DEMYSTIFYING IPV6 OVER MPLS
TACKLING THE CHALLENGE OF CONNECTING IPV6 ISLANDS

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HOW THIS SESSION IS STRUCTURED?

• We will cover
  • Basics of IPv6 and MPLS (101 with some oversimplification)
  • Need to IPv6 in modern networks
  • Current migration solutions
  • Outside the box thinking
  • Real world scenario
THE “OUT OF THE BOX” THING?

• **Our big issue as an industry; a bit off topic**

• Let’s look at some common themes:

  • The curios case of vulnerability scanning
    • New CISO or Security manager: Security strategy vs vulnerability scanning

    • ICS (Industrial Control Systems), SCADA/PLC scanning (Future NANOG?)
      • IoT scanning and even more scanning!

  • The curios case of IPv6 dual stacking and tunneling – Show of hands!
THIS SESSION…

• Adds yet another tool to your toolbox
  • Maybe an unusual one
LET’S FORGET ABOUT THE IP WORLD

- How many of you have travelled to more than 40 countries?
- How many of you have ever had issues overseas with non-local ID’s?
  - Driving on a non-local ID….
LET'S FORGET ABOUT THE IP WORLD

• The imaginary trip:
  • Your document is in English
  • No one understands English even a bit
  • You are passing through
LET’S FORGET ABOUT THE IP WORLD

• Can you think of a (semi-) common language?

  Perhaps numbers? attached to your actual ID.
HOW ABOUT THE IP WORLD?

• Applying the same concept:
  • The layer 2 and layer 3 headers are sometimes non-sense to the middle network
  • Can we still use numbers? And forget about the headers…
WHAT TO CALL IT?

• Let's pick a name for it…

• Multi Protocol Label Switching (MPLS)
  • Provides that common language for passing through foreign territories
  • “Staples” numbers (aka labels) to each packet passing through
  • The labels provide a means understandable throughout the new territory
  • Even you can change your path throughout the foreign territory without speaking their language
LET’S TAKE A CLOSER LOOK: HTTP

- Header of a HTTP packet in IPv6 going from 2006::6 to 2001::200

```
Frame 65:  82 bytes on wire (656 bits), 82 bytes captured (656 bits) on interface 0
Ethernet II, Src: ca:03:0b:f8:00:08 (ca:03:0b:f8:00:08), Dst: ca:02:00:08:00:1c (ca:02:00:08:00:1c)
MultiProtocol Label Switching Header, Label: 17, Exp: 6, S: 0, TTL: 253
MultiProtocol Label Switching Header, Label: 25, Exp: 6, S: 1, TTL: 255
Internet Protocol Version 6, Src: 2006::6, Dst: 2001::200
Transmission Control Protocol, Src Port: 80, Dst Port: 60121, Seq: 1, Ack: 11, Len: 0
```
ENOUGH FOR NOW…

• But, “I owe you”, a lot more on the topic.
NOW BACK TO NANOG 76

- **Where We Are At:** Companies already have an IPv4 network including LAN and WAN
- **The Challenge:** Now they are facing a growing need to connect IPv6 islands
- **The Option:** MPLS can help you without adding IPv6 to your IPv4 stable network (at least for years)
HANG ON...FIRST A BIT ON IPv6

- IPv6 Primer – Who doesn’t know?!
  - 128-bit address space instead of 32-bit in IPv6
  - 16-17 billion times larger than the IPv4 address space
  - IPv6 Internet is fully functional; ~69,000 IPv6 address globally
  - Most networking features are available across multiple vendors
    - BGP, ISIS, OSPF, RIP, EIGRP, QoS, Multicast (BSR, SSM) and more
IP VERSION 6 PRIMER

- So why don’t we all do IPv6 everywhere and call it a day?
  - Availability and stability concerns….bugs?
  - Security concerns
  - Fairly steep learning curve when rolled out globally
  - Systems and applications engineering are (still) lagging behind networking
    - AAA - Just one example
    - Hard coded applications and the list goes on
- **Complicated migration strategies (see next slide)**
IPV6 MIGRATION STRATEGIES

• Dual stack
  • Run both IPv4 and IPv6 on the same device
  • Still very invasive: stability, learning and troubleshooting
  • Umm, it’s not really a “migration” strategy

• Tunneling
  • Many techniques have come and gone
  • Vendor support issues
  • Our experience with vendors
WHERE DO WE SEE THE IPV6 DEMAND?

