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”
High level goals

- Goal: flexibility in network services
  - “Route to this destination”, route along a specified path, VPNs, quality of service, ...

- Goal: user choice
  - Reliability, path quality, throughput, promote competition, ...
Pathlet routing’s solution

- Goal: flexibility in network services
- Represent network as a virtual topology

**vnode** virtual node

**pathlet** fragment of a path: a sequence of vnodes

- Goal: User choice
- Source routing within virtual topology
• The protocol
• Uses
• Experimental results
• Comparing routing protocols
Pathlet routing

vnode  virtual node

pathlet  fragment of a path:
         a sequence of vnodes

Source routing over pathlets.
vnode: virtual node within an AS

Walla Walla
New York
Crumstown
San Diego
Roosterville
**vnodes**

**vnode**: virtual node within an AS

designated **ingress vnode** for each neighbor

Internally: a forwarding table at one or more routers
### Pathlets

#### Packet route field

<table>
<thead>
<tr>
<th>A</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>7</td>
</tr>
<tr>
<td>C</td>
<td>2</td>
</tr>
<tr>
<td>D</td>
<td></td>
</tr>
</tbody>
</table>

#### Forwarding table

<table>
<thead>
<tr>
<th>A</th>
<th>3</th>
<th>push 7,2; fwd to B</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>7</td>
<td>fwd to C</td>
</tr>
<tr>
<td>C</td>
<td>2</td>
<td>fwd to D</td>
</tr>
</tbody>
</table>

**delivered!**
• 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
Outline

• The protocol
• Uses
• Experimental results
• Comparing routing protocols
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”

Forwarding table size: 3 + #neighbors
Local transit policies provide some policy control for networks, while enabling a large number of paths for senders.

Choice for senders

source

destination
Emulating BGP
Mixed policies

local  BGP-like  local  local  local  local
Tricky bit: policy can depend on previous hops!
Emulating NIRA

NIRA: carry state about previous hops in destination IP address.

Pathlets: carry state about previous hops in vnode.
Outline

• The protocol
• Uses
• Experimental results
• Comparing routing protocols
Improved connectivity

- BGP-style
- Mixed
- LT policies
Tiny forwarding tables

Forwarding table size CDF

current Internet (CAIDA/APNIC):

BGP
132,158+ entries:
one per IP prefix
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.
Questions

• Are either of these protocols viable?
• Would ASes actually use “local” policies (permitting many routes) or would they stick with BGP-style?
• Are there security vulnerabilities in NIRA or PR that are not in the current Internet?