Enhancing Rate Control with Bandwidth Estimation

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Rate Control

Majority of Internet traffic such as email, web, file transfer, P2P file sharing and media streaming use Transmission Control Protocol (TCP) as the transport protocol. TCP provides reliable ordered delivery of a stream of bytes between two end systems. The other alternative, User Datagram Protocol (UDP) provides an unreliable service where messages can arrive out of order, duplicate or go missing without notice.

Future mobile Internet is a difficult environment for traditional reliable transport protocols since it introduces new traffic types which have different latency and throughput needs compared to traditional bulk transfer. Applications such as streaming media and audio are becoming more common among wireless devices. Reliable delivery is not a high priority in such applications.

New mechanisms and protocols have been developed to operate in this environment. While TCP is no longer adequate for these requirements, the new methods should not negatively influence TCP performance when competing for network resources as TCP is still the dominant protocol. For this reason UDP is not a long term solution since it lacks congestion control and can therefore contribute to a potential congestion collapse.

Rate Control mechanisms can be divided into two different approaches: window-based and rate-based:

Window-based rate control increases its sending rate after a successful transfer of a window of packets similar to TCP.

Rate-based rate control controls its sending rate by estimating the available bandwidth by some other way. A subset of this approach is called equation-based rate control. In such approaches the sending rate is controlled by a control equation which estimates the allowed sending rate.

Typically rate-based approaches react slower to packet loss than their window-based counterparts but are also slower to react to increases in available bandwidth. This allows them to provide a stable sending rate. However in a wireless setting vertical handoffs pose a problem for an application. Sharp increases and decreases in available bandwidth are not recognized in slowly responsive algorithms.

An ideal solution would combine the stable bandwidth with increasing aggressiveness in getting the flows fair share. Bandwidth estimation techniques could be the solution to detect bandwidth changes. Careful design is also needed in order for the solution to remain TCP friendly.

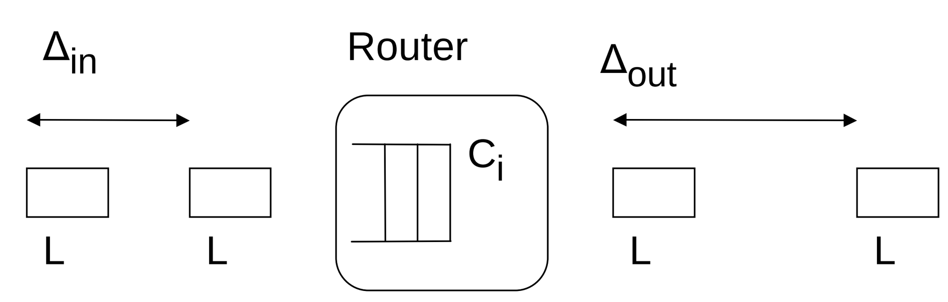
The traffic pattern of current (and near future) multimedia streams need also to be considered when designing a new approach. For example in VoIP the packets are small and long periods of sender inactivity occur (when caller is waiting for the other person to reply).

Bandwidth Estimation

Bandwidth estimation techniques are typically used to deduce the capacity of a path and the available bandwidth. On a given path the link with the minimum capacity is called a *narrow link* and the link with minimum available bandwidth is called a *tight link*. In the case when a link is both the narrow and tight link it is often called a bottleneck. In a wireless setting this is often the last hop router.

With the knowledge about available bandwidth and capacity, it is possible to optimize end-to-end performance of applications.

Packet dispersion techniques, such as packet pair or packet train probing measure the end-to-end capacity of a network path. These techniques send two or more packets back-to-back into the network. After traversing the narrow link, the time dispersion between the two packets in linearly related to the narrow link capacity. Crossing traffic and certain wireless features such as dynamic rate adaptation can cause problems to these methods. In the figure L is the size of the packets. C_i is the capacity and Δ_{in} and Δ_{out} are the time dispersions before and after traversing the router.



Available bandwidth estimation is harder and therefore a multitude of solutions exist. They can be roughly divided into two approaches:

Direct Probing
The sender transmits a periodic probing stream rate (packet pairs or packet trains) and the receiver measures the output rate. The basic idea is that if the sending rate is more than the available bandwidth, the available bandwidth can be calculated with a mathematical model. The caveat is that the capacity of the bottleneck needs to be estimated in advance.

Iterative Probing
With Iterative probing packet pairs (or trains) are sent at varying rates while the receiver observes the differences between input and output rates. When the output rate is lower than the input rate, the probing rate is higher than the available bandwidth. Tools using iterative probing then converge towards the available bandwidth by adjusting the input rate.

Iterative probing methods are more intrusive to the network compared to direct probing. However, the accuracy of direct probing has been called to question in recent studies

Prior work on bandwidth estimation has focused on creating new algorithms and methods to estimate the available bandwidth and capacity. Using these methods for multimedia streaming has not been extensively studied. The goal is to create a novel solution by including bandwidth estimation techniques into a rate control scheme to provide multimedia streaming. The method should be non-intrusive but still accurate, so having some of the actual traffic to provide measurement data is a focus.

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