pISSN: 2523-5729 eISSN: 2523-5739

Open Access
Full Length Article

ORIGINAL ARTICLE

ANALYSIS OF QUALITY OF SERVICE FOR VIDEO STREAMING USING USERS EXPERIENCE

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ABSTRACT

Video streaming has become an immensely effective technique to share videos over the internet. It is being widely used for video conferencing, e-learning, TV broadcasting, voice over IP and in different multimedia applications. The user's quality of experience for watching the video is most important for service providers primarily for providing a smooth users' experience. However, a number of factors affect video streaming quality such as delay and distortion in the network which affects user's perception of the quality of received videos. It is essential to ascertain the factors which can minimize the effects of these factors on video quality and ensure an adequate level of video streaming quality.

In this paper, we try to find out the effect of packet duplication and rate control on users' experience in the simulated videos. We try to evaluate the quality of experience perceived by the users and analyze the results using a mean opinion score obtained from different surveys conducted on users' experience on video streaming. Our in-depth analysis of users' experience about video streaming shows that the users' opinion about a video quality follows a similar trend. From our analysis, we were able to estimate a threshold level 1536kbit/s for bit rate and packet duplication level on 3.5%, which represent satisfactory levels of users' experience, given the constraints of network bandwidth. Our analysis and proposed solutions for maintaining and adjusting appropriate/affordable settings of bit rate and packet duplication are helpful for the service providers to deliver a smooth user experience.

Keywords: Video Streaming, VoIP, Network Bandwidth, Video over Internet, video conferencing, QoE

Author`s Contribution
[1]Development of algorithms, subjective analysis
[2]Experiments, Evaluation
[3]Development of subjective/objective criteria, data collection

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Article info.
Received: July 28, 2017
Accepted: December 27, 2017

Cite this article: *Shah GM, Sadhayo IH, Khan UA. Analysis of quality of service for video streaming using user experiences. J. inf. commun. technol. robot. appl.2017; 8(2):38-46.*

Funding Source: *Nil*
Conflict of Interest: *Nil*

INTRODUCTION

In recent years, Quality of Experience (QoE) has become a huge research theme in the telecom field. Quality of experience is an analysis of human experience when interacting it with technology and business point of view. Quality of experience improves the performance such as user's effectiveness, efficiency, and the satisfaction during usage of particular product or services[4]. The demand for multimedia applications is promptly increasing every day. Currently, it is being used in video conferencing, video on demand, telemedicine, e-learning and many other fields. Video quality services have rigged quality requirement both in technological perspective in quality of service and in user perspective in QoE. Nowadays, people are quality meters and their needs and perception carry big issue for service providers because it is hard to measure the user satisfaction during the usage of particular product or services[2]. The service providers desire to provide quality of service to all users

who use different products, but the problem is how to get satisfactory results because of so many reasons such as low bandwidth rate of network, variable bandwidth network and low resources of user devices.

Quality of Service

Quality of service is technology pertaining approach to make sure the quality to end users. It is a set of standards and mechanisms for ensuring high quality performance[9]. Quality of service is the perception of identifying how good the offered services are. Quality of service is the investigation of the distinct infrastructure components such as servers, routers or network traffic (IP Packets, transport streams, etc.).

Quality of Experience

Quality of the experience is a rapidly emerging field focused on social psychological, cognitive science, economic and engineering sciences to understanding overall human quality requirements[7]. QoE is the blueprint of all human needs and quality expectations. Quality of experience provides data on end-user satisfaction levels and perceptions of services or applications and measures a system's performance based on subjective and objective methods.

Quality of Experience in Video Streaming

Multimedia applications are rapidly increasing day by day. They are widely used in video conferencing, voice over IP, e-learning, and telecommunication based applications. Video streaming is an exciting area of research. There are many areas which take care of video streaming, including packet loss, packet delay, packet corruption, and packet reordering, packet duplication, and rate control. Due to affection in these areas, users experience a poor video quality.

Packet Duplication

A packet is said to be duplicated when it is received multiple times by the receiving host or node. When a sender node finds that a packet is not transmitted correctly, it retransmits it. However, the packet may have been received by the receiving node in the first attempt. In this case, the receiver has two copies of the same packet. Video quality is affected by the packet duplication in the network that reflects the poor perception of the user's experience and also increases traffic burden on the network.

