Determining Quality of Service in IEEE 802.11 Multi-hop adhoc Networks through End User Perception

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Abstract
This paper seeks to determine Quality of Service (QoS) in the transmission of multimedia traffic in Institute of Electrical and Electronics Engineers (IEEE) 802.11 multi-hop ad hoc networks as perceived by the end user in a simulated setup using NS-2 and EvalVid framework. Extensive simulations indicated that the QoS provision is a challenging task in multi-hop ad hoc networks. QoS is perceptible when the following QoS metrics are very low; delay, jitter, packet loss, frame loss and also when error rate is very low. Increased mobility, network size, packet loss and delay adversely affect QoS. Due to the rapid deployment of multimedia applications, network practitioners, network researchers and the telecommunication industry will gain insight in evaluating their network designs or setup as perceived by users.

Keywords: QoS, NS-2, Multi-hop ad hoc wireless network, Multimedia, EvalVid.

1.0 Introduction

Reliable network performance is an important factor in many network applications. The rate at which multimedia transmissions are deployed in multi-hop ad hoc networks is increasing tremendously. This increase has resulted in the need to provide QoS guarantees to be more important today than it ever was. Al-Sbou et al. (2008)

"Multi-hop Ad hoc Networks from Theory to Reality" (2007) defined a multi-hop ad hoc network as a self-administering wireless network that is temporarily and spontaneously created by mobile nodes According to Munyoka & Gombiro (2008),

In a multi-hop ad hoc network, mobile nodes establish a network on as they come within range of each other. Communication between two nodes is done either directly with 1-hop if they are within range of each other, or indirectly using multiple hops through intermediate nodes if they are not within each other's range. Nodes move freely, join and leave the network as per will. New links are always formed as nodes come within range of each other, and existing links always break as nodes move out of range of each other. Ad hoc network nodes operate in a very unstable environment where any connection could be dropped at any moment since interference is very high. Any node in an ad hoc network can transmit, receive, or work as an intermediate to relay signals.

QoS is an agreement to provide guaranteed services, such as bandwidth, delay, delay jitter and packet delivery rate, to users (Chen, 2006). Ahmed and Ramani (2007) defined Quality of Service as a generic term collectively used to assess the usefulness of any system with user's perspective. Chen (2006) states that real-time applications with appropriate QoS are made difficult due to limited battery power of communicating devices, mobility of the nodes in MANETs, and variable bandwidth. The network infrastructureless makes it difficult to maintain connection state reservations.

Multimedia is the combined use of several media, such as movies, slides, music, and lighting, especially for the purpose of education or entertainment (Brooks, 1997). Maddux et al. (2001) defined multimedia as a computer program that includes text along with at least one of the following: audio or sophisticated sound, music, video, photographs, 3-D graphics, animation, or high-resolution graphics. Multimedia is becoming so pervasive that many businesses have little choice but to incorporate it. Multimedia applications are affecting how businesses operate internally and how they compete for market share within their industry. User perception is a way of evaluating the quality of multimedia transmitted from one node to another using a Mean Opinion Scale (MOS) which ranges from 1 (worst) to 5 (best) and Peak Signal to Noise Ratio (PSNR) (Shaikh et al., 2002).

A number of papers (Aurrecoechea et al., 2004; Chen et al., 2002; Ahn et al., 2002; Saquib et al., 2009; Studi, 2003; Lee et al., 1999) have been dedicated to mechanisms supporting the QoS in different types of networks, and existing protocols and models in the provision QoS in multi-hop ad hoc networks, but much less has been done to support the assessment of the quality really achieved by the individual approaches through end user perception.

This research study seeks to determine a suitable video compression codec that can be used to reduce video distortions, to determine how QoS in the transmission of multimedia data streams is affected by Error rate, packet loss, delay and jitter in a multi-hop ad hoc wireless network, to determine how throughput is affected by packet size, to determine how delay is affected by the size of the multi-hop ad hoc wireless network, and to develop a user perception evaluation scheme to measure QoS in multi-hop ad hoc wireless networks.

In this research the following hypotheses were tested, Video compression codecs do not change the PSNR of a video after compression. Metrics such as Error rate, packet loss, delay and jitter do not affect QoS. Throughput is not affected by packet size and the rate of delay is not dependent on the size of the network. A user perception scheme cannot be used in rating QoS as seen by the end user.

