IPv6 Deployment Planning

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Presentation Slides

- Will be available on
  - http://bgp4all.com/ftp/seminars/SANOG25-IPv6-Deployment-Planning.pdf
  - And on the SANOG25 website
- Feel free to ask questions any time

Introduction

- Presentation introduces the high level planning considerations which any network operator needs to be aware of prior to deploying IPv6
- Content applicable for:
  - Business decision makers
  - Network managers
  - Network engineers
    - Will also require implementation detail

Agenda

- Goals
- Network Assessment
- Network Optimisation
- Procuring IPv6 Address Space
- IPv6 Address plan
- Deployment
- Seeking IPv6 Transit
- Customers

Goals

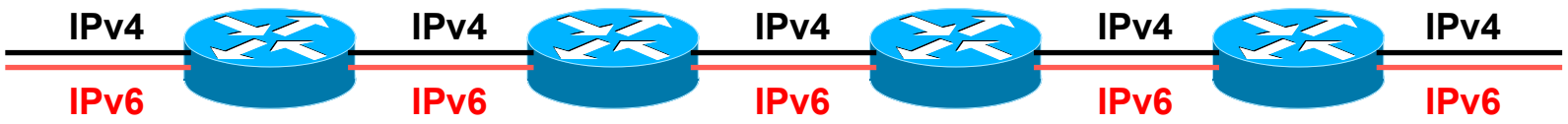
What do we want to achieve?

Goals

- Ultimate aim is to provide IPv6 to our customers:
  - Customers = end users
  - Customers = content providers
- Strategy depends on network transport:
  - Native IP backbone
    - Dual Stack is the solution
  - MPLS backbone (tunnels)
    - 6PE or 6VPE is the solution
    - The core infrastructure will remain IPv4 only

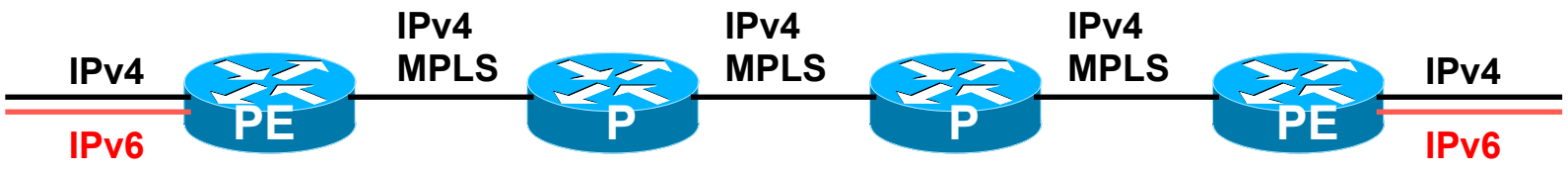
Native IP Backbone

- Routers are the infrastructure
  - Customer connections connect to the native backbone
  - VPN services provided using GRE, IPSEC, IPinIP etc
  - Providing IPv6 for customers means upgrading the native infrastructure to dual-stack



MPLS Backbone

- Routers are the infrastructure
  - Public and Private network access provided within the MPLS cloud
  - The core network does NOT need to be IPv6 aware
  - IPv6 access provided by 6PE or 6VPE
  - Provider Edge routers need dual stack capability



Network Assessment

What can run IPv6 today, and what needs to be upgraded?

Audit

- First step in any deployment:
  - Audit existing network infrastructure
- Primarily routers across backbone
  - Perhaps also critical servers and services (but not essential as initial focus is on routing infrastructure)

Process

- Analyse each location/PoP
- Document
  - Router or any other L3 device
  - RAM (installed and used)
  - FLASH memory
  - Software release versions
  - Most network operators already keep track of this info
    - If not, RANCID (www.shrubbery.net/rancid/) makes this very easy
- Sanity check
  - Check existing connectivity
  - Remove unused configuration
  - Shutdown and clean up unused interfaces

Software Issues (1)

- Does the existing software have IPv6 support?
  - Yes: deployment is straightforward
  - No: investigate cost of upgrade
- Is a software upgrade available?
  - Yes: is hardware suitably specified?
  - No: hardware replacement
- Implement software upgrade
  - Budget, purchase & schedule installation

Software Issues (2)

