User Experience Evaluation Based on Arbitration QoS Parameters in Video Stream Using NetFPGA in a Controlled Environment

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***Abstract*—A streaming video has some features that are different from others, such as the occupation of a large amount of bandwidth, and the possible scenes variation with a consequent increase or decrease in the amount of transmitted bytes. Applications for the video streaming transmission (YouTube, Vimeo, Netflix, Telecine Play, etc) have aroused the interest of the scientific community regarding to the networks behavior. The purpose of this paper is to measure, through a video stream, the user experience, also known as Quality of Experience (QoE) based on the arbitration of QoS parameters in a controlled environment using NetFPGA.**

Keywords–QoS; QoE; DiffServ; Correlation Models; NetFPGA.

I. INTRODUCTION

This paper presents some initial results that validate the environment tests in a simple scenario, with only one customer receiving the streaming video server. Its purpose is to measure the user experience in a controlled environment through Differentiated Services techniques (DiffServ) to adjust the routing of packets between client and server, following the appropriate adjustments according to the QoS parameters (Jitter, packet loss, latency and bandwidth) and their application (codec, latency, resolution). In our work, we have inserted one NetFPGA hardware among routers to compose a cloud of higher performance without QoS treatment.

From researches based on Alreshodi et al. [1] and Arousi et al. [2] works on QoS/QoE correlation models, it was possible to realize that these authors did not address papers related to wireless networks; Gahbiche et al. [3] investigated external/environmental factors that could affect the user experience without considering the QoS requirements of the network layer; Bingjin et al. [4] and Kyeong et al. [5] have developed/implemented methods for evaluating QoS, using simulators like the Object-Oriented Modular Network Simulator (OMNET) [6]. They used those simulators to shape the effect of traffic from Internet Services Providers (ISP). On the other side, Valente [7] proposed a prototype for QoS/QoE provisioning of wireless networks, using NS2 for its evidences.

The objective of this paper is to demonstrate the user experience in a real world scenario with router vendors that have contributed to the adoption of open Standards, as the Cisco example on the RFC 2475 and 2597 recommendations, which determine the behavior of the packet to each passage among routers on the Internet.

It is important to mention that the paper has been divided into six Sections: the first one is related to the introduction; the second one is dedicated to QoS and QoE concepts. The NetFPGA board characteristics are described in Section 3. Section 4 presents the scenario used in the experiment, and some preliminary results have been presented in Section 5. The last one, Section 6, suggests some ways to cover and to assess the proposed problem.

II. QUALITY OF SERVICE AND QUALITY OF EXPERIENCE

Works on the user experience analyze the seven layers of the Open Systems Interconnection (OSI) reference model. In this paper only two layers will be considered: the network and the application ones. According to Siller and Woods [8], we can see a pseudo-layer over both, and inside it the authors designed the user experience. These academics have defined QoS as ”the experience perceived by the user being presented by the Application Layer, which acts as a front-end user presenting overall results of the individual Quality of Service”.

Hohlfeld et al. [9] deal with the specifics of the differences between QoS and QoE, i.e., the first one is centered on the network, while the second one, centered on the user. The QoE depends on a multidimensional perceptual space that includes: factors of influencing system (such as QoS measures, transport protocols, or specific parameters of devices); the influence of human characteristics (such as humor, personality traits or expectations) and the context characteristics (location, activities or costs) [9].

Quality of Experience is based on the Mean Opinion Scores(MOS) Methodology. However, in Seshadrinathan et al. [10] work, the research focuses on the difference of the Difference MOS (DMOS). This technique was based on the Video Quality Assessment (VQA) that considers the objective aspects and the subjective human perceptions [10].

A. *Quality of Service*

The network layer allows the transfer of packets between origin and destination, which might go through several hops routers in order to get to the destination. In terms of services of this layer, TCP/IP model seeks to deliver the same packets with the ”least effort”. There are two ways of implementing services on this layer: the oriented and the connectionless ones. Despite of the Internet adopting connectionless services, Tanenbaum [11] makes a highlight in four aspects that must be resolved regarding the QoS:

1) What network applications are required;
2) How to regulate traffic entering the network;
3) How to reserve resources in routers to ensure performance, and;

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4) If the network can accept more traffic safely. No isolated technique deals, effectively, with all these aspects. In practice, there are two versions of QoS that are widely used in many Internet routers: Integrated Services and Differentiated Services.