Connection-less protocols, for example, UDP (User Datagram Protocol), that cannot identify duplicate packets because it does not contain the information of duplicated packets in its header. In that sense, it does not retransmit the packets. Connection-oriented protocols, for example, TCP, can detect duplicate packets. TCP uses an acknowledgment mechanism to identify missing data automatically and retransmits them it. The most common reason for duplicate packets is defective hardware and IP conflict. A properly configured network has less chance of packet duplication.

Rate Control

In video streaming, rate control is used to estimate and allocate the bandwidth. It plays an important role in distributing the traffic over the internet due to the inconsistent and variable behavior of network bandwidth. The user wants high speed and low delay with minimum using bandwidth required network applications. In real-time applications such as video streaming, TV broadcasting and video conferencing, the quality of service need to be maximized for satisfying the users. Rate control is used for sharing the network bandwidth among different network services for effective utilization of the rate of bandwidth.

Due to increasing demand for video streaming and watching videos without downloading (VoD), delay in video streaming affects the quality of experience. Delay in streaming cannot be controlled by service providers. Users' perception of the quality of the video is very important.

LITERATURE REVIEW

Due to increased demand for multimedia applications, video streaming is becoming the most prominent method of communicating the media over the network or on the internet [2]. Video streaming suffers from various factors which are either network dependent or independent. The network-independent factors include delay, throughput, etc. Whereas, the network independent factors are encoding, audio and video synchronization, etc. Most of the network service providers pay more focus on QoE than QoS. There are two ways to transmit videos over the network: streaming mode and download mode, the streaming mood to broadcast videos over the network because the download mode requires huge space on the

system for saving the files. In streaming mode, the user can watch the video when a network connection is available.

Video streaming uses several protocols to transmit the media over the internet[2], which are (UDP), (RTP), (RTSP) and (TCP), etc. All these protocols have their own advantages and disadvantages. We use UDP which is a transport layer used for video streaming but does not have retransmission[6] and data-rate management services. Therefore, it is fast for real-time audio and video transmission. There are other advantages of UDP such as congestion control, rate control, multiplexing, etc[7]

There are two methods for measuring users' quality of experience for video streaming. These methods are given as follows.

2.1. Subjective Assessment

The subjective method relies on human contributors providing useful and reliable QoE feedback about the particular video quality. Subjective testing is expensive and time-intense. The subjective assessment technique is based on surveys, interviews, and statistically sampling of users and customers to analyze their awareness[7]. There are two categories for conducting subjective QoE technique: (i) Qualitative techniques (ii) Quantitative technique

Qualitative techniques rely on verbal behavior and consist of words and remarks. These techniques capture human awareness, feelings, and opinions through verbal behavior. The open-ended survey, and questions recommendations, comments on blogs and social media produce substantial data. All of these methods produce prosperity of qualitative data[7]. The most significant metric for the examination of verbal behaviors is the ratio of positive and negative comments and it is commonly known as Catalog- Categories-Analyze (CCA) framework. CCA groups the ratio of positive and negative comments and produces results in the layout of histograms to be explored as a qualitative analysis technique.

Quantitative techniques are in the form of numbers and statistics. User studies and surveys are normally conducted in a laboratory environment and in the natural environment to measure human feelings, perception and their intentions. These methods involve the construction of questioners with rating scale to produce quantitative data.

2.2 Objective Assessment

The objective method involves purely technical factors or the human factors that predict human behavior using mathematical models and formulas. There are still no objectives metrics which can fully capture the complexity of QoE, The existing metrics are partial to only some features. Objective human factors are related to the human psychological and cognitive system[7]. These objective factors are difficult to obtain and understand but provide useful insights into human behavior and cognition.

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We used subjective assessment for which observers are given the chance of showing videos and to give the feedback about the quality of videos. We obtain the feedback in the form of a Mean Opinion Score (MOS) that consists values from 5 to 1 as recommended by International Telecommunication Unit ITU[6]

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2.3 QoE based framework for multimedia services

There is fast growth in multimedia services such as video conferencing, voice over IP, video on demand (VoD), IP TV and other multimedia applications. The users using different devices like smartphones, IPAD and laptop and other multimedia devices face various quality of service problem. The multimedia framework proposed by Venkataraman and Chatterjee in 2009 (named as Mintmos) is a light-weight, real-time and no-reference framework for multimedia services that consists of subjective quality of experience. The framework further consists of four parameters: encoding video bit rate, the severity of impact, motion complexity and loss fraction[1] Mintmos flavor delivers quantitative analysis of network level QoS (NQoS) and application level QoS (AQoS) to

calculate QoE scores. Another researcher Taichi Kawano proposed a framework for video services that calculate video quality by using objective quality of experience (QoS) based on application level (AQoS) parameters.