• A bit on Qualcomm
  • Founded in 1985
  • Leader in 5G, IoT and various SoC’s
    • 40+ major acquisitions, 10s of locations worldwide with up to 100Gbps WAN connections
    • Security through segmentation
  • Hundreds of labs supporting thousands of hardware design and Q/A engineers
• IPv6 is an integral part
• Not much on the corporate-side of the house YET
ALL IN ALL...

• The demand is real...
  • 1500+ open positions on LinkedIn...
DOWN TO THE BUSINESS

IPv4 packet
Typical Layer 2
Typical Layer 3 (IP v4 src/dst)
ICMP

Frame 14: 114 bytes on wire (912 bits), 114 bytes captured (912 bits) on interface 0
Ethernet II, Src: ca:01:2f:14:00:08 (ca:01:2f:14:00:08), Dst: ca:00:10:94:00:08 (ca:00:10:94:00:08)
Internet Protocol Version 4, Src: 6.6.6.6, Dst: 12.0.0.1
Internet Control Message Protocol
THE HAPPY IPV4 WORLD

2000 IPv4 routes all over the network

OSPFv2 or ISIS Single Area/Level

- Frame 14: 114 bytes on wire (912 bits), 114 bytes captured (912 bits) on interface 0
- Ethernet II, Src: ca:01:2f:14:00:08 (ca:01:2f:14:00:08), Dst: ca:00:10:94:00:08 (ca:00:10:94:00:08)
- Internet Protocol Version 4, Src: 6.6.6.6, Dst: 12.0.0.1
- Internet Control Message Protocol
THE HAPPY IPV4 WORLD

2000 IPv4 routes all over the network

OSPF or ISIS Single Area/Level

IPv4 Packet

R1 R2 R3 R4 R5 R6
THE HAPPY IPV4 WORLD

2000 IPv4 routes all over the network

OSPF or ISIS Single Area/Level

IPv4 Packet
THE HAPPY IPV4 WORLD

2000 IPv4 routes all over the network

IPv4 Packet
OSPF or ISIS Single Area/Level
THE HAPPY IPV4 WORLD

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OSPF or ISIS Single Area/Level

IPv4 Packet
THE HAPPY IPV4 WORLD

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THE HAPPY IPV4 WORLD

2000 IPv4 routes all over the network

OSPF or ISIS Single Area/Level

IPv4 Packet
THE HAPPY IPV4 WORLD

2000 IPv4 routes all over the network

R1 R2 R3 R4 R5 R6

OSPF or ISIS Single Area/Level

IPv4 Packet

DONE
THE SAME STORY BUT AN IPV6 PACKET

IPv6 packet
Typical Layer 2
Typical Layer 3 (IP v6 src/dst)
ICMPv6

Frame 394: 114 bytes on wire (912 bits), 114 bytes captured (912 bits) on interface 0
Ethernet II, Src: ca:01:2f:14:00:08 (ca:01:2f:14:00:08), Dst: ca:00:10:94:00:08 (ca:00:10:94:00:08)
Internet Protocol Version 6, Src: 2002::2, Dst: 2002::1
Internet Control Message Protocol v6
THE IPV4 NETWORK WITH IPV6 ISLANDS

