SOME CONSIDERATIONS IN THE USE OF FORWARD ERROR CORRECTION (FEC) IN BROADBAND VIDEO DISTRIBUTION OVER WIRELESS LANS

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Abstract

MSOs seeking to deploy broadband video services to subscribers who are using wireless LANs should consider the use of forward error correction (FEC) technologies as well as the pros and cons of the use of streamed video versus file-based video delivery.

INTRODUCTION

As MSOs look to deploy new services to broadband subscribers, they find a number of home networking products and technologies in place in their subscribers homes in much the same way that MSOs find a variety of PCs with different CPUs, memory configurations, and operating systems. The MSO is likely to seek to deploy services such as broadband video to as much of the equipment in place as is reasonably possible to accommodate their subscribers.

802.11

The majority of WLAN products in home use employ one form of the 802.11 standards. The more well known versions of 802.11 are summarized in Table 1.

Table 1 - Summary of Some 802.11 Standards

802.11 Standard	Modulation	Freq Band	Max Link Rate	Theo Max TCP Rate	Theo Max UDP Rate
802.11b	CCK	2.4 GHz	11 Mbps	5.9 Mbps	71. Mbps
802.11g (w/ 802.11b)	OFDM/ CCK	2.4 GHz	54 Mbps	14.4 Mbps	19.5 Mbps
802.11g (11.g only)	OFDM/ CCK	2.4 GHz	54 Mbps	24.4 Mbps	30.5 Mbps
802.11a	OFDM	5.2, 5.8 GHz	54 Mbps	24.4 Mbps	30.5 Mbps

The actual performance of the wireless LAN, of course, will be complicated by a huge array of factors including (but not limited to) the distance within the home, the configuration of the room, the number of walls and other solid objects between the access points and the client, and even RF interference. The 2.4 GHz modes of 802.11 can incur interference from a variety of other appliances in the home including cordless phones and microwave ovens.

In fact, even other factors such as packet size will affect the performance of the wireless network, as well.[1] Of course, the networking equipment itself which relies on chip sets in different versions from a variety of vendors will be one of the largest determining factors in the performance of the wireless network.

In open office environments, the observed performance of 802.11a using equipment based on previous generation semiconductor technology generally maintained at least 1 Mbps for distances of up to almost 60 feet and approximately 3 times that distance for equipment using a newer version of the chipset. [2]

The performance of the more common 802.11b in a similar open office environment generally stayed above 1 Mbps for up to about 140 feet. [2.] However in general usage such as in enclosed offices with walls, closed doors, and other solid objects common 802.11b home networking equipment, commercially available in 2003 and 2004, was not reliable at data rates above 700 kb/s.

<u>Forward Error Correction:</u>

The idea of using forward error correction (FEC) in communications is of course well-established and dates back to the birth of information theory and its legendary inventor Robert Shannon. Shannon, of course, proved that there is a capacity for any communications channel and that reliable communications is possible for rates approaching that theoretical capacity. That theoretical capacity is determined as follows:

$$C= W \log_2 (1 =P/N)$$

where:

C is the channel capacity in (in bits/sec)
W is the bandwidth (in Hertz)
P is the transmitter power (in Watts)
N is the noise (Watts)

From information theory, techniques emerge to model a channel that can be used to predict the probability of an error for N bytes of packet length such as below:

$$P^m{}_e (N) = (1-p^m{}_b)^{8N}$$

where $p^m{}_b$ is the bit error rate (BER) of the PHY mode at a given SNR (signal to noise ratio).

Bypassing most of the mathematics, in this discussion Shannon introduced the idea of codes as ensembles of vectors that are to be transmitted. If the number of vectors is $K=2^k$ each vector can be described with k bits. The vectors are assumed to be of equal length and we refer to this length as the block length. For a length of vectors "n", then n times k bits has been transmitted and the resulting code of has a rate of k/n bits per channel.[3]

Shannon went on to prove the existence of these codes that allow us to approach the capacity of the channel and since his groundbreaking work, a variety of coding techniques have been developed. This ended the concept that reliable communications meant that transmission power must be increased and/or messages must be sent repeatedly. By the early 1990s, the best coding solutions had achieved actual capacities within 3-5 dB of the theoretical limit shown by Shannon.

A breakthrough occurred in 1993, when two French engineers, Berrou and Glavieux, introduced turbo coding that resulted in a 3dB improvement over existing coding schemes. Turbo codes can be classified as turbo convolutional codes (TCC) and turbo product codes (TPCs). [3]

As coding technology advanced and the desire for better and simpler codes increased a class of codes previously discovered by Robert Gallagher some 30 years earlier reemerged. This coding scheme called LDPC – or low-density parity checking codes perform closer still to the Shannon limit.

A comparison of LDPC code to PCCCs (parallel concatenated convolutional codes), SCCCs (serially concatenated convolutional codes), and TPCs is shown in Table 2.

