IPv6 Addressing

ISP Workshops

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Acknowledgements

- This material originated from the Cisco ISP/IXP Workshop Programme developed by Philip Smith & Barry Greene

- Use of these materials is encouraged as long as the source is fully acknowledged and this notice remains in place

- Bug fixes and improvements are welcomed
  - Please email *workshop (at) bgp4all.com*

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Agenda

- Recap: how it worked with IPv4
- Getting IPv6 address space
- Constructing a scalable IPv6 address plan
- Client IPv6 addressing
- IPv6 address plan example

How it used to be

Looking back at IPv4

How did it work for IPv4?

- Up until 1994:
  - Operators applied to InterNIC for address space
    - 1993 onwards: included RIPE NCC and APNIC, the first two RIRs
  - Class A: Big organisations
  - Class B: Medium organisations
    - From 1992 onwards, multiple class Cs often handed out instead of single class Bs
  - Class C: Small organisations
- From 1994 onwards (classless Internet)
  - Address space distributed by InterNIC (replaced by ARIN in 1998) and the other RIRs
  - Distribution according to demonstrated need (not want)

IPv4 address plans (pre 1994)?

- Prior to 1994, doing an address plan in IPv4 was very simple
- Class C was used for one LAN
  - If entity had more than one LAN, they'd normally get a class B
- An organisation with a class B had 256 possible LANs
  - And that was more than most networks had in those days
- Organisations with more than 256 LANs tended to be Universities, big IT companies, etc
  - They either had multiple class Bs, or even a class A

Typical early 90s address plan

- Organisation was not connected to the Internet as such
  - But used TCP/IP internally
- Would generally use 10.0.0.0/8
  - Or any other class A that InterNIC had not handed out
- 10.X.Y.Z was a typical layout, where:
  - X = building number
  - Y = floor number
  - Z = host address
  - Where each subnet was a /24 (like a class C)
- When these organisations connected to the Internet, they had to renumber
  - Often into a /19 (the minimum allocation then)

IPv4 address plans (post 1994)?

- In the classful Internet days, IP address planning didn't really exist
  - The address space was big enough for most needs, as the number of devices and LANs were small
- With the arrival of classless Internet, and IPv4 run out in the early 90s
  - IP address planning was needed
  - Organisations got address space according to demonstrated need
    - A previous class B might now only get a /19
    - LANs no longer were automatically /24s
    - etc

IPv4 address plans (post 1994)?

- Advent of NAT assisted with delaying IPv4 runout
  - End-user got single public address, and NATed on to that address
    - (End-users could get lazy again)
- Operators became more careful:
  - RIR policy required "demonstrated need"
    - Further allocations made only when existing allocations were proven to be mostly used up
  - Started assigning address space across backbone according to the needs of the infrastucture
    - No gaps, but still no real plan
    - /30s for point-to-point links etc
    - Although the "plans" often separated infrastructure address space from what went to customers

IPv4 address plans (today)

- Chaotic?
- Unstructured?
- Undocumented?
- With IPv4 address space almost all depleted
  - Operators becoming ever more creative
  - Operators extracting the last “drops” from their address space holdings
  - It is a scramble just to keep network infrastructure addressed with public IPv4
  - Some operators even use NAT within their backbones
  - Some operators are reclaiming IPv4 address space loaned to their customers
  - This hotch potch cannot and does not lead to good planning

IPv4 address plans (today)

- More serious issues – because of the lack of structure, lack of planning:
  - Infrastructure security filters become very hard to manage
    - Adding yet another small block of IPv4 addresses to perimeter and control plane filters
  - Traffic engineering is more challenging
    - Lots of small blocks of address space to manage and manipulate
    - With impacts on size of the global routing table too!
  - Infrastructure addressing is difficult to manage
    - Loopbacks and backbone point-to-point links no longer out of one contiguous block
  - Access address pool resizing
    - Broadband access pools renumbering, reassigning, etc

