BCN: Overview of Theory and Simulations

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Some background

- Two flavors of network congestion…

  - Transient: Due to random fluctuations in the arrival rate of packets, and effectively dealt with using buffers and link-level pausing (or dropping packets, if applicable).

  - Sustained: Caused by an increase in the applied load either because existing flows send more traffic, or (more likely) because new flows have arrived.
    - The Backward Congestion Notification (BCN) mechanism is primarily concerned with dealing with the second type of congestion.

Congestion control in the Internet

- In the Internet
  - Various queue management schemes, notably RED, drop or mark packets using ECN at the links
  - TCP at end-systems uses these congestion signals to vary the sending rate
  - There exists a rich history of algorithm development, control-theoretic analysis and detailed simulation of queue management schemes and congestion control algorithms for the Internet
    - Jacobson, Floyd et al, Kelly et al, Low et al, Srikant et al, Misra et al, Katabi et al …
    - The simulator ns-2

A one-slide (extreme) summary

- Internet congestion control:
  - The router could
    - Send *simple* signals: signal (drop/mark) based on queue-size alone (e.g. RED)
    - Send *detailed* signals: signal based on queue-size and link utilization (e.g. REM, PI controller)
  - The end-systems could
    - Have *simple* reactions: Cut window by a factor 1/2 (e.g. TCP)
    - Or *elaborate* reactions: Various increase/decrease behaviors (e.g. High-speed TCP, Fast TCP)

- For high bandwidth-delay-product networks
  - The simple-simple combo doesn’t work
  - In addition, when buffers are short, it is v.useful (necessary?) to signal available rate or link utilization

The BCN proposal

- Has the following features
  - CPs signal queue-size and rate: (Q, Q_{delta})
  - RPs vary rate according to equations of AIMD
  - Similar to XCP and RCP in the Internet literature: change both router and end-host behaviors
- We consider the following issues re the BCN proposal
  - Stability
  - Optimality and fairness
  - Robustness
- We explain what each of these terms means and how one can verify them via theory and simulations

Stability

- View the BCN mechanism as a control system
  - CP--RP non-linear control loops
  - Linearize equations about an equilibrium operating point
  - Determine the “unit step response” of the linearized system
    - I.e. N sources supply unlimited amount of traffic indefinitely
    - Choose gain parameters for stability and responsiveness

- Large conclusions
  - Gain parameters depend on N and RTT
  - Some amount of “drift” necessary: for fail-safeness, fairness
  - Stability is a first-order property
    - Many schemes are stable, only some of these are fair and robust
    - Need to understand the performance of scheme under “dynamic inputs:” a situation where flows arrive and depart

Optimality and fairness

- Optimality and fairness
  - How responsive is the congestion control scheme to changes in the applied load?
  - How closely does it track an "ideal system?"
  - How quickly does a new flow achieve its fair rate allocation?
  - We will see that drift or "self-increase" plays a crucial part here because it allows sources to gently probe the network for available bandwidth

- Large conclusions
  - Dynamic loading, where flows arrive and depart, gives a lot of information
  - Three different types of drift introduced and their stability and fairness properties are studied
  - Main metric: Flow Completion Time (FCT)
    - Bdwdth = Flow size / FCT; therefore, can compare bdwdth obtained by flows of the same size
    - This gives fairness in a dynamic setting

Robustness

- Robustness: How “true” does the performance remain to changes in
  - Traffic or loading conditions
    - Change flow arrival rate, mean flow size, flow size distribution, etc
  - BCN parameter variations; including
    - Turning BCN off
    - Turning off switch-signaled rate increase
    - Varying the starting rate: 10 Gbps vs 1 Gbps
- Large conclusions
  - The proposed BCN is pretty robust
  - It gives consistent performance, measured in FCT and fairness
    - Even at high loads
    - And even when switch-signaled increase is turned off

Further work

- Want to see
  - How the sampling probability affects performance
  - How BCN(0,0) affects performance
  - Whether signaling can be cruder
- Generally, well-designed congestion management schemes are (and need to be) robust
  - The "law of large numbers" favors them
  - Not necessary to be exact on a per-packet basis
- Interactions with TCP

The related presentations

- Yi Lu
  - Stability analysis from paper presented at the Allerton conference
    - Available at: http://simula.stanford.edu/luyi/ and at http://www.ieee802.org/1/files/public/docs2006/au-Lu-et-al-BCN-study.pdf
  - Study of drift or “self-increase;” fairness of these schemes via FCT

- Ashvin Lakshmikantha
  - Detailed study of robustness of the BCN scheme
  - Under realistic network scenarios (topologies, varying loads …)
  - Fairly dramatic perturbations of the BCN scheme