Niche vendors also provide a way to measure QoE for multimedia services[5]. Niche vendors focus mostly on objective QoE than subjective QoE. The key parameters for the assessment of QoE using perceptual assessment of speech quality (PESQ) techniques are peak signal to noise ratio (PSNR).

The QoM framework is an innovative solution, which covers almost all the QoE management requirements that provide QoE assessment for multimedia services[4]. This framework mostly focuses on the subjective assessment of QoE based on QoS parameters and also includes a reporting tool that amends network administrator in the event of degradation in QoE. On the other hand, it does not support automatic policy change on users' demand or on the users' requirements.

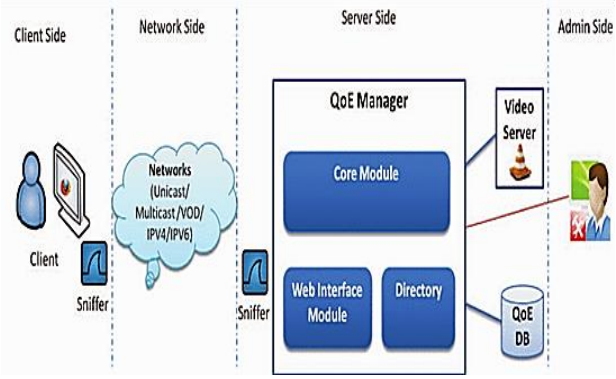


Figure01: QoM framework for multimedia

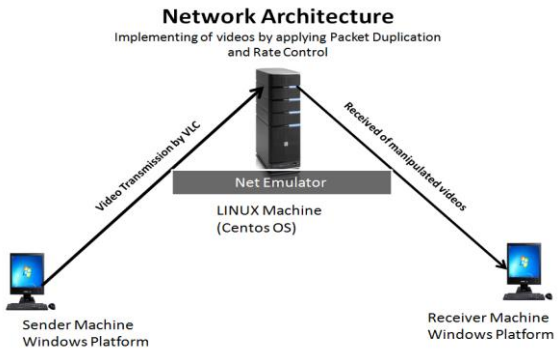
RESEARCH METHODOLOGY

Mostly the work is based on Netem (Net emulator), a tool available in Linux. In experiments, we use CENTOS operating system that has built-in net emulator tool, for broadcasting the videos using the VLC player. Two parameters of video streaming: packet duplication and rate control are used in the experiment.

3.1. Network model

The network architecture of experiment consists of three machines; one machine as sender broadcasting and other is a receiver which receives the manipulated videos for playing and recording them. The LINUX based router machine was in the middle of the sender and receiver machines that makes reshape the videos on demand or user predefined limit of the packet loss and corrupt in the network.

Figure 02: a Network model



3.2 Net Emulator (Traffic Shaper)

Net emulator offers the functionality of network emulation for analyzing protocols by emulating the properties of wide area network[11]. This tool helps to emulate the network traffic to analyze packet loss, packet delay, and jitter, etc. It is used in conjunction with traffic control (TC) and to add bandwidth limitation.

Netem is also called packet shaping that regulates the network for transferring and meeting definite performance level of (QoS). Traffic shaper controls definite features of packets to accomplish a defined task[15]. Traffic shaping implemented at the edge of a network controls incoming and outgoing traffic in the network.

Performance of different protocols and applications is not satisfactory when they disclose to network with parameter packet loss and delay. It is difficult to reproduce the network behavior in the controlled environment. Traffic shaping is used in network emulation for analyzing the impact of a network on protocols and applications. Netem has recently enhancement of Linux designed applying by the existing QoS and the differentiated in the service of the Linux kernel. Netem involves two components kernel modules for queuing discipline and command line for the configuration[15]. The queuing discipline used by Netem the FIFO queue, the queue discipline in between the network device and protocol output. Netem controlled by the command line tool tc (Traffic control) that is part of iproute2. Four basic operations are available in the current version of Netem,

they are a variable delay, packet loss, packet duplication and re-ordering of the packets. Traffic control consists of shaping, scheduling, dropping and policing.

