Experimental Analysis of Video Performance over Wireless Local Area Networks

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***Abstract*—This paper quantifies the performance degradation of video streaming over WLAN network (IEEE 802.11g) due to distance, obstacles and motion. Wireless networks are generally marked by the presence of noise and channel interferences which present an overhead to video quality. First, we present the research done on the metrics used for performance assessment which are: PSNR, transmission delay, jitter, and packet loss; the way they affect the quality of the video, and why they are considered in this study. Thereafter, we describe the tools used in this research and the way they were deployed. From the results, we find that distance and obstacles do have a negative effect on video performance. Moreover, background traffic does create a sort of bottleneck to the bandwidth making it difficult for the video to be well streamed. Additionally, both the delay and jitter increase with distance and background traffic. Finally, the effects of motion on video are mainly due to packet loss. Results have shown that even in small distances between the access point and the receiver, packet loss seems to be the major impact of motion on video performance over WLANs.**

***Index Terms*— Video quality, WLAN, Wireless mobility.**

I. INTRODUCTION

Video streaming over a wireless network is a growing technology that enables the transport of video over data networks. Multimedia sharing is very important to the convergence of consumer electronics and wireless. Nowadays, consumers want to be able to access stored video anywhere in their homes. Concurrently, a rapid and wide deployment of wireless local area networks (WLAN) is taking place in most corporate buildings, small offices, and home offices (SOHO) as well as public spaces such as commercial malls and airports. WLAN technology is based on the IEEE 802.11 network access standards. The issue of mobility is critically sensitive in wireless applications; during a user's mobility, Access Points (AP) transfer control of the mobile device between them as the user moves from one radio coverage to another.

This calls for a wireless networking technology that can provide high bit rates to support distribution of video (and HDTV) streams from a central location, along with total local area network coverage. Such video applications require no bandwidth fluctuations, and important QoS (Quality of Service) requirements. Additionally, a wireless network must provide a performance similar to a wired network regardless of changing environmental conditions, mainly mobility.

There are few papers that discuss the performance of video streaming over WLANs such as [1]. Other recent studies like [5] examine the impacts of delay and handover on video quality streamed over a WLAN. To the best of our knowledge there is no work in the literature that discusses the effects of motion on the performance of video streaming over WLANs. In this paper, several experiments are discussed treating distance, background traffic, and motion on the performance of video over an IEEE 802.11g network. Before experimenting, a good understanding of WLAN and video streaming is needed; hence, measuring this system's performance under realistic conditions is of paramount importance.

In this paper, we performed extensive experimentation. However, we mainly want to study the effect of motion on video over WLAN. Our work is to evaluate the impact of motion on video quality, transmission delays, and delay jitter. The remainder of this paper is organized as follows. In section 2, we discuss the issues and QoS requirements for video quality over WLAN. In section 3, we examine experiments conducted and finally present their results. Finally, we conclude this paper in the last section.

II. QOS METRICS

Video streaming is usually efficient in both Point-to-Point (PP) and Multipoint-to-Point (MP2P) ad-hoc network [2]: approximately 70% of the packets are successfully received in PP networks, and in MP2P the percentage is around 90%. Hence, the performance of video on ad-hoc networks does not face crucial issues. A wireless LAN however does introduce difficulties to applications such as voice and video over WLANs. That is because wireless networks generally are affected by several impairments.

This paper measures the performance of video on WLAN, and in order to measure it, we chose to analyze the following metrics: Peak Signal-to-Noise Ratio (PSNR), the transmission delay, delay jitter, and Packet loss.

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A. Peak Signal to Noise Ratio

The Peak Signal-to-Noise Ratio (PSNR) can be defined as the ratio of the maximum power of a signal over the noise affecting it. It is most commonly used as a quality metric of reconstruction of Lossy compression codecs. When making a comparison between two media files, it is used as an approximation to human perception of the quality.

In our context, given an original NxM video frame *f* (or image) and a streamed one *f'*, the Root Mean Squared Error (RMSE) is [3]:

$$RMSE = \sqrt{\frac{1}{N.M}\sum_{x=0}^{N-1}\sum_{y=0}^{M-1}\left[f(x,y) - f'(x,y)\right]^2}$$

With the maximum possible pixel values if an 8-bit image of 255, the PSNR is hence defined by:

$$PSNR = 20\log_{10}\left(\frac{255}{RMSE}\right)$$

Put differently, the formula compares each pixel of the frames and calculates the difference in their PSNR values. These values are expressed in the logarithmic decibel scale (dB).

