emotional involvement of the end-user. Nevertheless, understanding the QoS-QoE relationship is an indirect goal of this paper work. The literature review, the practical approaches and the experiments aim at a better understanding of the QoS-QoE relationship when dealing with multimedia traffic.

2. Types of Traffic in Multimedia Networks

Multimedia traffic in its most common understanding refers to video, audio and data traffic. Blended with the power of high-speed internet access, it leads to more advanced technologies such as Voice over IP (VoIP), video on demand, IPTV and other IP multimedia services. These lay under the umbrella of 'triple play'. Triple play refers to a network which deploys real-time applications like video, audio and data services. In addition, 'quadruple play' or 'quad play' combines the triple play service with wireless facilities.

2.1. Triple Play Traffic

The first classification of traffic we address regards the triple play service. The triple play service represents the ability of supplying at once: video, audio and data. The most popular utilization scenario of audio traffic is VoIP. VoIP is a voice service which falls into the VoX (Voice over X) category, where X represents the transmission protocol; the Internet Protocol (IP) in this case. A voice service is defined as "the ability to digitize and transmit signals across a packet-switched network and the ability to do this in a way that supports near-real-time, multidirectional voice exchanges" (Hardy, 2003). In such manner, VoIP can be referred to as the ability of exchanging voice across a packet-switched network by means of the Internet Protocol, in other words "the process of converting analogue audio signals to digital signals that can be transmitted over the Internet" (Harwood, Bird &Tittel, 2005). In order to successfully and efficiently deliver VoIP over a network, real-time traffic requirements must be met. QoS/QoE of VoIP is described by the number of calls supported by the network, the call distribution, the effect of VoIP occurrence on the network, the effect of co-existing applications on VoIP etc.

In the video category falls IPTV (IP Television) a complex technology that embeds the triple play in one system. IPTV "enables the delivery of real-time television programs, movies and other type of interactive video content and multimedia services over a managed IP-based network to provide required level of quality of service (QoS), quality of experience (QoE) and interactivity" (Hassnaa & Sherali, 2012). Concurrently to IPTV, another popular phenomenon occurs in the today's Internet world: the concept of ITV (Internet TV), also known as Internet Video. The terms are very much alike and there is the tendency of confusion among the users. The main difference lays in the fact that ITV uses the public Internet in order to deliver video content.

2.2. Traffic Classification According to the Bit Rate

Concerning the bit rate, six service categories have been proposed in ATM's Traffic Management Specification (ATM, 1996): Constant Bit Rate (CBR), Variable Bit Rate (VBR): real-time and non-real time, Unspecified Bit Rate (UBR), Available Bit Rate (ABR) and Guaranteed Frame Rate (GFR). We consider CBR and VBR in the experiments described in Section 5. CBR is an encoding method that varies the quality level in order to ensure a consistent bit rate throughout an encoded file. In this category are included uncompressed audio and video streams, where packets are generated at a fixed time interval and uniform rate. Services such as interactive media communications are widely using this type of traffic for interactive media communications, so bandwidth and/or delay bounds should be guaranteed. For this traffic type, network resource reservation is required because traffic periodically arrives at a constant rate. On the other hand, VBR is an encoding method that ensures consistent high audio quality throughout an encoded file by making intelligent bit-allocation decisions during the encoding process. VBR encoding produces in general higher and more consistent quality level than Constant Bit Rate encoding. Compressed audio and video streams such as MPEG traffic belong to this. Bandwidth and/or delay bounds should be guaranteed for VBR as for CBR traffic.