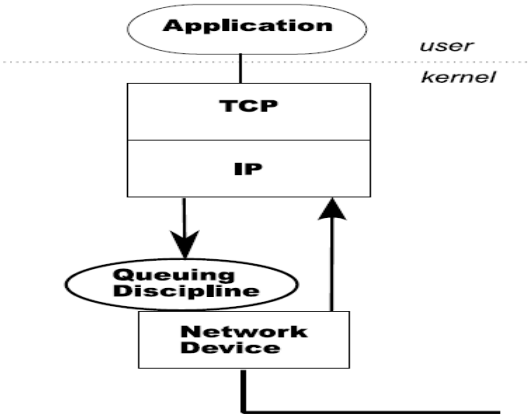


Figure 03: NetEm Queuing view

The resolution of the videos plays an important role in accessing the quality of the video. Users feel uncomfortable if the video is low quality. Use standard CIF resolution (352X288 @ 25 fps) for videos that were proposed by ITU-T[17]. There are some other resolutions such as QCIF, SQCIF, 4CIF, etc.

Select three videos: one fast motion video (Car Race) containing fast motion (moving objects), the second video is a news video with moving objects in the background, and the third video is a face expression video that is slow motion video because its background is static.

Figure04: Car Race video

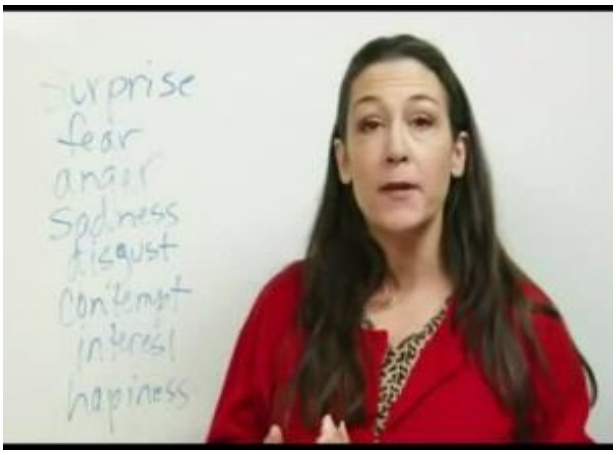


Figure 06: Face expression Video

3.3. Packet Duplication& rate control setting

In order to find out acceptable distortion and duplication rates in videos. Add some manual corruption and packet duplications on Linux router. Then analyze that impact of packet duplication in the videos that affect the users QoE. We have also manipulated bit rate of videos that reshape the quality of video to analyze the impact bit rates on video quality that affect the users' QoE. For this experiment of rate control, select three videos at different rate control variations.

The display setting for watching videos was 21 inches LCD display having resolution 1280X800. The videos were played in a sequence. The first original video was played and then packet duplication was added at an increasing rate. The subjects were unaware of the video packet duplication added to the network of the video. In the same way, videos of varying bit rate were played for viewers rating in different variations of the bit rate limitations and bandwidth limitations.

In car race videos, as we increase the packet duplication ratio, the quality of video degrades from original to degraded quality that shows when the packet duplication increases, the quality of videos decrease by artificially adding more packet duplication in the network of the particular videos. In real time video streaming, if the users are not satisfied with the video quality which shows that network services are low and the bit rate of the video is low. Users' ratings depend upon the perceived quality of the video. It clearly points out that as the network services degrade, the level of satisfaction changes.

RESULTS AND DISCUSSION

We analyze the obtained results by streaming the videos of a car race, news and face expression. We artificially apply packet duplication to make distortion in quality of the video. In order to analyze the impact of packet duplication in video affecting the users' QoE, we select three videos by applying different packet duplication variations using Netem (Net Emulator)[3].

The data acquired from lab experiments was converted in graphs. The graphs were plotted on packet duplication versus user ratings. In the subsequent step, we observed the impact of packet duplication on users' experience.

4.1. Average mean opinion (packet duplication)

We present results of packet duplication parameters of a car race, news videos and face expression videos for user video quality observation on each video in the experiments. If the user observes that the quality of the video is better, then they assign rating as excellent, and if they are merely satisfied then they ranked video as fair. If they completely disagree and the quality of the video is annoying, then rank them as bad.

