Towards Impactful Routing Research:
Running Your Own (Emulated) AS on the (Real) Internet

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CoNEXT Student Workshop
Santa Barbara, California, USA
December 2013
Recent Innovation in Networking
Focused Primarily on Intradomain Routing / SDN

Interdomain Routing
Limited Innovation, 20+ year old BGP protocol

Intradomain Routing
SDN, Enhanced IGP & Fabric Protocols
Recent Innovation in Networking

Islands of Innovation using BGP for communication

Islands of innovation interconnected with BGP
Border Gateway Protocol
Designed for a past era, BGP struggles to keep up

Interdomain Routing
Limited Innovation, 20+ year old BGP protocol

ISP #1 Router → ISP #2 Router → Border Gateway Protocol → ISP #3 Router

“Old”

Results in:
Inflated routes
Weak path selection
Security vulnerabilities
Lengthy convergence time
Failures related to route redistribution
QoS problems due to path oscillations
Network isolation instead of collaboration
Recent Innovation in Networking

*Islands of Innovation using BGP for communication*

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**Cannot replace BGP**

How can we transform it?

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*National ISP w/ MPLS, IS-IS routing*
Where are the interesting problems?
At the intersection of Inter and Intradomain Routing

Interdomain Routing
Limited Innovation, 20+ year old BGP protocol

Interactions = Interesting problems
Solving these problems can improve internet routing

Intradomain Routing
SDN, Enhanced IGP & Fabric Protocols
Anycast Experiment
Involves Both Intradoman and Interdomain Technologies

Example Experiment:
Intercontinental Anycast Network

Anycast requires:
1. BGP connectivity to advertise & exchange traffic
2. Intradomain routing to direct internal traffic

Want to understand how traffic flows given conditions
Experiment involves intradomain and interdomain routing
Wish List for Anycast Experiment:

1. Intercontinental private wide-area network (WAN) between US and EU
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Anycast Experiment Wishlist
Intradoman and Interdomain Technologies

Wish List for Anycast Experiment:

1. Intercontinental private wide-area network (WAN) between US and EU
2. Different routing domains in each datacenter (SDN & OSPF)
3. Ability to exchange *routes and traffic* via BGP with other peers
4. Rich peering connectivity with *REAL* providers in US and EU
Anycast Experiment
Experiment has substantial requirements and overhead

To conduct this experiment, you need to:

① Acquire ASN, IP space, equipment, colo, diverse connectivity
② Setup and maintain supporting infrastructure
③ Build control infrastructure to execute experiment(s)
Anycast Experiment

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Experiments often impossible given requirements
No testbeds support this experiment
Anycast Experiment
Using Testbeds to Lower Barriers

No testbeds support this experiment

However, we have pieces which bring us closer...
We’ll improve these pieces and then merge them to create a testbed for this Anycast experiment
Anycast Experiment
Intradomain and Interdomain Pieces of Experiment

Mininet Can Emulate
SDN components
Network topologies
Anycast Experiment
Intradoman and Interdomain Pieces of Experiment

Mininet *Can* Emulate
SDN components
Network topologies

Mininet *Cannot* Emulate
Inter & intra domain routing
Routing engines (Quagga)
Anycast Experiment

Intradomain and Interdomain Pieces of Experiment

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Transit Portal Provides
Network transit
BGP multiplexing
Connectivity with *real* ISPs
Mininet

Designed for Emulation of SDN Networks

```bash
> sudo mn
```

Emulates

- controllers
- switches
- hosts

Core vSwitch

Controller (NOX, Floodlight)

vSwitch

vSwitch

Host

Host
Mininet

Doesn’t Support Intra and Interdomain Routing

By default, cannot emulate:
- interdomain routing (BGP)
- intradomain routing (OSPF, RIP)
- routing engines (Quagga, BIRD)

> sudo mn

ISP #1 Router

ISP #2 Router

Not supported by Mininet

ISP #3 Router

Router

Router

Border Gateway Protocol

OSPF

OSPF

Border Gateway Protocol
Enhanced Mininet
Supports Intra and Interdomain Routing

> sudo mn

Enhanced Mininet Adds Support For:
- topologies with IGP + BGP support
- isolated routing engine instances (Quagga, BIRD) in Mininet
  requires significantly less resources than virtual machines
Anycast Experiment

Emulating Intradoman and Interdomain Pieces

Our Enhanced Mininet Can Emulate
SDN components
Intradomain routing
Network topologies
Routing engines (Quagga)

But We Cannot Emulate Interdomain Routing
Anycast Experiment

Why don’t we Emulate Peer ISPs / The Internet?

Peer ISP Level (3)

Cannot model / emulate peer ISP due to:
- Unpredictable routes
- Transient & persistent failures
- Impact of peering relationships
- Impact of neighboring networks
- Unknown policies, topologies, goals

Intradomain Emulated with Enhanced Mininet
Anycast Experiment
Using Transit Portal for Interdomain and Emulating Intradoman

Use Transit Portal instead of emulation
Transit Portal
BGP Multiplexing and Traffic Exchange Service

ASN: 47065  |  IP allocation: 184.164.224.0/19

BGP multiplexing provides private, isolated BGP sessions

6 points of presence across two continents

Connectivity to over 600 REAL ISPs via BGP

Infrastructure is constantly growing
Transit Portal
BGP Multiplexing and Traffic Exchange Service

Strengths of Transit Portal
Can send / receive routes and traffic via BGP
Connections to diverse set of REAL networks and ISPs
Exposure to unpredictable routes, policies and failures

Previous Use in Research [SIGCOMM 12’]
PoiRoot: Investigating the Root Cause of Interdomain Path Changes
LIFEGUARD: Practical Repair of Persistent Route Failures
Transit Portal
A Closer Look at the AMS-IX Multiplexer

