Comparison of Throughput with a Perceived Video Quality Metric as Performance Indicators of Streamed Video in IEEE 802.11g/a

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Abstract: In this paper we compare the use of two metrics that could be used as indicators of the quality of streamed video in a wireless home network based on 802.11. One of the metrics is throughput which is a traditional performance metric. The other metric is based on the perceived quality of a video clip. The results demonstrate that the throughput metric overestimates the perceived quality of video meaning that it is not a satisfactory indicator of the quality of video clips.

1. Introduction.

Broadband offers high speed internet access to an increasing number of homes. In the home internet access and services are no longer just a requirement of PCs. There is a requirement for internet access and services in other devices around the home. A future home network may consist of many home entertainment devices as well as PCs; TVs may receive streamed HDTV over the internet, or video may be streamed from media storage devices around the home. Communications services such as VOIP are increasing in popularity. Other household services could be provided to thermostats, air conditioning units, home security devices, and white goods. A home network is likely to be wireless allowing any device to provide its services anywhere in the home. The network should be able to provide quality of service (QoS) guarantees to meet with these extra demands of the network.

Potentially the most demanding of these services listed above is that for streaming of video. To provide QoS for video services we must ensure we are using the most appropriate performance metrics. In this paper we compare the use of two metrics that could be used to indicate the quality of streamed video. The first metric is throughput. This is commonly used to judge network performance. The second metric is a perceived quality metric (PQM). This is a performance indicator that analyses video pictures after decoding. The value of the metric indicates how the quality of the video output is perceived by a human.

The paper is based on the results found in [1] where an MPEG-2 video is streamed between two wireless stations using an 802.11g/a PHY. Both throughput and PQM characterisations are given for changing channel conditions.

Section 2 explains how MPEG-2 video is encoded and transmitted over 802.11g/a. Section 3 explains the limitations of throughput as a metric for streamed video, while section 4 explains how a PQM can be created. Finally sections 5 and 6 show the results and conclusions.

2. Video Transmission on 802.11a/g.

MPEG-2 [2] is a coding method that exploits the spatial and temporal redundancies found in video clips by using intra-frame and inter-frame coding respectively. Spatial redundancies are reduced at block level using a discrete cosine transform (DCT) which transforms an 8 by 8 matrix of samples into 64 DCT coefficients. Compression is then achieved by quantisation and variable length coding of these coefficients. Temporal redundancies are reduced by motion compensation using motion vectors at macroblock level. The prediction error is then encoded to remove spatial redundancies.

An MPEG-2 video sequence is formed by one or more groups of pictures (GOPs). Each GOP contains one or more pictures. There are three types of picture. This allows us to aid random access, while still achieving high compression. Intra coded pictures (I-pictures) do not require any reference pictures to be decoded. Predictive coded pictures (P-pictures) are motion compensated pictures that use the previous I- or P-picture as a reference picture. P-pictures achieve a higher coding efficiency than I-pictures. Bidirectionally-predictive coded pictures (B-pictures) require a past and future reference picture to be decoded. B-pictures cannot be used as reference pictures, but do have the highest coding efficiency. The loss of I-pictures, P-pictures, and B-pictures have a decreasing effect on the quality of a decoded GOP.

There are two types of stream defined for MPEG-2. One is the program Stream. This is intended to be used in a low error environment. This may be used for storage of video on a DVD. The other stream is a transport stream. This is intended for use in error prone environments. A transport stream uses fixed size packets that contain a 4 byte header and a 184 byte payload [3]. This is the likely method for streaming MPEG-2 video to devices in a home network.

The IEEE 802.11 standard defines both Medium Access Control (MAC) and physical layer (PHY) for WLANs with data rates up to 2 Mb/s. Amendments have been added to allow for increased data rates. 802.11b was added to allow data rates up to 11 Mb/s. 802.11a allows 54 Mb/s using orthogonal frequency division multiplexing (OFDM) in the 5GHz band. 802.11g uses almost identical methods to 802.11a to allow up to 54 Mb/s using OFDM in the 2.4 Mb/s band. This allows for backwards compatibility with the 802.11b PHY [4].