2.0 Materials and methods

Site description

The study was done at Midlands State University which is located in Gweru, latitude 19^{o} 28′ S and longitude 29^{o} 45′ E of the capital city of Zimbabwe (Harare). Simulations were done with NS 2.28 and EvalVid framework. We installed the NS 2.28 on an Intel Pentium IV Personal Computer (PC) with Microsoft Windows XP Professional operation system. The computer had 256 MB of RAM (Random Access Memory).The simulation parameters used in NS 2.28 during the ad hoc network simulation were configured as shown in **Table 1.** The bandwidth between the video or picture sender and the wireless access point was 10Mbps.The link between the wireless access point and the video or picture receiver/end user was IEEE 802.11 11Mbps. Maximum transmission packet size was 65 megabytes. Simulation environment had 3 to 60 wireless mobile nodes and a base station which formed a mobile ad hoc network, moving about a 100 x 100 meters area for 10 seconds of simulated time. All mobile nodes in the network were configured to run DSDV protocol.

Table 1: Simulation parameters

Simulation parameter	Value
Channel Type	Wireless Channel
Radio-propagation model	Two Ray Ground Model
Network interface type	Wireless Physical
MAC type	802.11
Interface Queue Type	Drop Tail Primary Queue
Antenna model	Omni Direction
Number of Mobile nodes	3-60
Ad Hoc Routing Protocol	DSDV
Simulation Area	100m x 100m
Simulation Time	10 s
Traffic Type	TCP
Nodal speed	3-10 m/s
Packet size	10- 65 MB

Video Compression Codecs

A video compression codec is software used both to compress and decompress a digital video. We encoded the foreman_qcif video (PSNR of 40dB) with the following video codecs, MPEG-4 ffmpeg, H.263 ffmpeg and H.264 X.264 codec so as to choose the one with the highest PSNR after compression.

Error rate

Error rate is a term used to describe the degree of errors encountered during transmission over a communication or network connection. A raw YUV video was encoded, decodable frames were measured and a distorted video was viewed using the YUV viewer. The encoded video was sent to the receiving node with different error rates in the range 0.01 to 0.02.

Packet loss, Delay and Jitter

Packet loss is a phenomenon whereby packets of data are lost during transmission and never arrive at their final destination. With respect to multimedia, packet loss is an important factor that can have a large effect on multimedia quality. Analysing packet loss is a valuable metric for determining multimedia quality especially the video quality (Barry, 2008). Delay jitter is a phenomenon that results when data packets are received at different rates (Barry, 2008). We congested the network by increasing the traffic, switching off intermediate nodes and thus gradually increasing delay and QoS was noted for each corresponding delay measured.

Throughput

Throughput is defined as the rate at which data is transferred per given time unit. We used different videos with different sizes and noted the packets transferred from source to destination nodes in 10 seconds.

Network size

Network size is the number of nodes in the network. The number of nodes were gradually increased , foreman video was sent keeping the error rate constant and noting the delay.

User perception Evaluation

Digital video quality measurements were based on the perceived quality of the actual video being received by the users of the digital video system because the impression of the user is what counts in the end. There are basically two approaches to measure digital video quality, namely subjective quality measures and objective quality measures. Subjective quality metrics always grasp the crucial factor, the impression of the user watching the video while they are extremely costly: highly time consuming, high manpower requirements and special equipment needed. The human quality impression usually is given on a scale from 5 (best) to 1 (worst).

Table 2: Mean Opinion Score Scale

Scale	Quality	Impairment
5	Excellent	Imperceptible
4	Good	Perceptible, but not annoying
3	Fair	Slightly annoying
2	Poor	Annoying
1	Bad	Very annoying

Source: Gross, J. *et al* (2000)

According to Klaue et al. (2003),

Many tasks in industry and research require automated methods to evaluate video quality. The expensive and complex subjective tests can often not be afforded. Therefore, objective metrics have been developed to emulate the quality impression of the human visual system (HVS). The most widespread method is the calculation of peak signal to noise ratio (PSNR) image by image. It is a derivative of the well-known signal to noise ratio (SNR), which compares the signal energy to the error energy Since the PSNR is calculated frame by frame it can be inconvenient, when applied to video or pictures consisting of several hundred or thousand frames. Furthermore, people are often interested in the distortion introduced by the network alone. So they want to compare the received (possibly distorted) video with the undistorted video sent. This can be done by comparing the PSNR of the encoded video with the received video or picture frame by frame or comparing their averages and standard deviations.

