LFA (Loop-Free Alternates) Case Studies in Verizon's MPLS Network

Ning So, Verizon Inc., ning.so@verizonbusiness.com
Fengman Xu, Verizon Inc., fengman.xu@verizonbusiness.com
Connie Chen, WANDL Inc., connie@wandl.com
Tony Lin, WANDL Inc., thl@wandl.com

www.mpls2010.com

Outline

- About Verizon and WANDL
- Verizon MPLS Network
- LFA Motivation for Verizon's MPLS Network
- LFA Modeling Requirements
- Coverage Case Studies and Observations
- Coverage Enhancement Study
- Conclusion

About Verizon

- Verizon is the leading communications solutions provider for global businesses, government agencies, and educational institutions
  - Data and IP services
  - Security
  - IT solutions
  - Managed networks
  - Premises equipment
  - Contact centers
  - Conferencing
  - Voice

About WANDL

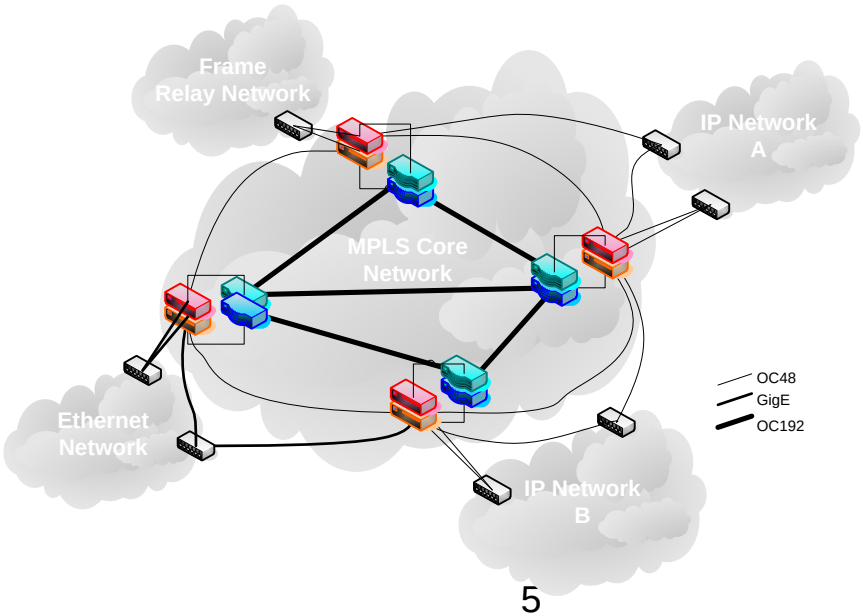
- WANDL is the leading supplier of software solutions for advanced network planning, management, design, and optimization
- 25 years expertise in software development for network optimization, planning, design, OSS/automation
- Work with Cisco, Juniper, Huawei, ALU, Tellabs, etc.
- Manage technologies including IP, MPLS, VoIP, Transport (SONET/SDH), FR/ATM, TDM
- Customers include carriers, ISPs, telcos, PTTs, service providers, enterprise, and government organizations

Verizon MPLS Network

Verizon's Global Private IP Network

- MPLS (LDP) based L2 and L3 VPN network
- 100% traffic re-route during any hardware or transmission facility failure
- Provide the minimal latency routes available between any two network elements

Data Network Diagram



LFA Motivation for Verizon MPLS Network

- Drivers
  - LDP Fast ReRoute (FRR) for < 50 ms local repair
  - Easy to provision and deploy
  - RSVP LSP scaling and inter-area interworking issues limits its deployment to Area 0
- Keep RSVP-TE LSP and FRR in core and run LFA at LDP edge

