Intradomain Routing

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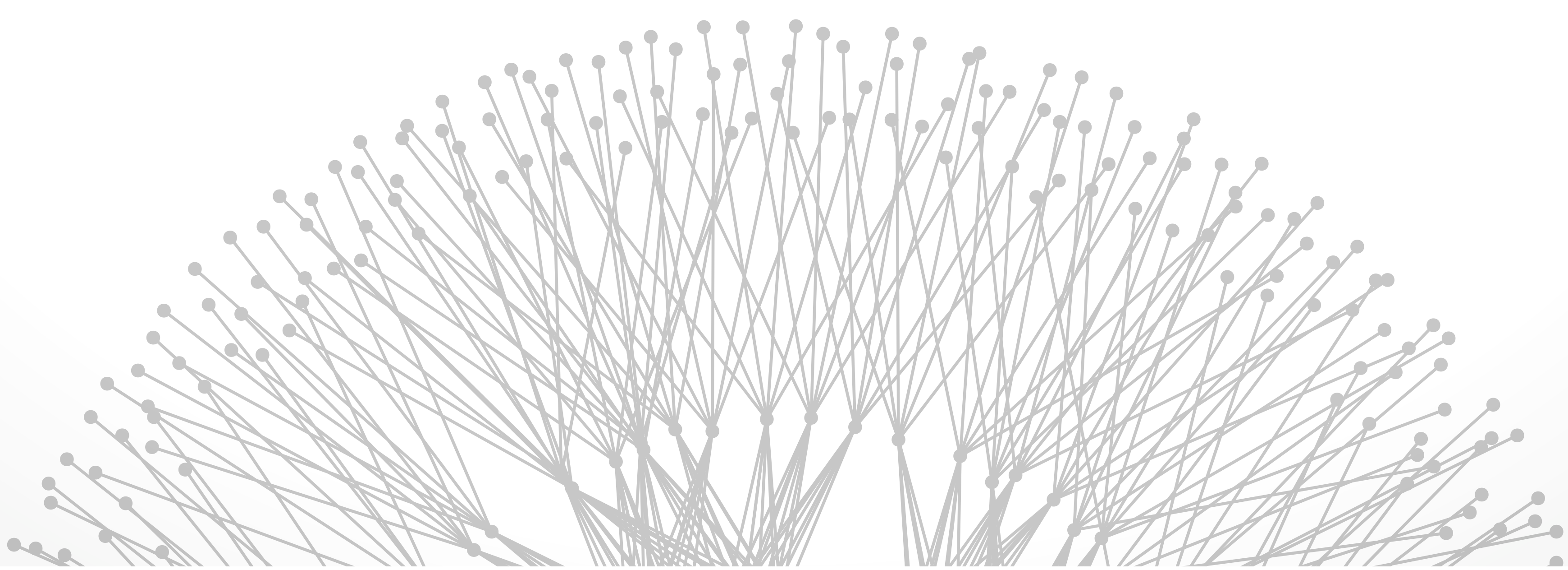
CS 538 September 24 2013



Dealing with difficult readings

Readings can be difficult to understand

- It gets easier
- Ask questions!

Readings can be difficult to criticize in the reviews

- Goal is to think critically about the paper, not to write the definitive judgement of the work
- This is part of the process of understanding!

Routing

Choosing paths along which messages will travel from source to destination.

Often defined as the job of Layer 3 (IP). But...

- Ethernet spanning tree protocol (Layer 2)
- Distributed hash tables, content delivery overlays, ... (Layer 4+)

Problems for intradomain routing

Distributed path finding

React to dynamics

High reliability even with failures

Scale

Optimize link utilization (traffic engineering)

The two classic approaches

Distance Vector & Link State

Far from the only two approaches!

- We'll see more later...

Distance vector routing

Original ARPANET: distance vector routing

Remember vector of distances to each destination and exchange this vector with neighbors

- Initially: distance 0 from myself
- Upon receipt of vector: my distance to each destination = min of all my neighbors' distances + 1

Send packet to neighbor with lowest dist.

