Enhancing TCP Performance Through Intelligent Activation/Deactivation

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Abstract

Improvements of TCP performance in wireless networks have been tossed around for several years. One mechanism that has received considerable attention is the use of error recovery techniques thereby compensating for the wireless loss characteristics. However, surprisingly, to our knowledge no study in error avoidance has been carried out. This paper proposed the use of an error avoidance scheme for improving the performance of TCP in wireless environments by simply avoiding transmitting data under poor radio coverage conditions. The decision to transmit or not is taken by comparing the signal to noise ratio (SNR). In effect, the transmissions are suspended when the SNR is decreasing and goes below a given threshold, and resume transmission when the SNR goes back above the SNR threshold. This can be realized without modifying TCP by using a thin layer between the network and transport layers. The result showed that the TCP sender could obtain significantly better performance, improvements up to 15 % on TCP throughput by using this technique.

1. Introduction

Recently, wireless networks have grown significantly as a result of the cost of wireless networking products going down. Therefore, wireless LANs are available in many places, for example, conference rooms, libraries and airports. One of the major problems in these wireless LANs is the variation in connectivity between the base station and a node depending on the location of node. Essentially, connectivity decreases as the node moves away from the access point as well as when there is channel interference due to by the other systems such as Bluetooth devices, microwave ovens and etc. giving rise to bursty errors. Therefore, the operation of these systems can be considered to be a two state model, namely operating in ether a “good” or a “bad” state. When in a bad state, if a mobile host keeps sending packets, the probability of packet loss increases. It is well known that in these situations TCP performs poorly. Many researchers have attempted to overcome the problems by modifying TCP in the mobile hosts. These protocols [5][6] can provide better throughput than the traditional TCP implementations used in the wired network. These modified protocols are reactive in that they take action after the error is detected at the protocol level. Thus, these schemes are not aimed at avoiding errors. We believe that, a better way of dealing with the variable connectivity in WAN environments is to have a reactive transmission scheme, with no modifications to TCP. There have also been attempts at scheduling depending on the state of the channel [9][10][11]. However, these scheduling techniques will be implemented on the base station instead of being on the mobile host.

We, therefore, propose the use of a thin layer as a packet scheduler for TCP connections which stops transmission during bad periods, periods in which the SNR is below a specified threshold. The proposed method is not intended to be a new protocol, rather a scheme to enhance the performance of existing protocols in wireless environments. Thus all protocol parameters will be shielded from the operation of this layer.

In this paper, we describe the design and implementation of such a TCP session scheduler. Then through experimentation and simulation, we show that the overall performance of TCP can be significantly improved without any modification to TCP. The remainder of this paper is organized as follows. Section 2 discusses previous work in the area of protocol improvement over wireless link. Section 3 describes the test environment metrics and the SNR tracing. Section 4 explains the thin layer, methodology and including implementation idea. The next section we discuss the result both in TCP performance and energy efficiency. We conclude our work and future work in section 6.

2. Related Work

TCP[1] has been widely used as a transport protocol for years. Initially, TCP was designed and tuned for wired networks in which the corrupted packets rates are rare. Most packet losses arise as a result of network congestion. TCP, therefore, assumes that all packet losses are due to congestion in the network, and has inbuilt functionality to alleviate the congestion. [2][3]. In wireless/wired networking environments, the packets will be dropped due to congestion as well as losses in wireless links. TCP, thus, as has been reported widely, does not perform well in wireless networks as it misinterprets packet loss due transmission errors as network congestion.

ELN[4] attempts to address this by using a mechanism to distinguish the losses in wireless environments due transmission errors from those due to congestion. It introduces a special bit in the TCP header, ELN, which is set when a wireless base station can establish that a loss of a segment was not due to congestion. The decision is in the base stations is taken by keeping track of holes[1] in the sequence space as it receives data segments. When the sender receives an ACK with the ELN bit set, it transmits the lost packet without invoking congestion control mechanism. Although this scheme is reported have good performance, it requires significant modifications to TCP.

