<u>Performance Evaluation of TCP Over Wireless Links</u>

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Abstract

When TCP is used over wireless networks, the performance of the protocol degrades. In wireless networks, the packets are dropped due to the bursty nature of errors on the wireless links. However, TCP assumes that these losses occur due to network congestion and it reacts by reducing the transmission rate resulting in performance degradation. Our project attempts to study the effect of various channel parameters on the performance of TCP. For this purpose we have simulated a file transfer over a wired and a wireless link using OPNET.

The protocol performance has been measured in terms FTP transmission delay experienced by the client, the FTP throughput, and the packet discard ratio with changes in the TCP segment size and burstiness of the channel.

For the purpose of simulating a wireless link, the client and the server are connected through a single-hop wireless link. The wireless link has been modeled as a Markov chain that allows us to vary both the burstiness and the average bit error rate. We have also designed an identical wired network so as to compare the performance of TCP over wired and wireless links.

From the simulations performed we were able to conclude the following:

- As the TCP segment size increases, FTP delay decreases. Also, for a constant TCP segment size, the FTP delay decreases as the channel becomes more bursty.
- As the burstiness increases, FTP throughput increases for a constant TCP segment size. As TCP segment size increases, the FTP throughput decreases and the decrease is less pronounced for a bursty channel.
- For a constant burstiness, the TCP packet discard ratio increases with an increase in the TCP segment size. Also, as the channel becomes more bursty, the TCP packet discard ratio decreases.
- For a wired network, FTP delay decreases with increase in the TCP segment size.

Introduction

We have chosen to model the behavior of a wireless link with regard to different parameters. The field of wireless communication has undergone a huge expansion during the past few years, however it is still in its infancy and not much research has been done in the area of modeling wireless channels. With the emergence of wireless LANs and mobile hand-held devices, there is a need for analyzing the behavior of existing protocols over wireless links. The dynamism of the wireless industry and its rapid evolution are some of the reasons for choosing this project.

Previous Work

A lot of research in the area of evaluating TCP performance over wireless links has already been performed. Most of this work has been dedicated towards improving TCP performance over wireless links.

A study of the effect of protocol performance over a single wireless link as well as multiple links has been conducted. It has been concluded that the low error rate assumption of TCP while valid for wired links has disastrous results for wireless links. Also, TCP has a lower throughput than UDP due to the larger size of the TCP header. Data compression has been used to reduce the header overhead and to improve TCP performance. [2]

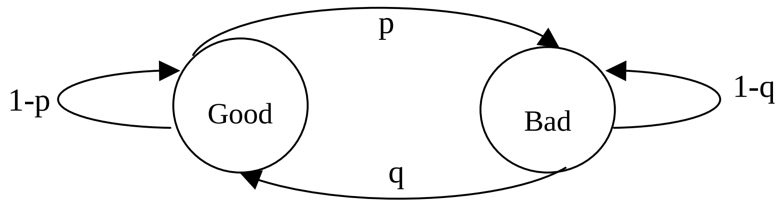
The effect of the error correction mechanisms: Automatic Repeat Request (ARQ) and Positive Acknowledgement with Retransmission (PAR) on error prone and temporarily disrupted wireless channels has also been studied. It has been shown that ARQ is better than PAR in this environment. [4]

A simple protocol called the Mobile-End Transport Protocol (METP) has been employed for communication between the mobile host and the base station. [3] By simulation over a real network, the TCP and UDP performance over a wireless LAN has been compared. [6]

This paper differs from the others in that it we have used a more realistic channel model taking into account the random nature of errors in the channel. We consider that the channel can generate errors with varying levels of burstiness.

Experimental Setup

In the physical layer the signal envelope is found to have a Rayleigh fading distribution. With changes in the environment, the signal power can go into a long or a short 'fade'. When it goes into a long 'fade' it tends to generate more bursty errors. We have modeled the wireless channel according to this theory.
The experimental setup consists of a server and a client connected by a wireless channel. The wireless link has a bandwidth of 1Mbps. The channel introduces errors into the bit stream that passes through it. The channel is modeled as a two-state Markov model that consists of a Good state and a Bad state. In the Good state no error is introduced while in the Bad state, the bit is in error. The channel can be made bursty or independent by varying the transition probabilities between these two states.