LFA Modeling Requirements

- LFA modeling requirements
  - Need to measure LFA coverage under extensive failure scenarios for large networks and complex topologies
  - Identify locations where coverage is insufficient or lacking, since current LFA solution cannot provide 100% coverage
  - Model and measure coverage enhancement techniques
- Simple LFA Coverage definition
  - LFA_RR = number of links configured for LFA protection
  - LFA_Fail = number of links within the LFA_RR set that are not LFA protected (if any demand fails to reroute) under any failure scenario
  - Coverage% = (1 – LFA_Fail / LFA_RR) x 100

Network Planning and LFA Modeling Requirements

- LFA modeling and simulation approach
  - Mark links and nodes to consider for LFA protection (the LDP part of the network)
  - Create flows amongst sources and sinks of traffic in the network (e.g. amongst PEs)
  - Perform LFA next hop computations while checking loop-free conditions (per RFC 5286) for various failure scenarios (e.g. exhaustive link and exhaustive node failure)
  - Record failure and reroute statistics

Coverage Case Studies and Observations

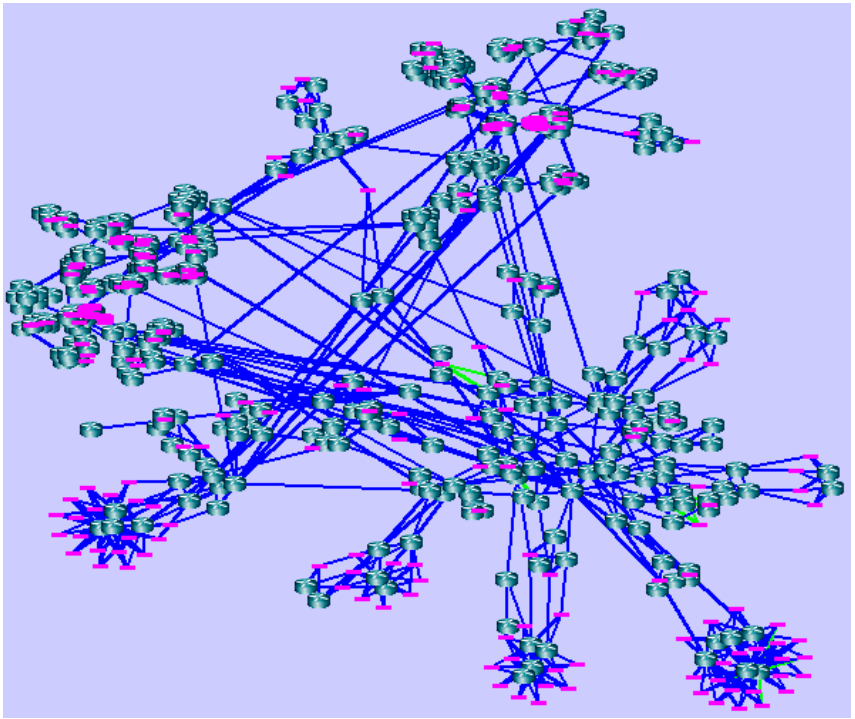
- Verizon MPLS network coverage study
  - Keep RSVP-TE LSP and FRR in core and run LFA at LDP edge
  - Routers “five nines” reliability vs. line cards “three nines” reliability, so focus on link coverage studies
  - Focus on per-link LFA rather than per-prefix LFA
- Coverage study result
  - LFA Link Coverage ~60% for exhaustive link failure simulation study
  - How can LFA coverage be improved further?