1) Integrated Services: It is a service designed for unicast and multicast applications that are able to deliver multimedia flows through the Resource Reservation Protocol (RSVP) [11]. This, in turn, it operates as following: each group of stations is assigned and addressed. For each transmitter that sends data, these places address to the group in their own packets; then a routing algorithm, through a multicast, builds a spanning tree covering all members (this algorithm is not part of RSVP). The Integrated Services have the key requirements admission control and the resource reservation. In essence, real-time services require some sort of service guarantee, but it is important to be careful on the use of this term. It would be more appropriate to use "enough" or even "acceptable" [12].

2) Differentiated Services: This service is based on the "class" concept, where there is no need for resource reservation to "ensure" the packet delivery, hence there will be no channel exclusivity after the connectionless establishment. It can be offered in a cloud of routers belonging to the same domain. Classes are defined as "Per-Hop Behaviors" (PHB) [11], each hop is a router, and each packet that is to arrive at a hop, after being sent back to the network, will not have any guarantee of delivery to the destination. This is a function of the Transport layer.

B. Quality of Experience

Siller and Woods [8] have defined QoE as "the experience perceived by the user that is being presented by the Application layer, which acts as a front-end of the user who has the overall result of quality individual services".

The QoE can be measured in all layers of the OSI model, as it was presented in the Introduction part. The most common action is to control the parameters of the network layer (bandwidth, delay, loss and change) to prevent the user to receive a stream with any low quantity during the playback. As it will be presented in the next Section, subjectivity in the user perception is a factor in his/her experience, like how to evaluate his/her level of satisfaction during the involvement in a particular site, or his/her enjoyment in a game, in real time [13].

C. Correlation between QoS and QoE models

There are two methodological approaches to evaluate the correlation between QoS and QoE models. They are the objective and the subjective assessments [1]. These techniques, whenever are observed separately, do not evaluate properly the user experience. The models evaluated by Alreshoodi and Woods were:

- IQX hypothesis (*exponential interdependence of quality*): based on a generic formula in which the parameters of QoS and QoE are connected through an exponential relationship [14].
- VQM (*Video Quality Metric)-based Mapping Model*: function *n* dimensional QoS (in which "*n*" is the number of different QoS parameters) [15].
- QoE *Model using Statistical Analysis method*: it is a technique employed that correlates QoS parameters and estimates QoE perceptions, and identifies the degree of influence of each of the QoS parameters on user perception [2].
- QoE *Models based on Machine Learning methods*: It is a new approach for the construction and adaptive QoE prediction models using classification algorithms in machine learning, with trained data for subjective tests [16].
- QoE *model using Crowdsourcing for subjective tests*: it is based on Microworkers platform, it allows driving *surveys* on-line tests as YouTube [17].
- QoE *model using a Resource Arbitration System*: it is based on the integration between the Network and Application layers (NQoS and AQoS) [8].
- QoE *model considering equipment and environment factors*: it is a technique that can be used when the source signal interference in the environment wireless (such as frame error rate, and delay variation) can occur. Different QoS parameters can be applied to the user equipment. Then, parameters such as noise, jitters and ambient light forming the interference environment in which QoE different parameters are used [4].
- QoE *model based on Quantitative and Qualitative Assessment*: this model is a combination of both of these approaches. The Set Gross Theory (RST) has been used here for the Quantitative Evaluation, while CCA framework (catalogue, categorize and analyze) has been used for the Qualitative one [1].

For finishing this section, we would like to highlight that it is necessary that the methodology for evaluating the user experience includes the QoS requirements. This work has studied the relationship between QoS and QoE influencing this experience, since all the authors that studied this subject have been treating these issues, most of them, by focusing between network layer and the application one. Issues on physical layer also have directly influenced the outcome after a broadcast, like the Cyclic Redundancy Check (CRC) errors during a Voice Communication over IP (VoIP).

Those who worked in the telephony industry during the migration to VoIP, were able to observe what the biggest problems were during this transition. There were constant complaints from the users related to interference during phone calls. The main reason was the CRC errors, and the main cause was related to the cabling, which was totally obsolete.

III. Features of the NetFPGA

The NetFPGA board, designed to assist researchers in research projects for computer networks, is flexible and operates at the rated speed of the Ethernet interfaces.