IPv4 ONLY Core

R1  R2  R3  R4  R5  R6

2000 IPv6 Routes

OSPFv2 or ISIS Single Area/Level

2000 IPv6 Routes
THE IPV4 NETWORK WITH IPV6 ISLANDS

IPv4 ONLY Core

OSPFv2 or ISIS Single Area/Level

IPv4/v6 DUAL STACK
THE IPV4 NETWORK WITH IPV6 ISLANDS

2000 IPv6 Routes

R1 R2 R3 R4 R5 R6

IPv4 ONLY Core

2000 IPv6 Routes

OSPFv2 or ISIS Single Area/Level

- Frame 394: 114 bytes on wire (912 bits), 114 bytes captured (912 bits) on interface 0
- Ethernet II, Src: ca:01:2f:14:00:08 (ca:01:2f:14:00:08), Dst: ca:00:10:94:00:08 (ca:00:10:94:00:08)
- Internet Protocol Version 6, Src: 2002::2, Dst: 2002::1
- Internet Control Message Protocol v6
THE IPV4 NETWORK WITH IPV6 ISLANDS

2000 IPv6 Routes

R1  R2  R3  R4  R5  R6

IPv6 Packet

OSPFv2 or ISIS Single Area/Level IPv4 Core

2000 IPv6 Routes
THE IPV4 NETWORK WITH IPV6 ISLANDS

2000 IPv6 Routes

IPv6 Packet

No Route

R1

R2

R3

R4

R5

R6

OSPFv2 or ISIS Single Area/Level IPv4 Core

2000 IPv6 Routes
THE IPV4 NETWORK WITH IPV6 ISLANDS

2000 IPv6 Routes

No Route

IPv6 Packet

R1 R2 R3 R4 R5 R6

OSPFv2 or ISIS Single Area/Level IPv4 Core

IDEAS?
THE IPV4 NETWORK WITH IPV6 ISLANDS

OSPFv2 or ISIS Single Area/Level
IPv4 Core

A TUNNEL MAYBE?
LET'S TUNNEL

2000 IPv6 Routes

R1 R2 R3 R4 R5 R6

IPv6 Packet

OSPFv2 or ISIS Single Area/Level
IPv4 Core

Cross vendor issues
Still evolving but…
LET’S TUNNEL

2000 IPv6 Routes

R1 R2 R3 R4 R5 R6

IPv6 Packet

OSPFv2 or ISIS Single Area/Level IPv4 Core

2000 IPv6 Routes

Scalability issues as you grow
FOR NOW…

- Your temporary proposal to the CIO, surgical change.
- Just get them off your back
- Day 1 ideas develop with or without you

In a year or two we will come up with better ideas. For now this will fix it for the two labs or sites. Off my back.
BUT THEY USUALLY DO NOT STOP…
THEY ACTUALLY “GROW” OR COOK
TUNNELS ACTUALLY “COOK”  NOT GROW
BUT WE ARE SMART AND...

• Won’t let that happen
• So after fixing it temporary for 6 months.....
• Now we have a plan so we’re upgrading everything to dual stack
IPv4 and IPv6 Everywhere!
GREAT BUT…

• For most features now you need to activate the IPv6 equivalent of them
  • Which means:
    • You have 50 routers in the core (pretty small scale)
    • Now you need the IPv6 version of them on 50 new routers
      • Automation is your friend!
    • Does your vendor support them for your code? Multicast maybe?
OH YEAH ALL DAY LONG...

• Just got off the phone with both vendors and they have the IPv6 equivalent of everything
NOW…

“Welcome to the first day of the rest of your life” – Negan.
CAN’T BE **THAT** BAD…

- To what extent?
- New features sometimes mean new codes (scrub it?)
- IPv6 features in many vendors are not “beaten up”
- Does your hardware support them?
- New codes means more maintenance windows
- New features (or even hardware) means new bugs
- Stability in the core?
CAN’T BE THAT BAD…

• New bugs perhaps new security issues in the core?
• How about core automation and monitoring?
• The learning curve…times the number of vendors!
A LITTLE BEYOND OUR SCOPE

- Routing instability
- Systems readiness (usually beyond your control)
- Unpredicted behavior
SHOW ME THE REQUIREMENTS

• Okay, it’s complicated. But show me the requirements.
THE BEST OF BOTH WORLD?