The 802.11g OFDM signal occupies around 16 MHz of a 20 MHz channel bandwidth. A PPDU to be transmitted is first scrambled and then undergoes convolution encoding and puncturing. This data is then interleaved before mapping it to a modulation constellation. An IFFT then transforms the mapped symbols into time domain signals that are modulated onto orthogonal subcarriers for transmission. To achieve different data rates the encoding and puncturing rate can be 1/2, 2/3, or 3/4. Also the modulation constellation can range from BPSK to 64-QAM. The 802.11g PHY provides capabilities for data rates of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s.

3. Limitation of Conventional Metrics.

Conventional network performance metrics such as throughput and PER may not give a reliable indication of video quality. Lost packets are likely to cause impairments to a video sequence. However, the effect that impairments have on a video sequence is affected by factors such as the coding rate, the codec used, and the video content. The spatial and temporal activity in a scene has a considerable effect on how perceptible video impairments are. Spatial impairments are less noticeable in video scenes with high temporal activity as less detail can be resolved in faster moving objects. Spatial impairments can be due to packet or bit errors in transmitted packets, but also down to the video encoding. Spatial impairments are more noticeable where high frequency picture information is lost such as object edges (blurring). This is mainly due to quantisation (adjusted by coding rate) of DCT coefficients. Blockiness is another spatial impairment. This is due to the block based DCT coding of MPEG-2.

4. PQM as an Alternative Metric.

In [1] a tool is used that creates an objective measure for the perceived video quality (PVQ) for individual frames. The PVQ takes into account the blockiness impairments and the temporal content of the video clip. A PQM value is created using a weighted mean of the PVQ values as shown in equation 1.

$$PQM_{abs} = \frac{1}{N}\sum_{n} n.F_n \qquad (1)$$

where N is the total number of video frames in the scene, n=0,10,20,…90 denotes the histogram ranges of the PQV scale and F_n is the number of video frames whose PVQ satisfies the condition $n \leq PQV < n+10$. The PQV_{abs} scale is fixed between 0 and 100.

From this absolute PQM value a relative PQM value is created that normalises the PQM of the received video sequence to the PQM of the transmitted video sequence as shown in equation 2.

$$PQM_{rel} = \frac{PQM_{rx}}{PQM_{tx}} \qquad (2)$$

At a receiver station a PQM value can only be used after the video clip frames have been decoded, meaning that this metric will come with a considerable delay in comparison to a throughput metric.

5. Results.

In [1] a 2Mbps MPEG-2 video clip is streamed from one station to another over an 802.11g/a PHY. The channel conditions are varied by changing the distance (D) between the two stations. Characterisations of normalised throughput and PQM_{rel} against D for 8 physical layer data rates are shown in figures 1 and 2 respectively. The calculation used for throughput is shown in equation 3.

$$\text{Throughput} = (1\text{-PER}) \times \text{data rate} \qquad (3)$$

A 90% threshold is typically used for judging acceptable throughput. Table 1 shows the coverage that meets this requirement for each transmission mode. Table 1 also shows the coverage for each transmission mode to meet 90% and 100% thresholds for the PQM.

Both the throughput and PQM results agree that better coverage can be achieved with lower data rate transmission modes as they are more robust modulation techniques. The exception in both sets of results is with transmission data rates of 9 and 18 Mb/s. These both use 3/4 coding rates making them less robust than the other low data rate transmission modes. When comparing the results it is shown that the 90% throughput coverage is always significantly greater than either the 90% or 100% PQM coverage values for each transmission mode.

