Class Lecture notes

EE 597
4/24/12

Congestion Control in Wireless Networks

- The need for Explicit Congestion Notification to deal with the problem of QoS differentiation.

- The need for Congestion sharing to alleviate fairness problem arising due to shared medium.

Both of these solutions require greater intelligence to be embedded at the core of the network, i.e., in the routers, violating the end-to-end architecture of traditional Internet.
Another new idea in congestion control is "explicit & precise rate control". Contrast w/ AIMD approach.

For general (i.e. wired) networks: \[ RCP \] by Duttipati & McKeown.

Also a router-centric approach (hence not adopted earlier).

Big # of industry development:
- OpenFlow Routers —
- Software defined routers

This is likely to speed adoption of router-centric protocols for wired networks.
Examples in wireless networks of E&P rate control:
- WRCP for sensor networks
- WCP-Cap for Mesh networks

Congestion Control with Backpressure

Rate Control

Congestion Control

Flow Control

Window-based congestion control
Rate-based congestion control

W-B
R-B
Observation: Can solve some of the congestion-control problems such as fairness, at the MAC layer.

Recall max weight algorithm:
Schedule independent set of links that max \( \sum_{i,j} w_{i,j} \)

where \( w_{i,j} = (Q_i - Q_j) \cdot R_{i,j} \)

\( \beta CP \) was a distributed impl. at the routing layer (mostly)

DiffsQ: an implementation of Backpressure at the MAC layer.
Basic idea of DiffQ:
choose the backoff interval based on $Q_{ij}$ (i.e. $w_{ij}$).

If we want to prefer transmissions on links of higher weight, want to make the $w_{ij}$ max backoff window smaller.

DiffQ: took 802.11e
which specifies different E.0. window sizes for different QoS classes, I map the $w_{ij}$ to classes.
Utility-based gate control

MAC layer: Slotted Aloha
Slotted Aloha Saturation Throughput
Region:
\[ \sqrt{R_1} + \sqrt{R_2} = 1 \]

Throughput efficient solution: \((1, 0)\) or \((0, 1)\)
Sum rate = 1.
Clearly least fair solution!

Most Fair solution: \((\frac{1}{4}, \frac{1}{4})\)
Least sum rate: \(\frac{1}{2}\)

With TDMA, can get 6th.
Utility-based rate allocation

\[
\max \sum \xi_i g_i(r_i)
\]

s.t. \( \forall \in \Delta \)

 rate region of the network.

Special cases of \( g_i(r_i) \).

Linear utility: \( g_i(r_i) = \xi_i r_i \)

Log utility: \( g_i(r_i) = \xi_i \log(1 + r_i) \)

"happiness" utility
Stated example

\[ c_i = 1 + i \]

Linear utility

\[
\text{max } R_1 + R_2 \\
\text{s.t. } \sqrt{R_1} + \sqrt{R_2} \leq 1
\]

\[ \Rightarrow \text{max } R_1 + R_2 \\
\text{s.t. } \sqrt{R_1} + \sqrt{R_2} = 1
\]

Solve: either \( c_1 = 1 \), \( c_2 = 0 \) or \( c_2 = 1 \), \( c_1 = 0 \).

Log utility - proportional fair utility

\[
\text{max } \log R_1 + \log R_2 \\
\text{s.t. } \sqrt{R_1} + \sqrt{R_2} = 1
\]

\[ \sqrt{R_2} = 1 - \sqrt{R_1} \]

\[ R_2 = (1 - \sqrt{R_1})^2 \]

\[
\text{max } \log R_1 + \log (1 - \sqrt{R_1})^2
\]
\[ \max (\log R_1 + 2 \log (1 - \sqrt{R_1})) \]

\[ \frac{d}{dR_1} = \frac{1 + \frac{2}{(1 - \sqrt{R_1})\sqrt{R_1}}}{R_1} = 0 \]

\[ (1 - \sqrt{R_1})(\sqrt{R_1}) = R_1 \]

\[ \sqrt{R_1} = R_1 = R_1 \]

\[ \sqrt{R_1} = 2R_1 \]

\[ \sqrt{R_1} = \frac{1}{2} \]

\[ R_1 = \frac{1}{16} \]

\[ R_1 = \frac{1}{4} \]

Solution: \((\frac{1}{4}, \frac{1}{4})\)
Generally: $x$-fair utility function

Prof. Mike Neely's Dissertation at MIT:
utility optimization in a backpressure framework

How to maximize utility (i.e. pick a desired rate allocation across the firms/commodities) while ensuring stable operation.
pb: max $E_{g}(r_i)$
s.t. $r_i \in$ stability region of the network

Solution:

Part 1: rate allocation
Each source provides rate $r_i$ to maximize:

$\left( V \cdot g(R_i) - Q_i \cdot R_i \right)$

Part 2: use max weight scheduling algorithm as before.
Part 1 rate control

\[ V g'(R_i) - Q_i = 0. \]

pick \( R_i : g'(R_i) = \frac{Q_i}{V} \)

\[ R_i = g^{-1}(\frac{Q_i}{V}) \]

Parameter tradeoff between utility optimization & average queue size (hence delay).

It can be hard to find the best value of \( V \) for a given network sensitive to the topology & traffic.