NetFPGA is the concept of Field Programmable Gate Array (FPGA) dedicated to computer networks. The NetFPGA has been increasing since its inception in 2001, being available in 03 plate versions: NetFPGA, 1G-CML, NetFPGA 10G and NetFPGA SUME. The NetFPGA 1G version was discontinued. The NetFPGA 1G-CML model will be soon presented.

A. NetFPGA CML model

This model was designed to operate under a PCIe 4X second generation interface. This model has four (04) Gigabit Ethernet ports, incorporating the Kintex-7 325TFPGA, Xilinx. This platform had been designed to support NetFPGA architecture, developed by Stanford University, with reference models available through GitHub NetFPGA community. It is totally compatible with the Xilinx Vivado software and ISE Suite Design, as well as embedded software projects of Xilinx SDK. The board has the following characteristics:

- A FPGA (physical chip);
- Four network ports Gigabit Ethernet;
- *Quad Data Rate Static Random Access Memory* (QDRII+ SRAM) - 36MBit (4.5MBytes);
- Double-Date Rate Random Access Memory (DDR3 DRAM), capable of 512MBytes;
- PCI Express Gen. 2;
- SD card storage and memory *flash* BPI (*Byte Peripheral Interface*)
- Expansion Interface (FMC and PMOD connectors);
- Additional features such as PIC micro-controller and USB, RTC, chip with Crypto authentication;
- PCIe standard *Form Factor*;
- Flexible, open source.

The purpose of using this hardware is to make it available to implement routing algorithms both at software (through Microbloze processor), and hardware levels, using the FPGA resources.

B. FPGA Configuration

All system programming logic is stored in SRAM Memory, and for the fact that it is a type of volatile memory, the device is setup each time it is powered up. The data configuration is known as bit-stream, whose formats are used as ”bit” or ”mcs”. It can be configured via BPI flash, USB drive off-board or via PC. Another very important feature is the Hardware Description Language (HDL), that allows to create an Intellectual Property (IP), in which the most populars are VHDL and Verilog, or use the creation of others. Among the possible uses for the NetFPGA card, we can mention an IP for Image and Video Processing Manipulation (Image Characterization).

IV. Proposed scenario

In order to simulate the closest testing environment of an Internet user, the following scenario has been created as depicted in Figure 1.

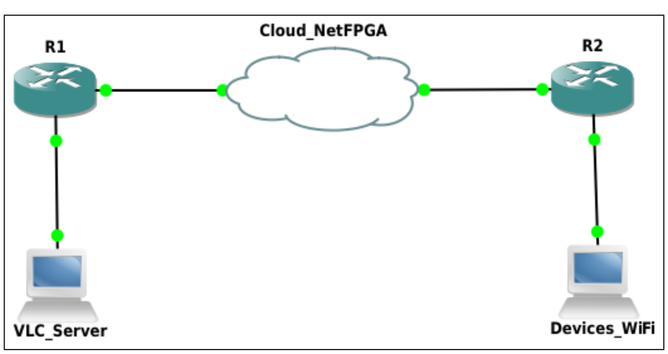

Figure 1. Proposed scenario.

In Fig. 1, the ”VLC_Server” represents a streaming server executing the VLC software; the ”Devices_WiFi” represents the devices on the LAN; R1 and R2 are the border routers that will make the QoS requirements. The Cloud_NetFPGA represents the various Internet routers, allowing the passage of simulated traffic generated by one of the following tools: iPerf, Harpoon or RUDE/CRUDE.

A. Real Scenario

The routers used in our test environment are the Cisco 1841 model. The streaming server is an HP Pavillion desktop, with Intel i3 CPU and 4GB RAM. The physical connection between VLC_server and R1 is Fast-Ethernet (100Mpbs), as well as the connection between routers and the NetFPGA cloud. The wifi devices are smartphones, notebooks and desktops with interface, and infrastructure as a router DLINK DIR-610 802.11n model, and that device it is connected to the router R2 via Fast-Ethernet. In order to capture frames, we will use Wireshark version 1.10.6 for the analysis of packets, forensic tool CapAnalysis 1.2.1 for the captured packets from the NetFPGA board interfaces, and for the Cisco routers counters analysis, we use the ManageEngine NetFlow Analyzer Tool. The PRTG tool has been evaluated here, although it has shown some inconsistencies regarding the counter reading on routers.