It has been shown that as long as the video content and the type of codec are not changed, the PSNR is valid as a quality measure [4]. The interpretation of its values in terms of quality is done simply using the following table:

TABLE I
PSNR INTERPRETATION IN TERMS OF QUALITY

PSNR ≥ 33 dB	Excellent Quality
33 dB ≥ PSNR ≥ 30 dB	Fair Quality
PSNR < 30 dB	Poor Quality

B. Transmission Delay and Delay Jitter

Transmission delays are caused by reasons. Since video packets and other types of packets are passed through the same communication channels, only priority queuing can guarantee timely delivery of video packets [5]. Additionally, wireless local area networks introduce other sources of transmission delay. For example, a SIP message can be as large as 2000 bytes. Such messages would take a significant time to transfer over the air interface, resulting in a significant delay.

Digital transmission, with its ability to avoid any cumulative noise-induced degradation, should provide error free communications however does not meet expectations because of many reasons like the untimely transmissions of generated data. When this mis-timing becomes large, more serious errors are formed making the system ineffective. Low values of mis-timing also lead to performance degradation because of the increase in sensitivity to amplitude and phase variations.

Jitter is another parameter in video traffic channel that causes delay. It is defined as a variation in the delay of the received video packets. In real time connections such as video streaming over LANs and WLANs, quality problems are usually due to jitter. In general, it is a problem in slow-speed links or with congestion. At the server side, packets are sent in a continuous stream with the packets spaced evenly apart. However, due to congestion of the network, improper queuing, or configuration errors, this steady stream may become lumpy, or the delay between packets can vary instead of remaining constant. Jitter between the source and destination should be less than 100 ms [6]. If jitter value is smaller than 100 ms, it can be solved through the use of the play-out buffer.

C. Packet Loss

Packet loss is another important element to be considered in measuring the performance of video over WLANs. In addition to blocking artifacts, blurring and mosaic pattern effect, streaming of video over a WLAN can lead to another type of video quality degradation caused by the inevitable packet loss [8]. Every packet is very important for the video reconstruction at the receiver side.

Packet loss varies depending on the play-out buffer at the receiver end and the packet size. A play-out buffer needs to be used in cache video (or audio) data so that it can be played out steadily while video packets arrive unevenly over time. This adds a certain amount of delay; the more sure you want to be about getting every packet, the more delay you need to add. However, excessive delay reduces the usefulness of the video; so a compromise needs to be reached. It has been shown that smaller play-out buffers lead to more packet drops and hence worse video quality [7]. Additionally, if no video recovery for video transmission is deployed, the video delivered quality of the larger packet size will be better than smaller packet size.

III. EXPERIMENTS

A. Experiment 1: Baseline Test: Video over Wired LAN

1) Description & Objective

The first experiment of this project will serve as a baseline for next experiments. Put differently, subsequent tests are going to be compared to the baseline experiment for interpretations. In order to effectively evaluate the Wireless LAN effect on video performance, we put the server the client connected to the LinkSys access point (AP) through RJ45 cables. The AP is 2 meters distant from the server, and 5 meters away from the client. *Figure 1* describes the experiment setup.

The streamed video is a 50 seconds movie clip compressed to an MPEG-4 codec, and containing 1497 frames.