Slow convergence and looping problems

- E.g., consider case of disconnection from destination
- Fix for loops in BGP: store path instead of distance

Link state routing

Protocol variants

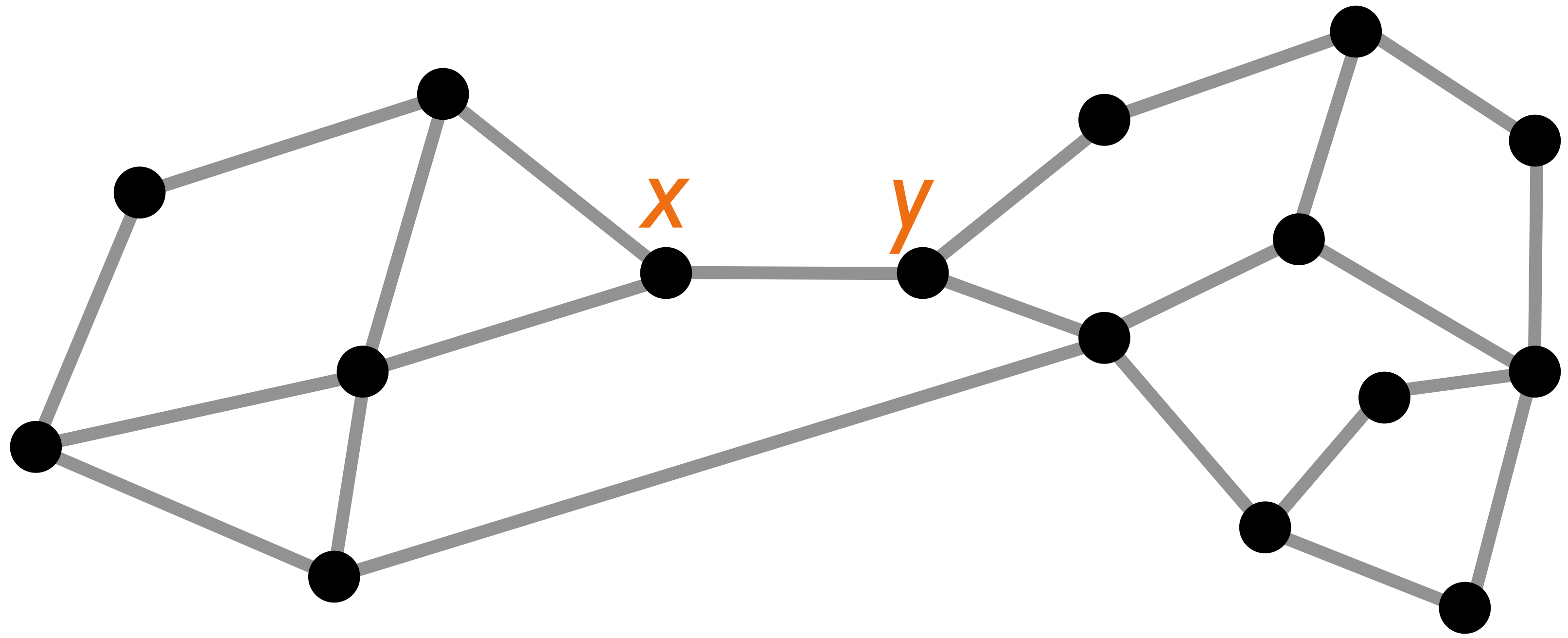
- ARPANET: McQuillan, Richer, Rosen 1980; Perlman 1983
- Intermediate System-to-Intermediate System (IS-IS)
- Open Shortest Path First (OSPF)

Algorithm

- Broadcast the entire topology to everyone
- Forwarding at each hop:
  - Compute shortest path (e.g., Dijkstra's algorithm)
  - Send packet to neighbor along computed path