B. Expected Experiments

Through this research, it has been aimed to measure the quality of the user experience, such as, for most part of them, the mobile device, as well as smartphones and laptops. The use of a residential router reflects, in general, the infrastructure in the user’s homes. Tanenbaum has mentioned that with 1Mbps, it is possible to watch a video from the Internet, using data compression, with reasonable quality [11]. If somebody wants to watch movies in High Definition (HD) quality with at the same rate, it probably will not be a pleasant experience since high-definition movies occupy an average of 2.5Mbps bandwidth. This situation is critical in some countries, like Brazil, where the average bandwidth contracted is 1Mbps [18].

V. Preliminary Analysis

This preliminary analysis consisted on watching two different movies, in order to realize their characteristics and aspects. The first film, ” Insurgent”, was played with a resolution of 1,920 x 800 dip per inch (dpi), frame rate equal to 23.97 frame per second (fps) and codec H.264. During playback, the image was freezing for several seconds, but the audio quality was good at all times. The second one, ”The Silver Dollar”, was presented at a resolution of 632 X 352 dpi, MPEG4 codec, frame rate equal to 25 fps and the movie was reproduced satisfactorily. In the first case, the codec has the characteristic of consuming a lot of processing, both for the image compression and decompression, but it uses low bandwidth (something around 2,5 Mbps). However, the MPEG-4 codec, from ”The Silver Dollar” movie, did not present frame loss. Fig. 2 depicts the bandwidth consumed in this same movie (lower curve), and the amount of bandwidth consumed in transmitting the ”Insurgent” movie. It is important to highlight that in both cases, we had a 100Mbps bandwidth, and we had used 2.5Mbps, but the user experience in the first movie was not satisfactory.

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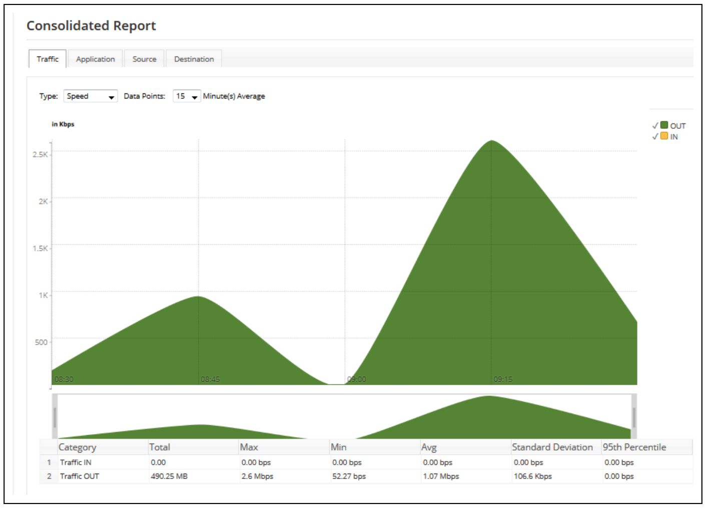

Figure 2. Use the channel during the transmission of movies.

In both cases, by unchecking the "activate transcoding" option at the VLC server, all processing happens to be executed on the client. When the resolution of the movie is performed in FULL HD mode, the CPU consumption increases considerably enough to stop its reproduction for several seconds. If this option has been checked, the processing reduces and the movie playback becomes acceptable, but it will depend on the processor speed and the amount of memory on the user device.

VI. Conclusion

In this paper we have shown that the problem associated to QoE is strongly dependent on multidimensional spaces, such as QoS measures, transport protocols and specific parameters of used devices, besides the influence of human and contextual factors. In spite of these dependences, many of the studies and researches have forgotten this correlation. For this reason, in our proposal we have suggested a real scenario for measuring the user experience in an environment controlled by Differentiated Services techniques to adjust the routing of packets between clients and servers, with appropriate adjustments to the QoS parameters (jitter, packet loss, latency and bandwidth) and application (codec, latency, resolution). We have used a NetFPGA hardware which is inserted among routers to represent a high performance cloud.

This experiment showed that it was necessary to make adjustments in the Internet layer and Application. Despite the low consumption of the channel, the film presented in FULL HD had frames loss during playback. A probable cause was the high consumption in the CPU processing on the client to decompress the bit-stream generated by the H.264 protocol. Another possible factor was the adjustment of the latency for video playback on the user device. If the player has been configured with low latency, frame loss increased considerably; if set to maximum latency, losses frames were reduced by the same proportion.

For future works we would like to suggest a deeper study and research about the real contribution and usage of NetFPGA in this experiment, to measure the quality of communication and different real scenarios using different QoE and QoS models.

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