Lecture 11:
WAN Routing Alternatives

CSE 222A: Computer Communication Networks
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Thanks: Brighten Godfrey
Lecture 11 Overview

- WAN Internet routing challenges
- Pathlet routing
Internet routing challenges

Multipath

- reliability
- path quality

Scalability

Policy

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Internet routing challenges

- Multipath
  - reliability
  - path quality

- Scalability

- Policy

[ F. Wang, Z. M. Mao, J. Wang, L. Gao, R. Bush ’06]

![Graph showing number of loss bursts over time]

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Internet routing challenges

- Multipath
  - reliability
  - path quality

- Scalability

- Policy

Lowest latency path

Highest bandwidth path

Path the network picked for you
Internet routing challenges

Multipath

reliability

path quality

throughput

Use multiple paths simultaneously

Scalability

Policy
Internet routing challenges

- Multipath
  - reliability
  - path quality
- Scalability
- Policy

Internet forwarding table size [Huston ’09]
Internet routing challenges

Multipath

reliability

path quality

Scalability

Policy
Pathlet routing

vnode virtual node

pathlet fragment of a path: a sequence of vnodes

Source routing over pathlets.

virtual graph: flexible way to define policy constraints

provides many path choices for senders
Flexibility

- can emulate BGP, source routing, MIRO, LISP, NIRA
- local transit policies provide multipath and small forwarding tables
- coexistence of different styles of routing policy
Design for variation

“Design for variation in outcome, so that the outcome can be different in different places, and the tussle takes place within the design, not by distorting or violating it.”

Clark, Wroclawski, Sollins & Braden, 2002

“Tussle in Cyberspace”
Pathlet routing

vnode  virtual node

pathlet  fragment of a path:
a sequence of vnodes

Source routing over pathlets.
vnodes

**vnode**: virtual node within an AS

- Walla Walla
- New York
- Crumstown
- San Diego
- Roosterville
Pathlets

Packet route field

Forwarding table

A

B

C

D

7,2

2

7 fwd to C

2 fwd to D

delivered!
Pathlets

Packet route field

Forwarding table

A

B

C

D

3

7,2

2

3

push 7,2; fwd to B

7

fwd to C

2

fwd to D

delivered!
Dissemination

- Global gossip fine, except for scalability
- So, let routers choose not to disseminate some pathlets
- Leads to (ironic) use of path vector — only for pathlet dissemination, not route selection
Local transit policies

Each ingress→egress pair is either allowed or disallowed.

Subject to this, any path allowed!

Represented with few pathlets: small FIB
“All valley-free” is local

“customers can route to anyone; anyone can route to customers”

-ingress from a provider-

-ingress from a customer-

-egress to a provider-

-egress to a customer-

Forwarding table size: 3 + #neighbors
Choice for senders

Local transit policies provide some policy control for networks, while enabling a large number of paths for senders.
Emulating BGP
Mixed policies

local BGP-like local local local
Improved connectivity

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Tiny forwarding tables

Forwarding table size CDF

Internet-Like

Current Internet (CAIDA/APNIC):

- 132,158+ entries: one per IP prefix
- BGP
- Pathlet routing, valley-free
- LT policies

2,264 entries, max
8.48 entries, mean
Control overhead

2.23x more messages, 1.61x more memory in LT than PV

This can likely be improved.
Comparing protocols

- Feedback-based routing
- Loose source routing
- Strict source routing
- MIRO
- Pathlet routing
- NIRA
- LISP
- Routing deflections, path splicing
- BGP
Conclusion

- Pathlet routing: source routing over a virtual topology formed by pathlets and vnodes
- Highly flexible; supports both "local" policies with small forwarding tables and many paths, and complex BGP policies
- Challenges for source routing: Incentives to provide multiple paths; selecting paths; security; ...
For Next Class...

- Go see Godfrey’s talk at 11:30 in CSE 4140
- Read and review DONA paper
- Keep moving on term projects!