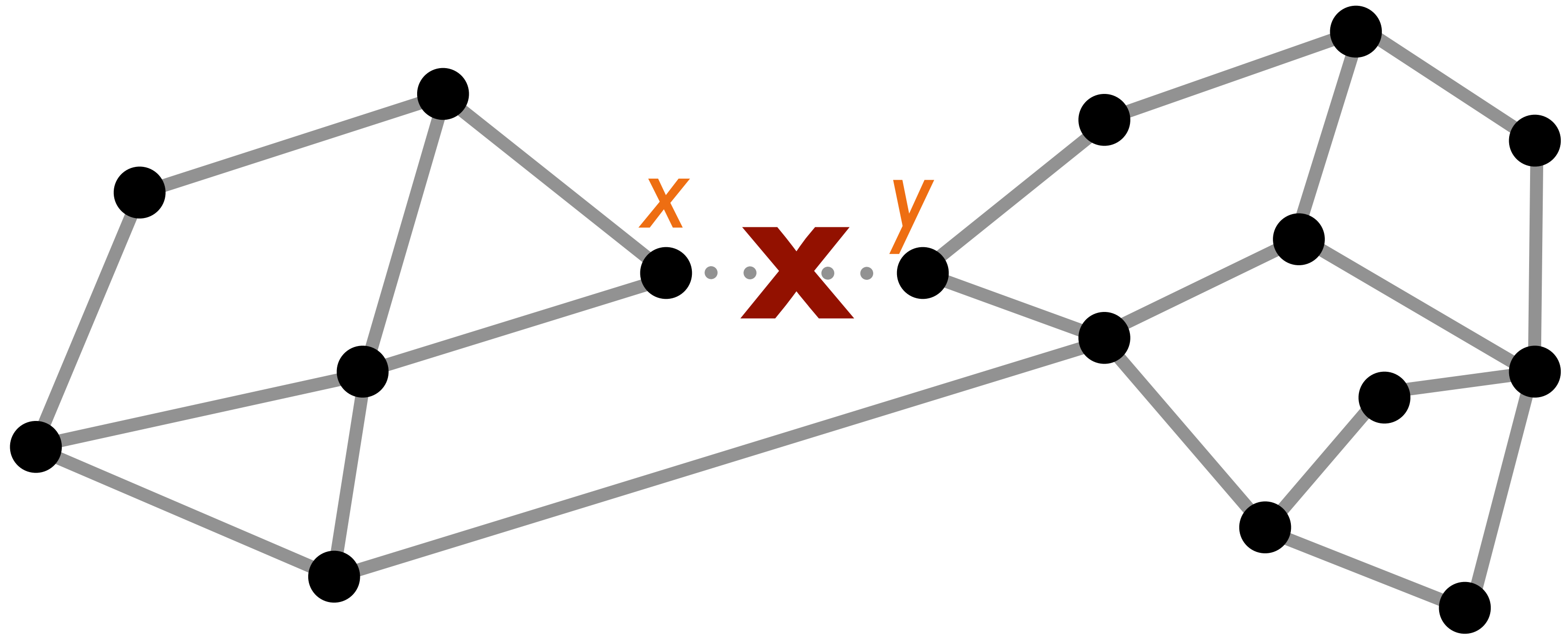
Question

We have a network...



Question

A link fails. How many total bytes of message does *x* send in immediate response?