Coverage Case Studies for Various Networks

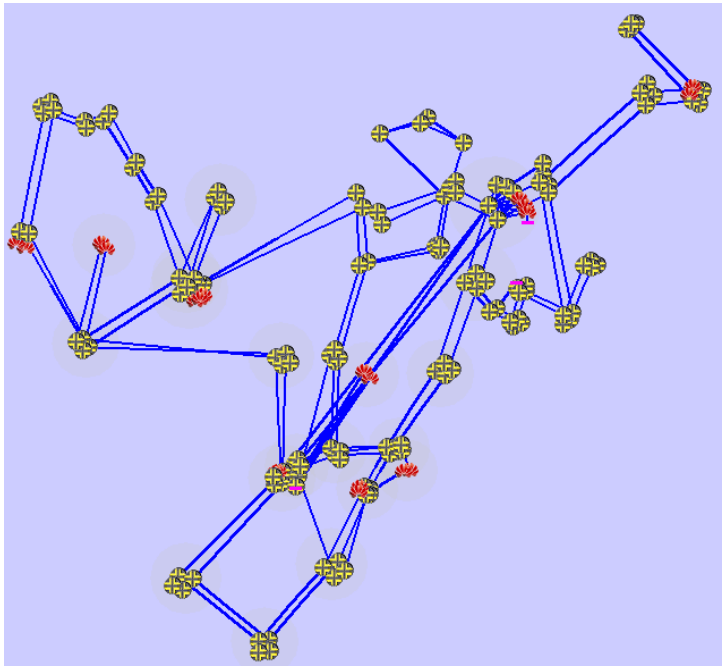
Topology	#links/#nodes	Per-link LFA Coverage	Per-prefix LFA Coverage
T1	4.2	49%	73%
T2	2.1	22%	73%
T3	6.5	51%	68%
T4	3.0	36%	70%
T5	5.7	45%	69%
T6	1.7	42%	72%
T7	2.5	56%	90%

- Coverage studies performed for various carriers and service providers.
- Topologies varied in terms of link-to-node ratio, protocols (RSVP-TE FRR in inner core and LDP in outer core), flat and hierarchical topologies.
- Per-prefix LFA coverage also computed and included for comparison.

