WINDOWS STREAMING MEDIA PERFORMANCE ANALYSIS ON A IEEE 802.11g RESIDENTIAL NETWORK

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ABSTRACT
This paper presents a performance evaluation of Microsoft Windows Media Streaming (WMS) on an IEEE 802.11g home network. Empirical measurements are used to determine the viability of streaming High Definition (HD) and high quality video over a wireless residential network using currently available multimedia streaming software. User experience is evaluated using visual testbed observations and performance criteria that include playback time, transmission data rate, playout buffer fill percentages and wireless frame losses. While the experiments show that 8.1 Mbps HD content is not currently playable with acceptable quality using a WMS server over a wireless LAN (WLAN), this investigation demonstrates that WMS services can provide high quality streaming services over a residential WLAN.

KEY WORDS
multimedia, 802.11g wireless LAN, high definition

1. Introduction

Major telephone service providers have invested significant resources to rollout broadband capabilities to their customers. Investment recuperation is expected to come from providing television (IPTV), gaming and centralized backup services. With Fiber to the Home (FTTN) and Fiber to the Premises (FTTP) bringing significant data capacity to the doorstep, telephony providers expect to compete against current broadband point-to-point services that deliver up to 30 Mbps to residential US customers. However, it is unclear whether home WLANs can currently support high capacity applications such as IPTV and avoid more expensive alternatives (e.g., optical wired gateway solutions [1]).

With the Windows Media Streaming server and clients exchanging information on current network conditions, WMS Intelligent Streaming [2] can estimate the available bandwidth and adjust server transmission rates to maximize the streaming user experience relative to the bottleneck link along the network path. Since these streaming application adjustments were designed assuming wired networks, high wireless LAN bit error rates not only hinder complete delivery of MPEG frames but they also impede the exchange of network condition information and thwart timely determination of the available bandwidth for WLAN streaming applications [3]. Moreover, the high unreliability of wireless links and the likelihood of congestion issues at wireless access points (APs) make it a challenge to satisfy Quality of Service (QoS) requirements when sending multimedia VBR videos to residential customers on WLANs [4].

This paper investigates the feasibility of WMS to meet the near-term broadband expectations of delivering HD and high quality video streams to home WLAN configurations under the assumption the residential user has neither the capability to acquire robust enterprise capable products nor the technical expertise to continuously fine-tune the streaming application software [5] or to make administrative adjustments to the newest wireless access points [6].

2. Background and Related Work

By measuring 802.11a performance in three homes, Yarvis et al [7] demonstrate the impact of the physical location of WLAN clients on network performance and that wireless transmission quality can be quite asymmetric. Jostschulte et al [5] measure wireless transmission characteristics and study the impact of home construction material choices on attenuation and signal strength in both Line-of-Sight (LOS) and Non-Line-of-Sight (NLOS) wireless scenarios. Focusing on multimedia streaming performance, they conclude that home characteristics, the physical wireless client locations and the details of wireless dynamic rate adaptation schemes need to be considered if wireless multimedia streaming performance is to be improved.

Several research efforts [2, 8-10] have studied multimedia streaming performance over 802.11 wireless networks. Using Real Media video streams, Kuang and Williamson [8] show that user perception quality and dynamic rate adaptation are greatly affected by wireless channel bit error rates. Bai and Williamson [9] demonstrate 802.11b performance can degrade for all streaming clients when even one mobile wireless clients moves to a weak signal strength location.

The two studies conducted on the WPI campus WLAN [2, 10] investigate performance effects on wireless clients at good and bad reception locations using WMS with both TCP and UDP to stream videos while concurrently contending with a single wireless TCP or UDP file download. One important observation made in this research is that for clients at good RSSI locations, the number of encoding levels available for a WMS video yields little difference in video quality. However, when streaming videos to clients at bad RSSI locations, providing multiple video encoding levels enables WMS to deliver the videos at higher average frame rates compared to singly-encoded videos. Generally, at fair or poor signal strength locations, video streaming quality deteriorated due to increased packet and wireless layer frame losses that can result in increased video playout durations.