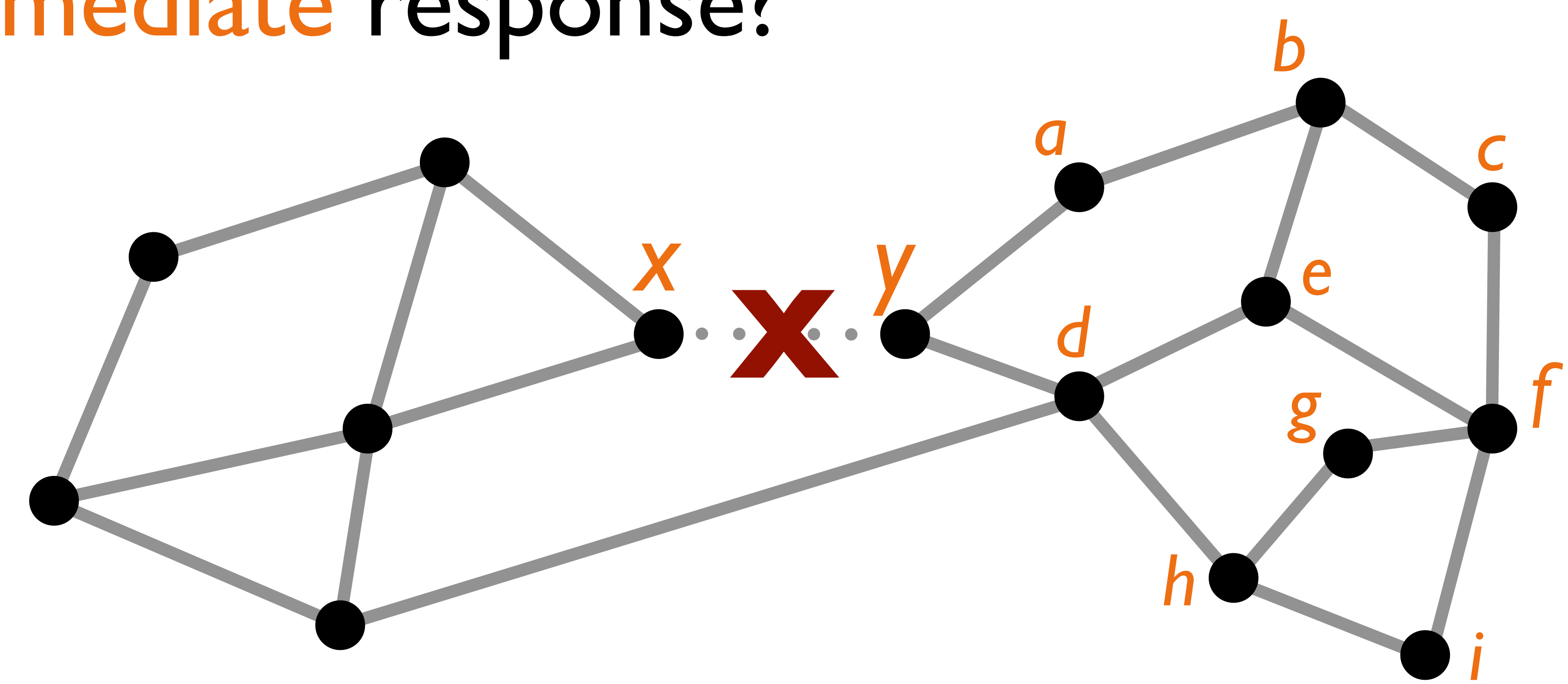


...using distance vector?

...using link state?

Question

A link fails. How many total units of message does *x* send in immediate response?



...using distance vector?

20 "My distance to *y* changed!
My distance to *a* changed!
My distance to *b* changed!
...
My distance to *i* changed!"
...to each of 2 neighbors

...using link state?

2 "Oh hey, link *x*-*y* failed"
...to each of 2 neighbors

Link state vs. distance vector

Disadvantages of LS

- Need consistent computation of shortest paths
  - Same view of topology
  - Same metric in computing routes
- Slightly more complicated protocol

Advantages of LS

- Faster convergence
- Gives unified global view
  - Useful for other purposes, e.g., building MPLS tables

Q: Can link state have forwarding loops?

LS variant: Source routing

Algorithm:

- Broadcast the entire topology to everyone
- Forwarding at source:
  - Compute shortest path (Dijkstra's algorithm)
  - Put path in packet header
- Forwarding at source and remaining hops:
  - Follow path specified by source

Q: Can this result in forwarding loops?

