Tutorial - IPv6 Address Management

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Tutorial Overview

• Introduction to IP Address Management
• Rationale for IPv6
• IPv6 Addressing
• IPv6 Policies & Procedures
• References
IP Address Management
"The assignment of numbers is also handled by Jon. If you are developing a protocol or application that will require the use of a link, socket, port, protocol, or network number please contact Jon to receive a number assignment." (RFC 790)
Global Routing Table: ’88 - ’92
Global Routing Table: ’88 - ’92
The boom years: 1992 – 2001

1992:

“It has become clear that … these problems are likely to become critical within the next one to three years.” (RFC1366)

“…it is [now] desirable to consider delegating the registration function to an organization in each of those geographic areas.” (RFC 1338)
IANA Address Consumption

various
assigned
ripencc
lacnic
arin
apnic
Global routing table

http://bgp.potaroo.net/as1221/bgp-active.html
Recent years: 2002 – 2005

2004:
Establishment of the Number Resource Organisation
IPv4 Distribution – Global

- Historical: 89 (35%)
- Reserved: 36 (14%)
- RIPENCC: 16 (6%)
- LACNIC: 2 (1%)
- APNIC: 16 (6%)
- ARIN: 22 (9%)
- Unused: 75 (29%)
IPv4 Allocations – Global top 10

The diagram shows the IPv4 allocations for various countries over the years from 1993 to 2005. Each bar represents a country's allocation, with different colors indicating the years. The y-axis indicates the allocation size.
Regional Internet Registries
What are RIRs?

• Regional Internet Registries
• Service organisations
  – Industry self-regulatory structures
  – Non-profit, neutral and independent
  – Open membership-based bodies
  – Representative of ISPs globally
• First established in early 1990’s
  – Voluntarily by consensus of community
  – To satisfy emerging technical/admin needs
• In the “Internet Tradition”
  – Consensus-based, open and transparent
What do RIRs do?

• Internet resource allocation
  – Primarily, IP addresses – IPv4 and IPv6
  – Receive resources from IANA/ICANN, and redistribute to ISPs on a regional basis
  – Registration services (“whois”)

• Policy development and coordination
  – Open Policy Meetings and processes

• Training and outreach
  – Training courses, seminars, conferences…
  – Liaison: IETF, ITU, APT, PITA, APEC…

• Publications
  – Newsletters, reports, web site…
How do RIRs do it?

• Open and transparent processes
  – Decision-making
  – Policy development
• Open participation
  – Democratic, bottom-up processes
• Membership structure
  – 100% self-funded through membership fees
  – National Internet Registries (APNIC)
• Community support (APNIC)
  – Training
  – R&D fund
  – Fellowships – funding received and given
  – Open source software contribution (GPL)
RIR Policy Coordination

- **OPEN**
  - Anyone can participate
  
- **TOP DOWN**
  - Internet community proposes and approves policy
  
- **BOTTOM UP**
  - ‘BOTTOM UP’
  
- **CONSSENSUS**
  - Consensus
  
- **TRANSPARENT**
  - All decisions & policies documented & freely available to anyone
  
Process:
1. **Need**
2. **Discuss**
3. **Evaluate**
4. **Implement**
Rationale for IPv6
IPv4 Lifetime

Historical Data

Projection

http://bgp.potaroo.net/ipv4
Rationale for IPv6

• IPv4 address space consumption
  – Now ~10 years free space remaining
  – Up to 17 if unused addresses reclaimed
  – These are today’s projections – reality will be different

• Loss of “end to end” connectivity
  – Widespread use of NAT due to ISP policies and marketing
  – Additional complexity and performance degradation
The NAT “Problem”

The Internet

ISP
61.100.0.0/16

61.100.32.0/25

61.100.32.1 .2 .3 .4

61.100.32.128

10.0.0.1 .2 .3 .4

*AKA home router, ICS, firewall
The NAT “Problem”

Internet

NAT
61.100.32.128

10.0.0.1

Phone Network

PABX
10 4567 9876

Extn 10
NAT implications

• Breaks end-to-end network model
  – Some applications cannot work through NATs
  – Breaks end-end security (IPsec)

• Requires application-level gateway (ALG)
  – When new application is not NAT-aware, ALG device must be upgraded
  – ALGs are slow and do not scale