3. THE QOS-QOE RELATIONSHIP

The current types of traffic are influenced by various parameters. For instance, voice traffic is impacted by jitter, packet delays or losses. In case of video streaming a network congestion occurrence may be destructive (Tobagi, el Noureddine, Chen, Markopoulou, Fraleigh, Karam, Pulido & Kimura, 2001). Therefore, the different multimedia applications ask for a certain 'level of service'. Thus, audio applications demand for a high quality of sound described by parameters as the distortion ration, frequency or noise ratio, minimal delay or good response time, while video applications reliable parameters are resolution, frame rate, color information etc. (Tsalinis & Economides, 2006). Nowadays, multimedia networks need to support and successfully provide for various multimedia applications. This requirement is what is called 'level of service' of the network and a certain degree of QoS needs to be maintained.

QoS is a broad term which embeds various technologies and can be regarded from different perspectives. From the networking perspective, QoS reflects the ability of utilizing the network most efficiently, in order to provide special treatment to the different classes of traffic that may traverse the network. From a subjective point of view, QoS reflects the user's degree of satisfaction in terms of performance. In such manner, QoS may often overlap with QoE (Quality of Experience), the quality of experience perceived at the user's side. Although the border between QoS and QoE may often be fuzzy, the two terms are different. One of the paper's goals is to describe the relationship between QoS and QoE in order to clarify what is the difference and what is the resemblance between the two. In the following, we are going to focus on the QoS-QoE parallel.

The relationship has been discussed in several paper works. For instance, in (Kuipers, Kooij, De Vleeschauewer & Brunnström, 2010) QoS is regarded as, more or less, a part of QoE, in the sense that the parameters that describe the QoS are able to define QoE too. It is our belief that the two concepts are proportional, dependent and bidirectional related. With an increased QoE need, the requirements for QoS grow, whilst there is not feasible achieving a high-level QoE without a strong QoS. Our findings reveal that the two concepts are diametrically opposed and intertwine at the same time.However, in order to perform a rigorous analysis of the concepts, parameters to describe both terms need to be considered.

3.1 QoS Parameters

In literature, multiple definitions of QoS have been formulated. Most are meaningful, some may be misleading and instead of clarifying the concept, they blur it, but all of them imply parameters. An approach regards QoS as being the term “to describe a broad set of problems and “solutions,” when the objectives themselves have not been properly articulated” (Ferguson & Huston, 1998). International Telecommunications Union defines QoS as the “collective effect of service performance which determines the degree of satisfaction of a user of the service” (ITU-T, 2008). The authors of (Tsalinis & Economides, 2006) divide QoS parameters into two categories: quantitative and qualitative. Quality of Service is defined as “the set of quantitative and qualitative characteristics of a telecommunication system that are necessary to achieve the required functionality of applications and furthermore to satisfy the user.” (Tsalinis & Economides, 2006)

QoS is an entity responsible for measuring the performance in a network and the QoS techniques need to maintain a certain degree of performance with respect to the user’s requirements. QoS comprises various network technologies and methodologies which can be combined towards an efficient network management and utilization. The main role of QoS is to manage the resources in the network and among the tasks; QoS needs to permanently monitor the bandwidth, to detect changes in the network conditions, to avoid congestion situations that may occur, to prioritize traffic and reserve resources and many others. An indirect role is to search to perform all these activities with the constant hidden purpose of enhancing the quality of experience of the user.

But, above all QoS is a measurable entity described by parameters. In a previous work (Mancas & Mocanu, 2013), we have stated that the level of service in a multimedia network can be very well described by parameters such as bandwidth, jitter, latency, and packet loss. To recall, the four parameters can be defined as follows: latency – the delay that may occur in a packet delivery, jitter – the delay in delivering a packet may vary, bandwidth – the number of bits/second being successfully delivered and packet loss – the occurrence of dropping a packet. In addition, Cisco states that the parameters that influence the quality in transmission over the network are: latency (delay), jitter (delay variation), and loss (packet loss). Moreover, Cisco defines QoS as “the measure of transmission quality and service availability of a network” (Cisco). Because QoS can be easily described in terms of such parameters it becomes a tangible concept. The issue of tangibility is treated by J. Goodchild, in (Goodchild, 2005). However, these metrics are related to transport and network performance and can be found at the network level. Due to the fact that they are hidden to the final user, they lack in subjectivity.