Source routing vs. link state

Advantages

- Essentially eliminates loops
- Compute route only once rather than every hop
- Forwarding table (FIB) size = #neighbors (not #nodes)
- Flexible computation of paths at source

Disadvantages

- Flexible computation of paths at source
- Header size (fixable if paths not too long)
  - Use local rather than global next-hop identifiers
  - $\log_2$(#neighbors) per hop rather than $\log_2$(#nodes)
- Source needs to know topology
- Harder to redirect packets in flight (to avoid a failure)

Traffic engineering

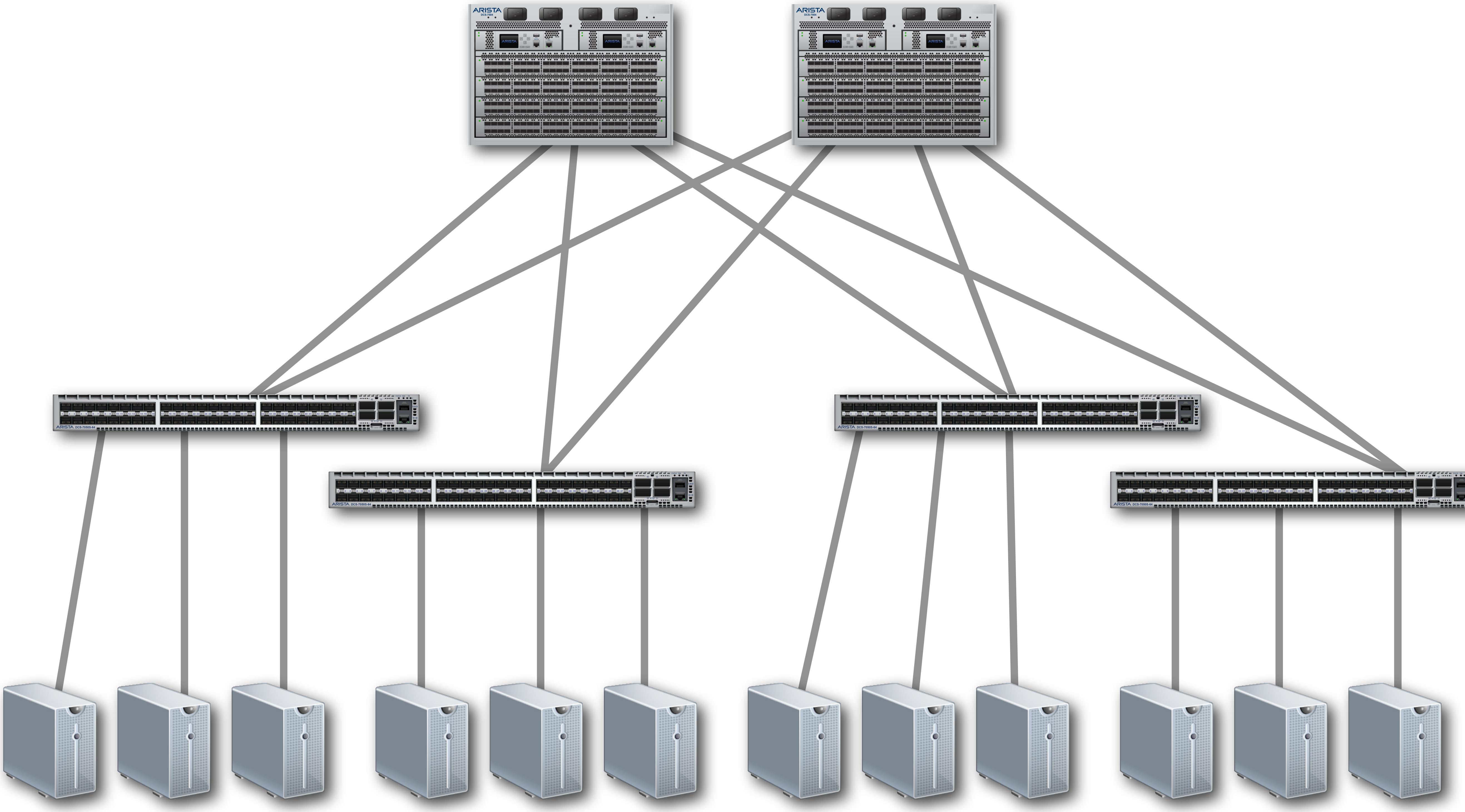
Key task of intradomain routing: optimize utilization

No TE: Shortest path routing

- How well does this work?