TCP probing [7] was recently proposed to differentiate the level of error, whether it is temporary or persistent and whether the system is performing appropriately. Probing in initiated when a data segment goes missing. Instead of retransmission and adjusting the congestion window and threshold, the sender initiates a probe cycle. This information is then used avoid transmitting packet under burst error conditions. As transient error conditions will not invoke the TCP congestion mechanisms, in avoid the bursty conditions overcomes the problem. Again, although this scheme is reported having good performance, it requires significant modifications to TCP.

In addition to the disadvantages associated with having to modify TCP, we believe, the above proposals suffer form the following problems. Firstly, the problems with long round trip times. In these networks, TCP would respond too late and the action itself might begin after event. In addition, this will result in increasing the probability of TCP keep sending packets while the link is a bad state, thus negating the advantages. Secondly, the modified TCP might be too aggressive or too conservative. If conservative, for example, slow start will be invoked when packet losses occur due to random errors. If aggressive, it may keep sending without adjust any window size while bad state. These problems are caused due to a lack of knowledge about the network condition and we believe that it cannot be overcome with modifications to TCP.

[1] A hole is a missing interval in the sequence space.

Hiroto Aida ,et.al.[11], proposed a packet scheduling scheme for wireless link based on receiver Signal to Noise Ratio (SNR) to improve TCP throughput . Bhagwat P., et.al.[9] proposed CSPD scheduling techniques to enhance the TCP throughput in wireless LAN. By contrast, Javier Gomez, et.al.[10] proposed the Havana framework to address on QoS in wireless network. However, these methods were proposed to improve performance by modifying the protocols at the base station instead of being on mobile host.

3. Intelligent Activation/Deactivation

The shortcomings of the above schemes can be overcome by simply determining the channel state. The channel state can be considered to be in one of two states: good or bad [9]. The state can be determined by measuring the SNR as described below. When then the channel is in a bad state, the mobile simply stops transmitting. It resumes transmission when the channel returns to a good state.

It is realized by implementing a thin layer between the network layer and the transport layer to control creation transmission of packets dependent on the channel state. The channel state was determined by analyzing the SNR measurements. The SNR measurements were collected and analyzed by the intelligent plane. This is schematically shown in Figure 1.

3.1 Collecting and Decision Processes

Both processes will be implemented on the intelligent plane. The functionality of collecting process is to gather the SNR information. While the decision process will analyze these information for what the TCP should do next. If the SNR is stable that means the mobile host is not being moved. On the other hand, when the SNR noticeably changes the decision process will consider this situation as mobility. The process will compare the SNR with the predefined level when the SNR is lower than the process will send the STOP signal to controlling process. The SEND signal will be sent to when the SNR become higher than threshold. The adaptive algorithm would be applied in the decision process to

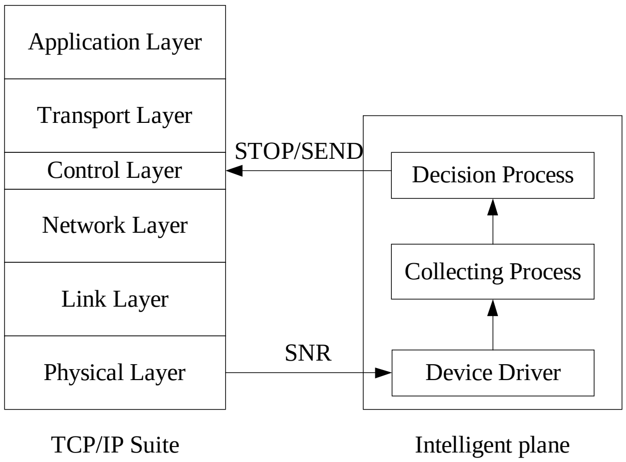


Figure 1. The control layer and intelligent plane

3.2 Control Layer

We suspend TCP sender by stopping generating new packets from TCP layer when link state was bad. An acknowledge packet was used to resume transmissions when the channel returned to a good state. This was accomplished by the thin layer signaling receiving window of 0 when the SNR measurements indicated that the channel was in a bad state. This in effect stopped TCP from generating new packets. Meanwhile, the control process will take control the interactive between TCP sender and the other end. The resumption was achieved by sending and acknowledgement with a greater than zero received window size.

However, this scheme will not stop any packet below TCP layer, therefore, it is possible that packets can be dropped during in suspension mode due to the packet in a lower layer buffer. This, we do not believe significantly affect the performance of the system as shown in Fig. 5.