- If existing software supports IPv6:
  - Are deployed software versions consistent across infrastructure?
    - Recommend maximum of two variations (easier troubleshooting, bug tolerance, etc)
- If existing software does not support IPv6:
  - Cost of upgrade to a version which does?
  - Testing for existing feature compatibility:
    - A software image with IPv6 may have “lost” features required for the existing operational network

Hardware Issues

- Can hardware specification be upgraded (eg RAM, FLASH etc)?
  - Yes: budget, purchase, installation
  - No: hardware replacement
- Hardware replacement:
  - Assess suitable replacement product
  - Analyse impact on operating network, existing services and customer

Result

- Once the previous steps are completed, entire network is running IPv6 capable software
- Deployment of IPv6 can now begin

Network Optimisation

Is the IPv4 network the best it can be?

Optimisation

- IPv4 networks have been deployed and operational for many years
  - Your network may fall into this category
- Optimisation means:
  - Does the interior routing protocol make sense?
  - Do all routing protocols have the latest best practices implemented?
  - Are the IGP metrics set so that primary and backup paths operate as expected?

Motivation for Optimisation

- IPv6 deployment (apart from MPLS cores) will be dual stack
  - Which means sitting alongside existing IPv4 configurations
- Aim is to avoid replicating IPv4 “shortcuts” or “mistakes” when deploying IPv6
  - IPv6 configuration will **replicate** existing IPv4 configuration
- Improvements in routing protocol BCPs should be deployed and tested for IPv4
  - Take the opportunity to “modernise” the network

Procuring IPv6 address space

Now we need addresses…

Getting IPv6 address space (1)

- From your Regional Internet Registry
  - Become a member of your Regional Internet Registry and get your own allocation
    - Membership usually open to all network operators
  - General allocation policies are outlined in RFC2050
    - RIR specific details for IPv6 allocations are listed on the individual RIR website
  - Open to all organisations who are operating a network
  - Receive a /32 (or larger if you will have more than 65k /48 assignments)

Getting IPv6 address space (2)

- From your upstream ISP
  - Receive a /48 from upstream ISP's IPv6 address block
  - Receive more than one /48 if you have more than 65k subnets
- If you need to multihome:
  - Apply for a /48 assignment from your RIR
  - Multihoming with provider's /48 will be operationally challenging
    - Provider policies, filters, etc

Address Planning

- IPv6 address space available to each network operator is very large compared with IPv4
  - Design a scalable plan
  - Be aware of industry current practices
  - Separation of infrastructure and customer addressing
  - Distribution of address space according to function

Why Create an Addressing Plan?

- The options for an IPv4 addressing plan are severely limited:
  - Because of scarcity of addresses
  - Every address block has to be used efficiently
- IPv6 allows for a scalable addressing plan:
  - Security policies are easier to implement
  - Addresses are easier to trace
  - An efficient plan is scalable
  - An efficient plan also enables more efficient network management

Nibble Boundaries

- IPv6 offers network operators more flexibility with addressing plans
  - Network addressing can now be done on nibble boundaries
    - For ease of operation
  - Rather than making maximum use of a very scarce resource
    - With the resulting operational complexity
- A nibble boundary means subdividing address space based on the address numbering
  - Each number in IPv6 represents 4 bits
  - Which means that IPv6 addressing can be done on 4-bit boundaries

Nibble Boundaries – example

- Consider the address block 2001:db8:0:10::/61
  - The range of addresses in this block are:

```
2001:0db8:0000:0010:0000:0000:0000:0000
                    to
2001:0db8:0000:0017:ffff:ffff:ffff:ffff
```

  - Note that this subnet only runs from 0010 to 0017.
  - The adjacent block is 2001:db8:0:18::/61

```
2001:0db8:0000:0018:0000:0000:0000:0000
                    to
2001:0db8:0000:001f:ffff:ffff:ffff:ffff
```

  - The address blocks don't use the entire nibble range

Nibble Boundaries – example

- Now consider the address block 2001:db8:0:10::/60
  - The range of addresses in this block are:

```
2001:0db8:0000:0010:0000:0000:0000:0000
                    to
2001:0db8:0000:001f:ffff:ffff:ffff:ffff
```