• Want to have to end IPv6 reachability
• Something point to multi-point without having the “Spaghetti effect”
• Do not want to introduce a lot of new features to the core (remember Negan?)
• Do not want downtime in the core (code upgrades etc.)
• Want something that’s proven and tested across multiple vendors for years at scale
THE BEST OF BOTH WORLD?

• Want something that the largest operators in the world beat up in “in the core”
• Would be nice to have some steering control over my traffic later
• Keep the v6 in my enclaves for now
• Do not want to add anything major to monitoring, Ops and automation burden
• Perhaps not a steep learning curve
THE BEST OF BOTH WORLD?

IDEALLY:

• Quick expansion and scalable
  • Might end up with 1000’s of IPv6 routes
  • Can I keep them out of the core?

• Some bonus points too maybe?
  • Future VLAN/L2 extension
  • Support VRF’s as well (a V-R-F or a Vurf!)
  • Very low convergence time (maybe 50-100ms?)
WHAT DID THE TUNNEL DO FOR YOU?

By carrying “something” that was understandable by the core
REMEMBER OUR ANALOGY?

• Maybe that **something** can be a number (a label?)
LET’S TAKE A CLOSER LOOK

Layer 2 Header
MPLS header(s)
Layer 3 Header (IPv6)
Payload

MPLS Label (20 bits)
EXP
BOS
TTL

- Frame 65: 82 bytes on wire (656 bits), 82 bytes captured (656 bits) on interface 0
- Ethernet II, Src: ca:03:00:00:00:08 (ca:03:00:00:00:08), Dst: ca:02:00:00:00:1c (ca:02:00:00:00:1c)
- MultiProtocol Label Switching Header, Label: 17, Exp: 6, S: 0, TTL: 253
- MultiProtocol Label Switching Header, Label: 25, Exp: 6, S: 1, TTL: 255
- Internet Protocol Version 6, Src: 2006::6, Dst: 2001::200
LET’S TAKE A CLOSER LOOK

- Header of a HTTP packet in IPv6
- Going from 2006::6 (www server) to 2001::200 (client)

```plaintext
Frame 65: 82 bytes on wire (656 bits), 82 bytes captured (656 bits) on interface 0
Ethernet II, Src: ca:03:0b:f8:00:08 (ca:03:0b:f8:00:08), Dst: ca:02:00:08:00:1c (ca:02:00:08:00:1c)
MultiProtocol Label Switching Header, Label: 17, Exp: 6, S: 0, TTL: 253
MultiProtocol Label Switching Header, Label: 25, Exp: 6, S: 1, TTL: 255
Internet Protocol Version 6, Src: 2006::6, Dst: 2001::200
Transmission Control Protocol, Src Port: 80, Dst Port: 60121, Seq: 1, Ack: 11, Len: 0
```
A BIT OF MPLS INTERNALS

- Each router assigns labels to its reachable destinations (for the most part)
- And tells its neighbors about his assignment

My loopback is 1.1.1.1 and it’s advertised in OSPF
A BIT OF MPLS INTERNALS

- Each router assigns labels to its reachable destinations
- And tells its neighbors about his assignment

My loopback is 1.1.1.1 and it’s advertised in OSPF

We are all running OSPF and I heard of 1.1.1.1
A BIT OF MPLS INTERNALS

My loopback is 1.1.1.1 and it’s advertised in OSPF

I am going to call “1.1.1.1” 2008
And tell my neighbors about my decision
A BIT OF MPLS INTERNALS

My loopback is 1.1.1.1 and it's advertised in OSPF

Righty! Label any packets destined to 1.1.1.1 as 2008 when sending them to me
A BIT OF MPLS INTERNALS

My loopback is 1.1.1.1 and it’s advertised in OSPF

Lefty! Label any packets destined to 1.1.1.1 as 2008 when sending them to me
A BIT OF MPLS INTERNALS

Everybody else does the same. So every router knows about their label assignments of their neighbors. So they label packets accordingly when sending packets to them.