IPv6

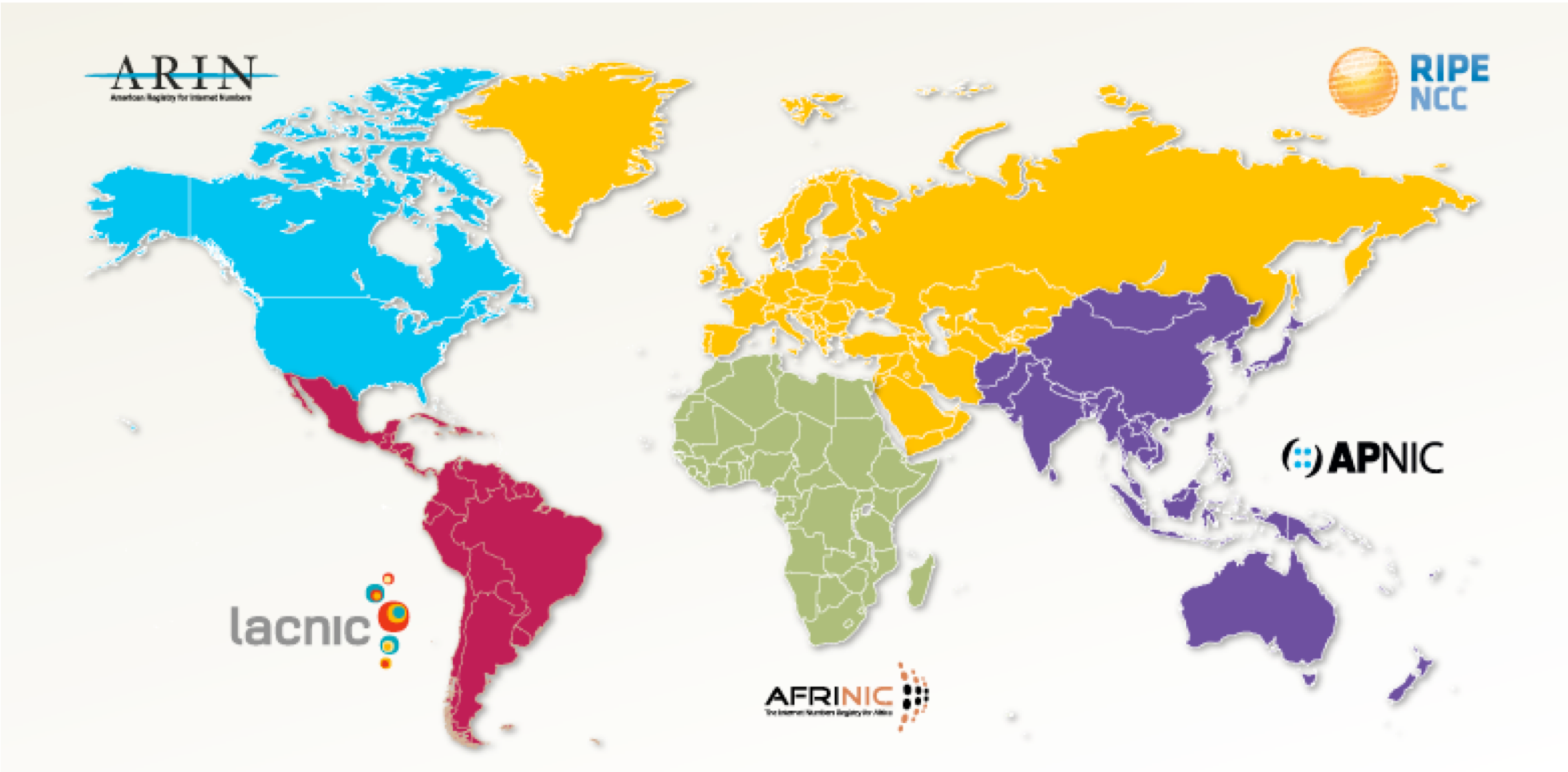
- IPv6 changes all this
- Address space delegations are generous
  - Reminders of the “old days” of classful IPv4
- No NAT
- Address planning is very possible
- Address planning is very necessary
- Documentation is very necessary
- Operators accustomed to handling IPv4 in the 1980s and early 1990s might be able to use those old skills for IPv6 !

