XQM: eXogenous-aware Queue Management

MINA GUIRGUIS msg@cs.bu.edu
AZER BESTAVROS best@cs.bu.edu
IBRAHIM MATTA matta@cs.bu.edu

Computer Science Department
Boston University, Boston, MA 02215

Introduction

Exogenous losses—which are produced outside the transmission control system of a traffic source, *i.e.*, independently of that source's behavior and its long-term (max-min, proportional, or weighted) fair share of network resources—have always been regarded as introducing undesirable "noise" that needs to be filtered out or hidden from end points. In this work, we show that they can be surprisingly beneficial. In particular, we show that while high levels of exogenous losses lead to inefficient network utilization, lower levels of losses help connections converge to their fair share. Since TCP, by its nature, adaptively seeks available bandwidth, exogenous losses in effect impose an upper limit on achievable TCP throughput. The extent to which exogenous losses limit achievable throughput makes the crucial difference between desirable and undesirable exogenous losses. Specifically, if this limit lies below a connection's long-term fair share, then exogenous losses cripple that TCP connection. Otherwise, we show that exogenous losses enable the fast and stable convergence of that TCP connection to its long-term fair share of network resources. Exogenous losses serve as early error notifications to the sources, which, similar to RED (Random Early Detection), randomize packet drops across all connections. This randomness prevents an individual TCP connection from monopolizing the bottleneck resource, in addition to preventing several connections from synchronizing their sending behavior which may result in high delay variance (jitter). Thus, low levels of exogenous losses, which do not force TCP throughput to dip below its long-term fair share, can be beneficial in reaching an *efficient*, *stable* and *fair* allocation of resources.

This observation suggests that the beneficial value of exogenous losses should be leveraged inside the network in favor of TCP connections. To that end, we propose an eXogenous-aware Queue Management (XQM) that actively accounts for exogenous losses to improve efficiency and fairness. XQM is envisioned to be placed at the edges of the network and maintains a profile for each flow passing through it. This profile includes estimates of the round trip time and the current connection's throughput. We use an equation based approach to derive the right value of packet losses to impose, based on the connection's profile and its fair share. In contrast to any other AQM, imposing the right value of losses may require XQM to *hide* losses, and not only introduce losses for a particular connection. XQM can be configured to work in an explicit mode that is based on classifying the effects of exogenous losses into long-term and short-term effects and applying the right control rules, or it can work in an implicit mode that is based on adapting the loss value it introduces or hides based on the dynamics of the network.

Methodology

We extended an analytical fluid model to capture the effect of exogenous losses on closed-loop TCP control. By numerically solving the resulting nonlinear dynamical equations, we were able to show how TCP could switch between open loop and closed loop depending on the level of exogenous losses. Through a control theoretic framework, we developed XQM that adjusts the loss value it imposes or hides based on how far the connection's throughput is from its fair share and how far the buffer size is from its target value. We implemented XQM in the *ns-2* simulator.

Results and Future Work

Our simulations show that XQM can achieve fairness among connections with different round trip times as well as connections traversing different number of congested links, without sacrificing efficiency. Our results confirm the superiority of XQM over RED, FRED, REM and PI. We are currently investigating XQM's parameter settings and their impact on its performance.

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Reference

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