Adaptive Congestion Control for Unpredictable Cellular Networks – Public Review

Sachin Katti
Stanford University
skatti@stanford.edu

Cellular networks have become the dominant mode of mobile connectivity. Yet, performance on these networks can be quite poor, its quite common for users to experience highly variable throughput, delay and consequently poor application layer performance. There are many reasons for this poor performance, but the underlying problem is the mismatch between the assumptions made in TCP's design and the underlying link layer design. For example, cellular networks have highly unpredictable links due to varying channel conditions. They also have deep per-user buffers and burst scheduling algorithms at the base stations which is at odds with TCP's link layer abstraction of a link with uniform but slowly varying rate and occasional packet losses due to packet drops on shared buffers.

Given its relevance, this problem has attracted significant attention in recent years. The general approach has been to build better ways to predict the idiosyncrasies of the cellular link. For example, much work has focused on building better bandwidth prediction techniques that can better track fluctuations in cellular links and adapt the TCP sending rate. The goal is to avoid queue buildup and consequent increases in self-inflicted latency. Other work has focused on revisiting classical work on cross-layer design, using physical and link layer information to track the link changes and inform transport parameters. But many aspects of the cellular link still remain unexplored and unmodeled, for example the choice of the scheduling algorithm used by the cellular basestation, the impact of competing traffic as well as the choice of different QoS parameters in the cellular network itself.

This paper brings a fresh approach to this problem by revisiting a classical congestion control technique: delay based congestion control. Classical delay based techniques such as TCP Vegas are known to perform poorly in cellular networks. But this paper introduces a twist on how to use delay, the basic idea is to learn a delay profile, a function that measures the relationship between the end-to-end packet delay of the connection and the sending window size over short epochs. The goal is to avoid explicit bandwidth estimation (which is potentially inaccurate given the limited information available at the end-hosts) but rather use changes in measured delay to increment or decrement the window size and react to short term channel variations.

The simple idea turns out to be quite effective, in both simulations and experiments, the technique outperforms TCP Cubic by an order of magnitude in packet delay while maintaining similar throughput. Against the state of the art technique Sprout, it provides nearly 30% higher throughput but with higher delay. Thus this paper pushes the envelope in this space, providing a better point on the throughput-delay tradeoff curve than the best known results.

Taking a step back, it still seems like there is much unexplored territory in this space. The work in this space seems to split into two categories: building models that inform the congestion control algorithm for cellular links purely based on observable parameters at the end-hosts at the transport layer (e.g this work and prior work such as Sprout), and second work that crosses layers and leverages information from the lower layers at the mobile device to get explicit information about the cellular link. Drawing an analogy to the large amount of work in congestion control in other domains, it seems like a third angle is still missing where the network itself is an active participant and influences the congestion control algorithm. For example, one can imagine explicit feedback from the basestation that informs the sender about load conditions and consequently helps improve the rate estimation. Coming up with the right mix of link modeling based on explicit feedback from the lower layers and the network (when available) seems like the natural next step for research in this space.