  - Note that this subnet uses the entire nibble range, 0 to f
  - Which makes the numbering plan for IPv6 simpler
    - This range can have a particular meaning within the ISP block (for example, infrastructure addressing for a particular PoP)

Addressing Plans – Infrastructure

- All Network Operators should obtain a /32 from their RIR
- Address block for router loop-back interfaces
  - Number all loopbacks out of **one** /64
  - /128 per loopback
- Address block for infrastructure (backbone)
  - /48 allows 65k subnets
  - /48 per region (for the largest multi-national networks)
  - /48 for whole backbone (for the majority of networks)
  - Infrastructure/backbone usually does NOT require regional/geographical addressing
  - Summarise between sites if it makes sense

Addressing Plans – Infrastructure

- What about LANs?
  - /64 per LAN
- What about Point-to-Point links?
  - Protocol design expectation is that /64 is used
  - /127 now recommended/standardised
    - http://www.rfc-editor.org/rfc/rfc6164.txt
    - (reserve /64 for the link, but address it as a /127)
  - Other options:
    - /126s are being used (mimics IPv4 /30)
    - /112s are being used
      - Leaves final 16 bits free for node IDs
    - Some discussion about /80s, /96s and /120s too

Addressing Plans – Infrastructure

- NOC:
  - ISP NOC is "trusted" network and usually considered part of infrastructure /48
    - Contains management and monitoring systems
    - Hosts the network operations staff
    - take the last /60 (allows enough subnets)
- Critical Services:
  - Network Operator's critical services are part of the "trusted" network and should be considered part of the infrastructure /48
  - For example, Anycast DNS, SMTP, POP3/IMAP, etc
    - Take the second /64
    - (some operators use the first /64 instead)

Addressing Plans – ISP to Customer

- Option One:
  - Use ipv6 unnumbered
  - Which means no global unicast ipv6 address on the point-to-point link
  - Router adopts the specified interface's IPv6 address
    - Router doesn't actually need a global unicast IPv6 address to forward packets

```
interface loopback 0
 ipv6 address 2001:db8::1/128
interface serial 1/0
 ipv6 address unnumbered loopback 0
```

Addressing Plans – ISP to Customer

- Option Two:
  - Use the second /48 for point-to-point links
  - Divide this /48 up between PoPs
  - Example:
    - For 10 PoPs, dividing into 16, gives /52 per PoP
    - Each /52 gives 4096 point-to-point links
    - Adjust to suit!
  - Useful if ISP monitors point-to-point link state for customers
    - Link addresses are **untrusted**, so do not want them in the first /48 used for the backbone &c
  - Aggregate per router or per PoP and carry in iBGP (not ISIS/OSPF)

Addressing Plans – Customer

- Customers get one /48
  - Unless they have more than 65k subnets in which case they get a second /48 (and so on)
- In typical deployments today:
  - Several ISPs are giving small customers a /56 and single LAN end-sites a /64, e.g.:

    /64 if end-site will only ever be a LAN

    /56 for small end-sites (e.g. home/office/small business)

    /48 for large end-sites
  - This is another very active discussion area
  - Observations:
    - Don't assume that a mobile endsite needs only a /64
    - Some operators are distributing /60s to their smallest customers!!

Addressing Plans – Customer

- Consumer Broadband Example:
  - DHCPv6 pool is a /48
    - DHCPv6 hands out /60 per customer
    - Which allows for 4096 customers per pool
- Business Broadband Example:
  - DHCPv6 pool is a /48
    - DHCPv6 hands out /56 per customer
    - Which allows for 256 customers per pool
  - If BRAS has more than 256 business customers, increase pool to a /47
    - This allows for 512 customers at /56 per customer
  - Increasing pool to /46 allows for 1024 customers
  - BRAS announces entire pool as one block by iBGP

Addressing Plans – Customer

- Business "leased line":
  - /48 per customer
  - One stop shop, no need for customer to revisit ISP for more addresses until all 65k subnets are used up
- Hosted services:
  - One physical server per vLAN
  - One /64 per vLAN
  - How many vLANs per PoP?
  - /48 reserved for entire hosted servers across backbone
    - Internal sites will be subnets and carried by iBGP