Topologies for Various Coverage Studies

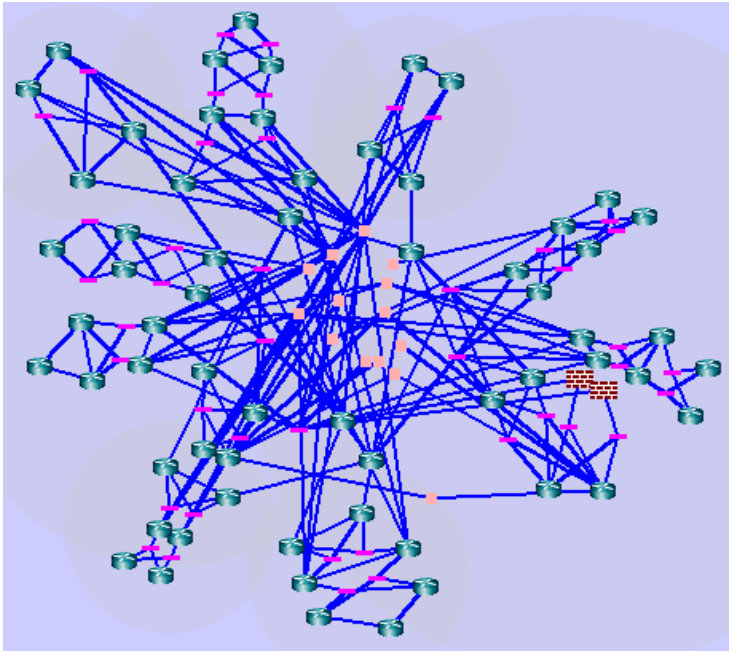


Network T1
49% coverage

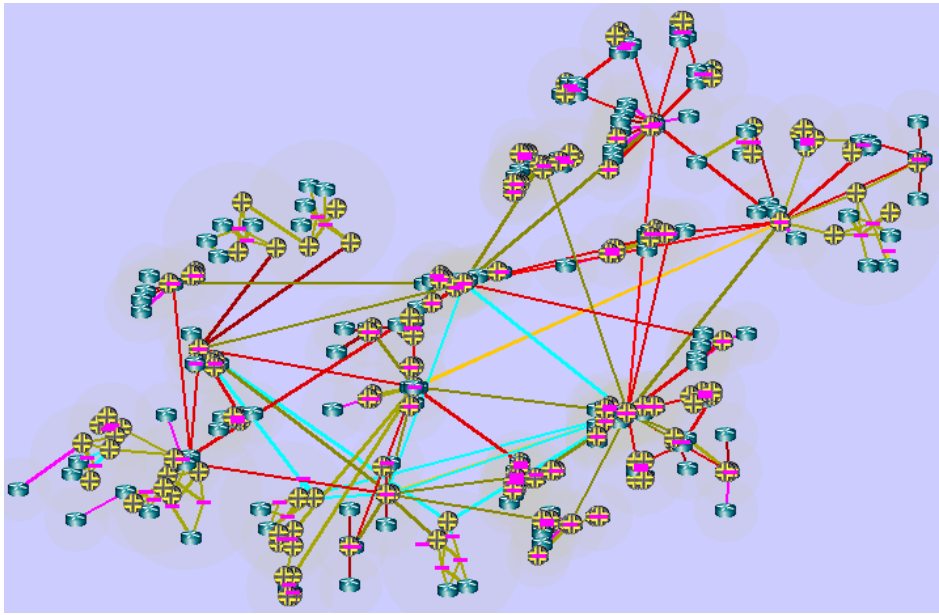


Network T2
22% coverage

Topologies for Various Coverage Studies

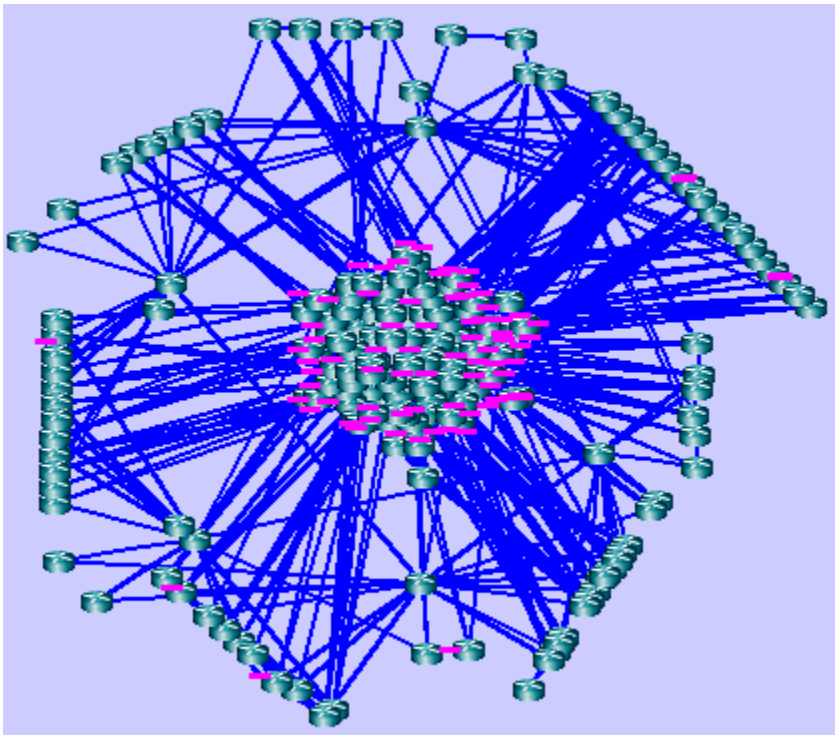


Network T3
51% Coverage

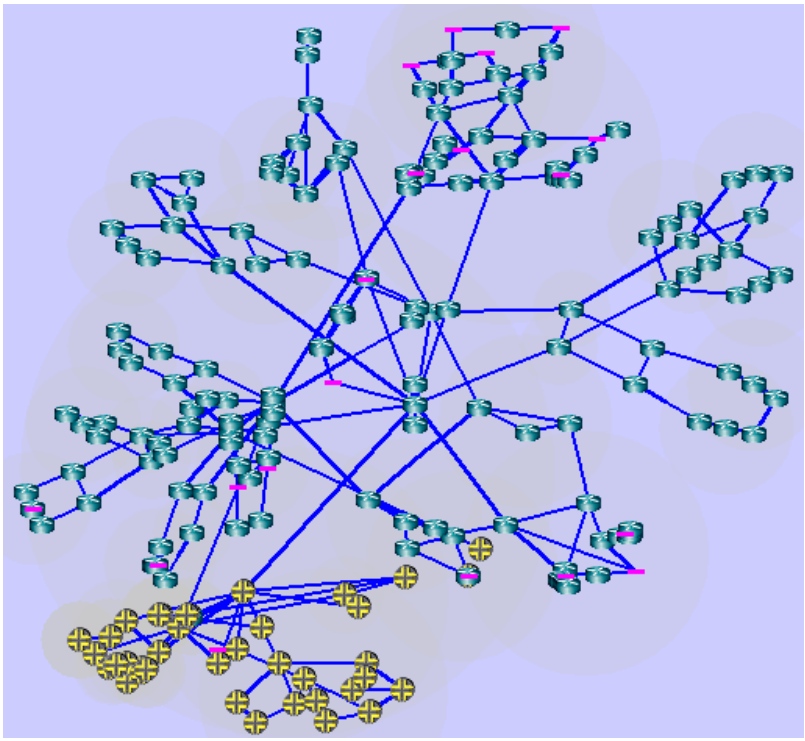


Network T4
36% Coverage

Topologies for Various Coverage Studies