• Merging of separate private networks is difficult
  – Due to address clashes

• See RFC2993
  – Architectural Implications of NAT
Features of IPv6
IPv6 feature summary

- Increased size of address space
- Header simplification
- Autoconfiguration
  - Stateless (RFC 2462) or stateful (DHCPv6)
  - Facilitates renumbering
- QoS
  - Integrated services (int-serv), Differentiated services (diff-serv and RFC2998)
  - RFC 3697
- IPSec
  - As for IPv4
- Transition techniques
  - Dual stack
  - Tunnelling
IPv6 addressing model

- **Unicast**
  - Single interface

- **Anycast**
  - Any one of several

- **Multicast**
  - All of a group of interfaces
  - Replaces IPv4 “broadcast”

- See RFC 3513
IPv4 vs IPv6

IPv4: 32 bits

- $2^{32}$ addresses
  - $= 4,294,967,296$ addresses
  - $= 4$ billion addresses

IPv6: 128 bits

- $2^{128}$ addresses?
  - $= 340,282,366,920,938,463,463,374,607,431,770,000,000$
  - $= 340$ billion billion billion billion addresses?

- No, due to IPv6 address structure…
IPv6 header

- IPv6 header is simpler than IPv4
  - IPv4: 14 fields, variable length (20 bytes +)
  - IPv6: 8 fields, fixed length (40 bytes)

- Header fields eliminated in IPv6
  - Header Length
  - Identification
  - Flag
  - Fragmentation Offset
  - Checksum

- Header fields enhanced in IPv6
  - Traffic Class
  - Flow Label
IPv6 transition

• Dual stack hosts
  – Two TCP/IP stacks co-exists on one host
  – Supporting IPv4 and IPv6
  – Client uses whichever protocol it wishes

Diagram:
- IPv4
- IPv6
- www.apnic.net
- TCP/UDP
- Application
- IPv4
- IPv6
- Link
IPv6 transition

• IPv6 tunnel over IPv4
IPv6 Addressing
How much IPv6?

- $2^{64}$ “subnet” addresses
  - $= 18,446,744,073,709,551,616$
  - $= 18$ billion billion subnet addresses

- $2^{48}$ site addresses
  - $= 281,474,976,710,656$
  - $= 281$ thousand billion site addresses
IPv6 address format

- 8 groups of 4 hexadecimal digits
  - Each group represents 16 bits
  - Separator is “:”
  - Case-independent

2001:0DA8:E800:0000:0260:3EFF:FE47:0001
IPv6 address format

2001:0DA8:E800:0000:0260:3EFF:FE47:0001

2001:DA8:E800:0:260:3EFF:FE47:1

2001:0DA8:E800:0000:0000:0000:0000:0001

2001:DA8:E800::1
IPv6 Address Structure
IPv6 address structure

- Current ISP allocation (min) is /32
  - Providing $2^{16} = 65,536$ customer site addresses
  - ISP allocation can be larger and can increase

- Each site address is /48
  - Providing $2^{16} = 65,536$ subnet addresses
IPv6 – ISP addressing

- Every ISP receives a /32 (or more)
  - Providing 65,536 site addresses (/48)
IPv6 – Site addressing

• Every “site” receives a /48
  – Providing 65,536 /64 (LAN) addresses
IPv6 – LAN addressing

• Every LAN segment receives a /64
  – Providing $2^{64}$ interface addresses per LAN
IPv6 – Device addressing

- Every device interface receives a /128
  - May be EUI-64 (derived from interface MAC address), random number (RFC 3041), autoconfiguration, or manual configuration
IPv6 Policy
IPv6 policy – Overview

- Policy background
- Addressing structure
- IPv6 utilisation – HD ratio
- Initial allocation criteria
- Subsequent allocation criteria
- Address assignment policies
- Other allocation conditions
- Other policies
IPv6 policy – History

- IPv6 policy is “Common Policy” of all RIRs
  - The same policy has been adopted by all
  - Regional adjustment is possible
- First policy published in 1999
  - “Provisional IPv6 Policy” adopted by all RIRs
- Policy revised in 2002
  - After extensive review by all RIRs
- Next policy review
  - Currently under discussion
- Public mailing lists and documentation
  - See http://www.apnic.net
IPv6 address space management