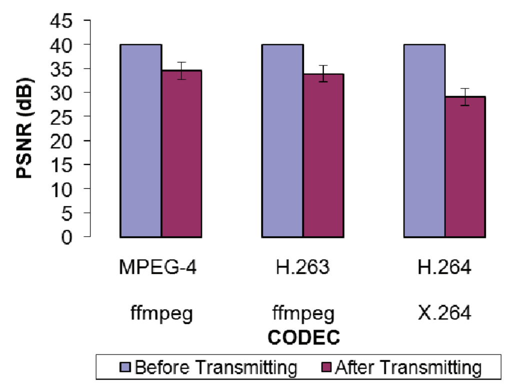
Another possibility is to calculate the MOS first (**see Table 2**) and calculate the percentage of frames with a MOS worse than that of the sent (undistorted) video. This method has the advantage of showing clearly the distortion caused by the network at a glance. In this study a subjective metric user perception evaluation scheme was designed.

Table 3: PSNR to MOS conversion

PSNR (dB)	MOS
>37	5 (Excellent)
31-37	4 (Good)
25-31	3 (Fair)
20-25	2 (Poor)
< 20	1 (Bad)

3.0 Results

Video Compression Codec



Error Rate

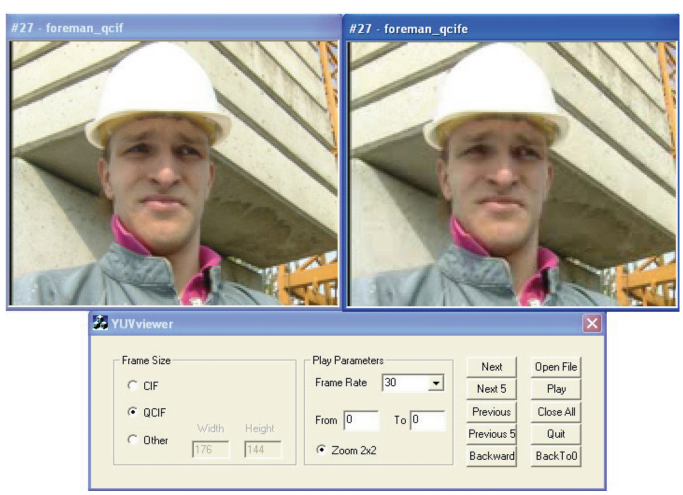


Figure 2: Snapshot of a user perceived video with 0.01 error rate

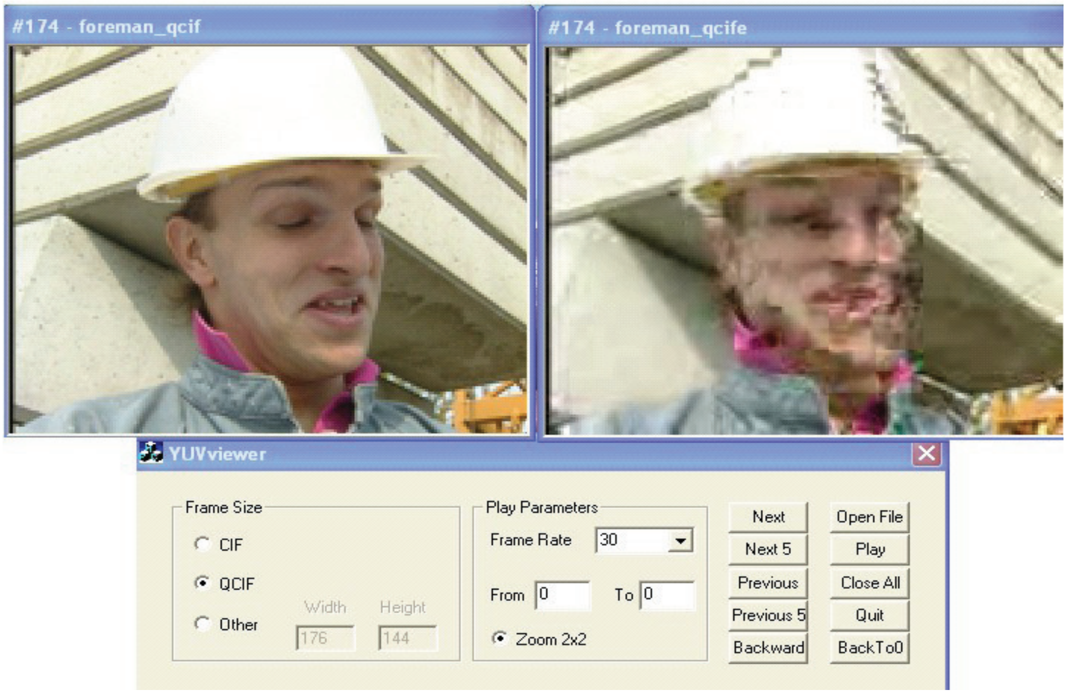


Figure 3: Snapshot of a user perceived video with 0.02 error rate

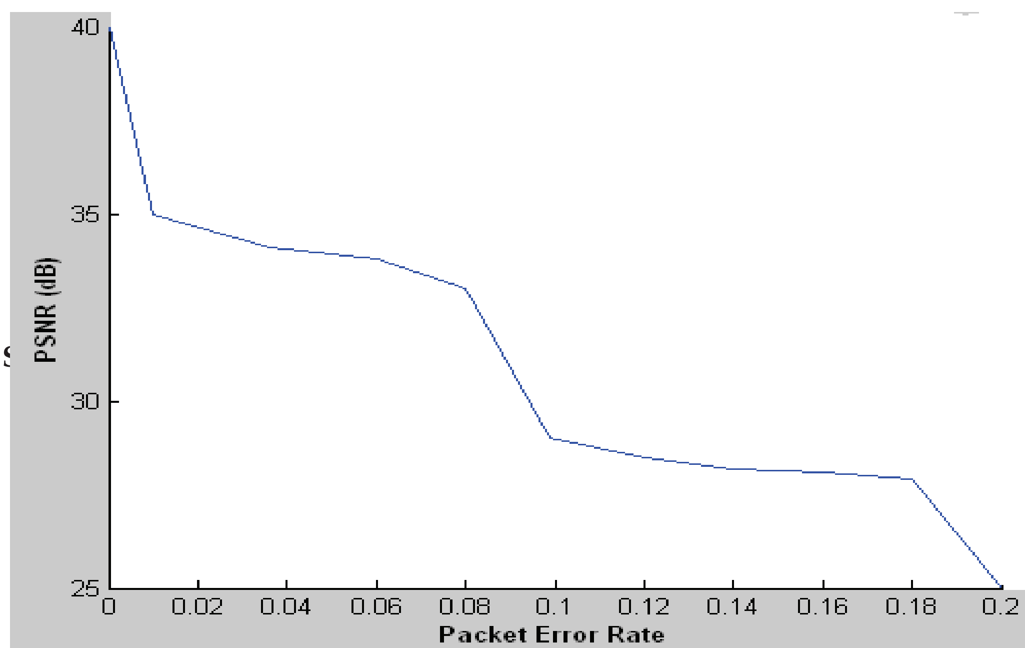


Figure 4: Graph showing PSNR versus Packet error rate

Packet Loss, Delay and Jitter

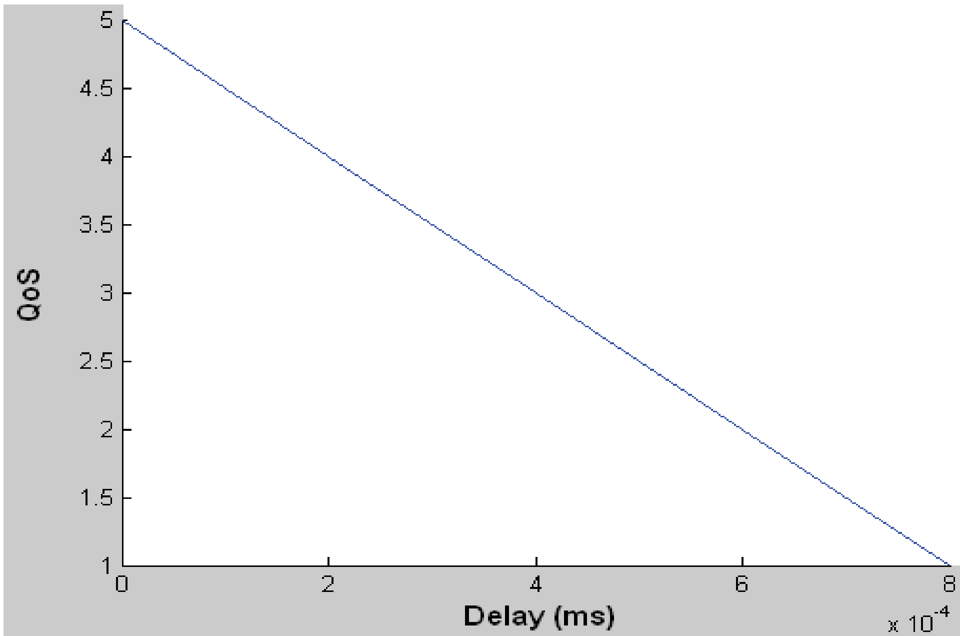