Linear television infrastructures implemented by AT&T (LightSpeed or Uverse) use a protocol referred to as Reliable UDP that requires a separate device to detect packet loss and request application layer retransmissions to deal with potential jitter and freeze up issues by managing a local buffer. Industry experience suggests non-linear services can be provided by highly specialized Web servers leveraging HTTP and TCP. Several Microsoft technical articles highlight the advantages of a dedicated streaming server versus developing intensive Web servers. Thus, proprietary service provider infrastructures suggest the potential for non-standard implementations. Non-linear streaming (e.g., VOD service) in the context of IPTV and broadband services is highly dependent on the quality of video delivered and directly tied to specific data delivery rate requirements.

This investigation differs from previous WPI measurement studies in that the WLAN testbed is located in an off-campus residence and the primary focus of this study is the viability of using WMS to stream HD video (to approximate IPTV) and other high quality video streams over an IEEE 802.11g home network.

3. Experimental Methodology

Windows Media Server Version 9 (WMS9) and Windows Media Player 9 were the server and client applications used throughout this research. A 60 sec. High Definition (HD) video sample singly-encoded at 8.1 Mbps was downloaded from Microsoft's Web site. To avoid having to use professional grade encoding software, Windows Media encoder (WM9) was used to encode two AVI videos. A high quality 120 sec. CBR video with 1280 x 720 pixel resolution was encoded at 5.1 Mbps and 29.97 fps such that it exceeded Standard Definition television (SD) quality while also being within the HD Quality range. This video is identified as the SD clip while the second AVI video encoded at 1.1 Mbps is labeled the Low Resolution (Low-Res) clip throughout this paper (see Table 1).

Table 1 Test Video Details

Name	CS577-SD.wmv	cs577-LowRes.wmv
Duration	120 (seconds)	126 (Seconds)
Total Video Frames	3609	3694
Number of audio samples	713	740
Total Frames and Samples	4322	4434
Bytes encoded	65.93 MB	14.44 MB
Video bit rate expected	5000 kbps	991 Kbps
Video bit rate average	4590.68 kbps	959.65 Kbps
Video Frames per second	29.97	29.51
Audio Bytes encoded	951.13 KB	1973.57 KB
Audio bit rate expected	64.03 kbps	128.02 Kbps
Audio bit rate average	64.03 kbps	128.02 Kbps
File size	70,203,652 B	17,347,586 B

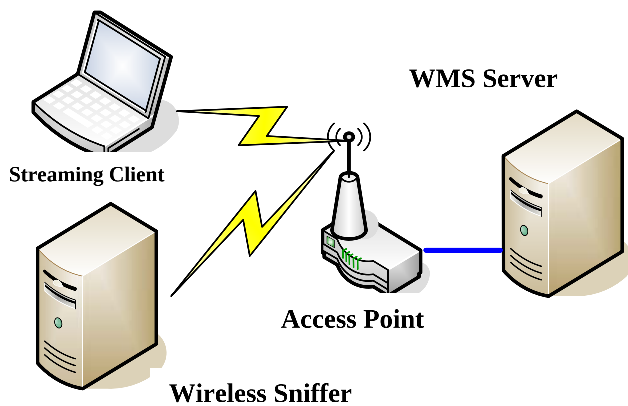

Figure 1: Experimental Topology

While the three video clips were streamed using TCP in their entirety for each test run, they were not of sufficient length to emulate IPTV video lengths. However, their duration lengths were adequate for capturing WLAN streaming performance characteristics. Streaming sessions were designed to emulate non-linear IPTV requirements and all experiments included no other network traffic to isolate and better understand the individual stream behaviors. Client requests were based on encoding rates that would mimic end user resolution that was at least as good as current television standards.

The residential testbed (see Figure 1) consists of a single wireless client (a Dell Latitude Desktop with an internal TrueMobile 1300 WLAN Card (Broadcom), a single wireless AP (a Linksys WRV54G with both a Hawking HSB1 signal booster and an upgraded 7dBi Rubber Duck antenna), a single WMS server (a Dual Pentium Dell Opteron 2.8GHZ Xeon with 2GB of memory running the VMWare GSX Virtual Machine on a Windows 2003 Server), and a PC wireless sniffer. Since the only neighbor AP runs on a different channel, RTS/CTS is turned off at the AP for all experimental runs.

The WMS server has a wired 100 Mbps Ethernet connection to the access point that provides a flexible environment for lab setup and the ability to utilize

Ethereal on the Linux OS instance running below GSX. Spot CPU and memory utilization audits of the server indicated no performance bottlenecks and adequate resources to conduct the tests and collect measurements. Additionally tools including editcap, tcptrace and xPlot, WRAPI [2] and MediaTracker [2] were used to collect measurement data on the streaming client and on the wireless sniffer for offline performance analysis.