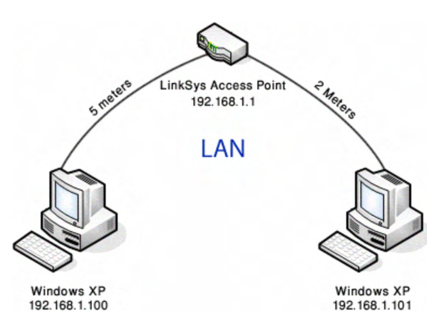

Fig. 1. Video streaming over wired LAN

2) *Results Analysis*

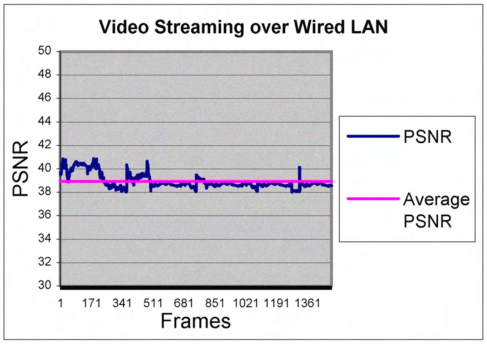

Fig. 2. Simple video streaming over wired LAN

The calculated average PSNR is approximately 39 dB. Using *table1*, we conclude that the streamed video quality is excellent. Furthermore, the graph shows slight changes in the PSNR values till the end of the streaming. A wired Local Area Network hence does so prove to be affected by serious impairment as no considerable fluctuations.

Concerning the delay and jitter in our wired LAN network, they are negligible (close to zero); therefore transmissions delay and jitter when the sender and receiver are close to the access point is not an issue. Moreover, WinSIP recorded no packet loss in this experiment.

The overall performance in this test proves to be excellent. Looking at received video at the client side, we notice no serious quality degradation. Now, we can move on to next experiments where wireless will be introduced.

B. *Experiment 2: Impact of Distance on Video over WLAN*

1) *Description*

Both the client and the server are connected wirelessly through the LinkSys Access Point. As the *figure 3* shows, the first measurement consists of a server that is 2 meters far from the AP and a client 5 meters away from it. In the second measurement illustrated in *figure2.2*, the server was put 15 meters far from the access point with the presence of obstacles consisting of concrete walls. The streamed video is kept the same.

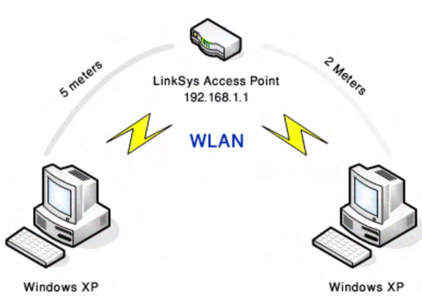

Fig. 3. Simple video streaming over WLAN

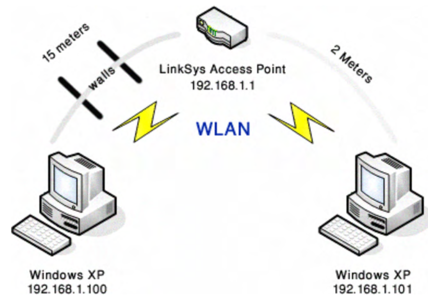

Figure2.2: Video streaming over WLAN with obstacles

2) *Objective*

This test's objective is to study the effect of distance on the video quality. It was conducted under suitable conditions where external noise was minimized.

In addition to getting familiarized with video streaming process and output analysis, this experiment examines the impact of distance and obstacles on video quality. Obstacles in this test are represented with concrete walls which are known to reduce the SNR of the transmitted signals.

3) *Results Analysis*

Before analyzing the video quality, the signal strength ought to be measured in order to evaluate the noise in the environment of the experiment. In the first test of this experiment, the signal strength at the client side is -43 dBm which is a very good signal. In the second test, however, the signal strength is -70 dBm.

Concerning the video quality of this experiment, MSU Measurement Tool showed the following graph, consisting of the PSNR value of each compared frame:

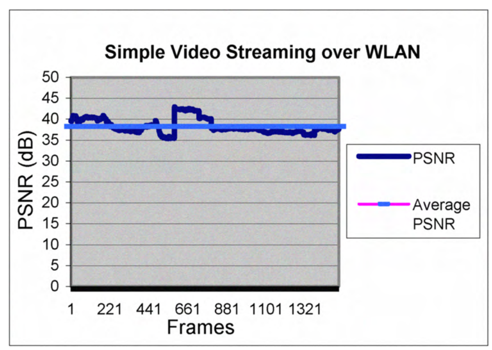

Fig. 4. Simple video streaming over WLAN

The average PSNR in this test is: 38.3 dB. Using *table 1*, this value indicates that the quality of the streamed video is excellent since it exceeds 30 dB. This experiment serves as a baseline for next experiments.