Addressing Plans – Customer

- Geographical delegations to Customers:
  - Network Operator subdivides /32 address block into geographical chunks
  - E.g. into /36s
    - Region 1: 2001:db8:1xxx::/36
    - Region 2: 2001:db8:2xxx::/36
    - Region 3: 2001:db8:3xxx::/36
    - etc
  - Which gives 4096 /48s per region
  - For Operational and Administrative ease
  - Benefits for traffic engineering if Network Operator multihomes in each region

Addressing Plans – Customer

- Sequential delegations to Customers:
  - After carving off address space for network infrastructure, Network Operator simply assigns address space sequentially
  - Eg:
    - Infrastructure: 2001:db8:0::/48
    - Customer P2P: 2001:db8:1::/48
    - Customer 1: 2001:db8:2::/48
    - Customer 2: 2001:db8:3::/48
    - etc
  - Useful when there is no regional subdivision of network and no regional multihoming needs

Addressing Plans – Routing Considerations

- Carry Broadband pools in iBGP across the backbone
  - Not in OSPF/ISIS
- Multiple Broadband pools on one BRAS should be aggregated if possible
  - Reduce load on iBGP
- Aggregating leased line customer address blocks per router or per PoP is undesirable:
  - Interferes with ISP's traffic engineering needs
  - Interferes with ISP's service quality and service guarantees

Addressing Plans – Traffic Engineering

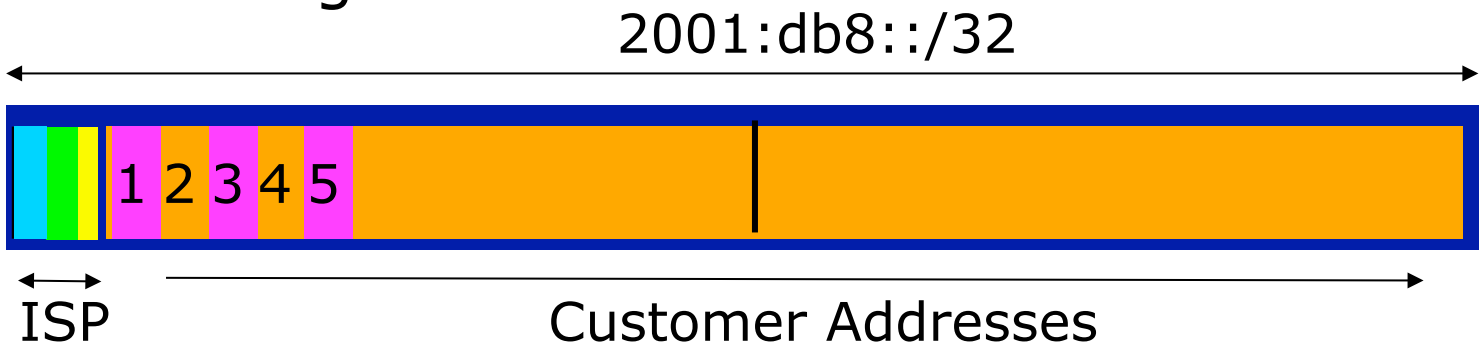
- Smaller providers will be single homed
  - The customer portion of the ISP's IPv6 address block will usually be assigned sequentially
- Larger providers will be multihomed
  - Two, three or more external links from different providers
  - Traffic engineering becomes important
  - Sequential assignments of customer addresses will negatively impact load balancing

Addressing Plans – Traffic Engineering

- ISP Router loopbacks and backbone point-to-point links make up a small part of total address space
  - And they don't attract traffic, unlike customer address space
- Links from ISP Aggregation edge to customer router needs one /64
  - Small requirements compared with total address space
  - Some ISPs use IPv6 unnumbered
- Planning customer assignments is a very important part of multihoming
  - Traffic engineering involves subdividing aggregate into pieces until load balancing works