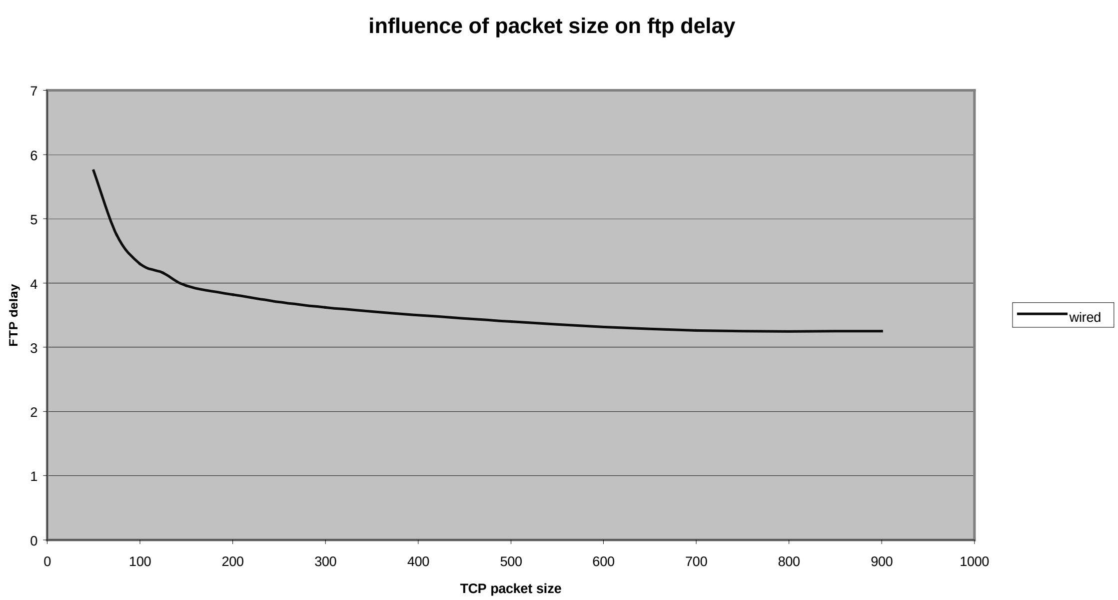
The average bit error rate = Steady state probability of the bad state = p/(p+q)

(1-q) is the probability that the channel remains in the Bad state if the previous state was Bad. If (1-q) = p, then the channel is independent. But as the ratio (1-q)/p increases above 1, the burstiness also increases. This implies that there is a higher probability that the current bit will be in error if the previous bit was in error. The ratio (1-q)/p can be thought of as a measurement of the burstiness of the channel with the ratio equal to 1 being the independent case.

The client and the server are connected through a single-hop wireless link modeled as above. Also, an identical wired network is designed.