The second testing shows how distance and obstacles affect the performance of the video streaming. The average PSNR of 26.2 dB indicates that the quality is poor. *Figure 5* shows how PSNR values corresponding to each frame of the movie clip.

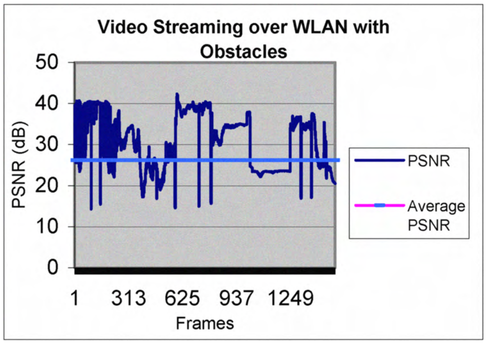

Fig. 5. Simple video streaming over WLAN with Obstacles

Compared to the baseline experiment our wireless LAN does introduce quality degradation to the video. The frequent variations in the PSNR values can be explained by the external noise affecting the transfer. External noise in this case is fading and attenuation which are mainly caused by distance. Therefore, the latter does affect negatively the video streaming performance.

Furthermore, WinSIP shows that, in the test 1, the transmission delay for a video of 50 seconds is: 67 ms which is very small, if not negligible. Compared to the baseline experiment, where the same conditions applied to this test, the signaling delay is higher. This proves that Wireless LANs, as opposed to wired LANs, increase the transmission delay due to the several impairments that the air interface introduces. As for test 2 of this experiment, WinSIP results show that the delay increases to 220 ms. The presence distance and obstacles between the sender and the receiver in a video streaming solution does create problems for the performance.

Delay jitter in the first test is approximately 3.5 ms; this can also be an explanation for the high video quality in this test. The very low jitter can be explained by the high signal strength at the receiver. Whereas in the second test, the delay jitter is about 15.4 ms which is very much higher than that of test 1 in this experiment. Distance hence does increase the delay jitter resulting in a lower video streaming performance.

As far as packet loss is concerned, WinEyeQ shows that no packet was lost in test 1 of this experiment. Moreover, by looking the video itself, we notice no video distortion or artifacts. While in test 2, 3.26% of the packets were lost resulting in minor artifacts in the video. Looking at the video, we see the packet loss effect on the video; *figure 6*, captured by Fraps, is a frame seen in the streamed video that illustrates the packet loss effect in this test.

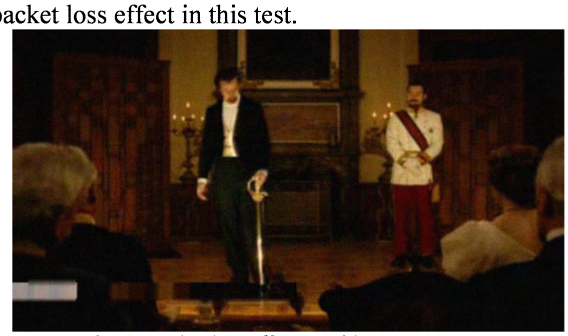

Fig. 6. Packet loss effect on video over WLAN

C. Experiment 3: Impact of Traffic on Video over WLAN

1) Description

As in the baseline experiment, the same platform is kept. Hence, two tests were conducted in order to examine how background throughput would affect video quality. During the first testing, the client is put 5 meters far from the AP, whereas in the second one, it is 15 meters away with the presence of obstacles. *Figure 7* and *figure 8* describe this experiment.

The background throughput is transferred through the UDP protocol, and each packet is of size 2000 bytes with an Inter Packet Delay of 2 ms in both tests.