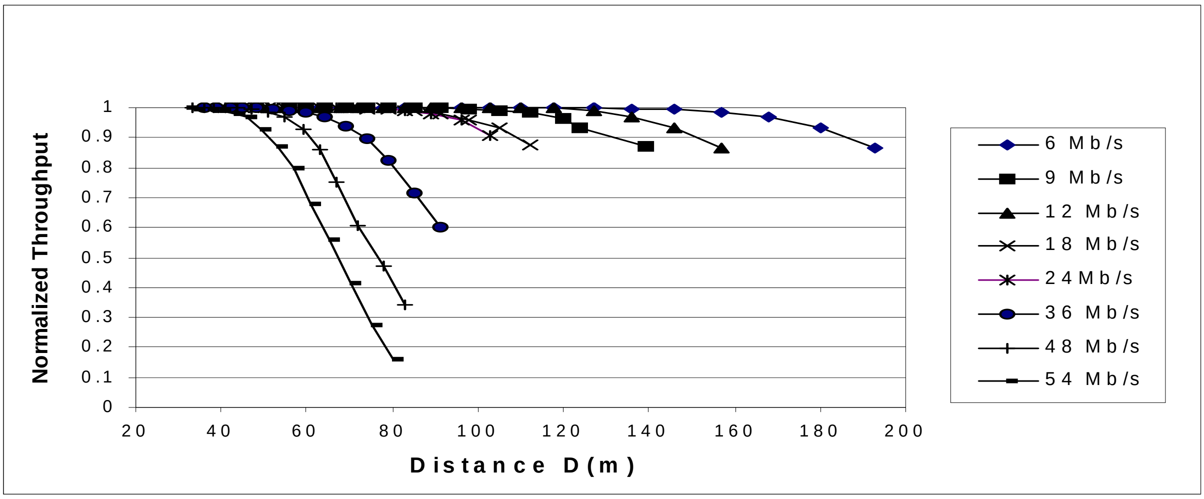

Figure 1 Normalised throughput vs distance (D) for the 8 transmission modes of 802.11g/a

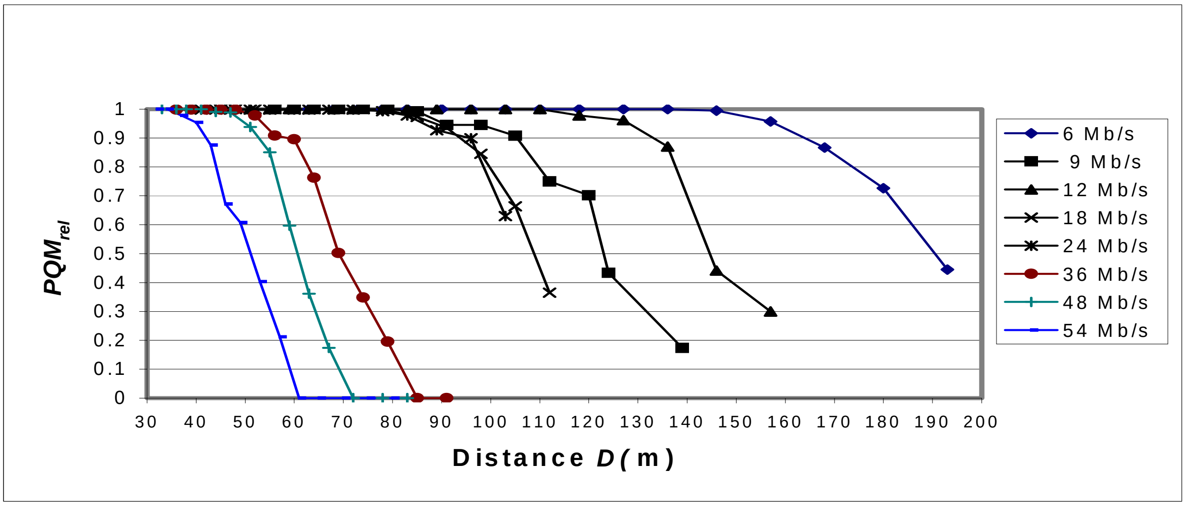

Figure 2 PQM_{rel} vs distance D for the 8 transmission modes for 2 Mb/s video clip

Data Rate (Mb/s)	Maximum Coverage at 90% throughput (m)	Maximum Coverage at 100% PQM (m)	Maximum Coverage at 90% PQM (m)
6	180	146	164
9	131	85	105
12	150	110	134
18	109	79	95
24	103	75	93
36	74	51	58
48	59	43	52
54	51	34	42

Table 1 Maximum 802.11g coverage at 90% throughput, 100% PQM, 90% PQM

6. Conclusions.

This paper has compared the use of a conventional throughput metric with the use of a perceptual video quality metric as a potential metric for judging QoS of streamed video in a wireless home network. The results show that the throughput metric always overestimates the quality of the streamed video. This could cause video to never satisfy its QoS requirements in an 802.11 home network. The results also showed that more robust modulation rates offer better coverage. The video used had a much lower data rate than even the lowest transmission data rate, so this observation is likely to change with high data rate video clips.

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