- RIR receives allocations from IANA
  - Currently in /23 units (/16 proposed)
- RIR makes allocation to “ISP” (or “LIR”)
  - ISP must demonstrate need for addresses
  - Policies dictate how need can be demonstrated
  - First allocation minimum is /32
  - Subsequent allocations as needed, when current allocation is fully utilised
- ISP makes assignment to customers
  - Including downstream ISPs
- Provider-based addressing
  - ISP should aggregate address announcement
  - Customer addresses are not portable
IPv6 address structure
IPv6 utilisation – HD Ratio

· Under IPv4, address space utilisation measured as simple percentage:

\[
\text{Utilisation} = \frac{\text{assigned}}{\text{available}}
\]

· IPv4 utilisation requirement is 80%  
  – When 80% of address space has been assigned or allocated, LIR may receive more  
  – E.g. ISP has assigned 55,000 addresses from /16

\[
\frac{\text{assigned}}{\text{available}} = \frac{55,000}{65,536} = 84\%
\]
IPv6 utilisation – HD Ratio

- Under new IPv6 policy utilisation is determined by HD-Ratio (RFC 3194):

\[
Utilisation_{HD} = \frac{\log(\text{assigned})}{\log(\text{available})}
\]

- IPv6 utilisation requirement is HD=0.80
  - Measured according to end-site assignments only (intermediate allocations are ignored)
  - E.g. ISP has assigned 10,000 addresses from /32

\[
\frac{\log(\text{assigned})}{\log(\text{available})} = \frac{\log(10,000)}{\log(65,536)} = 0.83
\]
IPv6 utilisation (HD = 0.80)

\[
\frac{\log(\text{utilised})}{\log(\text{total})} = 0.80
\]

RFC3194 “The Host-Density Ratio for Address Assignment Efficiency”
IPv6 utilisation (HD = 0.80)

- Percentage utilisation calculation

<table>
<thead>
<tr>
<th>IPv6 Prefix</th>
<th>Site Address Bits</th>
<th>Total site address in /48s</th>
<th>Threshold (HD ratio 0.8)</th>
<th>Utilisation %</th>
</tr>
</thead>
<tbody>
<tr>
<td>/42</td>
<td>6</td>
<td>64</td>
<td>28</td>
<td>43.5 %</td>
</tr>
<tr>
<td>/36</td>
<td>12</td>
<td>4096</td>
<td>776</td>
<td>18.9 %</td>
</tr>
<tr>
<td>/35</td>
<td>13</td>
<td>8192</td>
<td>1351</td>
<td>16.5 %</td>
</tr>
<tr>
<td>/32</td>
<td>16</td>
<td>65536</td>
<td>7132</td>
<td>10.9 %</td>
</tr>
<tr>
<td>/29</td>
<td>19</td>
<td>524288</td>
<td>37641</td>
<td>7.3 %</td>
</tr>
<tr>
<td>/24</td>
<td>24</td>
<td>16777216</td>
<td>602249</td>
<td>3.6 %</td>
</tr>
<tr>
<td>/16</td>
<td>32</td>
<td>4294967296</td>
<td>50859008</td>
<td>1.2 %</td>
</tr>
<tr>
<td>/8</td>
<td>40</td>
<td>1099511627776</td>
<td>4294967296</td>
<td>0.4 %</td>
</tr>
<tr>
<td>/3</td>
<td>45</td>
<td>35184372088832</td>
<td>68719476736</td>
<td>0.4 %</td>
</tr>
</tbody>
</table>
IPv6 initial allocation criteria

• Initial allocation size is /32
  – Allocated to any IPv6 LIR (ISP) planning to connect 200 End Sites within 2 years
  – Need not be connected to the Internet
  – This is the default initial allocation to “new” ISPs (“slow start” policy)

• Larger initial allocations can be made if justified according to:
  – IPv6 network infrastructure plan
  – Existing IPv4 infrastructure and customer base
IPv6 allocation to existing network

- Existing ISP infrastructure (IPv4)
  - Policy assumes that transition is inevitable
  - Large IPv4 ISPs will receive IPv6 allocations consistent with the scale of existing networks
IPv6 allocation to existing network