3.2 QoE Parameters

QoS is the set of parameters measuring the accuracy of packages delivery over the network. QoE considerably extends QoS, by adding factors describing the user’s perception of multimedia presentation quality. QoE may be defined as the “overall acceptability of an application or service as perceived subjectively by the end-user”. (ITU-T, 2008) However, QoE is considered to be “a multidimensional construct, encompassing both objective (e.g., performance related) and subjective (e.g., user related) aspects” (Baraković & Skorin-Kapov, 2013) and (De Moor, Joseph, Ketykó, Emmeric, Deryckere, Martens & De Marez, 2010). There is evidence that QoE can be described by quality parameters too. The authors of (Perkis, Munkeby & Hillestad, 2006) propose two types of parameters: measurable parameters, which regard the technological aspects, and non-measurable parameters, considering the user’s point of view. The same approach is addressed in (Martinez-Yelmo, Seoane & Guerrero, 2010) - “Fair Quality of Experience (QoE) Measurements Related with Networking Technologies”. The paper tries to explain the relationship between networking and QoE, how networking affects QoE and how QoE may improve networking solutions. As often encountered in literature, the paper starts with providing a definition of the QoE concept: in a nutshell, QoE is “a subjective measure of customer’s experience” (Martinez-Yelmo, Seoane & Guerrero, 2010). The definition supports the idea of measurable/nonmeasurable parameters describing QoE (Perkis, Munkeby & Hillestad, 2006), in the sense that QoE is a measureable term, because it relies on the results of various mechanisms – measurements. Secondly, it is the user’s opinion that defines QoE, because the quality of the measurements may vary from an individual to another. QoE is a user-centric approach which regards the user as a key subject, as being the person paying for the service. It appears that, at the user side, it is very much important how benefic some feature may turn out, and not the implementation itself. The non-measureable side of QoE is also the most problematic. It is difficult to comprise it within a generic definition or by means of concise parameters. In order to “capture such a subjective measure, (…) is an art on its own” (Kuipers, Kooij, De Vleeschauewer & Brunnström, 2010). The authors of (Perkis, Munkeby & Hillestad, 2006) and (Martinez-Yelmo, Seoane & Guerrero, 2010) have studied the QoE’s subjectivity by means of some frameworks, while the authors’ of (Kuipers, Kooij, De Vleeschauewer & Brunnström, 2010) focus is the freely available tools and methodologies. They, as well, place the user in the spot light, and, define QoE as a matter of acceptability, very much affected by the user’s expectations and needs. Apparently, QoE parameters are non-measurable parameters. The first category comprises the parameters that describe the quality of the content at the source. According to (Kuipers, Kooij, De Vleeschauewer & Brunnström, 2010), it depends very much on the codec used. The second class of parameters, concerns the behavior of the initiated content over the network. This behavior is best described by the level of service. QoS of a network very much relies on parameters as latency, jitter, packet loss and bandwidth (Mancas & Mocanu, 2013), (Kuipers, Kooij, De Vleeschauewer & Brunnström, 2010). These are measurable (Perkis, Munkeby & Hillestad, 2006), performance-oriented (Goodchild, 2005), tangible (ITU-T, 2008) parameters.

Finally, after traversing the network, the content is being measured at the user side, in a subjective perspective. Such measurements are non-measurable parameters and best fit in the third proposed category. These parameters could be managed to achieve expected QoE levels.

4. Case Studies: QoE in Practice

In practice, QoE of multimedia networks has been promoted by Psytechnics, today NetScout (NetScout). To some extent, we can state that Psytecnics invented QoE, being a leader in the call quality assessment and performance management of VoIP and Video.

They provide comprehensive management of the quality of IP Voice, Video and Telepresence service delivery. For this purpsose, both QoS and QoE analysis is required. NetScout's solution provides real-time and objective analysis of the call quality regarding factors as delay, distortion, echo, noise, blocking, blurring or freezing.