4. Test Environment

The viability of the proposed scheme was evaluated through simulation. The simulations were done using NS2. The input for the simulations was based on real life measurements.

4.1 Simulation Environment

The topology used in our simulation is a three nodes network including a mobile host, base station and a fixed host as shown in Figure2. The mobile host functions as a TCP source connecting to the base station with a low bandwidth and high error rate link. The link between the base station and the fixed host is a relatively high bandwidth and high latency link.

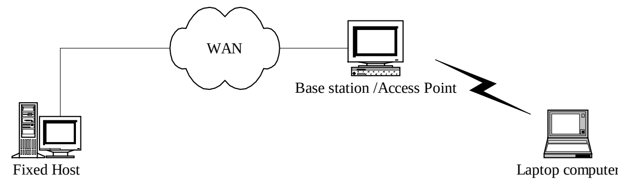


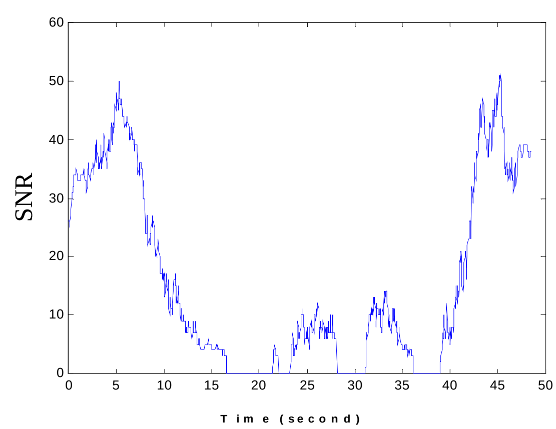
Figure 2 Simulation Topology

In wireless connection, the bit rate was assumed to be 5.5 Mbps and link delay to be 2 msec. The bandwidth is 1Mbps and link delay is 100ms was assumed for the WAN environment. We evaluated the scheme by simulating a FTP to transfer of 5Mbytes from the mobile host to the fixed host.

Channel characteristics were implemented the by tracing the SNR as described below. It was assumed that the wired link is reliable and not congested. Further it was assumed that packets are not dropped at base station due to buffer overflows and there were no MAC layer retransmissions.

4.2 SNR tracing

We used the WaveLan network interfaces from Lucent Technologies, a DELL Lattidude 1GHz running on Linux operation system for the experiments. SNR measurements made available by the WaveLan interfaces were sampled every 100 ms and collected into a file. Then the packet error rate (PER) of the channel was deduced directly from the SNR values using CCK-5.5 coding at 1000 bytes packet as described in [8] and illustrated in Figure 3.



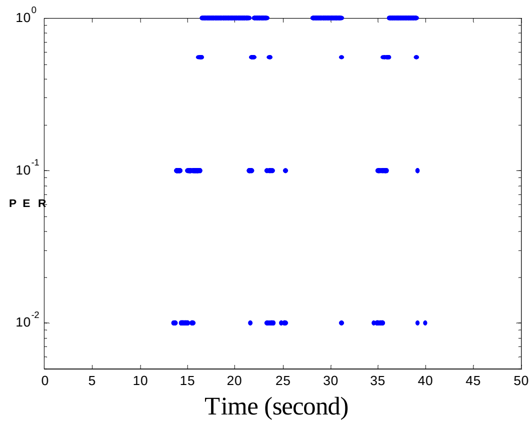


Figure 3 SNR trace and Channel characteristic

4.3 Performance Metrics

We used 3 metrics: throughput, overhead, connection time as the performance metrics. Throughput is an indication of how much data the TCP layer can receive per second. The connection time is a total amount of time from a connection starts until finishing. The overhead is calculated as:

Overhead = (Total bytes sent – Original data) / Original data * 100

By observation, the result in various TCPs have the same direction therefore we only show the results by comparing the TCP throughput, the overhead of transmission and the connection time of TCP Reno and TCP Reno with enhanced scheme.

5 Simulation Result

The extensive results of proposed technique can be founded in [12]. To examine the sensitivity of the proposed scheme, the SNR thresholds for detecting good/bad state were set at 3,4,5 and 6 dB respectively. The results in Figure 4 and 5 can be clearly seen that the standard TCP, Reno, cannot perform as well as proposed technique. Throughput will be slightly improved approximately 2K, 4K bytes/sec at threshold 3 and 4 dB respectively. The technique will dramatically increase the throughput when given threshold stays at 5 and 6 dB.