IPv6 Address Planning

Where to get IPv6 addresses

- Your upstream ISP
- Africa
  - AfriNIC – http://www.afrinic.net
- Asia and the Pacific
  - APNIC – http://www.apnic.net
- North America
  - ARIN – http://www.arin.net
- Latin America and the Caribbean
  - LACNIC – http://www.lacnic.net
- Europe and Middle East
  - RIPE NCC – http://www.ripe.net/info/ncc

Internet Registry Regions



Getting IPv6 address space (1)

- From your Regional Internet Registry
  - Become a member of your Regional Internet Registry and get your own allocation
    - Membership open to all organisations who are operating a network
  - Address allocation policies listed on the individual RIR website
  - Minimum allocation is 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 the provider's /48 will be operationally challenging
    - Provider policies, filters, etc

Do NOT use 6to4

- Some entities still use 6to4
  - Deprecated in May 2015 due to serious operational and security issues
  - Read https://tools.ietf.org/rfc/rfc7526.txt (BCP196) for the reasoning why

- FYI: 6to4 operation:
  - Take a single public IPv4 /32 address
  - 2002:<ipv4 /32 address>::/48 becomes your IPv6 address block, giving 65k subnets
  - Requires a 6to4 gateway
  - 6to4 is a means of connecting IPv6 islands across the IPv4 Internet

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 subnetting address space based on the address numbering
  - Each number in IPv6 represents 4 bits = 1 nibble
  - 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
    - Some equipment doesn’t support /127s ☹

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 – Link from ISP to End-Site

- 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 – Link from ISP to End-Site

- 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 – End-Site

- RFC6177/BCP157 describes assignment sizes to end-sites
  - Original (obsolete) IPv6 design specification said that end-sites get one /48
  - Recognise that end-sites need to get enough IPv6 address space (multiples of /64) to address all subnets for the foreseeable future
- In typical deployments today:
  - /64 if end-site will only ever be a LAN (not recommended!!)
  - /56 for small end-sites (e.g. home/office/small business)
  - /48 for large end-sites
- Observations:
  - RFC7084 specifies Basic Requirements for IPv6 Customer Edge Routers
    - Including ability to be able to request at least a /60 by DHCPv6-PD
  - Don't assume that a mobile end-site needs only a /64 – 3GPP Release 10 introduces DHCPv6-PD for tethering
  - Some operators are distributing /60s to their smallest customers!!

Addressing Plans – End-Site

- 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 customers, increase pool to a /47
    - This allows for 512 customers at /56 per customer
  - The whole nibble (/44) allows for 4096 delegations
  - In all cases, BRAS announces entire pool as one block by iBGP

Addressing Plans – End-Site

- 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 – End-Site

- 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 – End-Site

- 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

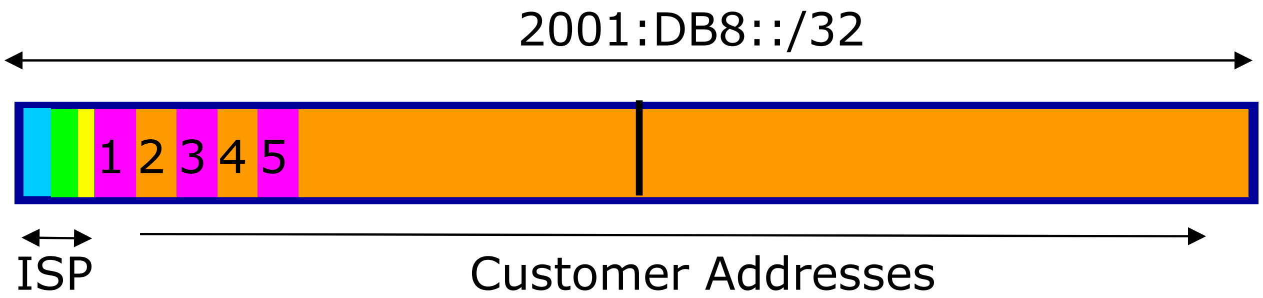
- Smaller providers will be single homed
  - The customer portion of the ISP's IPv6 address block will usually be assigned sequentially
- Larger providers will be multihomed
  - Two, three or more external links from different providers
  - Traffic engineering becomes important
  - Sequential assignments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