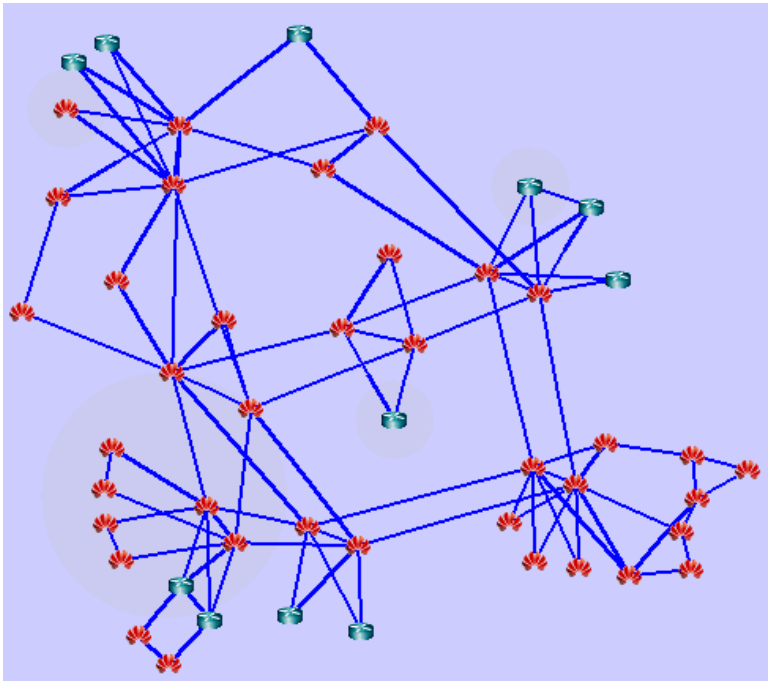


Network T5
45% Coverage



Network T6
42% Coverage

Topologies for Various Coverage Studies

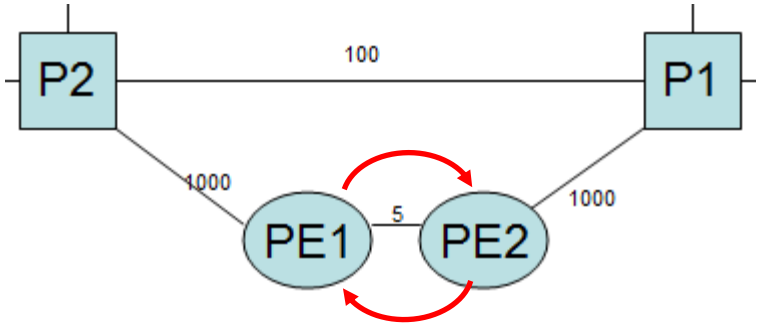


Network T7

56% Coverage

Improving Coverage

- Verizon MPLS network coverage enhancement study
  - For places where coverage is lacking or low, identify topology patterns needing coverage enhancement