A start: Equal Cost Multipath Protocol (ECMP)

- Each router splits traffic across equally short next-hops
- Hash header to pin flow to a pseudorandom path (why?)
- When do you think this works well?



Traffic engineering

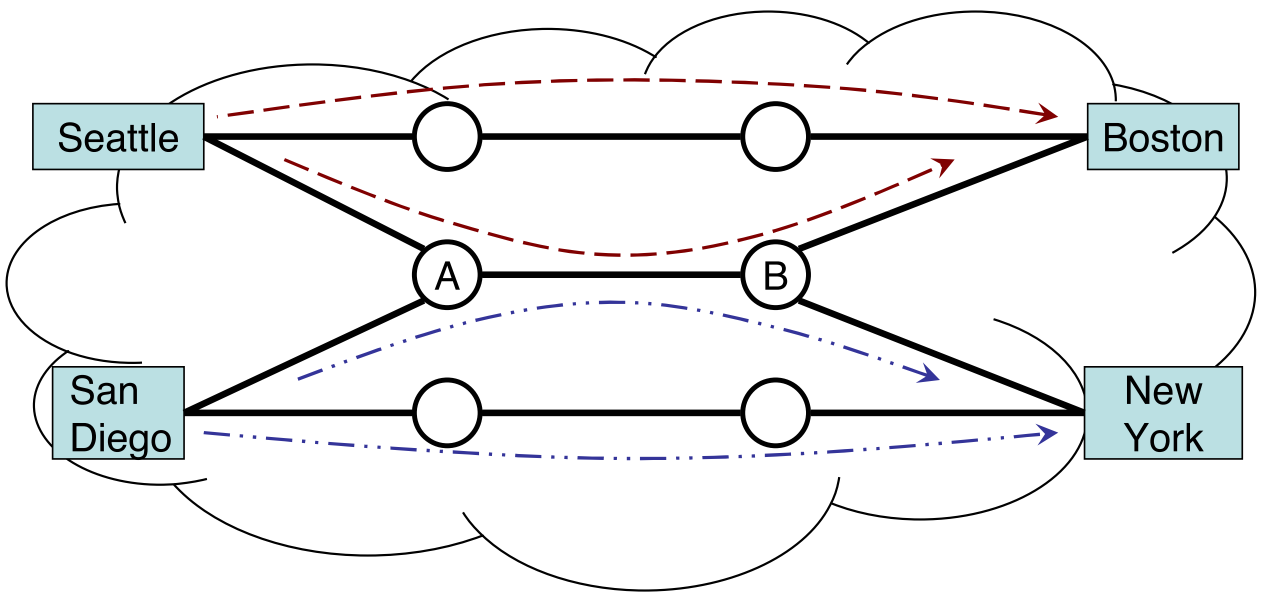
Key task of intradomain routing: optimize utilization

Classic TE: optimize OSPF weights

- Need to propagate everywhere: can't change often
- Single path to each destination

Modern TE: load balance among multiple MPLS paths

- e.g., TeXCP [Kandula, Katabi, Davie, Charny, 2005]



[Kandula et al, "Walking the Tightrope", SIGCOMM 2005]