As expected, the connection time decreased as the threshold is increased giving savings of up to 12 %.

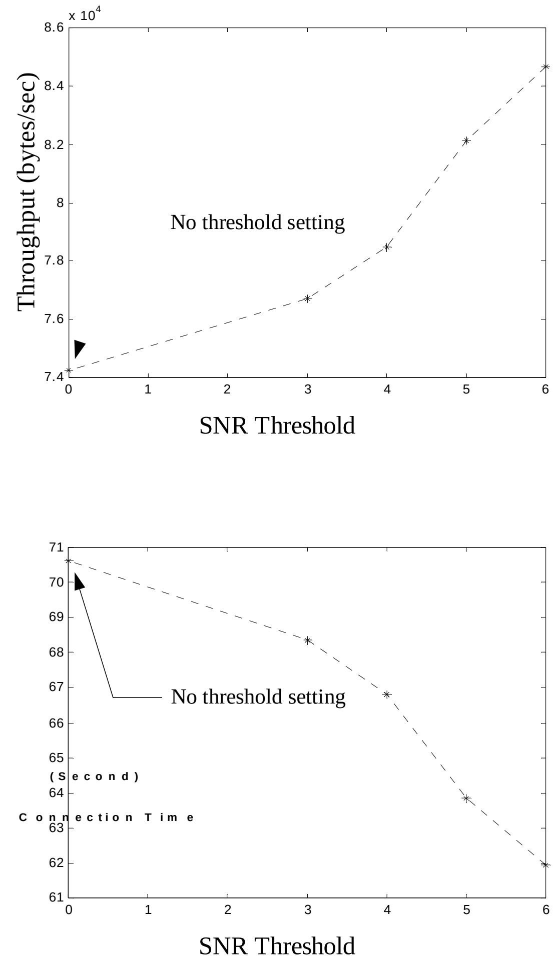


Figure 4: Throughput and Connection time at various SNR thresholds

The graph in Figure 5 shows that the overheads will decreases linearly with the increase in the threshold. By increasing the threshold, the probability of packet error in wireless is reduced. As a result, the number of retransmission is cut down which can save the overhead of transmission up to 0.7%. This is significant in wireless environments where energy is at a premium.

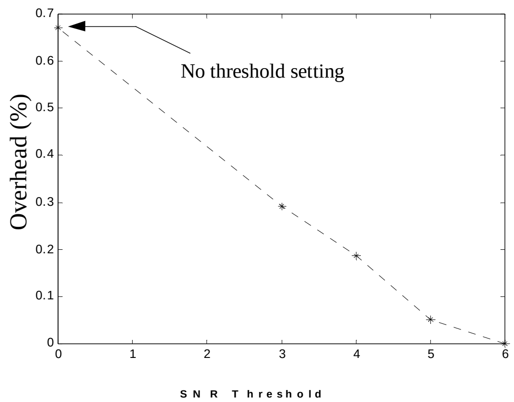


Figure 5: Overhead at various SNR thresholds

6. Conclusion and Further Work

It was shown in [12] that error avoidance provides significant improvements in TCP performance under WAN environment, and lower layer information can efficiently be used for this purpose. Furthermore, this avoidance scheme can be effectively deployed without changing TCP mechanisms. The tracing pattern used in this paper show the signal that experience a deep fading which can often occur in mobility. We have shown in simulation result, Fig.5 and Fig.6, it is possible for TCP to spend less time (up to 12 %), have lower overheads (0.7 %) and improving its throughput (up to 15 %). By setting the higher threshold, the lower the packet error rate in wireless link. We have done experiment based on the assumption that the PER is depended only upon the Guassian noise and a simply algorithm implemented. Nevertheless, the other crucial factors, such as the geographical environment, speed of movement, can be taken into account. Additionally, the intelligent algorithm to analyze the SNR pattern can be implemented for controlling TCP more efficiently.

However, the achievement of this scheme is relied upon how precise the system can predict the possibility of packet error rate over times. Thus, these are currently being investigated.

7. References

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