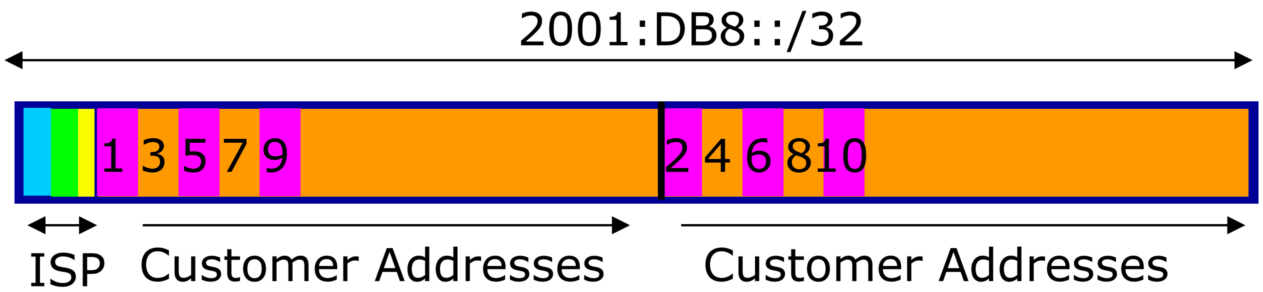
- ISP fills up customer IP addressing from one end of the range:



- 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

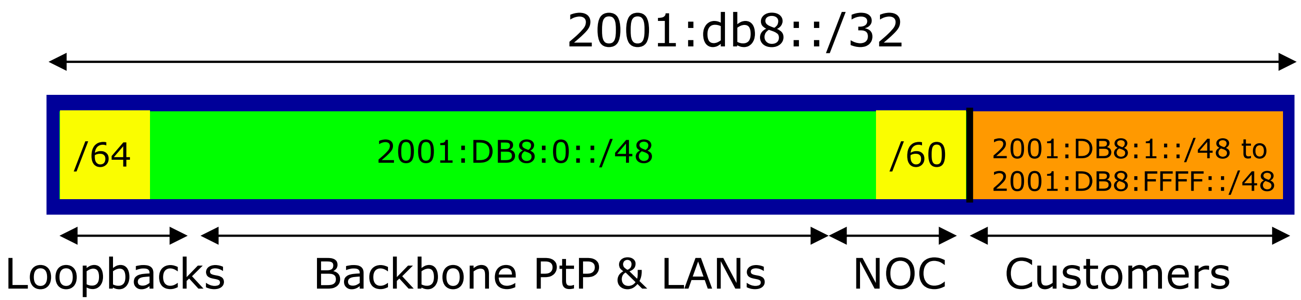
- This works fine for multihoming between two upstream links (same or different providers)
- Can also subdivide address space to suit more than two upstreams
  - Follow a similar scheme for populating each portion of the address space
- Consider regional (geographical) distribution of customer delegated 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

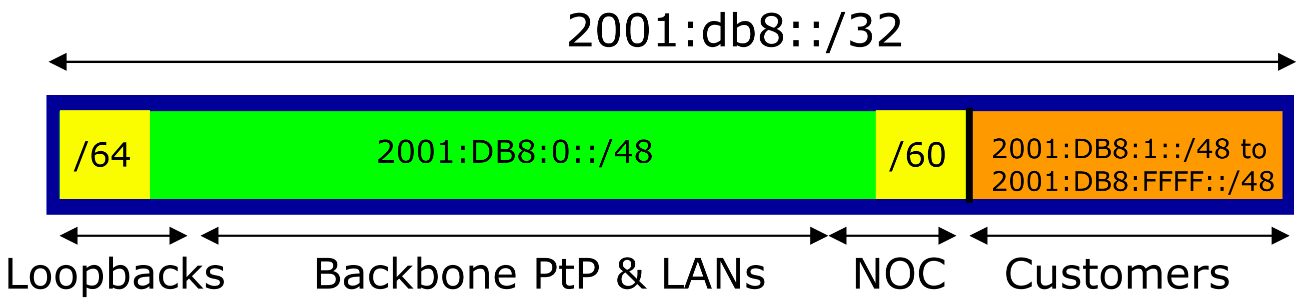
Addressing Plans – Scheme

- Looking at Infrastructure:

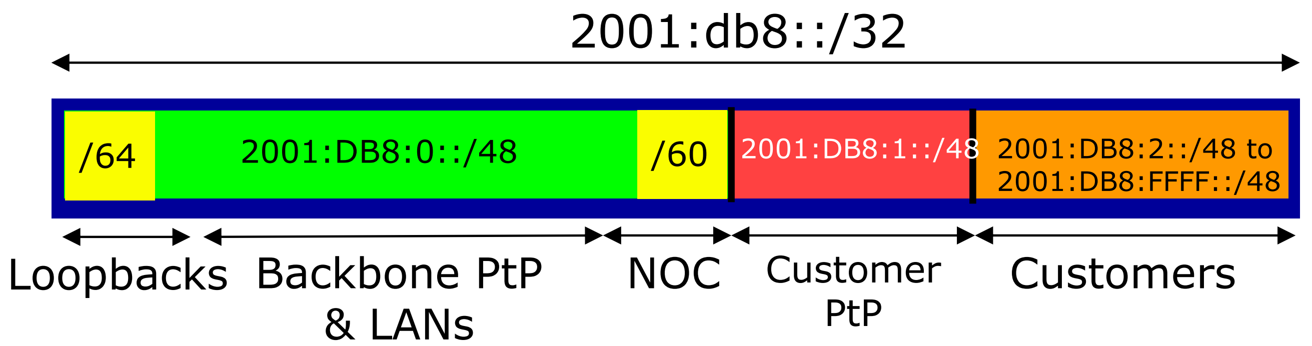


Addressing Plans – Scheme

- 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
  - OpenNetAdmin opennetadmin.com
  - HaCi sourceforge.net/projects/haci
  - Racktables racktables.org
  - 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/

Client IPv6 Addressing

IPv6 Addressing on LANs (fixed & wireless)

- StateLess Address AutoConfiguration (SLAAC)
  - Client learns IPv6 address, default gateway, and DNS resolver, from the router on the LAN

- DHCPv6
  - Client learns IPv6 address, default gateway, and DNS resolver, from a DHCP server
    - Can be on the same LAN (not advised)
    - Can be the router (usually limited feature set)
    - Standalone, via DHCP relay on the router (most common)

SLAAC: Router side

- Router does not need any specific configuration
  - But there are some good practice suggestions to improve general behaviour
    - Setting router preference high (default is medium)
    - Make the RA interval 30 seconds
    - If supported, also supply DNS resolver using RA
    - Set Multicast Listener Discovery query interval to 30 seconds

```
interface FastEthernet0/0
 ipv6 address 2001:DB8:100::1/64
 ipv6 nd router-preference high
 ipv6 nd ra interval 30
 ipv6 nd ra dns server 2001:DB8:100:F::53
 ipv6 mld query-interval 30
!
```

SLAAC: Client side

- IPv6 client learns address “from the LAN”
  - IPv6 is enabled on most end-user devices today
    - Laptop, PC, tablet, smartphone
  - Device sends out “router solicit”
  - Router responds with “router advertisement” containing subnet and default gateway
  - Initial client state (eg macOS laptop):

```
Client:
en3: flags=8863<UP,BROADCAST,SMART,RUNNING,SIMPLEX,MULTICAST> mtu 1500
          ether 68:5b:35:7d:3b:bd
          inet6 fe80::6a5b:35ff:fe7d:3bbd%en3 prefixlen 64 scopeid 0x8
```

SLAAC

- On receiving response from the router:

```
en3: flags=8863<UP,BROADCAST,SMART,RUNNING,SIMPLEX,MULTICAST> mtu 1500
          ether 68:5b:35:7d:3b:bd
          inet6 fe80::6a5b:35ff:fe7d:3bbd%en3 prefixlen 64 scopeid 0x8
          inet6 2001:db8:100::6a5b:35ff:fe7d:3bbd prefixlen 64 autoconf
          inet6 2001:db8:100::18eb:2861:458e:862b prefixlen 64 autoconf temporary
          nd6 options=1<PERFORMNUD>

Internet6:
Destination        Gateway            Flags        Netif Expire
default            fe80::219:30ff:fee UGc            en3
```

  - Note the temporary address – this is the one used for all IPv6 connectivity, and has a lifetime determined by the client's operating system

DHCPv6

- Behaves like DHCP on IPv4 infrastructure:
  - DHCPv6 server distributes addresses from a pool on request from client
  - DHCPv6 client configures IPv6 address, default gateway, and DNS resolver
  - Sample server configuration (Cisco IOS)
    - Note we tell neighbour discovery that address and other configuration will be handled by DHCP

```
ipv6 dhcp pool LABNET
 dns-server 2001:DB8:100:F::53
 domain-name labnet
!
interface VLAN1
 ipv6 address 2001:DB8::1/64
 ipv6 nd managed-config-flag
 ipv6 nd other-config-flag
 ipv6 dhcp server LABNET
!
```