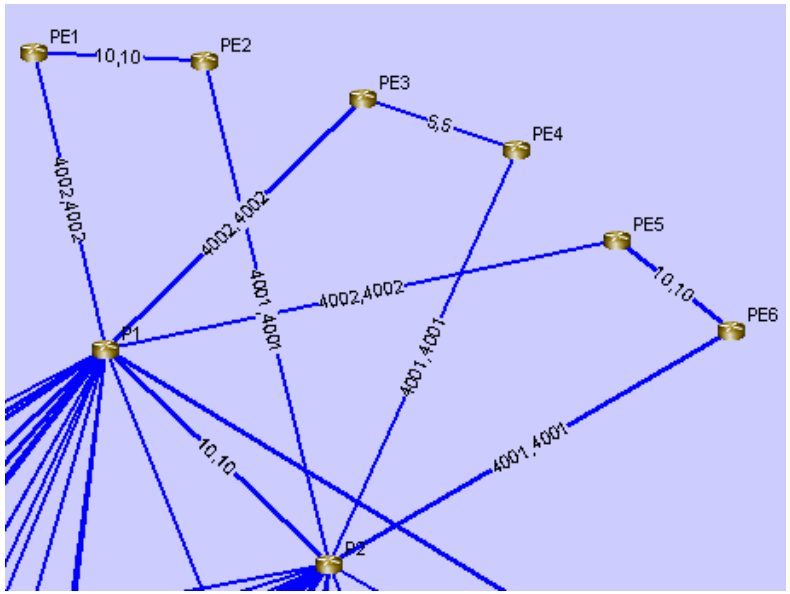
Common topology in SP networks: PEs not individually dual-homed to reduce cost

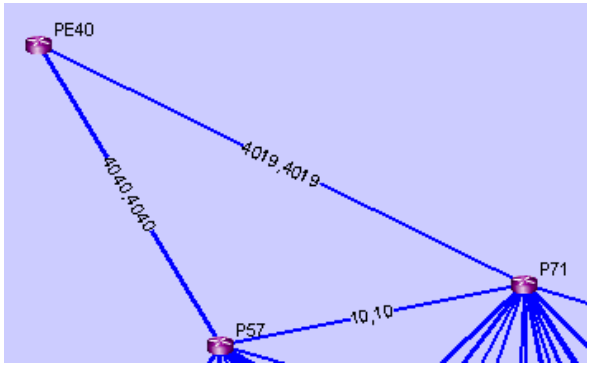
Example topology pattern identified:

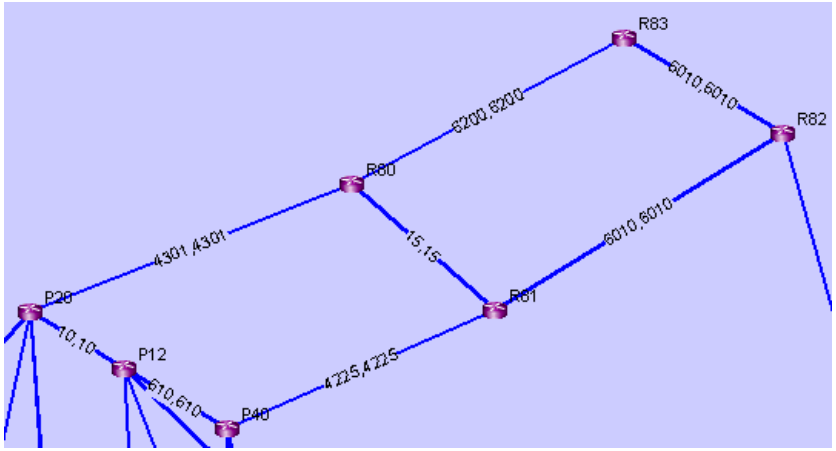
- PE1 and PE2 are connected in same site. P1 and P2 can be geographically spread out (inter-site).
- Low metric is set between PE1 and PE2 to ensure lowest latency from/to other remote PEs.
- when failure occurs on link between P2 and PE1 or on link between P1 and PE2, micro-loop occurs between PE1 and PE2.