Assigning appropriate scores to each user's opinion, we calculate the mean opinion score for each video's quality. The average MOS rating for different videos with different packet duplication settings.

Table01: Packet duplication results

Packet Duplication Ratio	Car Race video	News video	Face video
	Avg MOS	**Avg MOS**	**Avg MOS**
0.5%	4.56	4.72	4.36
1.%	4.36	4.48	4.32
1.5%	4.04	4.2	3.92
3%	2.92	3.04	2.8
3.5%	2.68	2.8	2.64
5%	1.08	1.12	1.08
7%	1.04	1.12	1.04

The results show that there is little difference in users' ratings of all videos because there has depended upon the video movement of slow and fast motion videos. The impact of packet duplication parameter that affects car race video their quantitative analysis of results is given in following graphs.

4.2 Average mean opinion (Rate control)

In the second experiment, use bit rate parameter and conduct user experience on rate control to optimize the video quality according to user's perception. The results of the second experiment are given below

Table 02: Rate control results

Rate Control Kbit/s	Car Race video	News video	Face video
	Avg MOS	**Avg MOS**	**Avg MOS**
512 kbit	1.08	1.04	1.04
768 kbit	1.04	1.04	1.08
1024 kbit	1.20	1.20	1.20
1280 kbit	1.68	1.80	1.60
1536 kbit	3.88	4.08	3.72
1792 kbit	4.56	4.68	4.32
2048 kbit	4.60	4.76	4.60

Average MOS ratings for a different videos sequence of different bitrate settings. The table is divided into three columns, where the first column is assigned to a video sequence of a car race, second for news video sequence and the third allotted to face video sequence.

GRAPHS AND DISCUSSIONS

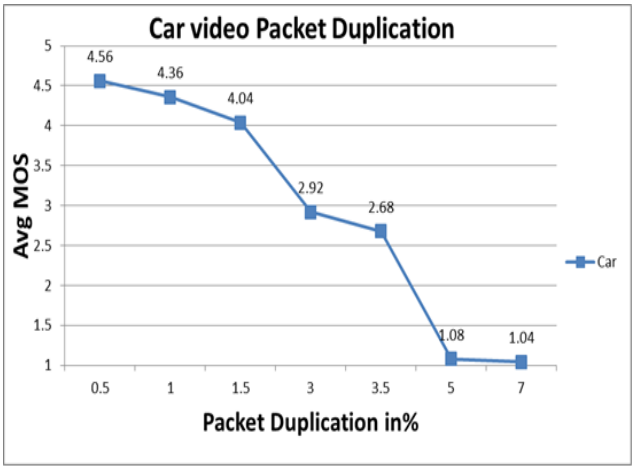


Figure 07: Graph of car race video packet duplication)

The X-axis consists of packet duplication variation and Y-axis represents the average MOS calculated from 25 users' results. At 0.5% of packet duplication, the quality of the video is approximately equal to the original video. The user MOS rating is high at around 4.56%. As the packet duplication increases to the higher levels, the graph linearly decreases to the lower level of the Avg MOS.

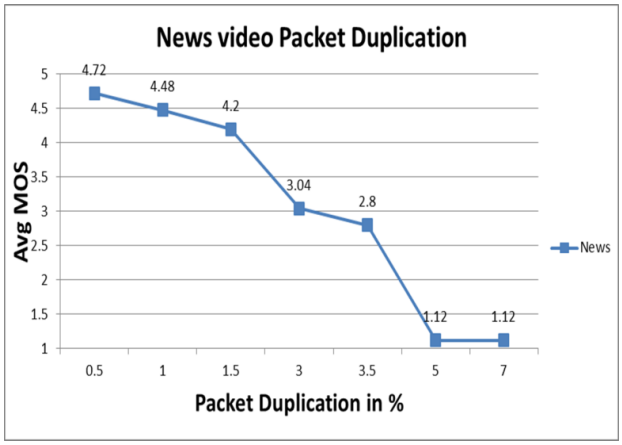


Figure 08: Graph of news video (packet duplication)

At 0.5% of packet duplication of news video, quality is good and similar to the original video. News video was given a good rating at the initial, compared to car race video and face expression video, which is clearly seen in Figure 5.4.