Figure 5: Graph showing QoS versus Delay

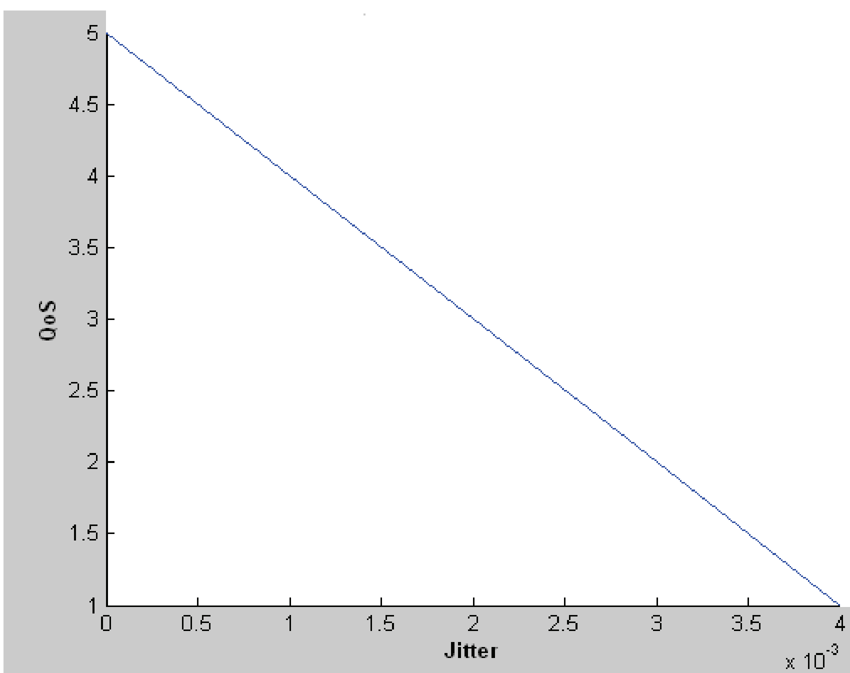


Figure 6: Graph showing QoS versus Jitter

Throughput

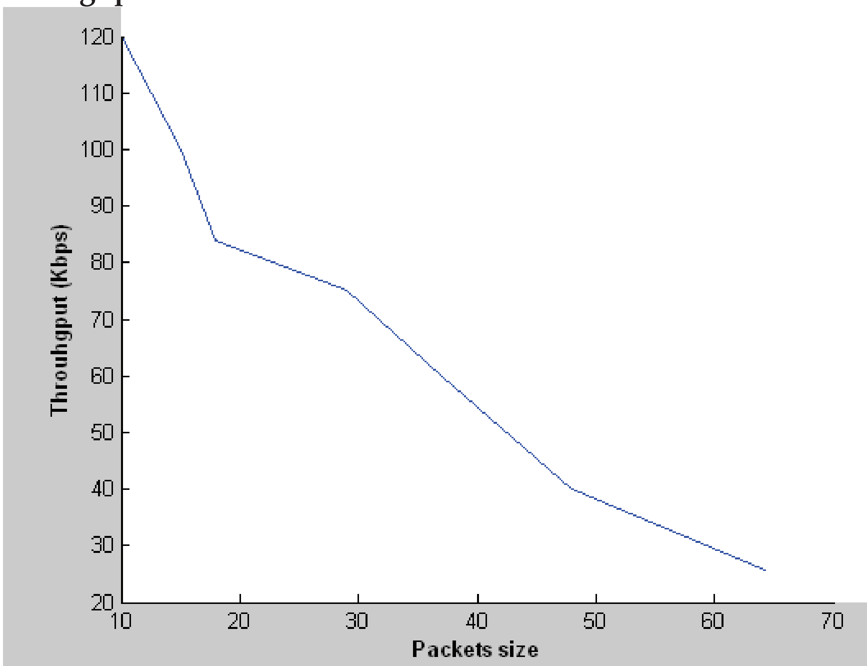


Figure 7: Graph showing Throughput versus Packet size

Network Size

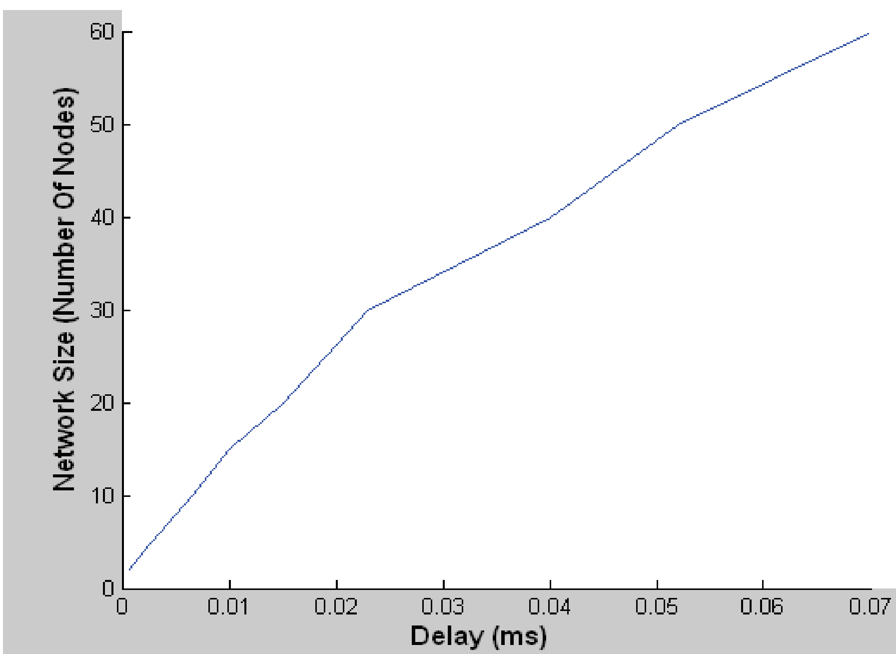


Figure 8: Graph showing Network size versus Delay

User perception Evaluation Scheme

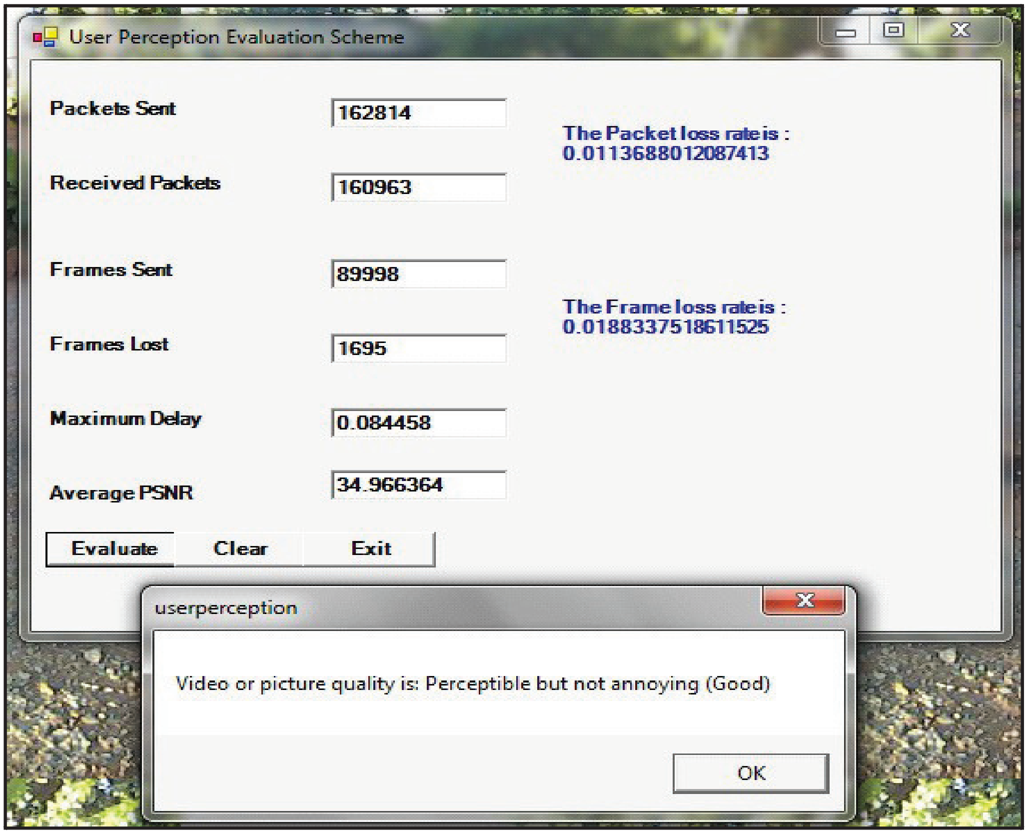


Figure 9: User perception Evaluation Scheme

4.0 Discussion

Video Codecs

Before compression the video quality was excellent with PSNR of 40dB for the foreman video and after encoding with different codecs the quality deteriorated shown by drop in PSNR, 35dB for MPEG-4 ffmpeg, 34 for H.263 ffmpeg and 29 for H.264 X.264 codec.

Error rate

The encoded video was sent to the receiving node with an error rate of 0.01 and the results obtained showed that, the decodable frames and the value of the decodable frame rate (Q) were 350 and 0.877193 respectively; Q is large and shows that the video received by the user is of good quality. 