4. Wireless Multimedia Streaming Results

Using more than 3000 client signal strength samples collected over a month, the average measured RSSI was -40db with maximum and minimum RSSI values of -25db and -58 db respectfully. Based on the classification from [8], the fixed streaming client was always in a good signal strength location.

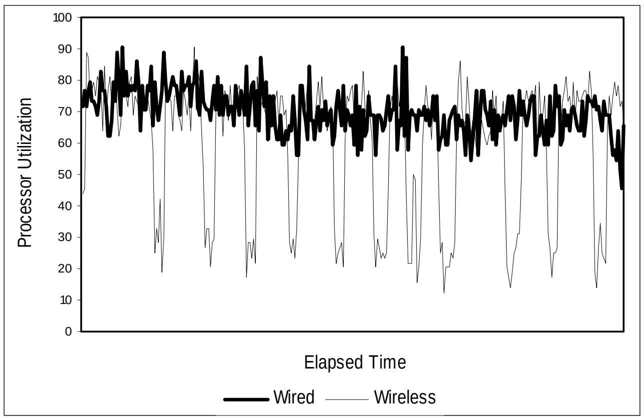

Figure 2: Wireless Playback Starvation

Initial HD test runs indicated a large gap between 802.11g capabilities and the performance needed to stream High Definition content. Figure 2 shows the streaming client CPU utilization with the 8.1 Mbps HD video being played over 100Mbps Ethernet and then over the 802.11g WLAN. Note the client CPU utilization drops for significant inactivity periods for the wireless stream. Without error concealment techniques, when a streaming client does not receive a complete video frame by its playback deadline, the client drops the video frame and the video suffers playback starvation. Audio/video stalls were frequently encountered for periods as long as 20 seconds. Further tests indicate (see Figure 3 where average CPU utilization over the 100 sec. playback duration is 96.65%) that the wireless client struggles to handle the video rendering workload. Subsequent test runs with a faster wireless client reduced the average client CPU utilization to 69.98%. However, these experiments still consistently produced visual playback degradation in the form of stalls and rebuffering events. Additional HD streaming tests with a 100 Mbps wired Ethernet connection to the client yielded similar CPU utilization but without any visual degradation of audio/video playback.

Figure 3: Streaming Wireless Client CPU Utilization

The 60 sec. HD clip was streamed 10 times over both the 802.11g LAN and the 100 Mbps Ethernet LAN. During the wired runs the actual video playback time rarely exceeded a minute. However, the WLAN average playback time was 117 sec. and varied between 95 and 135 sec. This adds further evidence to the conclusion that the primary inhibiter to successful HD video streaming was the WLAN.

Figure 4 graphs video data rates for two SD stream runs (one wireless and one wired) and one wireless Low-Res video run. The oscillation of the data rate for the wireless SD stream demonstrates the interaction between WMS Intelligent Streaming and the wireless dynamic rate adaptation strategy. Note, the data rate for the wired SD video experiment remains fixed at the 5.1 Mbps encoded rate and that the Low-Res video encounters no problems when sent over the 802.11g network. Figure 5 contrasts the client's buffer fill percentages against the data rate during the wireless SD experimental run.

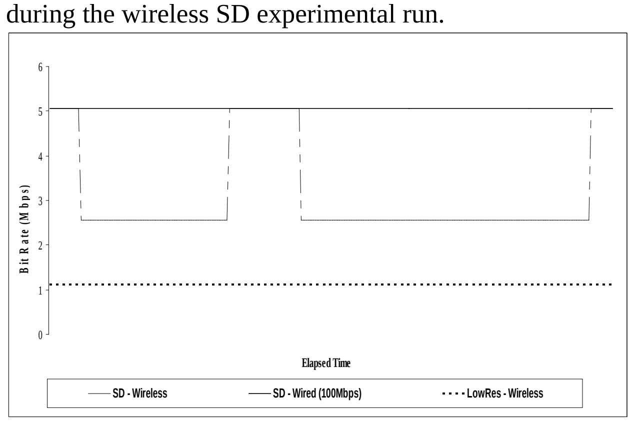

Figure 4: SD and Low-Res Streaming Data Rates

Utilizing the WMS Fast Cache, a video stream can accelerate the initial filling of the client playout buffer. When conducting HD and SD video experiments, it was determined that there are restrictions on both the maximum encoded data rate and the size of the rate multiplier for the