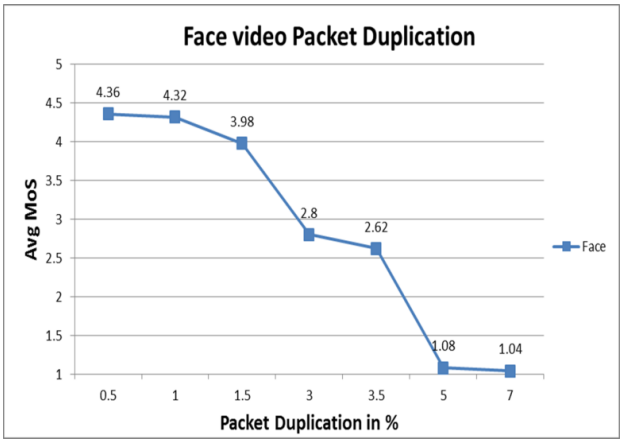


Figure09: Graph of Face expression video (packet duplication)

The Average MOS rating for the face expression video is shown in the graph. The X-axis represents packet duplication variation applied on the videos and Y-axis represents the Avg MOS rating obtained from viewer's perceptions of the videos.

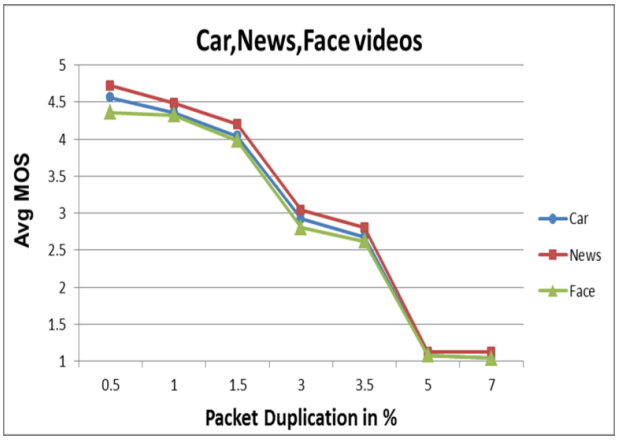


Figure 10: Comparison Graph of videos (packet duplication)

The aggregated average MOS ratings for three videos of a car race, news and face expression video are plotted in Y-axis and packet duplication variation is given in X-axis. The average MOS decreases by adding more packet duplication in the network. Initially, packet duplication is 0.5% and the Avg MOS rating is higher. By increasing the packet duplication, the MOS curve linearly decreases. At the point of 3.5% of the packet duplication, the Avg MOS abruptly decreases to the lower level because below that percent of the packet duplication, videos were underrated by the viewers. According to viewer's perception, this is the minimum satisfaction level where users were satisfied with the video quality and this is the threshold level by the user evaluation in our experiments.

The impact of bit rate parameter that affects car race video and the quantitative analysis of results are given in following graphs.

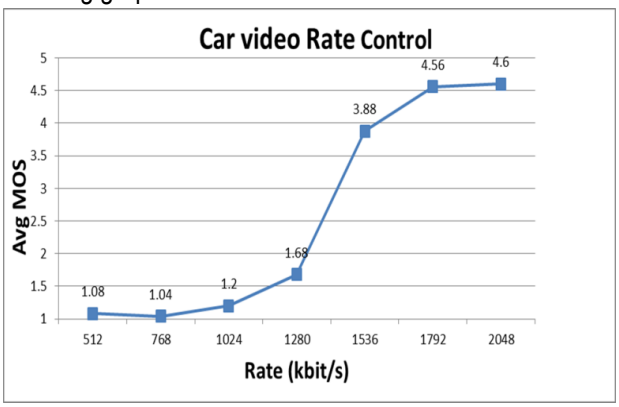


Figure 11: Graph of Car race video (Rate Control)

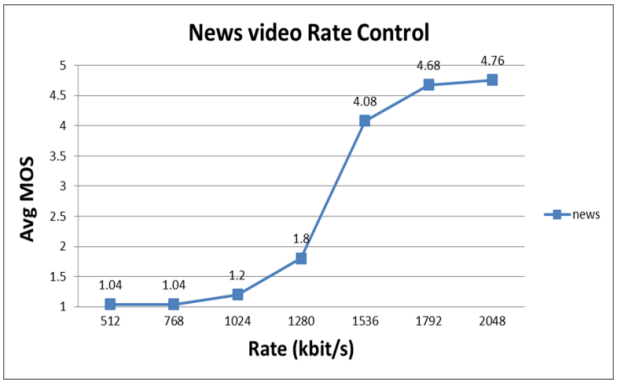


Figure 12: Graph of News video (Rate Control)