350 frames were decoded out of 400 sent frames, 50 frames were lost before reaching the destination node. The distorted video was viewed using a YUV viewer as shown in **Figure 2**. The video quality is good as perceived by the end user though frames were lost. There are three type of frames and their importance is not the same, I frames are the most important followed by P frames and B frames are the least important. From the results it was noted that the frames lost were the P and B frames which are not of great importance resulting in a good video quality decoded. In **Figure 2** Foreman_qcif was sent by the source node and the foreman_qcife was received by the user and was of good quality. The frames were lost due to mobility of the receiving node. The sending node continues to send video frames and data packets even if the receiving node is not in the radio range of the neighboring nodes resulting in frame and packet loss.

The error rate was repeatedly increased until 0.2 and the video quality recieved by the end user was annoying at error rate 0.2, this may be caused by nodes moving out of their neighbouring radio range or interference hindering communication thereby causing high delay in the transmission of frames and data packets from sender to receive, high jitter in the frames received at unexpected time and high loss rate in video frames transmitted from source to destination node. The decoded video is shown in **Figure 3** where foreman_qcif was the video frame sent and foreman_qcife was the video frame received.

The graph in **Figure 4** shows the relationship between PSNR and Packet error rate. When error rate is 0 then PSNR is 40 and the video quality produced is excellent from **Table 2: PSNR to MOS conversion** and video quality deteriorates as error rate is increased. In a real Mobile ad hoc network error rate can be interferences disturbing communication or data transfer, mobility of nodes who may be far away from each other thereby causing drop in packets, node energy exhaustion thus the sending or receiving node may die due to energy exhaustion causing a link to break and loss of packets.
Figure 4 gives test results which show video transmitted quality with different packet error rate. When the error rate is zero then video transmitted will have maximum quality which is excellent with PSNR above 37dB. Introducing error rate deteriorated video quality.

Packet loss, Delay and Jitter
The delays from sending the foreman video are shown in **Figure 5**. Delay is the time taken by the packet to reach the destination successfully. **Equation 1** show delay calculations.

$$\textbf{Delay} = \textbf{time received by sink} - \textbf{time sent by agent} \qquad (1)$$

When delay increases QoS is negatively affected. QoS is excellent when there is no delay in the transmission of multimedia packets.