Unplanned IP addressing

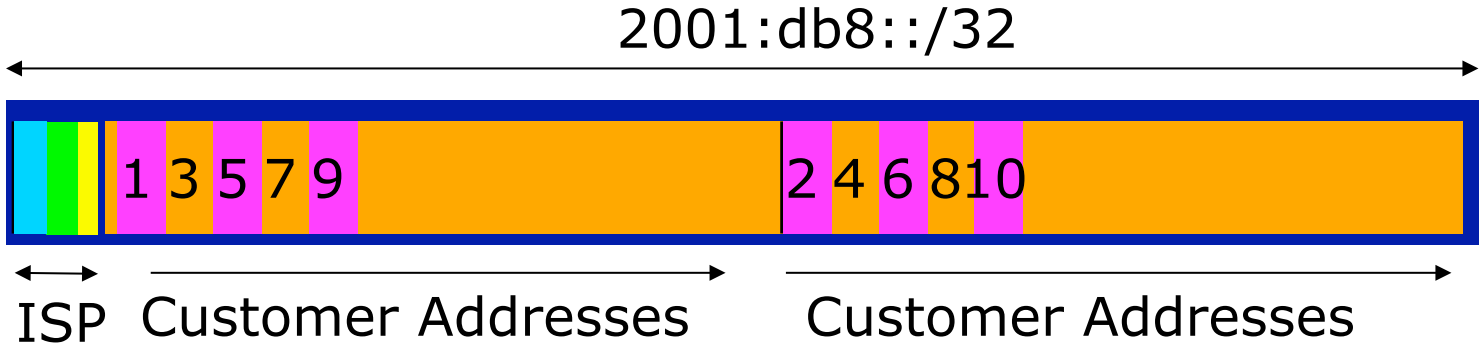
- ISP fills up customer IP addressing from one end of the range:



- Customers generate traffic
  - Dividing the range into two pieces will result in one /33 with all the customers and the ISP infrastructure the addresses, and one /33 with nothing
  - No loadbalancing as all traffic will come in the first /33
  - Means further subdivision of the first /33 = harder work

Planned IP addressing

- If ISP fills up customer addressing from both ends of the range:



- Scheme then is:
  - First customer from first /33, second customer from second /33, third from first /33, etc
- This works also for residential versus commercial customers:
  - Residential from first /33
  - Commercial from second /33

Planned IP Addressing

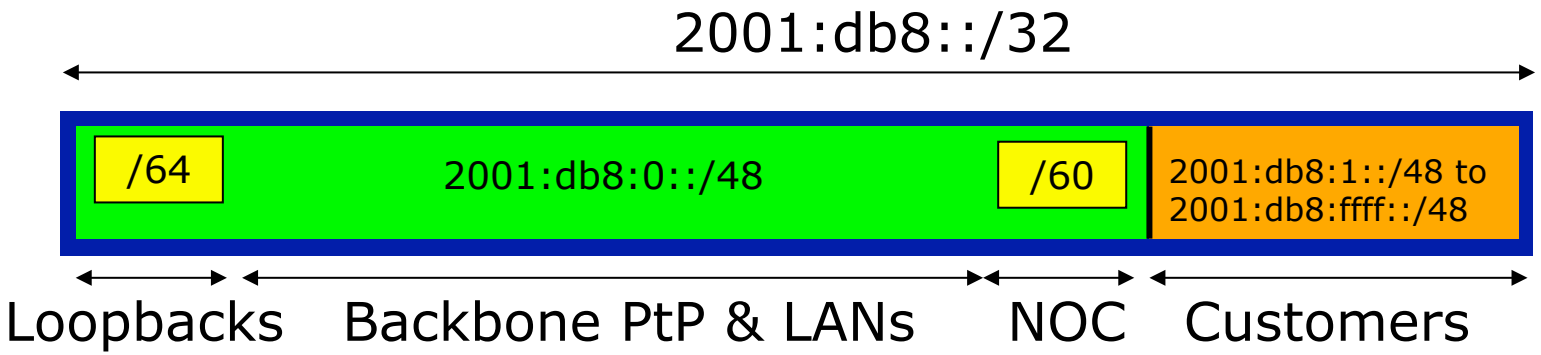
- This works fine for multihoming between two upstream links (same or different providers)
- Can also subdivide address space to suit more than two upstreams
  - Follow a similar scheme for populating each portion of the address space
- Consider regional (geographical) distribution of customer delegated address space
- Don't forget to always announce an aggregate out of each link