Stateless DHCPv6

- Where DHCPv6 is used to distribute other information
  - But not IPv6 addresses (usually done by SLAAC)
  - Documented in RFC3736
- For example:
  - SLAAC is used to distribute IPv6 address and default gateway
  - DHCPv6 is used to provide DNS resolver and other network information
  - Compare this configuration with that from the earlier example

```
ipv6 dhcp pool LABNET
 dns-server 2001:DB8:100:F::53
 domain-name labnet
!
interface VLAN1
 ipv6 address 2001:DB8::1/64
 ipv6 nd other-config-flag
 ipv6 dhcp server LABNET
!
```

Distributing subnets to End-Users

- Static assignment (as in IPv4)
  - Tell the customer what subnet they have
    - Not dynamic!
    - Usually with Internet service documentation

- DHCPv6-PD
  - Use DHCPv6 Prefix Delegation feature to distribute subnets automatically
    - Prefix delegated can optionally be made persistent if desired

DHCPv6-PD

- New for IPv6, is Prefix-Delegation (PD)
  - Allows DHCP server to delegate subnets to clients
  - Especially useful for Broadband deployments
    - Also can be used for enterprise
  - Server example on BRAS (Cisco IOS)
    - Distribute /56 to client network out of /40 pool

```
ipv6 dhcp pool BB-CUST-1
 prefix-delegation pool BBCUST1 lifetime 1800 600
!
ipv6 local pool BBCUST1 2001:DB8:F00::/40 56
!
interface FastEthernet0/0
 ipv6 enable
 ipv6 dhcp server BB-CUST-1
!
```

DHCPv6-PD

- Client receives address delegation from the server:

```
interface Dialer0
 description ADSL link to MY ISP
 ipv6 address autoconfig default
 ipv6 dhcp client pd ADSL-PD rapid-commit
!
interface Vlan1
 description Home Network
 ipv6 address ADSL-PD ::0:0:0:0:1/64
!
interface Vlan2
 description Home IP/TV Network
 ipv6 address ADSL-PD ::1:0:0:0:1/64
!
```

```
Vlan1 – IPv6 address: 2001:DB8:F00:3100::1/64
Vlan2 – IPv6 address: 2001:DB8:F00:3101::1/64
```

DHCPv6-PD Servers ?

- Many vendor hardware products
  - Routers, firewalls, etc
- Example of standalone software (like IPv4 DHCP):
  - ISC's KEA (replaces ISC's DHCP server)
    - http://kea.isc.org
  - Jagornet DHCP server
    - http://www.jagornet.com
- Persistent address delegation
  - Available using DHCP Option 37 "remote hardware ID"
    - The client gets the same address block delegated each time

Example Address Plan

Example Address Plan

- Generic Network Operator
  - Has 2001:DB8::/32 address block
  - Takes first /48 for network infrastructure
    - First /64 for loopbacks
    - Last /60 for NOC
  - Takes second /48 for point to point links to customer sites
  - Remainder of address space for delegation to customers, content hosting and broadband pools
- Network Operator has 20 locations (Points of Presence) around the country

Example: Loopback addresses

- 2001:DB8:0::/48 is used for infrastructure
- Out of this, 2001:DB8:0:0::/64 is used for loopbacks
  - Each loopback is numbered as a /128
- Scheme adopted is:
  - 2001:DB8::XXYY/128
    - Where XX is the PoP number (01 through FF)
    - Where YY is the router number (01 through FF)
  - Scheme is good for:
    - 255 PoPs
    - 255 routers per PoP
    - keeping addresses small/short

Loopbacks Example

PoP 1 Routers	Loopbacks
cr1	2001:DB8::101/128
cr2	2001:DB8::102/128
br1	2001:DB8::103/128
br2	2001:DB8::104/128
sr1	2001:DB8::105/128
sr2	2001:DB8::106/128
ar1	2001:DB8::110/128
ar2	2001:DB8::111/128
gw1	2001:DB8::120/128
gw2	2001:DB8::121/128
etc…	

PoP 10 Routers	Loopbacks
cr1	2001:DB8::A01/128
cr2	2001:DB8::A02/128
sr1	2001:DB8::A05/128
sr2	2001:DB8::A06/128
ar1	2001:DB8::A10/128
ar2	2001:DB8::A11/128
gw1	2001:DB8::A20/128
gw2	2001:DB8::A21/128
etc…	