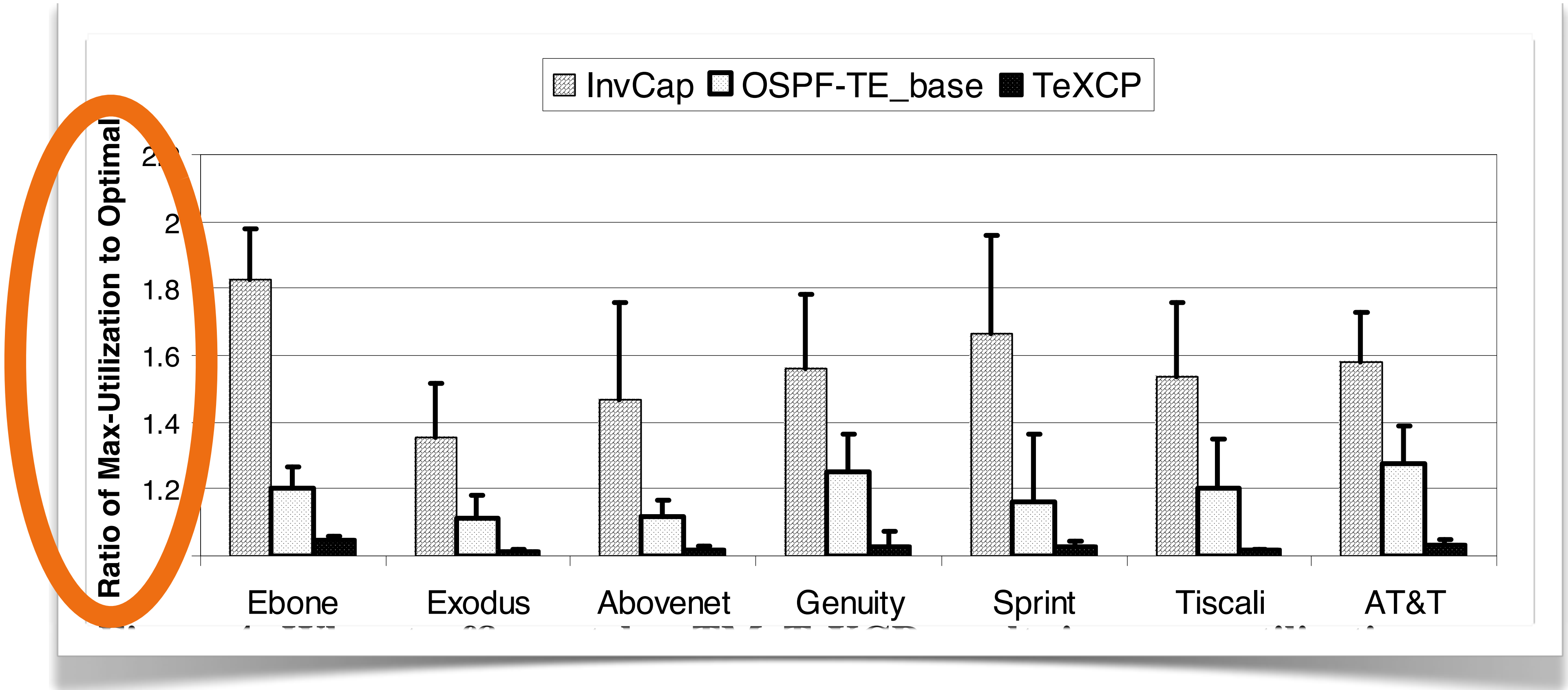
Traffic engineering

Cutting-edge TE: SDN-based control

- we'll see this soon!

TeXCP discussion

In OSPF-TE, "Finding optimal link weights that minimize the max-utilization is NP-hard". Why is this harder than finding the best possible (non-OSPF) solution?



TeXCP discussion

Is minimizing max utilization what we are really looking for?

How does it scale up to large networks? Do we need more than 10 paths? [Jianxiong]

How would the congestion control protocols work along with the load balancing protocols? [Shayan]

Announcements

What's to come

Thursday:

- No lecture; project proposals due!

Tuesday:

- Interdomain routing basics

After:

- Big Challenges for networking

Project proposals

Project proposals due 11:59 p.m. Thursday

- via email to Brighten, subject: CS 538 project proposal
- 1/2 page, plaintext preferred, or else PDF

Format (see course syllabus):

- the problem you plan to address
- your planned first steps
- related work
  - $\geq$ 3 full academic references
  - why it has not addressed your problem
- if there are multiple people on your project team, who they are and how you plan to partition the work