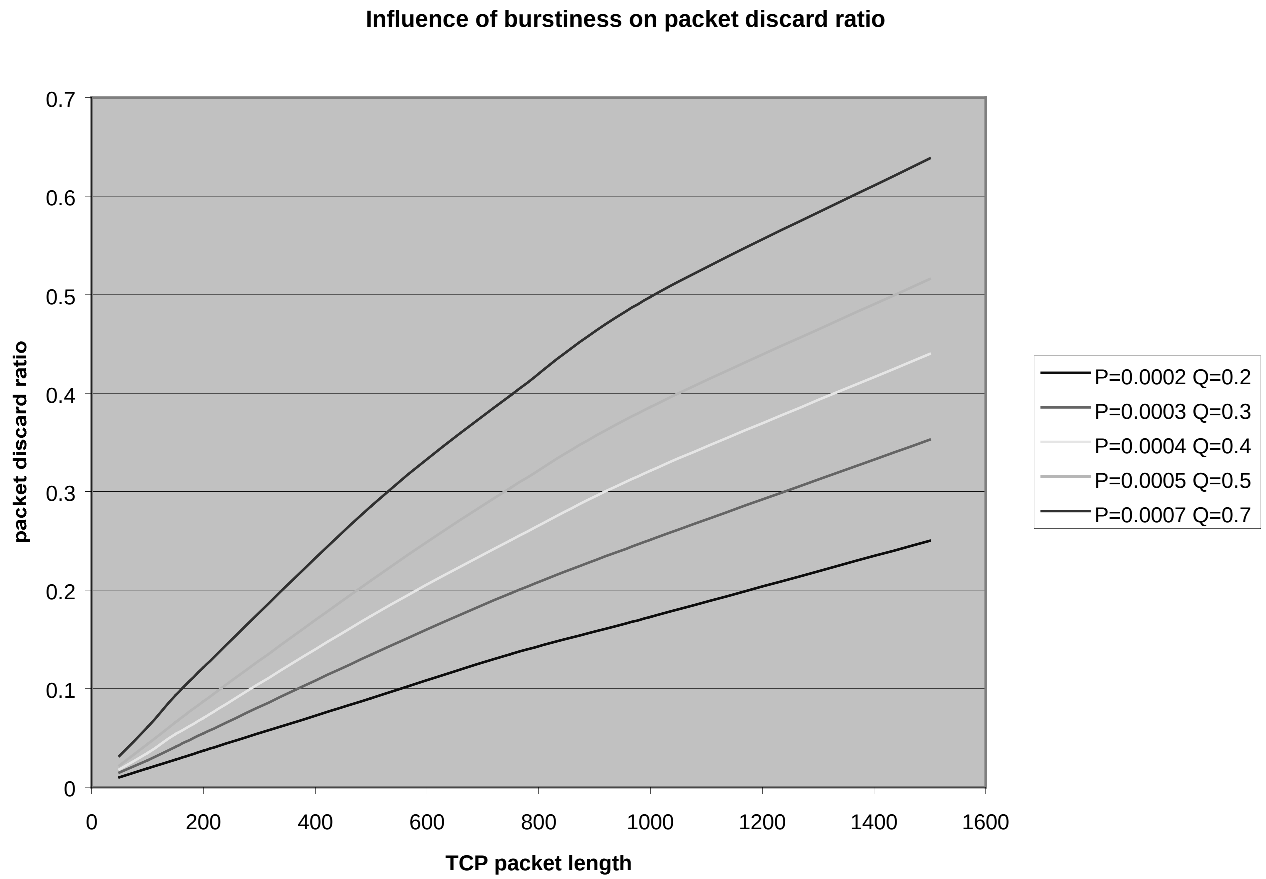
Results

As (1-q)/p increases, burstiness increases. A constant average bit-error rate has been used for the simulations.
1. Wired



In the wired network, as the size of the TCP packet increases, the number of packets that need to be transmitted for a given file size decreases. This decreases the total number of packets in the network that reduces congestion. The lower the congestion in the network, the faster will the file get downloaded on the client side. Hence as the packet size increases, the FTP download response time decreases.

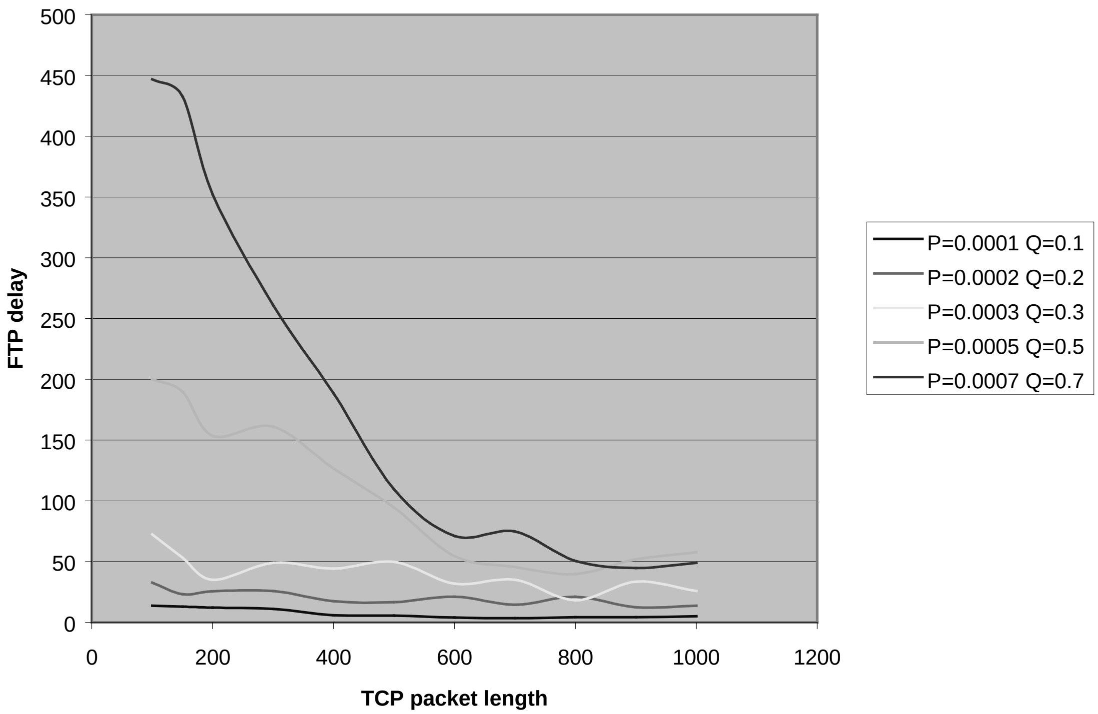
2. Wireless



As the TCP segment size increases, the packet discard ratio increases for a constant burstiness and a constant average bit-error rate. This is because, as the packet size increases, the probability of a bit being in error is higher, and hence there is a greater probability of the packet being in error.

Also, for a constant average bit-error rate, as burstiness increases, the packet discard ratio decreases. This is because as the burstiness increases, more error-bits are aggregated into one packet and hence the overall packet error rate decreases. Hence lesser number of packets is discarded.