Addressing Plans – Advice

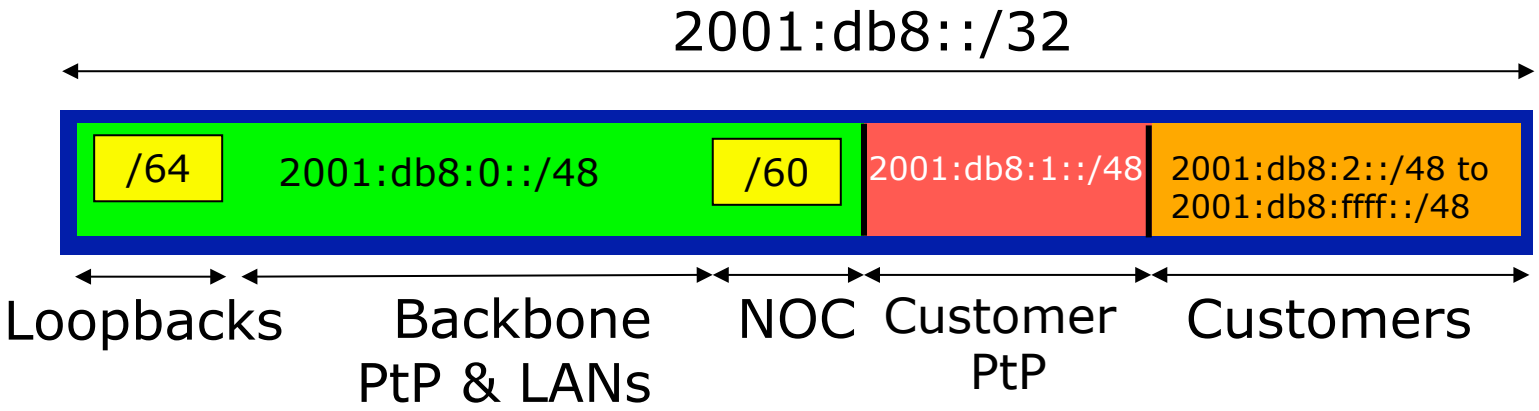
- Customer address assignments should not be reserved or assigned on a per PoP basis
  - Follow same principle as for IPv4
  - Subnet aggregate to cater for multihoming needs
  - Consider regional delegation
  - ISP iBGP carries customer nets
  - Aggregation within the iBGP not required and usually not desirable
  - Aggregation in eBGP is very necessary
- Backbone infrastructure assignments:
  - Number out of a single /48
    - Operational simplicity and security
  - Aggregate to minimise size of the IGP

Addressing Plans – Scheme

- Looking at Infrastructure:



- Alternative:



Addressing Plans Planning

- Registries will usually allocate the next block to be contiguous with the first allocation
  - (RIRs use a sparse allocation strategy – industry goal is aggregation)
  - Minimum allocation is /32
  - Very likely that subsequent allocation will make this up to a /31 or larger (/28)
  - So plan accordingly

Addressing Plans (contd)

- Document infrastructure allocation
  - Eases operation, debugging and management
- Document customer allocation
  - Customers get /48 each
  - Prefix contained in iBGP
  - Eases operation, debugging and management
  - Submit network object to RIR Database

Addressing Tools

- Examples of IP address planning tools:
  - NetDot netdot.uoregon.edu (recommended!!)
  - HaCi sourceforge.net/projects/haci
  - IPAT nethead.de/index.php/ipat
  - freeipdb home.globalcrossing.net/~freeipdb/
- Examples of IPv6 subnet calculators:
  - ipv6gen code.google.com/p/ipv6gen/
  - sipcalc www.routemeister.net/projects/sipcalc/

Deploying IPv6

Now we put it onto the network

Deploying addressing and IGP

- Strategy needed:
  - Start at core and work out?
  - Start at edges and work in?
  - Does it matter?
- Only strategy needed:
  - Don't miss out any PoPs
  - Connectivity is by IPv4, so sequence shouldn't matter
  - Starting at core means addressing of point to point links is done from core to edge (many ISPs use strategy of low number towards core, high number towards edge)
  - But it really doesn't matter where you start…

IPv6 Deployment

- Number all the infrastructure interfaces according to the established addressing plan
  - No customers yet
- Care needed on LANs
- Secure routers and L3 devices for IPv6 access
  - Once a device is enabled for IPv6, it must have all the same security policies applied as for IPv4