- Allocation size calculated from existing IPv4 network infrastructure and customers:
  - 1 IPv6 /48 per customer
  - 1 IPv6 /48 per POP

- Total allocation according to HD-ratio utilisation requirement
  - Eg if 500,000 /48s are required then /24 can be allocated
IPv6 assignments

• Default assignment /48 for all “End Sites”
  – Providing /16 bits of space for subnets
  – Each end site can have 65,536 subnets
• “End Site” defined as an end user of an ISP where:
  • The ISP assigns address space to the end user
  • The ISP provides Internet transit service to the end user
  • The ISP advertises an aggregate prefix route that contains the end user's assignment
  • Multiple subnets are required

• Examples
  – Home, small office, large office, mobile devices?
  – ISP POPs are also defined as End Sites
IPv6 assignments

- Larger assignments: Multiple /48s
  - Some end sites will need more than one /48
  - Requests to be reviewed at RIR level

- Smaller assignments: /64
  - Single subnet devices should receive /64 only
  - e.g. simple mobile phone

- Smaller assignments: /128
  - Devices with no subnets should receive /128 only
  - E.g. remote sensor

- See RFC3177 (Sep 2001)
IPv6 assignments

- IPv6 assignments to End Sites are used to determine utilisation of IPv6 address blocks
  - According to HD-Ratio
  - Intermediate allocation hierarchy (i.e., downstream ISP) not considered
  - All assignments must be registered
  - Utilisation is determined from total number of registrations

- Intermediate allocation and assignment practices are the responsibility of the LIR
  - Downstream ISPs must be carefully managed
IPv6 registration

- LIR is responsible for all registrations
Subsequent IPv6 allocation

• Subsequent allocation can be made when ISP’s existing address space reaches required utilisation level
  – i.e. HD >= 0.80

• Other address management policies must also be met
  – Correct registrations
  – Correct assignment practices etc (eg RFC 3177)

• Subsequent allocation size is at least double
  – Resulting IPv6 Prefix is at least 1 bit shorter
  – Or sufficient for at least 2 years requirement
Other allocation conditions

• License model of allocation
  – Allocations are not considered permanent, but always subject to review and reclamation
  – Licenses renewed automatically while addresses in use, consistent with policies

• Existing /35 allocations
  – A number of /35s have been assigned under previous “provisional” IPv6 policy
  – Holders of /35s are eligible to request /32
IPv6 IXP assignments

• Available to Internet Exchange Points as defined
  – Must demonstrate ‘open peering policy’
  – 3 or more peers

• Portable assignment size: /48
  – Not to be announced
  – All other needs should be met through normal processes
  – Previous /64 holders can “upgrade” to /48
IPv6 critical infrastructure

- Available to facilities defined as “critical infrastructure”
  - Root servers
  - RIRs and NIRs
  - ccTLD registries

- Assignment size: /32
IPv6 experimental allocation

- Available for experimental purposes
  - Public experiments only
  - Legitimate experiments documented by RFC, I-D or other formal process
  - APNIC may seek independent expert advice

- Allocation size: /32
  - May be larger if required
  - Address space must be returned after 1 year
IPv6 policy – Current issues

• Size of IANA allocation to RIRs
  – Currently under review

• Size of initial allocation
  – /32 for normal allocations
  – HD-ratio applied for allocation to existing IPv4 infrastructure

• HD-ratio
  – Is 0.8 the appropriate value?

• Assignments under RFC 3177
  – No experience yet

• All issues can be reviewed through APNIC open policy process
IPv6 Policy – Summary

• IPv6 address space is easily available
  – Criteria may be hardened in future

• Policy is subject to review
  – Policies evolve as experience is gained
  – Any member of the community may propose changes, alternatives

• Public mailing lists and documentation
  – http://www.apnic.net/
References
APNIC References

• APNIC website
  – http://www.apnic.net

• APNIC IPv6 Resource Guide
  – http://www.apnic.net/services/ipv6_guide.html

• Includes:
  – Policy documents
  – Request forms
  – FAQs
Other References

• IPv6 Forum
  – http://www.ipv6forum.org

• 6Bone
  – http://www.6bone.net

• “The case for IPv6”
  – http://www.6bone.net/misc/case-for-ipv6.html
Questions?

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