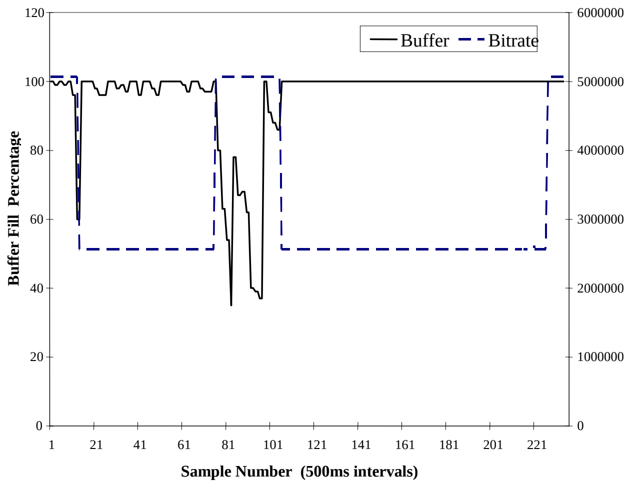

Figure 5: SD Rate and Buffer Fill Percentages

accelerated buffer fill stage of the WMS streaming algorithm. These restrictions are needed because this early accelerated stage can significantly stress the underlying network and produce a large number of early packet drops [2]. The evidence from the SD video runs implies these restrictions will be bypassed when the initial WMS bandwidth estimation determines that the initial available wireless capacity is higher than the highest encoded rate for a multi-encoded video.

Figure 6 provides three graphs that indicate MAC layer frame losses, identified as FCS (Frame Check Sum) errors, measured for a Low-Res video stream where the top graph shows only the accelerated buffer fill stage, the middle graph covers the remainder of the playout interval and the bottom graph shows frame losses over the complete stream interval. Notice the high count of wireless frame losses during the accelerated buffer fill stage. Given these high loss counts are produced from a Low-Res video experiment, it is clear HD clips streamed over WLANs are unable to employ the current WMS accelerated buffer fill scheme because wireless MAC layer issues will produce significant frame losses during the accelerated buffer fill stage. As noted by Li et al [11], the frame losses shown in this graph coupled with high MAC layer retry settings (the default setting is 4 retries) can often result in these wireless layer frame retries being hidden from the streaming server's bandwidth estimations. This can produce overestimates of the true available bandwidth on the WLAN causing the streaming server to select an encoded data rate that is too high for streaming a multi-encoded video clip over the WLAN. These over-optimistic target streaming data rates coupled with the volatility of WLAN capacities due to current wireless dynamic rate adaptation algorithms can yield poor multimedia streaming performance results.

Figure 7 provides a composite measurement picture for an SD video sent over the 802.11g home network. Several WRAPI and Media Tracker measurements are graphed to