Deploying on PoP LANs

- LANs need special treatment
  - Even those that are only point to point links
- Issues:
  - ISPs don't want to have Router Advertisements active on network infrastructure LANs
  - Activating IPv6 on a LAN which isn't adequately protected may have security consequences
    - Servers may auto configure IPv6
    - No firewall filtering means no security ⇒ compromise

IPv6 Interior Routing Protocols

- Make a decision about which IGP to use
  - (continue with OSPF vs deploy ISIS?)
- Enable chosen IPv6 IGP
  - Care needed not to break IPv4 connectivity
  - Adjacencies in IPv6 should match existing adjacencies in IPv4
  - IGP v6 routing table should match v4 routing table
- Check that the IPv6 network's operation compares with IPv4 operation
  - Fix any problems
  - In a dual stack network the protocols must function the same way

IPv6 Routing Protocol Deployment

- Enable IPv6 BGP
  - iBGP – should replicate IPv4 iBGP
    - Same number of active neighbours
    - IPv6 version of the IPv4 configuration
    - Modify existing templates
  - eBGP comes next
- Check that the IPv6 network's operation compares with IPv4 operation
  - Fix any problems
  - In a dual stack network the protocols must function the same way

Seeking IPv6 Transit

Hello World, I'd like to talk to you…

Seeking Transit

- ISPs offering native IPv6 transit are still in the minority
- Next step is to decide:
  - whether to give transit business to those who will accept a dual stack connection

    or
  - Whether to stay with existing IPv4 provider and seek a tunnelled IPv6 transit from an IPv6 provider
- Either option has risks and challenges

Dual Stack Transit Provider

- Fall into two categories:
  A. Those who sell you a pipe over which you send packets
  B. Those who sell you an IPv4 connection and charge extra to carry IPv6
- Operators in category A are much preferred to those in category B
- Charging extra for native IPv6 is absurd, given that this can be easily bypassed by tunnelling IPv6
  - IPv6 is simply protocol 41 in the range of IP protocol numbers

Dual Stack Transit Provider

- Advantages:
  - Can align BGP policies for IPv4 and IPv6 – perhaps making them more manageable
  - Saves money – they charge you for bits on the wire, not their colour
- Disadvantages:
  - Not aware of any

Separate IPv4 and IPv6 transit

- Retain transit from resolute IPv4-only provider
  - You pay for your pipe at whatever $ per Mbps
- Buy transit from an IPv6 provider
  - You pay for your pipe at whatever $ per Mbps
- Luck may uncover an IPv6 provider who provides transit for free
  - Getting more and more rare as more ISPs adopt IPv6

Separate IPv4 and IPv6 transit

- Advantages:
  - Not aware of any
  - But perhaps situation is unavoidable as long as main IPv4 transit provider can't provide IPv6
  - And could be a tool to leverage IPv4 transit provider to deploy IPv6 – or lose business
- Disadvantages:
  - Do the $$ numbers add up for this option?
  - Separate policies for IPv4 and IPv6 – more to manage

Managing and Monitoring the Network

Watching the Infrastructure…

Managing and Monitoring the Network

- Existing IPv4 monitoring systems should not be discarded
  - IPv4 is not going away yet
- How to Monitor IPv6?
  - Netflow
  - MRTG
  - Syslog
  - Commercial systems?
  - Others?

Netflow for IPv6

- Public domain flow analysis tool NFSEN (and NFDUMP) support Netflow v5, v7 and v9 flow records
  - IPv6 uses v9 Netflow
  - NFSEN tools can be used to display and monitor IPv6 traffic
  - More information:
    - http://nfdump.sourceforge.net/
    - http://nfsen.sourceforge.net/
- ISPs using existing IPv4 netflow monitoring using NFSEN can easily extend this to include IPv6

MRTG

- MRTG is widely used to monitor interface status and loads on SP infrastructure routers and switches
- Dual stack interface will result in MRTG reporting the combined IPv4 and IPv6 traffic statistics
- MRTG can use IPv6 transport (disabled by default) to access network devices

Other Management Features

- A dual stack network means:
  - Management of the network infrastructure can be done using either IPv4 or IPv6 or both
  - ISPs recognise the latter is of significant value
- If IPv4 network breaks (e.g. routing, filters, device access), network devices may well be accessible over IPv6
  - Partial “out of band” network
- IPv6 is preferred over IPv4 (by design) if AAAA and A records exist for the device
  - So remote logins to network infrastructure will use IPv6 first if AAAA record provided