Jitter is also related to delay, since it is understood as the variation of the delay. Jitter has several definitions e.g., the maximum variation of the delay, but the most common one is probably the standard deviation of the delay. Jitter can be calculated from the exact delay measurements, but not from the average values. Jitter is easier to calculate than absolute delay, since it only needs the delay difference between sequential packets, but not absolute clock synchronization of the measurement points. Jitter can be controlled with buffers, but this is done at the expense of delay. **Equation 2** show jitter calculations. When jitter increases QoS deteriorates as shown in **Figure 6** and it is excellent when there is no Jitter, thus the packets would have arrived at their expected times. Zero jitter occurs when delay is zero.

$$\text{Jitter} = \text{second delay} - \text{first delay} \qquad (2)$$

Throughput

Throughput is defined as the rate at which data is transferred per given time unit. As the packet size of data being sent is increased, throughput is reduced. The reduction in throughput is due to queuing delays, traffic congestion in the network, packet loss resulting in retransmission of packets and as a result the video quality deteriorates and "jerkiness" increased as the packet size increases. The relationship between throughput and packet size is shown in **Figure 7.**

Network Size

The number of nodes were increased, foreman video was sent keeping the error rate constant and the delay was noted. When the number of nodes were increased the size of the network also increased and the delay increased. In sending the video routes must be chosen in such a way that per-flow QoS requirements are met and the total bandwidth is well-utilized. In order to set up a route, it is necessary to contact every potential node to determine its level of load and whether it can provide the service level guaranteed to the flow. Unfortunately, the traffic resulting from flooding the network and contacting every node in the path clogged the network, wasted bandwidth and increased delay. The relationship between the network size and the delay is shown in **Figure 8**. When the network was made up of two nodes the delay was 0.0008ms and under such circumstances video quality perceived by the end user is excellent compared to the video quality produced when the network has 60 nodes corresponding to 0.07ms delay which produces an annoying video quality.

User perception

The metrics from the simulation results in the trace file were entered in the user perception evaluation scheme and the results shown in **Figure 9** were obtained alerting the user the quality of the video decoded.

Conclusion

The purpose of this study has been to determine QoS in the transmission of multimedia traffic streams in IEEE 802.11 based multi-hop ad hoc wireless networks. Simulation modeling experiments and end user perception were used to gather data. The study enabled us to establish how QoS is affected by different metrics in the transmission of multimedia data streams. In order to make recommendations EvalVid framework was integrated with NS-2 and a video sent from a source node (video server) to the destination mobile node. This was in an effort to assist in the calculation of average PSNR, delay, jitter and decodable frames.

Basing on the research findings from the simulation experiments QoS provision is a challenging task in MANETs. The findings showed that when error rate increases the quality of the video sent deteriorates, when packet size of the video increases the rate of which data is transferred per unit time decreases and this decrease cause the quality of video to be annoying , and when network size is increased the time taken for packets to reach the destination node increases and this increase also increase jitter and results in jerkiness of a video thereby negatively affecting quality of multimedia traffic streams. Also it was seen from the findings that nodes transmit even if they do not fit into the available bandwidth and this waste resources causing packet and frame loss, this affects the quality of video sent in MANETs.

We conclude by stating that if EvalVid framework, the user perception evaluation scheme are implemented, a great improvement in services not only in IEEE 802.11 based MANETs but, especially for telecommunications industry such as Internet Service Providers and Mobile phone services will be noticed. EvalVid framework and end user perception evaluation scheme has been presented that alerts a user the quality of video or picture received under different conditions, it will also allow network researchers and practitioners to analyse their proposed new network designs in the presence of real video traffic in a straightforward way.

Recommendations

This research paper gave an insight to a few ideas to be researched which are: Showing packets movement in the Network Animator (NAM) in wireless network simulation; Integrating the user perception evaluation scheme and EvalVid framework; Running simulations using different routing protocols (AODV) and (DSR); Forming a new routing protocol which estimates the available bandwidth before each node in the network sends multimedia data packets.

Acknowledgement

Our heartfelt and abysmal appreciation goes to the following for their inestimable support during the course of this research study;

Prof Masaka, our academic supervisor for his commitment and guidance throughout this paper. He provided us with the freedom of choosing a research topic, endless source of ideas, and encouragement. His enthusiasm in research, systematic organization in work, and optimistic attitude towards life positively affected our study and life. We thank him for guidance not only in academic but also in life attitude. He is our example in personality, intelligence, and career.

Finally, we would like to thank the Midlands State University for making it possible for us to write this research paper.

My heavenly Father Thank you for always being there for us.

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