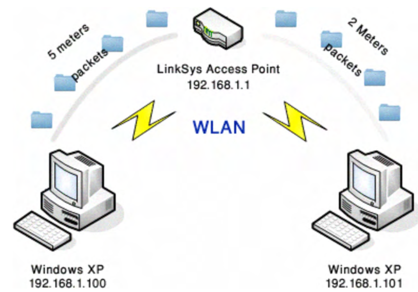

Fig. 7. Video streaming over WLAN with LAN traffic

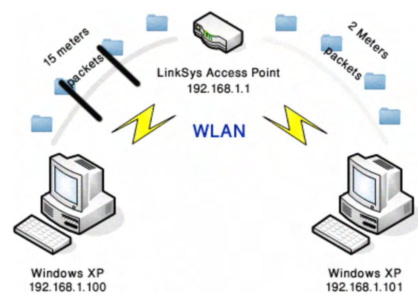

Fig. 8. Video Streaming over WLAN with LAN traffic and obstacles

2) Objective

The object now is to see and explain the background throughput effect on the video streaming. In the first test (test3.1), the throughput is examined and compared to test 1 of experiment 1, and re-examined in more realistic conditions in test 2 (test3.2) where obstacles will be present and client much farther from the access point. Again, in the same conditions of test 2 of experiment 1, obstacles are represented by concrete walls.

3) Results Analysis

First of all, the Signal-to-Noise Ratio is examined in order to measure the strength of transmitted signals. Again, in the first test of this experiment, the signal strength at the client side is approximately -45 dBm which defines an excellent signal. In the second test, however, the signal strength is around -77 dBm.

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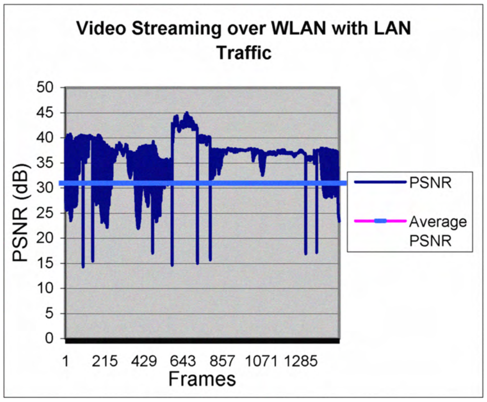

Fig. 9. Video streaming over WLAN with LAN traffic

The average PSNR recorded in this test is approximately 31 dB, which means a fair quality video. If compared to the first test of experiment 1 (≈38dB), this test proves that even with the client 5 meters far from the AP, the throughput reduces the average PSNR by 7 dB. This is because the streaming of the video does not take full advantage of the bandwidth as the additional traffic is disturbing it.

The second test's results confirm this result. From *Figure 9*, the average PSNR is 21 dB which means that the quality is very poor. The extra traffic has clearly affected the performance because, when compared to the same test without the traffic, the average PSNR is approximately 5dB higher, 26dB.

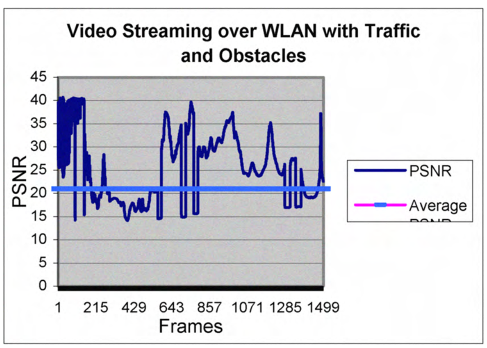

Fig. 9. Video streaming over WLAN with LANtraffic and obstacles

In test3.1, transmission delay has increased compared to test1.1. WinSIP shows a transmission delay of 150 ms which seem to not be of dangerous effects on the video quality. The delay is increased because of the additional traffic in the bandwidth. In test 2 of this experiment, the signaling delay increases even more and reaches approximately 625 ms creating small artifacts in the first 150 frames (5 seconds). This delay is not necessarily a problem; initial delay of a few seconds sometimes is sufficient to enable jitter buffers to deal with any subsequent variability.

Delay jitter in test3.1 also increased to 165 ms as shown by WinEyeQ. This jitter value does not seem to have a serious effect on the video quality (as can be noticed from the PSNR and transmission delay). Test 2 however shows a higher delay jitter: 343 ms. As mentioned earlier, test 2 involves not only a distance of 15 meters of the receiver from the access point, but also concrete walls as obstacles to the signal strength. Jitter thus in this test is caused by the slow-speed link between as well as congestion as a result of the extra packets sent through the network.

