Monitoring and Managing QoE in the Wide Area: Programmable Routers to the Rescue?

Nick Feamster
Princeton University
(with apologies to Arpit Gupta, Marco Canini, Laurent Vanbever, Jen Rexford, and others)

http://sdx.cs.princeton.edu
We Have Neither Visibility Nor Control at Interconnection Points

• **No control**
  – Routing only on destination IP prefixes
    (No customization of routes by application, sender)
  – Can only influence **immediate neighbors**
    (No ability to affect path selection remotely)
  – **Indirect** control over data-plane forwarding
    (Indirect mechanisms to influence path selection)

• **No visibility**
  – Monitoring is limited to byte counters and NetFlow
  – No precise packet timings along path segments
  – No active probes along path segments
SDX: SDN at Internet Exchanges

• **Leverage:** SDN deployment even at single IXP can yield benefits for tens to hundreds of ISPs

• **Innovation hotbed:** Incentives to innovate as IXPs on front line of peering disputes

• **Growing in numbers:** ~100 new IXPs established in past three years*

*https://prefix.pch.net/applications/ixpdir/summary/growth/*
Conventional IXPs

- AS A Router
- AS B Router
- AS C Router
- BGP Session
- Switching Fabric
- Route Server
SDX = SDN + IXP
Improving Control

• Forwarding on **multiple header fields** (not just destination IP prefixes)

• Ability to **control entire network** with a single software program (not just immediate neighbors)

• **Direct control** over data-plane forwarding (not indirect control via control-plane arcana)
Inbound Traffic Control

<table>
<thead>
<tr>
<th>Incoming Traffic</th>
<th>Out Port</th>
<th>Using BGP</th>
<th>Using SDX</th>
</tr>
</thead>
<tbody>
<tr>
<td>dstport = 80</td>
<td>C1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

AS A Router

\[10.0.0.0/8\]

AS C Routers

AS B Router

Incoming Data

Outbound Traffic Control

dstport = 80
C1
Inbound Traffic Control

Fine grained policies not possible with BGP

<table>
<thead>
<tr>
<th>Incoming Traffic</th>
<th>Out Port</th>
<th>Using BGP</th>
<th>Using SDX</th>
</tr>
</thead>
<tbody>
<tr>
<td>dstport = 80</td>
<td>C1</td>
<td>?</td>
<td></td>
</tr>
</tbody>
</table>
Inbound Traffic Control

Enables fine-grained traffic engineering policies

<table>
<thead>
<tr>
<th>Incoming Traffic</th>
<th>Out Port</th>
<th>Using BGP</th>
<th>Using SDX</th>
</tr>
</thead>
<tbody>
<tr>
<td>dstport = 80</td>
<td>C1</td>
<td>?</td>
<td>match(dstport = 80) → fwd(C1)</td>
</tr>
</tbody>
</table>
We Can Do This at IXP-Scale

BGP Routes and Updates for DE-CIX in a Commodity Hardware Switch.
Better Visibility: In-Band Network Telemetry

- Network elements collect, report, modify state in-real time as data packets go through switch.

- **Writing state into packets**
  - (switch, in, out) tuples
  - Latency
  - Link Utilization

- **Dynamic counters** based on different hash buckets
- **Dynamic actions** based on (say) counter thresholds
  - Dynamic rule creation
  - Reactive probing
What is Possible

• In-band traceroute/topology discovery
• Per-hop latency/loss/utilization recording
• Active probing based on counter thresholds
• Dynamic redirection of traffic flows
• …
SDX Software Release

• Running code with full BGP integration

• Used in Coursera course
  (10s of thousands of students)

• Ongoing Deployment Efforts:
  – Inter-agency exchange (NSA)
  – Large IXP (DE-CIX)

http://sdx.cs.princeton.edu
Compared to SNMP

• Faster
• Less CPU Overhead
• In-band (exporting data, not polling)
• Can pre-filter
• Packet-level granularity
• Publish/subscribe