While for some the border between QoS and QoE is uncertain, for NetScout: "QoS and QoE are completely different", as stated by Joe Frost, Marketing Vice President at former Psytechnics. The company experience with videoconferencing and telepresence deducts that problems with voice and video instantly generate an emotional reaction at the user side. For instance, when users cannot hear each other and keep on repeating themselves, beside the fact that they become irritated by the experience, they will quickly switch to mobile telephony. "People just don't tolerate packet delay, echo or strange sounds" and NetScout place the user at center: "in the QoS versus QoE debate, there's a lot more focus now on QoE from the perspective of the actual user experience. " (Grigonis, 2009) However, one user is different from another – is the argument of Empirix 3 (Empirix). They prove it with their Hammer Edge, a top testing and monitoring tool which simulates various user scenarios: web browsing, large size downloads, voice or video calls etc. And what is the reason special attention must be paid about the end-user? Because, users leave so fast and new users are very expensive to acquire.

In addition, from practice we learn that the customer experience has always been "the blind spot for providers" and this is a weakness providers need to overcome. This is a QoS-QoE relationship matter. Providers manage to guarantee a high level of service but they cannot understand the degree of QoE. The greatest problem for most providers is that they do not know what happens at the user side and why dissatisfaction occurs, if the case. A solution to such situations is Networking Intelligent Solutions, like Customer Experience Management (CEM) solutions. CEM tries to answer question as: 'How long did it take to make the transaction happen?' or 'Where is the gap and how did it occur?' in order to uncover multiple facets of each transaction. Regarding these practical approaches, we end up with the following conclusions: QoE is a very important factor and a user-centric approach is meaningful, users are easy to lose and hard to get, each user generates a different use scenario that asks for QoE guarantee and the greatest weakness providers' is the user experience.

5. QOS IN MULTIMEDIA NETWORKS. EXPERIMENTS.

Congestion Management works based on some queuing algorithms or protocols. Experiments scenarios vary the queuing algorithm. We have tried First In, First Out (FIFO), Priority Queing (PQ) and Weighted-Fair Queing (WFQ). FIFO mechanism applies to traditional routers with a single waiting queue. It is simplest to implement as it does not differentiate the flows; FIFO applies the same treatment to each flow. The only criteria FIFO considers is the arrival time of the packet in the waiting queue. On the other hand, PQ enables traffic prioritization and allows you to decide which flow is prioritized in the network. For instance, Cisco allows you to define four degrees of priority: high, medium, normal and low priority. Each degree of priority uses a different queue. Each packet that has not been classified to any of these queue is automatically driven to the normal queue. Prioritization is performed using priority lists. "A priority list is a set of rules that describe how packets should be assigned to priority queues." (Cisco 2) Cisco PQ enables packets prioritization classification according to criteria as: protocol or subprotocol type; incoming interface; packet size; fragments; access list. PQ acquires better results than FIFO when dealing with mission-critical traffic. PQ enables preferential treatment to high priority traffic and a faster response time than FIFO. In principle, PQ can be used for any interface, but it is recommended to be applied to low-bandwidth, congested serial interfaces.Moreover, WFQ provides fair treatment to all traffic in the network. With WFQ, instead of allocating priorities, weights are assigned to flows. The available bandwidth is distributed to the flows according to these weights. Standard Cisco IOS WFQ uses IP Precedence values, which are simply divisors of weights. With respect to the IP Precedence Value assigned to a certain flow, the bandwidth reserved for that flow equals IP Precedence Value + 1 parts. In such manner, WFQ manages to overcome limitations of both PQ and WFQ. WFQ automatically adapts to changing network traffic conditions and dynamically WFQ provides solution for situations in which adding excessive bandwidth used to be the only solution.

