IPv6 Addressing

ISP Workshops

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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 usually open to all network operators
  - General allocation policies are outlined in RFC2050
    - RIR specific policy 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

Using 6to4 for IPv6 address space

- Some entities still use 6to4
  - Not recommended due to operational problems
  - Read http://datatracker.ietf.org/doc/draft-ietf-v6ops-6to4-to-historic for some of 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

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

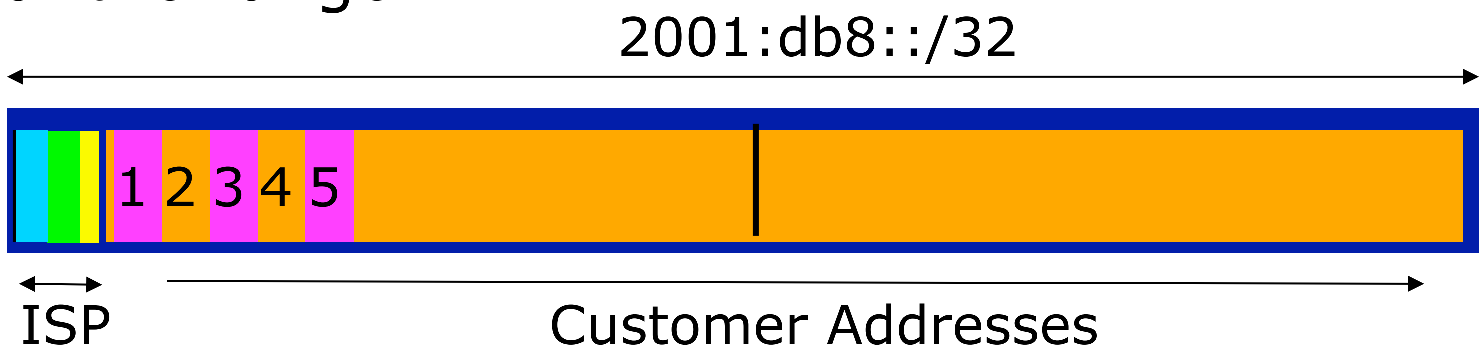
- Smaller providers will be single homed
  - The customer portion of the ISP's IPv6 address block will usually be assigned sequentially
- Larger providers will be multihomed
  - Two, three or more external links from different providers
  - Traffic engineering becomes important
  - Sequential assignments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

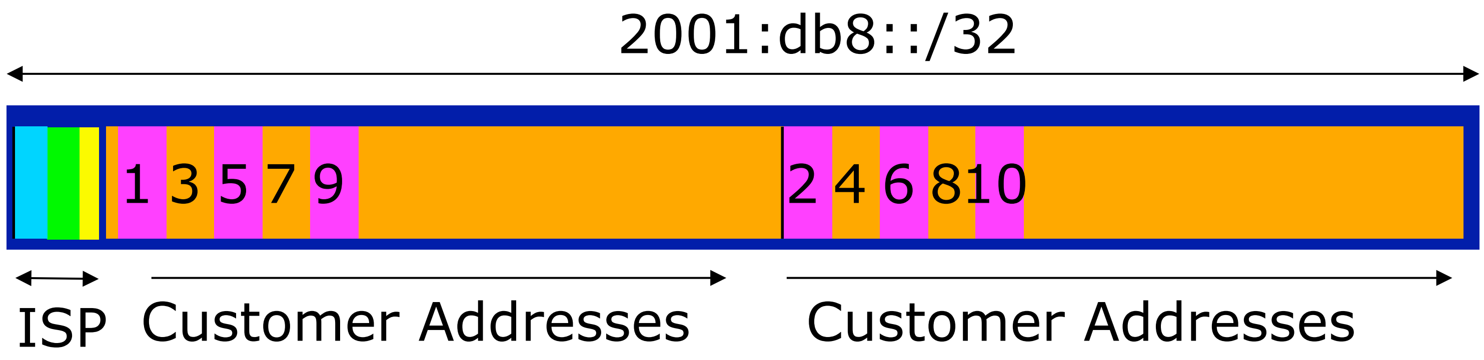
- ISP fills up customer IP addressing from one end of the range:



- 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

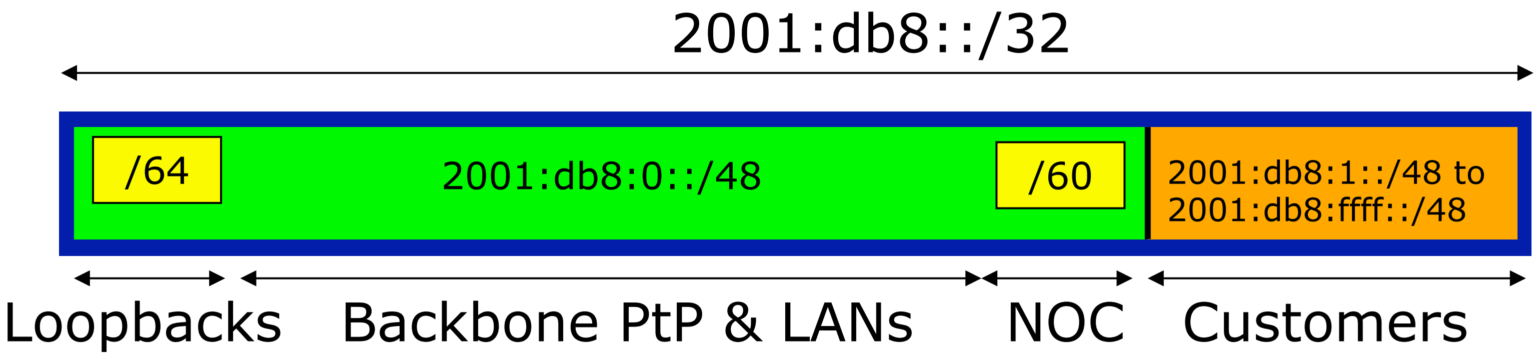
- This works fine for multihoming between two upstream links (same or different providers)
- Can also subdivide address space to suit more than two upstreams
  - Follow a similar scheme for populating each portion of the address space
- Consider regional (geographical) distribution of customer delegated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

