Application-Level Congestion Control: Overcoming TCP's limitations in Cellular Networks

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Recent delay-based congestion control protocols have demonstrated significant performance gains over highly variable cellular channels in comparison to TCP. Unfortunately, despite this, TCP remains the de-facto standard and deploying new transport protocols is difficult at scale. We motivate the need for better congestion control protocols at the application layer based on the following two observations: most mobile and middlebox applications adopt the standard TCP stack and these legacy software stacks are difficult to change; the wide scale adoption of end-to-end encryption techniques induces a tight coupling between the TLS/SSL layer and the underlying TCP layer [1]. We propose *Application Layer Congestion Control (ALCC)*, a framework that executes congestion control protocols at the application-level without making any modifications to the underlying TCP layer. ALCC enables careful calibration of the congestion window to enable both cross-compatibility with the TCP stack and the protocol control loop. The key building block that allows ALCC to execute a second control loop on top of TCP is the ability to control the application-level sending window and keeping it strictly smaller than the TCP window. TCP tends to ramp up to larger windows while significantly driving up the packet delays in cellular networks. ALCC constrains the application-level sending window to reduce bufferbloat in the network and maintain low end-to-end packet delay.

ALCC's main function is essentially to replace the congestion window of TCP with the congestion window computed at the application layer by the application congestion control protocol. Based on this computed window, ALCC constrains the application data flow to the transport layer. The design of ALCC works especially well for cellular networks where TCP and its variants often stabilize at large congestion window sizes due to the bufferbloat problem. This allows ALCC to transmit at a lower rate than the TCP window and thus achieve better delay. Surprisingly this strategy enables ALCC to achieve similar delay-throughput trade-offs as the native delay-based congestion control protocols. By actively controlling the congestion window, ALCC can reduce network buffer sizes and hence end-to-end packet delays without sacrificing throughput in comparison to TCP.

To help easily integrate ALCC-based protocols into existing applications, we created a C++ library as a wrapper around the default BSD TCP library and expose the same socket APIs. The purpose of the library is to be used at the application implementation to open an ALCC socket instead of a TCP socket. The main philosophy of the ALCC library is to provide place-holder functions to easily integrate any congestion control implementation. The idea is to split the congestion control implementation into three pieces: the basic congestion control logic, the sending related functionality, and the receiving related functionality. For recently developed congestion control protocols [2, 3], we show that ALCC running at the application layer on top of TCP can achieve roughly the same performance as that of the native protocol without making any changes to the underlying TCP protocol (within $3-5\%$ packet delay and throughput).

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