Improving Coverage

- Few example topology patterns that can benefit from coverage extension

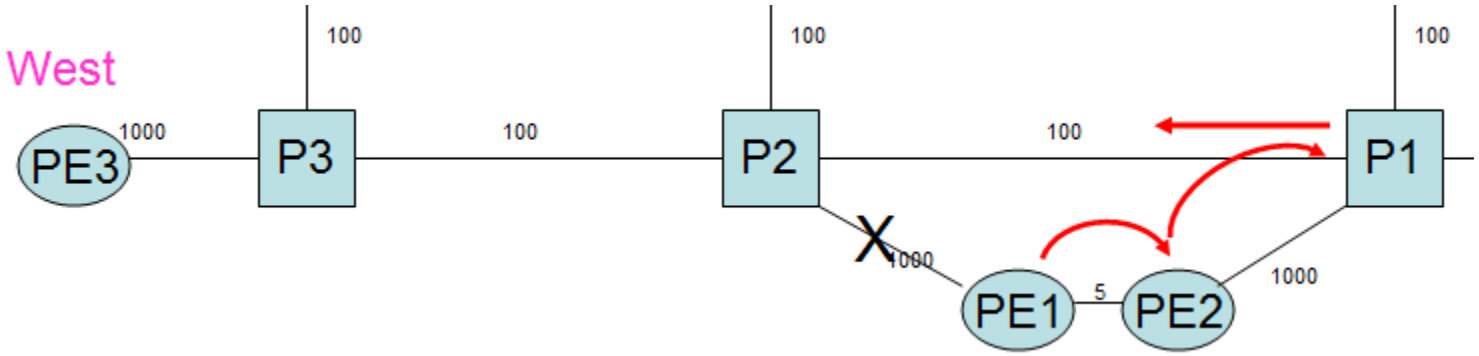






Improving Coverage

- Verizon proposes coverage extension method



- Suppose traffic flows west to PE3 and link between P2 and PE1 fails.
- Then PE2 can break the micro-loop if traffic is forwarded instead to a next-next-hop P1.
- This can be achieved by using two outer LDP labels. The outer label targets P1 to "cheat" PE2; the inner label is for the real destination PE3 from P1.
- In order to let PE1 learn the second label from PE2 that P1 uses to reach PE3, a very simple label learning protocol between PE1 and PE2 can be created.

Improving Coverage

- Verizon proposes coverage extension method
  - Simple label learning protocol (NNHL) enhancement to LDP can be created
  - Remote LDP Session can also be utilized for label learning and exchange
  - Alternative to using RSVP tunnel to extend coverage since support for both RSVP-TE and LFA on the same box/interface found challenging by certain vendors
- Coverage extension method proposed by Verizon modeled and simulated (exhaustive link failure)
  - Regular LFA coverage measured ~60% coverage
  - LFA with Coverage Extension gives ~99% coverage

Conclusion

- LFA coverage can vary a lot depending on the provider backbone topology
- LFA complementary to RSVP-TE FRR, where highly-deterministic protection or advanced TE features desired
- Coverage statistics reporting and coverage extension mechanism are both important for wide-spread LFA adoption
  - Interesting to see upcoming automatic coverage extension methods by router vendors

Thank you for attending