Customer Connections

Network is done, now let's connect paying customers…

Customer Connections

- Giving connectivity to customers is the biggest challenge facing all ISPs
- Needs special care and attention, even updating of infrastructure and equipment
  - Mobile
  - Cable/ADSL
  - Dial
  - Leased lines
  - Wireless Broadband

IPv6 to Mobile Customers

- Access technologies include 3G/LTE, Wifi (802.11) and WiMax
- End-sites could range from handsets to major corporations
- Strategy depends on infrastructure and device capability:
  - Dual-stack
  - IPv4-only with NAT46
  - IPv6-only with NAT64

IPv6 to Mobile Customers

- Dual-stack:
  - Most probably IPv4-NAT and native IPv6
  - Handset / device / infrastructure support?
- IPv4-only with NAT46:
  - Availability of IPv4 to IPv6 protocol translators?
  - Are there IPv6-only sites as yet?
- IPv6-only with NAT64:
  - Deployment of CGN
  - Handset / device / infrastructure support?

IPv6 to Broadband Customers

- Method 1: Use existing technology and CPE
  - This is the simplest option – it looks and feels like existing IPv4 service
  - PPPoE v6 + DHCPv6 PD
  - Used by ISPs such as Internode (AU) and XS4ALL (NL)
- Issues:
  - IPv6 CPE are generally more expensive (not the "throwaway" consumer devices yet)
  - Cheaper CPE have no IPv6 yet – need to be replaced/ upgraded

IPv6 to Broadband Customers

- Method 2: use 6rd
  - This is for when Broadband infrastructure cannot be upgraded to support IPv6
  - Used by ISPs such as FREE (FR)
  - Example:
    - 2001:db8:6000::/48 assigned to 6rd
    - Customer gets 192.168.4.5/32 by DHCP for IPv4 link
    - IPv6 addr is 2001:db8:6000:0405::/64 for their LAN (taking last 16 bits of IPv4 address)
    - DHCPv6 PD can be used here too (eg to give /56s to customers)
- Issues:
  - All CPE needs to be replaced/upgraded to support 6rd

IPv6 to Dialup Customers

- Use existing technology:
  - Most dialup access routers are easily upgradable to support IPv6
  - Service looks and feels like the IPv4 service
  - PPPv6 with DHCPv6 PD (perhaps)
  - CPE is usually PC or laptop (and most OSes have supported IPv6 for many years)
  - Service already offered for several years by many ISPs

IPv6 to Fixed Link Customers

- Use existing technology:
  - Most access routers (PE) and Customer routers (CPE) are easily upgradeable or replaceable to include IPv6 support
  - Service looks and feels like existing IPv4 service
- Configuration options:
  - IPv6 unnumbered on point to point links (or address them)
  - Static routes, subnet size according to business size
  - Or use BGP with private or public (multihomed) ASN
  - Whatever is done for IPv4 should be repeated for IPv6
- Fixed link Customers are probably the easiest to roll IPv6 out to
  - Customer deploying IPv6 within their own networks is a separate discussion (rerun of this presentation!)

IPv6 to Customers

- What about addressing? Here is a typical strategy:
  - Mobile Handset:
    - /64 = 1 subnet
  - Home/Small Organisation:
    - /60 = 16 subnets
    - Reserve the whole /56
    - Reserve a /48 for small orgs = 256 small orgs per /48
  - Medium Organisation:
    - /56 = 256 subnets
    - Reserve the whole /48
  - Large Organisation:
    - /48 = 65536 subnets

Customer Connections

- What about customer end systems?
  - Is IPv6 available on all their computers and other network connected devices?
  - How to migrate those which aren't?
  - What needs to be available on IPv6?
  - How to educate customer operations staff
  - What about their CPE?
  - What about the link between your edge device and their CPE?
  - What about security?

Conclusion

We are done…!

Conclusion

- When deploying IPv6 for the first time, a strategy and planning are of paramount importance
- Presentation has highlighted the steps in the planning and presentation process
  - Variations on the theme are quite likely – there is no single correct way of proceeding

IPv6 Deployment Planning

End of Tutorial