Influence of the TCP packet length on the FTP delay with regard to burstiness

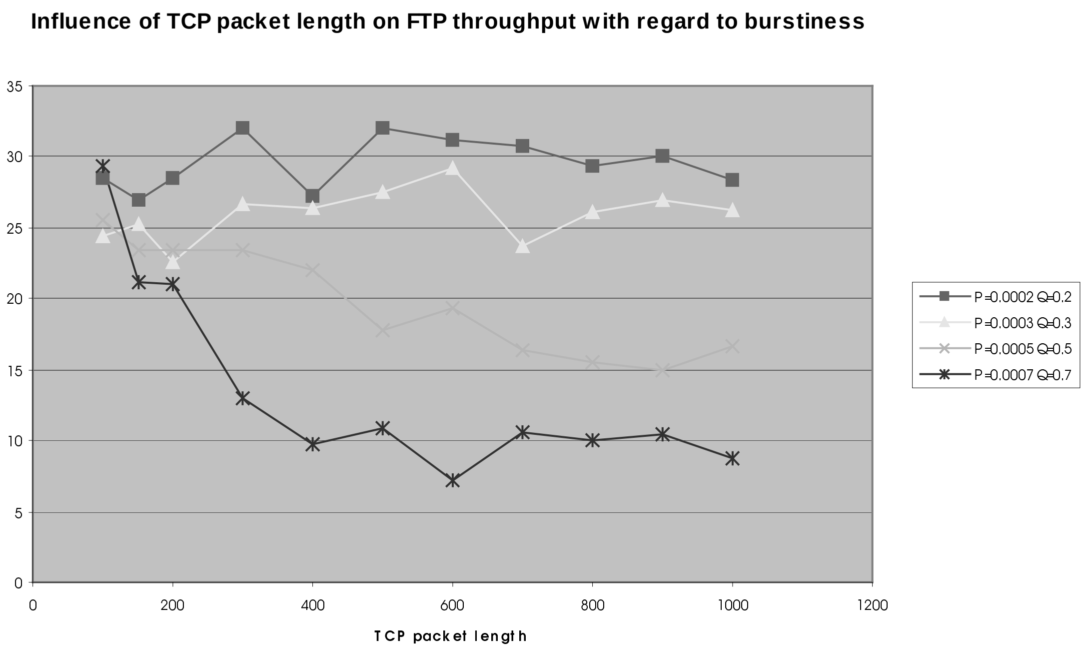


We observe that as burstiness increases, the FTP delay i.e. the time difference between the file transfer request and the completion of file transfer, decreases. This is because as burstiness increases, less number of packets is dropped according to the previous graph. As a result, the number of retransmissions of packets decreases, the file transfer takes less time, and the FTP delay decreases.

Also, for a constant burstiness, the FTP delay decreases as the TCP segment size increases. This is because, for a constant file size, as the segment size increases, a lesser number of packets need to be transmitted per file. Even though the number of bit-errors per packet increases, more error-bits are aggregated into one packet. Hence the number of packets in error decreases, thereby decreasing the total number of retransmissions.

The total number of retransmissions plays a more important role in deciding the delay as compare to the size of the retransmissions, as the TCP layer has a significantly higher delay than the physical layer. Hence, the decreasing total number of retransmissions results in decreasing the FTP delay.

It is observed that the FTP delay does not vary significantly with the variation of TCP segment size for a very bursty channel. This is because, for a very bursty channel, even though the TCP segment size decreases, the errors tend to be more clustered in the same segment. But when the channel tends to be more independent, the delay has a greater variance as described above.



It was observed that for a constant file size, as the TCP segment size increases, the number of file transfers completed within a certain span of time decreases. In our experimental setup, we use a 10K file and a file transfer rate of 10 files/hour. So if the channel had been a ‘perfect’ channel without any errors, the FTP throughput would have been around 36 bytes/sec.

But we observe that the FTP throughput, i.e. the measure of file transferred per sec with respect to the total requests per sec, decreases as packet size increases. This is because as packet size increases, there is a higher probability of the packet being in error. Hence there is a higher probability that the file transfer is not completed. Hence the FTP throughput decreases. However for a very bursty channel, the FTP throughput does not decrease significantly as packet size increases.

Also we observe that as burstiness increases, the FTP throughput increases. For higher values of burstiness, there is a greater probability of the bit-errors being aggregated in a single packet, and hence the overall number of packets in error decreases. This increases the probability of a successful file transfer within a given time. Hence the FTP throughput increases.

Conclusions:

We have implemented a simple network to analyze the effects of various channel parameters on TCP performance. We have focused on modeling a more realistic wireless channel that allowed us to vary the burstiness. The results obtained can be extended to study the effect of burstiness on the congestion window size. Also the effect of burstiness on various other factors such as the connection abortion rate, round-trip time etc. can be studied.

References:

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