On the Prevalence and Characteristics of MPLS Deployments in the Open Internet

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The elephant in the room

- ISPs spend considerable effort managing traffic
- MPLS: one (big?) tool in the TE toolbox
  - How widely deployed? What are the characteristics of deployed tunnels?
  - Implications for Internet measurement?
  - RFC 4950 enables observation of some tunnels
Detecting MPLS

Pipe Mode (hidden to traceroute)

TTL in IP header

TTL in outermost protocol header

k hops inside the MPLS tunnel

(New TTL in MPLS header)

(IP TTL copied to MPLS header)

(TTL in MPLS header copied back to IP header)

Uniform Mode (visible to traceroute)
Example traceroute with MPLS

1 129.186.6.251  0.341
2 129.186.254.131  0.416
3 192.245.179.52  3.214
4  4.53.34.13  4.699
5  4.69.135.238  17.945
6  4.69.132.53  53.546
7  4.68.105.44  44.481
8 192.205.36.153  44.856
  9 12.122.146.174  74.801
      MPLS Label 16424 TTL=1 CoS=0x0
10 12.122.31.129  74.451
      MPLS Label 16354 TTL=1 CoS=0x0 | MPLS Label 22767 TTL=1 CoS=0x0
11 12.122.2.22  74.352
      MPLS Label 16354 TTL=1 CoS=0x0 | MPLS Label 23741 TTL=1 CoS=0x0
12 12.122.2.217  74.745
      MPLS Label 16761 TTL=1 CoS=0x0 | MPLS Label 11345 TTL=1 CoS=0x0
13 12.122.4.69  73.864
14 12.122.248.49  73.934
15 199.37.170.202  73.775

Full MPLS stack included in ICMP
time exceeded response
(scamper and paris-traceroute show
MPLS response)

Round-trip times are similar for
each LSR in the tunnel: suggests
basis for inferring the presence of
tunnels
Objectives

• Understand extent and characteristics of (visible) MPLS deployments
  • How many ASes employ MPLS? Which ones? What are the characteristics of deployed tunnels?
  • How have MPLS deployments changed over time?
  • Can we infer the presence of uniform-mode MPLS tunnels even if we can’t positively identify them using ICMP?
• Little existing empirical work that examines MPLS deployments across the internet
Data analyzed

- 3 years of CAIDA Archipelago data: June 2008-August 2011
- Ark “team” collaborates to probe all routable /24’s
- Starting in May, 2008, measurements include ICMP extension data
- Used first full set of data for each month => more than 250M traceroute measurements analyzed
- Additionally used CAIDA IPv4 prefix to AS mapping data and UCLA Cyclops data to classify AS by ISP type
Results summary

- About 7% of ISPs are observed to employ MPLS
  - Basically all tier-1 providers and half of large ISPs
  - About 25% of end-to-end paths in Ark cross at least 1 tunnel
  - Number of tunnels over time has varied widely
  - Tunnel length distribution is skewed; most are short, but some are very long
  - Stacking and CoS field usage suggests a variety of TE practices
MPLS prevalence

About 7% of all ISPs use (uniform mode) MPLS
Number of observed tunnels over time

Number of tunnels rebounding from low in mid 2009
## Top ASes using MPLS

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<td>10318 Cablevision SA</td>
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</table>
Tunnel lengths

Tunnels have grown slightly longer over the past three years
Stacking and classes of service

Stacking suggests fast failover engineering, among other possibilities

Use of CoS field varies widely across ISPs
Likelihood of encountering MPLS on a path

About 25% of paths between Ark hosts cross at least 1 tunnel
Inference intuition

Given distributions of pair-wise latency and IP subnet, we may be able to discriminate between MPLS and non-MPLS pairs of interfaces.

Distributions produced using 5% of April 2011 data
Inference formulation

Combining both observed characteristics of latency and IP subnet, we devised a Naïve Bayesian classifier to determine the probability of an interface existing in an MPLS tunnel.

\[
\log \hat{P}(\text{MPLS}_i) = \sum_{k=-K}^{K} \log \hat{P}_{\text{lat}}(\ell_{i,i+k} | \text{MPLS}) + \sum_{k=-K}^{K} \log \hat{P}_{\text{IP}}(s_{i,i+k} | \text{MPLS})
\]

Log-probability interface \( i \) is in an MPLS tunnel

Probability of MPLS given observed latency

Probability of MPLS given observed IP subnet

Iterate over \( K \) consecutive interfaces found in traces with \( i \).
Inference results

Interface classification

Path classification

Data from April 2011; training on 5%, testing on 95%
Summary & ongoing work

- Uniform-mode MPLS tunnels are widely deployed
- Clear impact on traceroute delay measurements
- Unclear by how much we underestimate deployments; can we do better?
- Probe based study of traffic engineering: how do CoS bits relate to observable performance characteristics?
- Can inference method be applied to larger corpus of historical data (e.g., Skitter)?
Additional slides
More on tunnel lengths

After shrinkage in 08, tunnel lengths have remained stable
Number of tunnels over time, specific ASes

![Graph showing the number of observed MPLS tunnels over time for specific ASes. The graph includes lines for AboveNet (6461), Cable & Wireless (1273), Chinanet (4134), Deutsche Telekom (3320), and AT&T (7018). The x-axis represents dates from 01/2009 to 01/2011, and the y-axis represents the number of observed MPLS tunnels.]
Number of tunnels per AS

![Graph showing the distribution of MPLS tunnels per AS]

- 07-2008
- 01-2009
- 07-2009
- 01-2010
- 07-2010
- 01-2011

Number of MPLS tunnels per AS

Probability P(X ≤ x)
Average tunnel lengths, specific ASes
Tunnel length distributions (hops)
Tunnel length distributions (milliseconds)
Fraction of tunnels employing different stack depths
Additional tunnel inference results

- Good accuracy, especially if trained on temporally close data

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<td>8.1%</td>
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<td>3.1%</td>
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