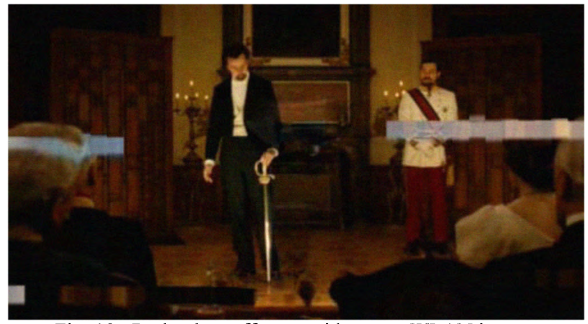

Fig. 10. Packet loss effect on video over WLAN in test

WinEyeQ recorded a packet loss of 22% in the first test; this is illustrated in *figure 10*. Again, this is mainly caused by the jamming on the receiver side caused by the high throughput added by the additional packets over the WLAN creating a sort of competition on the bandwidth. With the presence of distance and obstacles in the second test, the packet loss will eventually be more affected. In test 2, 41% of packets were lost making the streaming of video a very poor performance.

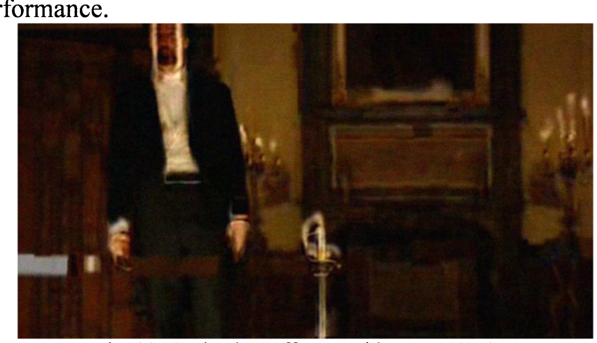

Fig. 11. Packet loss effect on video over WLAN

Generally, deterioration in perceived video quality is typically caused by packet loss. In this test, most packet losses result from congestions in network nodes as more and more packets are dropped off when congestion occurs and the severity increases.

D. *Experiment 4: Impact of Motion on Video over WLAN*

1) *Description*

In this experiment we measure the motion effect on the video performance over WLAN. In order to keep the analysis on the motion's effect only, we make sure to keep the receiver from a constant distance of the access point. So the access point should be at the center of the receiver's circular path. In the first test (test 4.1), the client is 10 meters away from the access point, and in slow motion (walking speed). Whereas in the second test of this experiment (test 4.2), we keep the same conditions and increase the speed to around 15 km/h.

2) *Objective*

The objective of this experiment is to see the impact of motion of video quality over WLAN. As stated in the introduction, we are not aware of any study looking at the effects of mobility on performance of video over WLAN. This is important as the results in the experiment come with no expectations. Nevertheless, we assume that motion will have a negative impact on the quality.

3) *Results Analysis*

First, the signal strength in both tests shows to be excellent: -30 dBm which is good for our experiment to be able to only observe the motion impact.

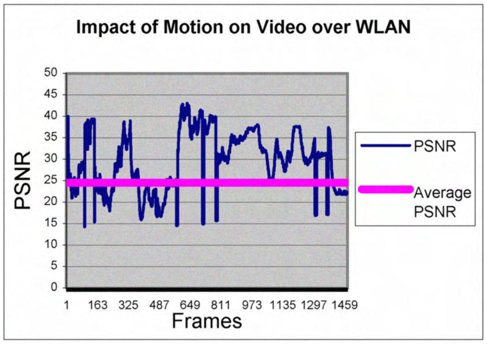

Fig. 12. Impact of motion on Video over WLAN

The average PSNR calculated is 24.5 dB; a value that represents a video of poor quality. One more remark we can make is that the graph shows large and numerous fluctuations in the PSNR values of the frames. If we compare these results to those of test 2.1 where *figure 3* shows very little variations, we can say that motion does have a negative impact on quality of the video. From the graph, we notice that the minimum PSNR value is around 14 dB and the maximum value is nearly 43dB with a standard deviation of 7 dB. Motion hence tends to brusque effect on quality.