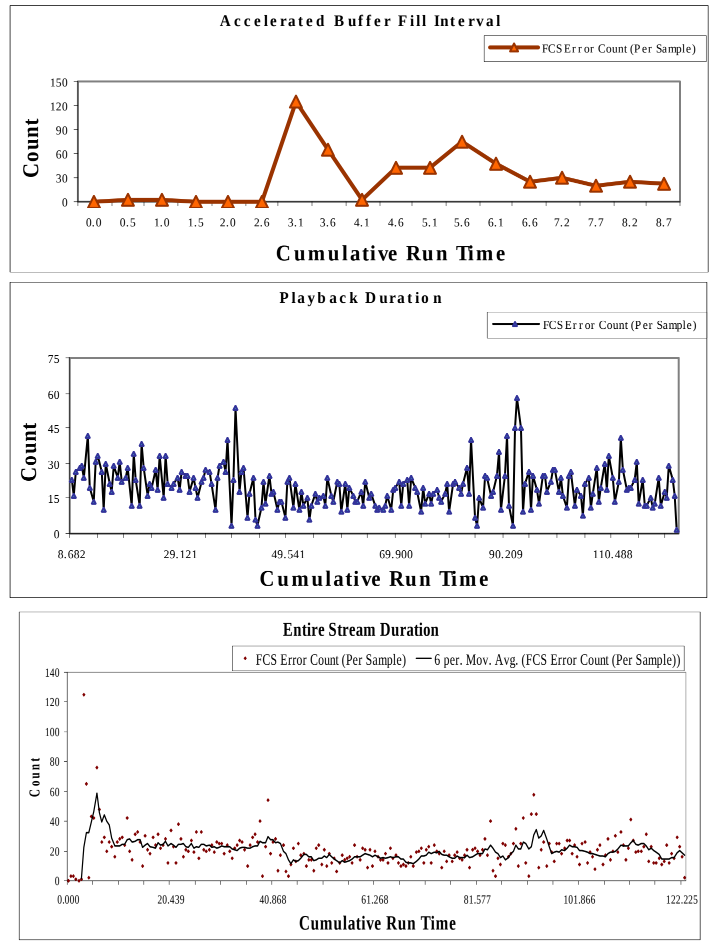

Figure 6: Low-Res Stream Buffer and Playout Durations

show the correlation and interactions between MAC layer performance indicators and higher layer video quality indicators such as buffer fill percentage and streaming data rate. The graph indicates good correlation between FCS errors, frame retry counts and fragmentation of the wireless frames.

5. Conclusions and Future Work

The goal of this project was to evaluate whether current off-the-shelf Windows Media Streaming software could successfully stream High Definition videos over a IEEE 802.11g home network. HD video clips were used to approximately emulate the near-term anticipated demands of IPTV streams that will soon be available in US homes via telephony technologies.

A series of multimedia streaming tests using a WMS9 server to transmit video clips were conducted over a residential 802.11g testbed. Using empirical measurement data collected using several network measurement tools, data analysis produced the following results: the WLAN could not successfully stream a 8.1 Mbps HD video; the WLAN could successfully stream a high quality SD video when the streaming client was at a good location; and WMS Fast Cache settings need to be reviewed and adjusted to handle HD streams. Thus, to reliably provide quality delivery of high capacity applications such as HD IPTV coming from telephony providers through residential wireless infrastructure networks, further research is needed to improve the ability of network protocols to handle cross-layer interactions such as bandwidth estimation at the video application layer and dynamic rate adaptation algorithms and frame retry strategies at the wireless MAC layer.

Possible future work envisioned includes conducting concurrent tests of multiple voice, video and data streams, looking at the impact of contending and crossing wireless traffic that includes neighboring access points, utilizing the WMS 11 video server and using IEEE 802.11e or IEEE 802.11n APs in the residential testbed.

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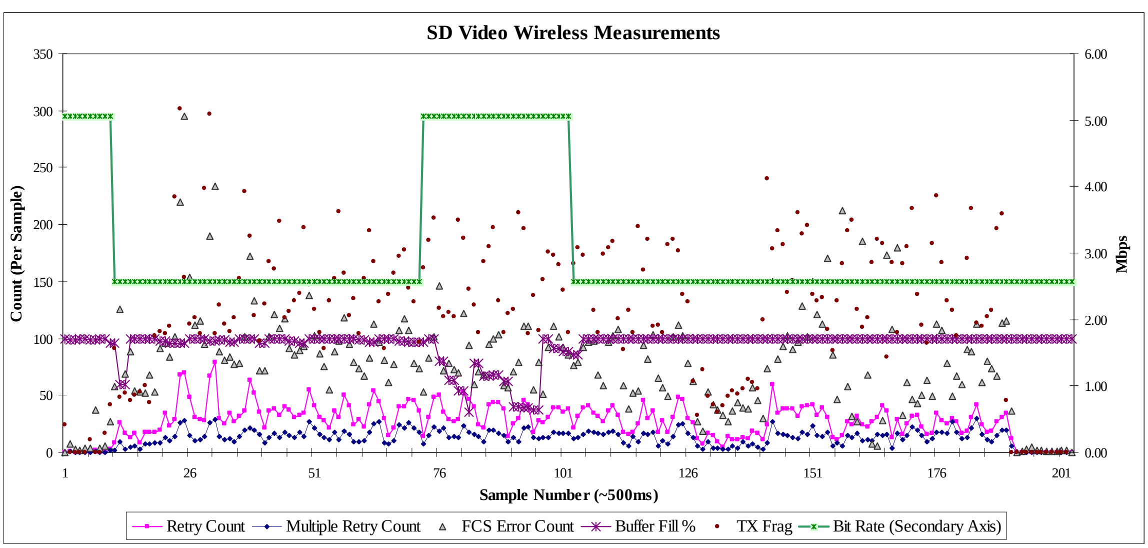

Figure 7: Comprehensive Streaming SD Measurements