LDP (Label Distribution Protocol) is one way of doing it
My loopback is 1.1.1.1 and it's advertised in OSPF

IP packet destined for 1.1.1.1

MPLS label

Loop0: 1.1.1.1/32
A BIT OF MPLS INTERNALS

My loopback is 1.1.1.1 and it’s advertised in OSPF

# MPLS label

Loop0: 1.1.1.1/32

We PUSH the label

230

IP Packet
A BIT OF MPLS INTERNALS

My loopback is 1.1.1.1 and it's advertised in OSPF

Loop0: 1.1.1.1/32

We SWAP the label

MPLS label

#
My loopback is 1.1.1.1 and it's advertised in OSPF.

Loop0: 1.1.1.1/32

We SWAP the label 2008

Remember? It wanted me to label the 1.1.1.1 bound stuff as "2008".
A BIT OF MPLS INTERNALS

My loopback is 1.1.1.1 and it’s advertised in OSPF

Loop0: 1.1.1.1/32

# MPLS label

We SWAP the label

3034

IP Packet
A BIT OF MPLS INTERNALS

My loopback is 1.1.1.1 and it's advertised in OSPF

Loop0: 1.1.1.1/32

MPLS label

1358

IPv4 Packet

We SWAP the label
My loopback is 1.1.1.1 and it's advertised in OSPF

Loop0: 1.1.1.1/32

We SWAP the label

IPv4 Packet

547

MPLS label

#
A BIT OF MPLS INTERNALS

IPv4 Packet

We POP the label

LSP

Loop0: 1.1.1.1/32
A BIT OF MPLS INTERNALS

IPv4 Packet

Loop0: 1.1.1.1/32

LSP

DONE
A BIT OF MPLS INTERNALS

- It does sound like a tunnel but it's technically an LSP.
  - LSP: label-Switched Path
  - LSP's are one way

IPv4 Packet

Loop0: 1.1.1.1/32

LSP
IPv4 Packet

Loop0: 1.1.1.1/32

Wasn’t it cool?

We didn’t look at the IP header and payload. It could have been anything: IPv4 packet, IPv6 packet, even bunch of beans, nails, coins etc.

All we cared about, looked at and processed were the labels
WHAT TO CALL IT?

- The label operations
  - PUSH
  - SWAP
  - POP
Sample MPLS National Backbone

MCO: PUSH
ATL: SWAP
ORD: SWAP
MCI: SWAP
DEN: SWAP
PHX: POP
LAX: Receive
CHECK POINT

- Any questions on why we might need MPLS?
- We know we have a problem and a potential solution
ALL IN ALL

• Each router assigns labels to its reachable destinations
• Going by the passport example we care about sources and destinations
• Sources and destinations are usually edge (aka PE devices)
• Such addresses are usually loopbacks advertised in IGP
LET’S INTRODUCE MPLS

• Seems like MPLS can solve our problem(s) here
Let’s Introduce MPLS

- Simple configuration to get the basic feature started
- Interface-level config for the labeling to work in regular IOS
- You can always tweak it a lot more including LDP settings

Cisco IOS snippet:

```bash
Rtr(config-if)#int g0/0
Rtr(config-if)#mpls ip
```
MPLS SET-UP

LDP will distribute labels

OSPfv2 or ISIS Single Area/Level IPv4 Core

So all the routers along the path will soon tell their neighbors:
**What they call the loopback addresses of R1 and R2**
aka: The source and destination
THINGS LOOK GOOD...ALMOST