Addressing Plans – Advice

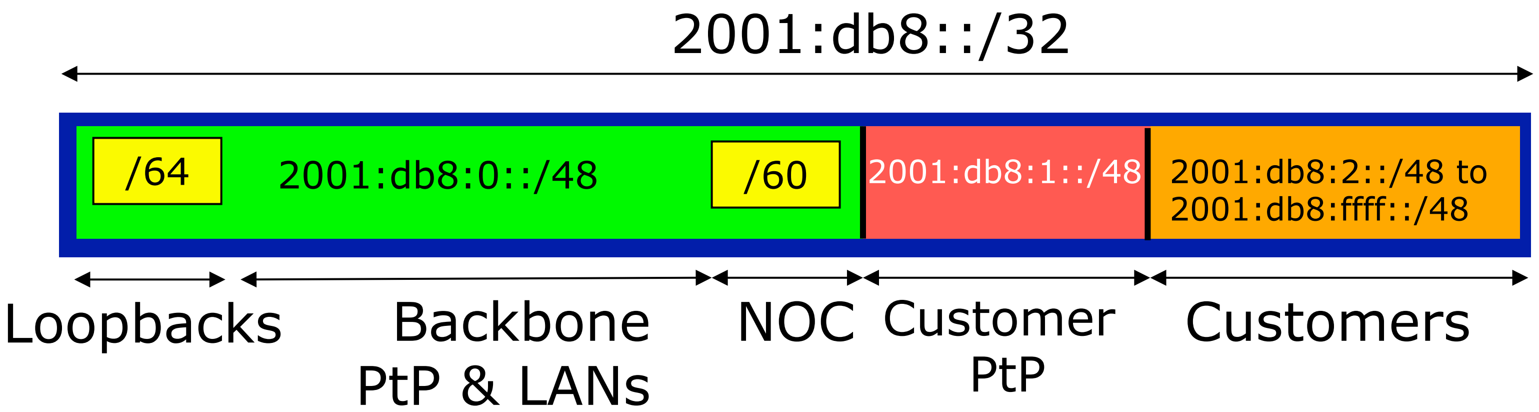
- Customer address assignments should not be reserved or assigned on a per PoP basis
  - Follow same principle as for IPv4
  - Subnet aggregate to cater for multihoming needs
  - Consider regional delegation
  - ISP iBGP carries customer nets
  - Aggregation within the iBGP not required and usually not 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
  - 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/

IPv6 Addressing on LANs

- Two options:
  - Stateless Autoconfiguration (SLAAC)
    - Client learns IPv6 address from the router on the subnet
  - DHCPv6
    - Client learns IPv6 address from a DHCP server (as for IPv4)

SLAAC

- IPv6 client learns address "from the LAN"
  - Sends out "router solicit"
  - Router responds with "router advertisement" containing subnet and default gateway
  - Initial client state:

```
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
```

  - Router does not need any specific configuration

```
interface FastEthernet0/0
 ipv6 address 2001:db8::1/64
 ipv6 nd router-preference high
!
```

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

- Works like DHCP on IPv4 infrastructure:
  - DHCPv6 server distributes addresses from a pool on request from client
  - DHCPv6 client configures IPv6 address
  - Sample server configuration (Cisco IOS):

```
ipv6 dhcp pool LABNET
 dns-server 2001:DB8:1::1
 dns-server 2001:DB8:2::2
 domain-name labnet
!
interface VLAN1
 ipv6 address 2001:DB8::1/64
 ipv6 dhcp server LABNET
!
```

Distributing subnets by DHCP

- Two options:
  - Static assignment (as in IPv4)
    - Tell the customer what subnet they have
  - DHCPv6-PD
    - Use DHCPv6 Prefix Delegation feature to distribute subnets automatically

DHCPv6-PD

- New for IPv6, is Prefix-Delegation (PD)
  - Allows DHCP server to delegate subnets to clients
  - Especially useful for Broadband deployments
  - Server example on BRAS (Cisco IOS):

```
ipv6 dhcp pool BB-CUST-1
 prefix-delegation pool BBCUST1
!
ipv6 local pool BBCUST1 2001:DB8:100::/56
!
interface FastEthernet0/0
 ipv6 address 2001:DB8::1/64
 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 ::1/64
!
interface Vlan2
 description Home IP/TV Network
 ipv6 address ADSL-PD 1::1/64
!
```

```
Vlan1 – IPv6 address: 2001:db8:100::1/64
Vlan2 – IPv6 address: 2001:db8:101::1/64
```

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 PoPs 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:MNXY::Z/64
  - Where
    - MN is the PoP number (01 through FF)
    - XY is the LAN number (00 through 0F)
    - XY 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!

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