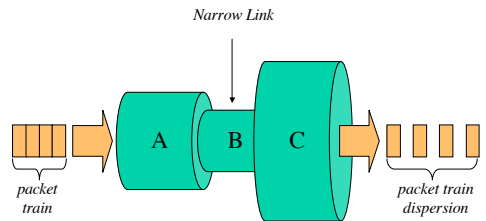


Introduction

The objective of this research is to investigate if current bandwidth estimation tools can be embedded in a transport layer protocol. Bandwidth estimation has been very useful in network management, routing, overlay networks, etc. However, it is not clear if they can be directly applied to transport layer protocols such as TCP. We need to investigate if the accuracy, overhead and convergence time of these tools are appropriate for TCP. The interest in applying these tools and techniques in TCP is because of the known deficiency of the protocol in providing good performance over next generation high-speed optical networks. Currently, TCP makes rate adjustment decisions without good knowledge of the characteristics of the channel. Any improvement in the performance of TCP is VERY significant, as this is the most widely used protocol over the Internet.



Pathrate

We are evaluating a tool called *pathrate*. The sender transmits a train of packet pairs to the receiver across a network path. When *pathrate* receives the packet pairs they are more dispersed than the original train. From the dispersion, *pathrate* estimates the capacity of the narrow link.

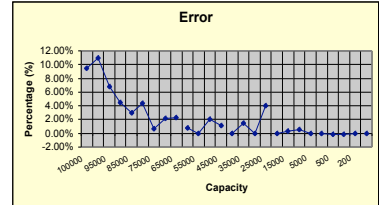
WAN Emulator Testbed

An emulated Wide Area Network (WAN) was created to perform experiments in a controlled manner. Four Unix-based machines acting as routers and packet shapers were set to perform as real hops within a network path that have specific link capacities much like the Internet.

Experiments and Results

Varying capacities and location of the narrow link, we evaluate three related metrics across our emulated WAN:

- *Overhead*: number of bytes introduced by the tool to the network.
- *Convergence time*: number of seconds required to have the estimation.
- *Estimation error*: relative variation of the estimated and the real value.



Experiment results show that:

- The tool introduces too much overhead.
- The convergence time is not appropriate for TCP; it takes too long to provide the capacity estimation.
- The accuracy of the tool is affected by high link capacities. This is due to a dispersion noise at the receiver that is generated by the low clock frequency when packets are time stamped. This issue is known as the granularity problem. We are studying hardware alternatives for the time stamping process to make it operating system independent.
- The results prove the effectiveness of our emulated WAN. We are performing experiments with traffic generators to emulate cross traffic.