2000 IPv6 Routes

R1 -- R2 -- R3 -- R4 -- R5 -- R6

MPLS-enabled Core

OSPFv2 or ISIS Single Area/Level IPv4 Core

25 IPv6 Routes

145 IPv6 Routes
THINGS LOOK GOOD...ALMOST

MPLS-enabled Core

OSPFv2 or ISIS Single Area/Level

Traffic Flow (HTTP, SSH etc. Packets)
THE IPV4 NETWORK WITH IPV6 ISLANDS

MPLS-enabled Core

R1  R2  R3  R4  R5  R6

2000 IPv6 Routes

IPv6 Packet

320

25 IPv6 Routes

145 IPv6 Routes
THE IPV4 NETWORK WITH IPV6 ISLANDS

MPLS-enabled Core

R1 R2 R3 R4 R5 R6

2000 IPv6 Routes

IPv6 Packet

1078

25 IPv6 Routes

145 IPv6 Routes
THE IPV4 NETWORK WITH IPV6 ISLANDS

MPLS-enabled Core

R1  R2  R3  R4  R5  R6

2000 IPv6 Routes

IPv6 Packet

867

25 IPv6 Routes

145 IPv6 Routes
THE IPV4 NETWORK WITH IPV6 ISLANDS

MPLS-enabled Core

R1  R2  R3  R4  R5  R6

2000 IPv6 Routes

145 IPv6 Routes

25 IPv6 Routes

IPv6 Packet

PHP behavior
REMEMBER…

2000 IPv6 Routes

MPLS-enabled Core

145 IPv6 Routes

This segment is still part of the IPv4 ONLY core!
A few issues can happen including:
R5 now has to use the IPv6-specific Ethernet header (L2 header; 0x86DD) while it is not IPv6-aware and potentially does not support IPv6 at all.
LET’S FIX IT

IDEAS?
LABEL STACKING

- In most real world cases we have more than one label
- For instance:
  - **Top label**: How we pass through the transit network (the “staple” solution)
  - **Bottom label**: When packets arrive at the destination where to put it next.
    - E.g. What downstream VRF to go to?
    - E.g. What IPv6 network to pass onto?
REMEMBER?

Two MPLS labels!

Bottom Label
Stays the same all the way

Top Label (Transport label)
Changes hop-by-hop
SMART SOLUTION: 2 LABELS

MPLS-enabled Core

OSPFv2 or ISIS Single Area/Level

Traffic Flow (HTTP, SSH etc. Packets)
SMART SOLUTION: 2 LABELS

IPv6 Packet

2000 IPv6 Routes

R1 320
1358

IPv6 Packet

MPLS-enabled Core

R2
R3
R4
R5
R6

25 IPv6 Routes
145 IPv6 Routes
SMART SOLUTION: 2 LABELS

2000 IPv6 Routes

MPLS-enabled Core

R1

R2

R3

601

1358

IPv6 Packet

R4

R5

R6

25 IPv6 Routes

145 IPv6 Routes
SMART SOLUTION: 2 LABELS

MPLS-enabled Core

IPv6 Packet

2000 IPv6 Routes

R1

R2

R3

1078

1358

R4

R5

R6

25 IPv6 Routes

145 IPv6 Routes
SMART SOLUTION: 2 LABELS

MPLS-enabled Core

2000 IPv6 Routes

R1

R2

R3

R4

867

1358

IPv6 Packet

R5

R6

25 IPv6 Routes

145 IPv6 Routes
SMART SOLUTION: 2 LABELS

The bottom label remains and helps with the last segment of the trip.
HOW DID THE LABEL DISTRIBUTION WORK?

1- **The TOP label**: PE finder aka next-hop finder

Everybody uses LDP here. So every router knows about the label assignments of their neighbors. They label packets accordingly when sending packets to them.
HOW DID THE LABEL DISTRIBUTION WORK?

The BOTTOM label:
- Bottom labels are assigned to IPv6 prefixes on the two ends
- They are assigned by each edge device (PE)
- But the labels have to be shared with other edges of the network
2- The **BOTTOM** label: BGP updates can transfer MPLS labels for each IPv6 prefix from one edge to another.
HOW DID THE LABEL DISTRIBUTION WORK?