Table 2 - Comparison of Turbo Coding Schemes [4]

Attribute	PCCC	SCCC	LDPC	TPC
Code Rate	fair	poor	good	poor
Block Size	good	good	poor	poor
Modulation	good	best	good	good
Complexity (throughput)	fair	fair	good	good
Performance	poor/ best	good/ fair	fair/ good	fair/ good

A large number of researchers worked on LDPC codes which has also resulted in a variety of vendors for coding products that use LDPC. Some of these additions to the basic LDPC theory bear the names of the researcher or company that has developed them and each puts forth some advantages over the base LDPC coding developed by Gallagher. However, LDPC coding (as shown in Table 2) provides a good compromise of attributes for use in file-based broadband video distribution over wireless LANs.

The codes can be implemented to utilize variable amounts of overhead to provide different degrees of error correction depending on the noise on the channel – overhead may typically vary from 5%-50% and provide resistance to data loss.

Considerations of Actual Use of FEC:

Now, in actual use, the success of achieving data integrity with a coding scheme such as LDPC is due to a number of factors (some mentioned here) as well as the overhead and the particular coding scheme chosen. Of course, one critical issue is the way the video content itself is distributed.

LDPC coding works particularly well for file distribution. There is an added advantage in the distribution of large files since the use of a large file mean your code is operating over a large number of bits. Thus, the loss of any small number of bits is likely to be corrected quite easily with an extremely high probability.

Take the example of a one hundred (100) packet message, that is transmitted, using an LDPC code with 10% overhead. The loss of say any 7 packets has less than a 10^{-6} chance of resulting making the video file unviewable. Or put another way, the probability that any particular 7 message packets that are lost would result in a correction that could not be performed is less than 1 in a million.[5]

Now, of course, there are other issues with regard to packet loss. One view is that packets lost will typically be the same from one subscriber as another in an IP Multicast distribution scenario. So, the idea that you can request replacement packets that were lost and correct the files that way has been suggested.

In this author's view, while there are undoubtedly network incidents that occur which result in the loss of the same packet or packet for some number of subscribers, there are also random events not only at different points in the network but on each subscribers computer, as well. These random and singular losses are better corrected by using an LDPC coding scheme with say 5%-10% overhead. This amount of overhead is barely noticeable and in the case of IP Multicast distribution the overall efficiency of content distribution is so higher anyway as opposed to unicast file distribution that an additional 10% of overhead is a very small price to pay.

Of course, FEC can also be used in video streaming. The one penalty incurred in using FEC for streamed video is that a delay is imposed on the stream to perform the error correction calculations over some number of packets. The issues regarding what is an acceptable delay are dependent upon a number for factors including amount of delay is tolerable to the viewers.

Then again, in a streamed video environment, the loss of a few packets may not be significant in the same way as it is in file-based video delivery. The loss of few packets might only momentarily degrade the signal and still make the quality of the video experience acceptable to the subscriber.

Again, the question of what is acceptable is dependent upon the many factors from the video quality that is trying to be achieved to the wireless LAN performance from the access point to that particular subscriber to the length (in time) of the disruption, as well as what packets are lost and how frequently the loss reoccurs.

The delay considerations may also make the preferred coding scheme in streamed video different than that of the coding scheme in file-based video distribution.

One such proposal for video streaming is the system for packet loss protection for the H26L-FGS. This employs Reed Solomon coding along with a system of requests and acknowledgements. The combination of feedback and error correction may be more suitable than in streaming than the FEC coding schemes used in file-based video delivery.[6]

CONCLUSION:

Overall, however, the one factor that can not be overcome in a wireless LAN is of course the network performance. If you can not reliably distribute data at over 700 Kb/s, due to whatever factors, then the use of FEC is not going to allow you to distribute video at a higher data rate whether it is streamed or delivered file-based.

For streamed video, the limitations of the wireless LAN performance will of course also limit the encoding rate you can choose for streamed video. You will always be limited in video resolution by the lowest common denominator of what data rates the network can tolerate.

A file-based video distribution system has no such limitations. In fact, even across a network with a 700 kb/s or less bandwidth limitation, it is easily possible to distribute files that are encoded at high definition quality. The use of FEC and IP Multicast makes such distribution across home wireless networks in place today entirely possible and implementable.

Table 3. summarizes some of the considerations in video delivery methods and the use of forward error correction of current wireless LANs. From the table, it can be seen that the combination of FEC with file-based delivery and is very efficient – especially when these files are delivered with IP Multicast.

Table 3 - Comparison of Video Delivery and Quality w/ FEC.

Video Distribution Method	**Tolerance to Minimal Packet Loss**	**FEC Delay**	**FEC Value to Video Quality**	**Achievable Video Quality over Most WLANs**
Streamed w/out FEC	Fair	None	N/A	Worst
File-Based w/out FEC	Poor	None	N/A	Fair
Streamed w/ FEC	Good	Worst	Fair	Fair/poor
File-Based W/ FEC	Best	Not Noticed	Best	Best

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