Example: Backbone Point to Point links

- Backbone Point to Point links come out of Infrastructure block 2001:DB8:0::/48
  - Scheme adopted is:
    - 2001:DB8:0:XXYY::Z/64
  - Where
    - XX is the PoP number (01 through FF)
    - YY is the LAN number (00 through 0F)
    - YY is the P2P link number (10 through FF)
    - Z is the interface address (0 or 1)
  - Scheme is good for 16 LANs and 240 backbone PtP links per PoP, and for 255 PoPs

LANs and PtP Links Example

PoP 1	Subnet
LAN1	2001:DB8:0:101::/64
LAN2	2001:DB8:0:102::/64
LAN3	2001:DB8:0:103::/64
PtP1	2001:DB8:0:111::/64
PtP2	2001:DB8:0:112::/64
PtP3	2001:DB8:0:113::/64
PtP4	2001:DB8:0:114::/64
PtP5	2001:DB8:0:115::/64
PtP6	2001:DB8:0:116::/64
PtP7	2001:DB8:0:117::/64
etc…	

PoP 14	Subnet
LAN1	2001:DB8:0:E01::/64
LAN2	2001:DB8:0:E02::/64
LAN3	2001:DB8:0:E03::/64
LAN4	2001:DB8:0:E04::/64
LAN5	2001:DB8:0:E05::/64
PtP1	2001:DB8:0:E11::/64
PtP2	2001:DB8:0:E12::/64
PtP3	2001:DB8:0:E13::/64
etc…	

Note: PtP links have /64 reserved but are addressed as /127s

Links to Customers

- Some ISPs use "ip unnumbered" for IPv4 interface links
  - So replicate this in IPv6 by using "ipv6 unnumbered" to address the links
  - This will not require one /48 to be taken from the ISP's /32 allocation
- Other ISPs use real routable addresses
  - So set aside the second /48 for this purpose
  - Gives 65536 possible customer links, assuming a /64 for each link

Customer Links Example

Customer	Point to point link address
Customer 1	2001:DB8:1:0::/64
Customer 2	2001:DB8:1:1::/64
Customer 3	2001:DB8:1:2::/64
Customer 4 (link one)	2001:DB8:1:3::/64
Customer 4 (link two)	2001:DB8:1:4::/64
Customer 5	2001:DB8:1:5::/64
Customer 6	2001:DB8:1:6::/64
etc…	

Note1: PtP links are numbered out of 2001:DB8:1::/48

Note2: PtP links have /64 reserved but are addressed as /127s

Example: Allocations from the /32

- Master allocation documentation would look like this:

Category	Purpose
Single /64	Loopbacks
Single /60	NOC
Single /48	Backbone Point to Point links (/64 each)
Single /48	Customer Point to Point links (/64 each)
Single /40	65536 Broadband Customers in Region 1 (/56 each)
Single /40	256 Enterprise Customers in Region 1 (/48 each)
Single /40	65536 Broadband Customers in Region 2 (/56 each)
Single /40	256 Enterprise Customers in Region 2 (/48 each)
Etc…	

Example: Allocations from the /32

- Detailed documentation:

Address Blocks	Purpose
2001:DB8:0::/48	Infrastructure (Loops, NOC, PtP)
2001:DB8:1::/48	Customer Point to Point Links
2001:DB8:0110::/48	Customer One in Region 1
2001:DB8:0111::/48	Customer Two in Region 1
2001:DB8:0112::/48	Customer Three in Region 1
2001:DB8:1100::/40	Broadband Pool 1 in Region 1
2001:DB8:1200::/40	Broadband Pool 2 in Region 1
2001:DB8:8110::/48	Customer One in Region 2
2001:DB8:8111::/48	Customer Two in Region 2
2001:DB8:9100::/40	Broadband Pool 1 in Region 2
2001:DB8:9200::/40	Broadband Pool 2 in Region 2

Summary

- First /48 for infrastructure
  - Out of that, first /64 for Loopbacks
- PoP structure within IPv6 addressing is very possible
  - Greater flexibility than with IPv4
  - Possible to come up with a simple memorable scheme
- Documentation vitally important!

Presentation Recap

- How it worked with IPv4
- Getting IPv6 address space
- Constructing a scalable IPv6 address plan
- IPv6 addressing on LANs
- IPv6 address plan example

IPv6 Addressing

ISP Workshops