Amsterdam Internet Exchange (AMS-IX)
600+ peer ISPs, 70,000+ prefixes, world’s largest IXP
Transit Portal
A Closer Look at the AMS-IX Multiplexer

Amsterdam Internet Exchange (AMS-IX)

BGP multiplexer

TP Mux AS47065

Microsoft
XO
HE.net
PCH

peer BGP Session

private, multiplexed BGP session

routing engine (Quagga)

AS64514
AS64515

private AS number
Transit Portal
A Closer Look at the AMS-IX Multiplexer

Amsterdam Internet Exchange (AMS-IX)

My experiment

Advisor’s experiment
Transit Portal
A Closer Look at the AMS-IX Multiplexer
Transit Portal
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Amsterdam Internet Exchange (AMS-IX)

routes & traffic can be exchanged via mux client controls inbound & outbound routes
Transit Portal
A Closer Look at the AMS-IX Multiplexer

Amsterdam Internet Exchange (AMS-IX)

AS81
HE.net

Microsoft

XO
AS952

PCH

TP Mux
AS47065

Announcement

announced routes received by multiplexer
transparently forwarded to private AS

Received Routes:
Prefixes
>77.78.39.0/24
77.78.39.0/24
AS-Path
952
81 952
Transit Portal
A Closer Look at the AMS-IX Multiplexer

Amsterdam Internet Exchange (AMS-IX)

AS81
HE.net

Microsoft

AS952

XO

PCH

TP Mux
AS47065

Network Traffic

traffic to
AS 65112

Received Routes:
Prefixes
>77.78.39.0/24
77.78.39.0/24

AS-Path
952
81 952

AS64514
Transit Portal
A Closer Look at the AMS-IX Multiplexer

Amsterdam Internet Exchange (AMS-IX)

Advertised Routes:
Prefixes 184.164.252.0/24
AS-Path 6432 94
Transit Portal
A Closer Look at the AMS-IX Multiplexer

Amsterdam Internet Exchange (AMS-IX)

Advertised Routes:
Prefixes: 184.164.252.0/24
AS-Path: 6432 94

creates loop, poisons upstream AS
Transit Portal
A Closer Look at the AMS-IX Multiplexer

Amsterdam Internet Exchange (AMS-IX)

multiplexer forwards routes to upstream peers

Advertised Routes:
Prefixes: 184.164.252.0/24
AS-Path: 6432 94

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Transit Portal
A Closer Look at the AMS-IX Multiplexer

Amsterdam Internet Exchange (AMS-IX)

Multiplexer forwards routes to upstream peers

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Prefixes: 184.164.252.0/24
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Transit Portal
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Amsterdam Internet Exchange (AMS-IX)

Multiplexer forwards routes to upstream peers

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Let’s build using Transit Portal + Enhanced Mininet
Anycast Experiment
Building with Transit Portal and Enhanced Mininet

Emulated w/ Enhanced Mininet

① Mininet container initialized with no topology
Anycast Experiment
Building with Transit Portal and Enhanced Mininet

Emulated w/ Enhanced Mininet

② Border routers & virtual WAN link with latency
Anycast Experiment
Building with Transit Portal and Enhanced Mininet

US SDN Datacenter

Emulated w/ Enhanced Mininet

EU OSPF Datacenter

Executed on single laptop

③ Internal routing domains created with Quagga
Anycast Experiment
Building with Transit Portal and Enhanced Mininet

Executed on single laptop

④ Transit Portal Mux connectivity established
Anycast Experiment
Building with Transit Portal and Enhanced Mininet

Emulated w/ Enhanced Mininet

⑤ Anycast announcements propagate
Anycast Experiment
Building with Transit Portal and Enhanced Mininet

Anycast Advertisement:
Prefix 4.16.22.0/24

Emulated with Enhanced Mininet

Anycast route originates from EU OSPF domain
Anycast Experiment
Building with Transit Portal and Enhanced Mininet

- Propogates to US border router
Anycast Experiment
Building with Transit Portal and Enhanced Mininet

Emulated w/ Enhanced Mininet

Anycast Advertisement:
Prefix 4.16.22.0/24

Executed on single laptop

Announcement

Propagates through Transit Portal Muxes
Anycast Experiment
Building with Transit Portal and Enhanced Mininet

Announcement:
Prefix 4.16.22.0/24
Executed on single laptop

Emulated w/ Enhanced Mininet

Propogates to peers at Georgia Tech and AMS-IX
Anycast Experiment
Building with Transit Portal and Enhanced Mininet

Traffic from REAL peers exchanged at 2 continents

Emulated w/ Enhanced Mininet

Anycast Advertisement:
Prefix 4.16.22.0/24

Executed on single laptop

Traffic Path

Ten: Traffic Flow for 4.16.22.0/24
Transit Portal and Enhanced Mininet Capabilities

1. Users can emulate complex ISP / AS topologies
   a. Comprehensive emulation of intra & inter-domain
   b. Isolated instances of routing engines (Quagga, BIRD)

2. BGP route and traffic exchange via Transit Portal
   a. Rich peering & BGP connectivity at multiple locations
   b. Exposure to real (unknown) internet policies and failures

3. Entire ISP can be emulated from a laptop
   a. Significantly reduced overhead, no VMs, easy config
Conclusion
Enabling Community’s Future Experiments

Intended to be a *Community Testbed*

- Wide-range of applicable experiments
- Enhancements to Mininet available on GitHub
- Access to Transit Portal available to researchers / operators

**Contact:** bschlink@usc.edu | http://nsl.cs.usc.edu

Looking to expand Transit Portal further

- More IXP locations (AMS-IX first Transit Portal IXP)
- Collaboration opportunities with other universities
- Vantage points within Tier-1 ISPs

```> sudo mn +
```