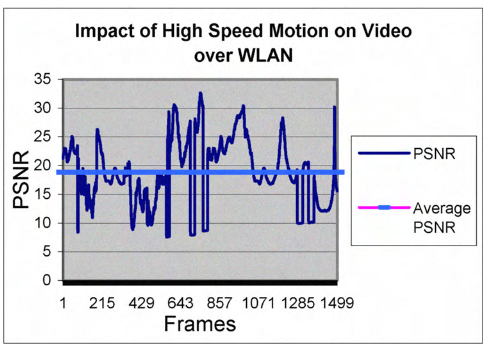

Fig. 13. Impact of high speed motion on video over WLAN

Concerning the second test, the calculated average PSNR in this test is very low: 18 dB, meaning the quality of the video is very poor according to *table 1*. As in test 4.1, frequent variations in the PSNR values are noticed which is not seen in results of test 1.1 where the same distance conditions applied. The maximum PSNR value in this test is about 32 dB and minimum is around 7 dB with a standard deviation equal to that of previous test, approximately 7 dB. This test differs from the previous one because the average PSNR value decreased by 6.5 dB due to the increase of speed. *Figure 14* illustrates some of the artifacts noticed while the video streaming in this test.

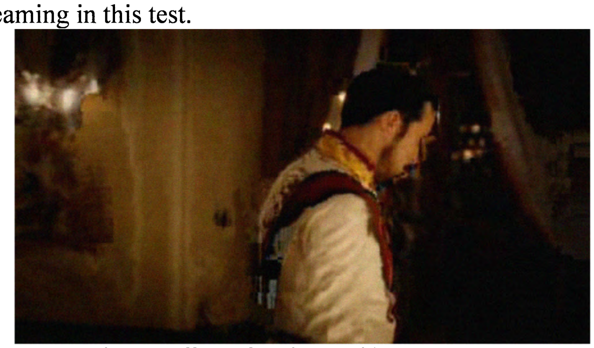

Fig. 14. Effects of motion on video over WLAN

During the live streaming of data, WinSIP notifies that the transmission delay is of 16ms only, a very low latency that would not be of any harm to the video performance. The access point seems to be sensing the receiver easily even if it is moving. Hence, the transmission delay in this experiment does not prove why the average PSNR is low. In test 2, the delay is not important only 70 ms is recorded by WinSIP, and again, this does not fully explain the decrease of the average PSNR value in this test.

The same applies to delay jitter (20 ms) because its value is stable compared to that of test 2.1 (15 ms). In this test, jitter seems to be of no effect on the streaming. As for the second test, the delay jitter actually increased to 26 5ms. Although its large increase as opposed to test 1 of this experiment, it should not create serious damage the quality of the video, and hence could not explain the very low PSNR value.

As for packet loss, WinEyeQ indicates that 4% of sent packets were not received successfully at the destination. This proves that while packets are sent in a continuous stream, they become unevenly spaced apart. The network in the case of motion suffers a little from improper connection between the access point and the destination. As for results of test 2, the percentage of packets lost is higher: 37%. Regardless of distance and background traffic, the packet loss is due to congestion or errors in play-out jitter buffer which seems to not effectively handle the steady stream of sent video packets that become lumpy.

TABLE2:
EXPERIMENTS 2&3&4 COMPARISON

	Distance & Obstacles		Background traffic		Slow & fast motion	
	Test1	Test2	Test1	Test2	Test1	Test2
PSNR (dB)	38.3	26.0	31.0	21.0	24.5	18
Delay (ms)	67	220	165	625	16	70
Jitter (ms)	15	92	165	343	20	265
Packet loss (%)	0%	3%	22%	41%	4%	37%

IV. CONCLUSIONS

In this report, we have presented an experimental analysis of video performance over wireless local area networks. We studied the impact of distance, throughput, and motion on the quality of video streaming in a wireless network. The study was oriented towards the assessment of the variation of the Peak Signal-to-Noise Ratio, transmission delay, jitter, and packet loss. The results presented in this report show the effect of obstacles and distance, background traffic, and motion on video performance over an IEEE 802.11g based LANs. The results show the PSNR drops by 12dB when we add a distance of 10 meters and concrete walls. Additionally, we found that adding background throughput to WLAN decreases the video performance by running two tests involving distance as well. Furthermore, slow motion drops the video quality by approximately 14 dB, and results have also shown that an increase in speed of the receiver's motion to 15 km/h decreases the quality by 6.5 dB. Finally, we concluded that slow and fast motions have impact mainly on packet loss due to congestion errors in the play-out buffer.

Acknowledgement

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