Sample configuration in regular IOS on a Cisco router

PE 1 – R1

```plaintext
router bgp 100
neighbor 6.6.6.6 remote-as 100
neighbor 6.6.6.6 update-source Loopback0
!
address-family ipv6
neighbor 6.6.6.6 activate
neighbor 6.6.6.6 send-label
exit-address-family
```

PE 2 – R6

```plaintext
router bgp 100
neighbor 1.1.1.1 remote-as 100
neighbor 1.1.1.1 update-source Loopback0
!
address-family ipv6
neighbor 1.1.1.1 activate
neighbor 1.1.1.1 send-label
exit-address-family
```
LET’S ADD AN IPV6 PREFIX TO AN ISLAND

Sample configuration in regular IOS on a Cisco router

PE 1 – R1

router bgp 100
  neighbor 6.6.6.6 remote-as 100
  neighbor 6.6.6.6 update-source Loopback0
!
address-family ipv6
  neighbor 6.6.6.6 activate
  neighbor 6.6.6.6 send-label
  network 2031::31/128
exit-address-family
LET’S ADD AN IPV6 PREFIX TO AN ISLAND

Sample configuration in regular IOS on a Cisco router

PE 1 – R1

router bgp 100
  neighbor 6.6.6.6 remote-as 100
  neighbor 6.6.6.6 update-source Loopback0
  !
  address-family ipv6
  neighbor 6.6.6.6 activate
  neighbor 6.6.6.6 send-label

  network 2031::31/128
  exit-address-family

• Now PE1 R1 tells the other PE what label it’s decided to assign to 2031::31/128.
• Let’s say 18
BGP UPDATE – BOTTOM LABEL TRANSFER

Frame 1223: 146 bytes on wire (1168 bits), 146 bytes captured (1168 bits) on interface 0
Ethernet II, Src: ca:00:18:94:00:08 (ca:00:18:94:00:08), Dst: ca:01:2f:14:00:08 (ca:01:2f:14:00:08)
MultiProtocol Label Switching Header, Label: 404, Exp: 5, S: 1, TTL: 255
Internet Protocol Version 4, Src: 1.1.1.1, Dst: 6.6.6.6
Border Gateway Protocol - UPDATE Message
   Marker: ffffffff
   Length: 88
   Type: UPDATE Message (2)
   Withdrawn Routes Length: 0
   Total Path Attribute Length: 65
   Path attributes
   Path Attribute - ORIGIN: IGP
   Path Attribute - AS PATH: empty
   Path Attribute - MULTI_EXIT_DISC: 0
   Path Attribute - LOCAL_PREF: 100
   Path Attribute - MP_REACH_NLRI
      Flags: 0x80, Optional, Non-transitive, Complete
      Type Code: MP_REACH_NLRI (14)
      Length: 41
      Address family identifier (AFI): IPv6 (2)
      Subsequent address family identifier (SAFI): Labelled Unicast (4)
      Next hop network address (16 bytes)
      Number of Subnetwork points of attachment (SNPA): 0
      Network layer reachability information (20 bytes)
         Label Stack=18 (bottom), IPv6=2031::31/128
LET’S REVIEW THE FLOW ONE LAST TIME

IPv6 Packet

2000 IPv6 Routes

R1

R2

R3

R4

R5

R6

OSPFv2 or ISIS Single Area/Level

MPLS-enabled Core

Traffic Flow (HTTP, SSH etc. Packets)

25 IPv6 Routes

145 IPv6 Routes
LET'S REVIEW THE FLOW ONE LAST TIME

Run BGP and exchange labels for the IPv6 prefixes: Each PE tells his BGP peer how it wants its v6 prefixes to be called

Traffic Flow (HTTP, SSH etc. Packets)
END TO END FLOW

MPLS-enabled Core

R1 R2 R3 R4 R5 R6

IPv6 Packet

2000 IPv6 Routes

25 IPv6 Routes

145 IPv6 Routes

320

18
END TO END FLOW

MPLS-enabled Core

R1  R2  R3  R4  R5  R6

IPv6 Packet

2000 IPv6 Routes

601
18

25 IPv6 Routes

145 IPv6 Routes
END TO END FLOW

MPLS-enabled Core

IPv6 Packet

R1 R2 R3 R4 R5 R6

2000 IPv6 Routes

774

18

145 IPv6 Routes

25 IPv6 Routes
END TO END FLOW

MPLS-enabled Core

2000 IPv6 Routes

25 IPv6 Routes

145 IPv6 Routes

IPv6 Packet

867

18
The bottom label remains and helps with the last segment of the trip. It refers to an IPv6 prefix.
USE CASE

• Ready to discuss a real-world scenario?
• Any questions before we move on?
Company A is a laptop manufacturer with around 15000 employees. They receive parts from their partners and assemble in their facilities in Taiwan.

