Wide-Area Traffic Management
COS 597E: Software Defined Networking

Jennifer Rexford
Princeton University
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Traffic Management
• Assigning resources to traffic
  – Optimize some objective
    – Min congestion, max utility, min delay, ...
  – Given network resource constraints
• Three main “knobs”
  – Routing: what path(s) the traffic takes
  – Link scheduling: how to share each link
  – Rate control: how much a source can send
• Host/network split
  – Host: rate control
  – Network: routing and link scheduling

Simple Traffic Management
• Protocols adapt automatically
  – TCP senders send less traffic during congestion
  – Routing protocols adapt to topology changes
• But, does the network run efficiently?
  – Congested link when idle paths exist?
  – High-delay path when a low-delay path exists?
• How should routing adapt to the traffic?
  – Avoiding congested links in the network
  – Satisfying application requirements (e.g., delay)

Automatically Adapting the Link Weights
ARPAnet Routing

Original ARPAnet Routing (1969)
• Routing
  – Shortest-path routing based on link metrics
  – Distance-vector algorithm (i.e., Bellman-Ford)
• Link metrics
  – Instantaneous queue length plus a constant
  – Each node updates distance computation

Problems With the Algorithm
• Instantaneous queue length
  – Poor indicator of expected delay
  – Fluctuates widely, even at low traffic levels
  – Leading to routing oscillations
• Distance-vector routing
  – Transient loops during (slow) convergence
  – Triggered by link weight changes, not just failures
• Protocol overhead
  – Frequent dissemination of link metric changes
  – Leading to high overhead in larger topologies
New ARPAnet Routing (1979)

- Averaging of the link metric over time
  - Old: Instantaneous delay fluctuates a lot
  - New: Averaging reduces the fluctuations
- Link-state protocol
  - Old: Distance-vector computation leads to loops
  - New: Link-state protocol where each router computes paths based on the complete topology
- Reduce frequency of updates
  - Old: Too many update messages
  - New: Send updates if change passes a threshold

Performance of New Algorithm

- Light load
  - Delay dominated by the constant part (transmission delay and propagation delay)
- Medium load
  - Queuing delay is no longer negligible on all links
  - Moderate traffic shifts to avoid congestion
- Heavy load
  - Very high metrics on congested links
  - Busy links look bad to all of the routers
  - Routers may send packets on longer paths

Revised ARPAnet Metric (1987)

- Limit path length
  - Bound the value of the link metric
    - "This link is busy enough to go two extra hops"
- Prevent over-reacting
  - Shed traffic from a congested link gradually
  - Starting with alternate paths that are slightly longer
  - Through weighted average in computing the metric, and limits on the change from one period to the next
- New algorithm
  - New way of computing the link weights
  - No change to routing protocol or path computation

Optimizing the “Static” Link Weights

Routing With “Static” Link Weights

- Routers flood information to learn topology
  - Determine “next hop” to reach other routers...
  - Compute shortest paths based on link weights
- Link weights configured by the operator

Setting the Link Weights

- How to set the weights
  - Inversely proportional to link capacity?
  - Proportional to propagation delay?
  - Network-wide optimization based on traffic?
Pros and Cons

- **Advantages**
  - Network-wide optimization
  - Avoids oscillation
  - No changes to the routing protocols

- **Disadvantages**
  - Overhead of collecting the measurements
  - Limited splitting of traffic over multiple paths
  - Computational complexity of the optimization
  - Transient disruptions during weight changes

- So, performed at a slow time scale (hours)

Explicit End-to-End Paths

- Establish end-to-end path in advance
  - Learn the topology (as in link-state routing)
  - End host or router computes and signals a path

- Routers supports virtual circuits
  - Signaling: install entry for each circuit at each hop
  - Forwarding: look up the circuit id in the table

MPLS-TE

- Learn about congestion
  - Dynamically changing link weights
- Reserve resources on paths
  - Pick a path, and signal to reserve resources
- Change paths during congestion
  - Pick a new path, and reserve resources
- More flexible, but still some limitations
  - Uncoordinated decisions at different nodes
  - Suboptimal decisions, and non-deterministic
  - Complex interaction of several protocols