The multiple types of traffic that traverse the network ask for special treatment and raise various constraints. A packet is treated differently at different network layers by QoS tools located at each layer. The routers in the test bed in the experiment in this paper are Cisco 2610 running IOS release 12.0, and the switches are Cisco Catalyst 2900 XL. With just a couple of commands, AutoQoS automatically configure Cisco recommended QoS on Cisco Catalyst switches and Cisco IOS Software routers (Cisco). Classification and Marking occurs when a packet enters the network. Classification can be done at Layers 2-7, while marking at Layer 2 or 3. It is recommended Layer 3 marking: DSCP (DiffServ Code Point), IP Precedence and/or IP/ECN. In our experiments we use IP Precedence. Marking occurs in the IPv4 header, in the field labeled ToS (Type of Service). ToS is a one-byte field, out of which only three bits are used for marking, more precisely the first three bits. These are used to specify the priority of the packet or the IP Precedence hence they are labeled IP Precedence bits and run from 0 to 7. Scheduling tools re-order and selectively drop packets whenever congestion occurs. Congestion happens when incoming traffic is larger than the network bandwidth. A priority list is a set of rules that describe how packets should be assigned to priority queues and also describe a default priority or the queue size limits of the various priority queues. Packets that are not classified by the priority list mechanism are assigned to the normal queue. Keep-alive messages sourced by the sender are always assigned to the high – priority queue; all other management traffic must be configured.

One of the laboratory experiments conducted in within our Competence Center for Network Management has considered a Cisco based network environment, depicted in Figure no. 1. Router 1 to Router 4 are Cisco 2610 running IOS release 12.0, and switches in LAN A and LAN B are Cisco Catalyst 2900 XL. QoS was configured on each router under different scenarios. The multimedia traffic was generated using real time applications such as videoconference, as well as a traffic generator developed within our competence center. For generating audio traffic, it can also be used the ITGSend traffic generator application which is freeware software. The origin and destination networks are 100 Mbps LANs interconnected through an ISDN network. The test bed includes, within the origin network, several traffic generators used for creating traffic with various characteristics: video, audio (G.723.1 codec was used) and FTP. Within the destination network a sniffer machine and traffic monitor application were used for measuring the traffic. When no fair-queuing policy is used, all flows are truncated almost equally. This is the case of FIFO Queuing. PQ assigns priorities to the flows. PQ works fine when a certain type of traffic requires highest priority. One of the scenarios assigns high priority for video, medium for audio and low for data. The measurements results reveal the fact that in case of CBR traffic, PQ is not the most appropriate choice.

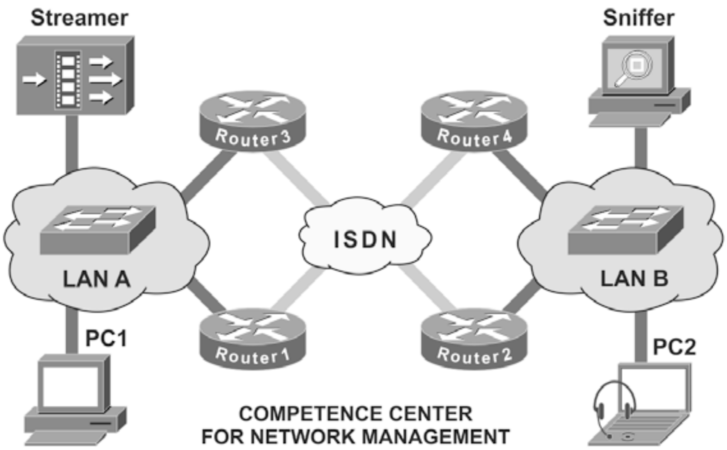

Figure 1. The test bed environment

The first two flows use all available bandwidth and the data flow, having the lowest priority, starves for bandwidth. On the opposite, if the ISDN connection is not overloaded, and the traffic is of VBR type, PQ achieves better performance. The priority lists can be made based on the source/destination address. The algorithms are the same, so the address policy based queuing behavior is the same as the port policy based queuing. Even if the ISDN connection is congested, the FTP service is still operational while the video stream is received at good quality. Comparing the results of the CBR, PQ scenario with the VBR with PQ results, we may conclude that PQ is more suitable in case of VBR traffic.