They have 150 offices including 100 small sales offices, 20 engineering or Q/A sites and 30 corporate only and customer service locations.

The engineering teams in Europe and NA, choose hardware, design and Q/A.

Users have all sort of PC’s and laptops plus a lot of different machines including SCADA, 6-axis robots, PLC’s, scanners, engineering printers and thin-clients.
THE CURRENT NETWORK

- Their existing network includes a sprawling global all-IPv4 WAN with some single points of failure. Although most of these points had redundant devices in the original designs yet due to the organic growth both are actively in use.
- BGP is used for WAN connectivity with mighty route reflectors
- IT has concerns about quite a few tier-2 WAN routers and their remaining memory and CPU horsepower.
- The WAN core also includes several POP’s and was mostly built between 2012 and 2014
- While the leadership understands the future trends of IPv6 yet they prefer to keep it out of the core until it’s either proven or they’ve upgraded the WAN core to more up-to-date hardware.
SAMPLE PROJECT REQUEST

Dear IT,

Although we understand no corporate application currently needs IPv6, yet; 3 of our engineering labs are in urgent need to IPv6 connectivity. The number and scope might increase with little notice. Those labs are in Santa Clara, Frankfurt and Vancouver.

Our new hardware (mix of everything; IoT and stations) will arrive in 30 business days and we should be prepared to start testing using IPv6 almost right after.

Any delay on your side can delay a major product shipping.

John G.

Head of Engineering Connectivity
KEY POINTS ABOUT THE DESIGN

COMPANY A

- Unknown machine types and IoT
  - Rules out machine to machine tunneling solutions
- Expediated deadline
  - Rules out invasive and high risk changes such as dual stack everywhere
- Vendor support
  - They might have different vendors and IPv6 tunneling support is not consistent
- Stability is key
  - Keep in mind you don’t want to risk/destabilize the entire corporation to support 3 labs
- Scope can grow
  - Solution must scale
LET’S RULE OUT SOME DESIGN OPTIONS

- IPv6 only sites
- Client to client tunnels
- Site to site tunnels
- Dual stack everywhere
A POSSIBILITY…

• 6PE and MPLS in the core:
  • The 3 sites can run both IPv4 and IPv6 as needed
  • Stable and pretty “beaten up” by the largest operators in the world
  • Gradual learning steps aka learn as-needed (v6-free core)
  • Reduced number of new “features” and protocols in the core
    • Load and risks of bugs
  • Quick new expansion
  • Can easily be automated and monitored compared to a dual stack IPv4 IPv6 global core
  • MPLS is not as “new” as v6 in the core and chances are low that you have to upgrade codes
  • Benefits of larger users community: MPLS in the core vs IPv6 in the core
  • And it scales well
USE CASE – LOCAL BGP ROUTE REFLECTORS

Tier-2 POP

Tier-1 POP

BGP sessions with label transfer capability to the local RR
KEY TAKEAWAYS

• The core does not “understand” IPv6 unless it directly participates in the control panel
  • Such as the route reflectors and edge devices

• This design opens doors to other enhancements and bonus points
  • Traffic Engineering
  • Fast Reroute (~50ms convergence)
KEY TAKEAWAYS

• What if Company A decides to roll out virtual routing instances or VRF’s and treats each site/lab as a segmented customer?
  • The same concept can be used and it’s called 6VPE.
  • Can be a future presentation
KEY TAKEAWAYS

• 6PE is a yet another tool in your toolbox