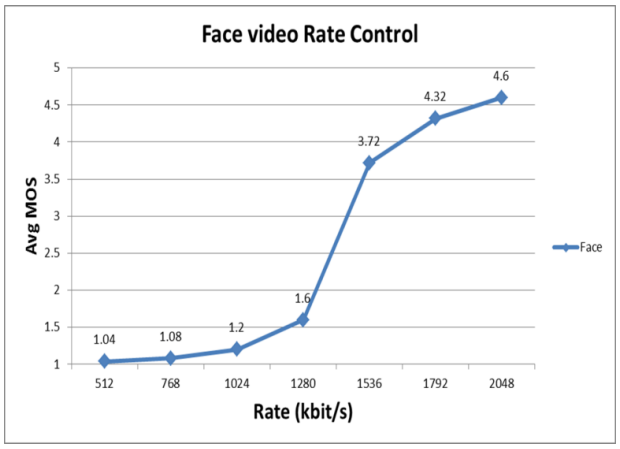


Figure 13: Graph of Face video (Rate Control)

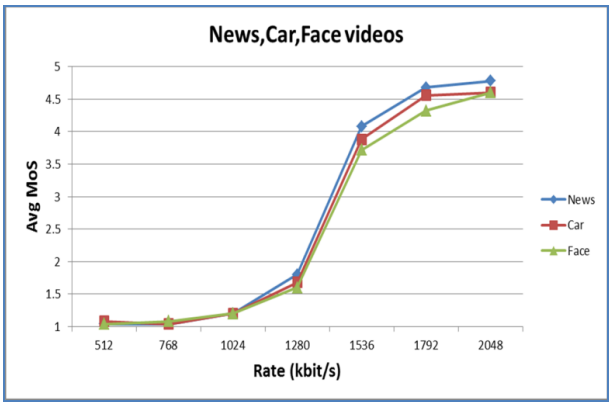


Figure 14: Comparison Graph of videos (Rate Control)

The aggregate and comparison graph of all three videos of a car race, news and face expression video. In these figures, X-axis consists of rate control limits and Y-axis represents the Average MOS ratings calculated from 25 individual users results obtained. At the initial rate of 512 kbit/s in our experiments, the average MOS ratings are highly degraded at decreased level because the quality of the video perceived by the viewers was annoying and no information was perceived from the video. By adding more rates in the network, the quality of video streaming gradually improved. At the point of 1536 kbit/s, the Average MOS suddenly increases. According to the user's experience, this level is a minimal satisfying level where user maintained an adequate satisfaction level for the quality of the video. In our experiments, this is the threshold level where users were adequately satisfied by the quality of the video.

CONCLUSION

Multimedia streaming is becoming a prominent method for sharing the audio and video over a network. There are various factors that affect the quality of video streaming, some are network dependent and others are network independent. The quality of experience of the users is directly or indirectly related to the quality of video streaming. The effect of packet duplication and rate control variations, directly and indirectly, influence video streaming, which in turn affects users' quality of experience, the quality of experience of video streaming is perceived by the users' evaluation using a mean opinion score (MOS). Considered three videos at three various rates (fast, alternating, slow) for analyzing the quality of experience received from the users. We took a survey of 25 users and analyze their ratings for each video. Showed the results of the survey in the form of graphs. From the results concluded that if the packet duplication rate is above 3.5%, the quality of experience drastically decreases, and if the rate control is below 1536 kbit/s, the user's experience drops to the acceptance level.

According to lab experiment and users' experience, changed the service parameters based on users' ratings. Additionally, also found a consistent trend of users' satisfaction level based on the lab experiment. Finally suggested the default policy of the criteria of the service based on users' satisfaction level.

A plethora of research has been done on the parameters affecting the quality of video streaming such as packet loss, packet re-ordering, packet corruption and others. However, there is not much work on packet duplication and rate control and their quality of service as well as the quality of experience. We analyzed the effect of packet duplication and bit rate and their quality of experience using mean opinion score from the users.

FUTURE DIRECTION

There are a lot of research areas in the field of video streaming. Our future work includes testing the videos as well as audio encodes and analyzing the results. There are many open areas to work on in the field of video streaming.

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