Instead, in the CBR scenario, WFQ is much more recommended. WFQ assigns to each flow an IP Precedence value. IP Precedence values run from 0 to 7. For our test, there were considered the following IP precedence values: value 7 for Video, value 3 for audio and 0 for Data. WFQ is QoS signaling-aware and each flow receives IP Precedence value + 1 parts of the ISDN connection bandwidth. In such manner, video receives 8 (IP Precedence: 7+1) parts, audio receives 4 parts and data receives 1 part out of 13 (8+4+1). With a bandwidth of ~64Kbps, the reserved bandwidths are: 64*8/13 = ~39; 64*4/13 = ~20;64*1/13 = ~5. The audio flow does not use the entire reserved bandwidth, so the remaining bandwidth is used by the first flow. This is an automated WFQ decision.

6. CONCLUSIONS

The QoS experiment referenced in this paper was based on the following queuing policies: FIFO, Priority Queuing and Weighted-Fair Queuing. The FIFO queue represented a first step toward flow control, but the intelligent networks nowadays require much more complex algorithms. PQ is useful when we need to provide a higher priority to a specific traffic with particular requirements. The disadvantage of PQ is that it uses a static configuration and therefore it is not able to self-adapt to the traffic requirements changes. Furthermore PQ produce an overload which is acceptable in case of low rate interfaces such as ISDN but it might be unacceptable in case of fast LAN interfaces such as FastEthernet. WFQ was designed in order to minimize the configuration effort and also to ensure a flexible policy, to self-adapt to the traffic characteristics changes, without using predefined access lists. In order to guarantee the services, WFQ uses signaling techniques such as ‘IP Precedence’ and ‘Resource Reservation Protocol’. The performance evaluation demonstrates that WFQ is able to provide some level of QoS for streaming media and

VoIP. The results show that the total bandwidth of the bottleneck connection (ISDN) is not fully used because the monitoring is performed at Layer 3, while the overhead caused by the Layer 2 header is not taken into consideration. The overhead depends on the packet size. As the video stream packets are larger than the VoIP packets, the overhead is higher in case of VoIP traffic is generated.

Video, voice and data services will continuously expand. One interesting theory is whether the Internet will support all these services in the future (Grigonis, 2009) As, the demand for triple play traffic increases, constant effort needs to be deployed towards a guarantee of QoS and QoE. According to (U4EA Technologies), GoS (Guarantee of Service) represents the successor of QoS. GoS is a queuing system for multiple real-time services which works with multiple queuse and manages to solve delay and loss issues, believed to be QoS greatest enemies. U4EA's theory is that "voice, video and data will increasingly travel over packetswitched networks. Over the past 20 years, many techniques appeared to solve QoS and QoE. You've had standards such as RSVP, diffserv and MPLS. They address different aspects of the network, so to speak. MPLS concerns itself more with the network core/backbone. But we can see that there's a bottleneck forming at the network edge, which will degrade QoS and QoE, and that's where we've focused our efforts", states U4EA's Vice President of Marketing, Jim Greenway (Grigonis, 2009). This could be one future direction. Under this perspective, the proposed solution is GoS, which enables multiple real-time queues. The problem GoS solves is achieving quality communication without being forced to add bandwidth.

Efforts need to be invested into developing tools which corelate QoS and QoE. Although several QoS tools and QoE frameworks exist nowadays, the strong belief that understanding the QoS-QoE relationship is meaningful motivates the development of a QoS-QoE framework. Such a framework could accept as input parameters QoS and QoE parameters and could solve issues as lightening-up the user position for the service provider or classifying users into behavioural categories.

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