IPv6 Address Design

A Few Practical Principles

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Abandon IPv4 Thinking!

- Foremost IPv4 address design consideration: Address Conservation
- Balancing act between:
  - Number of subnets
  - Number of hosts on each subnet
- Result: VLSM
  - Complex
  - Hard to manage
- Legacy “class” categories still occasionally used in IPv4
  - Outdated and misleading
- No such thing as subnet masks in IPv6
  - CIDR-style prefix length notation always used

### IPv6 Global Unicast Address Structure

The IPv6 global unicast address structure consists of 128 bits, divided into four parts:
- **Global Unicast Prefix**: 64 bits
- **Subnet**: 64 bits
- **Interface ID**: 64 bits
- **Public Topology**: 3 bits (always 001)
- **Site Topology**: Variable length, varying from 0 to 64 bits
- **Network (Location)**
- **Node (Identity)**

The diagram illustrates the structure with the following breakdown:
- **Global Unicast Prefix**: 64 bits
- **Subnet**: 64 bits
- **Interface ID**: 64 bits

The first 3 bits are always 001, indicating that the address is a global unicast address.
How Big is the IPv6 Address Space?

- IPv4 developed 1973 – 1977
  - $2^{32} = 4.3$ billion addresses
  - More than anyone could possibly use!
- IPv6 developed mid-1990s
  - $2^{128} = 3.4 \times 10^{38}$ addresses
  - More than anyone could possibly use?
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Some Perspective:

1 picometer = $10^{-12}$ (one trillionth) meter

$2^{32}$ picometers = 4.29 millimeters
  - length of a small ant

$2^{128}$ picometers = $3.4 \times 10^{23}$ kilometers
  - 34 billion light years
  - Furthest visible object in universe: 13.2B LYs
In Practical Terms…

• Typical IPv6 prefix assignments:
  – Service provider (LIR): /32  ➔ $2^{32}$ /64 subnets
  – Large end user: /48  ➔ 65,536 /64 subnets
  – Small end user: /56  ➔ 256 /64 subnets
  – SOHO: /64 or /60  ➔ 1 or 16 /64 subnets

• Address conservation is *not* a major consideration
  – Is this wasteful?
  – Yes! (But that’s okay)

• If you don’t have enough subnets, you don’t have the right prefix allocation
What Do I Get in Exchange for Waste?

- **Simplicity**
  - One-size-fits-all subnets
- **Manageability**
  - Hex is much easier to interpret at binary level than decimal
- **Scalability**
  - Room to grow
- **Flexibility**
  - Room to change
Designing for Simplicity

- Start by mapping “working” bits
  - Generally the bits between assigned prefix and Interface-ID
- Group by hex digit
  - 4 bits per hex digit
- Define “meanings” you need to operate
  - Geographic area? Logical topology? Type designation? User ID?
- Try to keep “meanings” on hex boundaries
  - Defined meanings will then be some multiple of $2^{4n}$
    - Ex: 16, 256, 4096, 65536…
- Don’t get carried away with meanings
  - No need for 10 layers of address hierarchy if 4 will do
Designing for Simplicity (continued)

• Use zero space as much as possible
  – Which address is easier to read?
    • 2001:DB8:2405:C::27

• Benefit: Operations quickly learns to focus on meaningful bits
  – Ignore public prefix (usually)
  – Ignore Interface-ID (usually)
  – A few hex digits tell operations most of what they need to know

2001:DB8:2405:C::27

Region    Office    Subnet
Designing for Scale

- Leave “zero” space whenever possible
  - Designate as Reserved
- Insert between “meaningful” digits or bits
  - Allows future expansion in two directions
Designing for the Future

• Trying to anticipate the unanticipated
  – A challenge for any kind of design
• Another reason for well-placed Reserved (zero) space
  – Horizontal Reserved space
  – Vertical Reserved space
• Do not integrate IPv4 into an IPv6 design!
  – Reading IPv4 in hex is (almost) meaningless
  – IPv4 will (eventually) go away
What About Point-to-Point Links?

• 18 million trillion addresses in a /64 link
  – And I will only ever use 2 of them?
  – Are you kidding???

• People have a very hard time accepting this
  – Again: This is not IPv4!
  – What else are you going to do with those addresses?

• It’s a matter of comprehending the scale
  – 500 out of $2^{64}$ is not really any bigger than 2 out of $2^{64}$
Point-to-Point Subnets

• Reasons for using /64:
  – RFC 3627
  – RFC 5375 => /64 usage endorsed and encouraged
    • IANA and RIRS also encourage /64 everywhere
  – Design consistency
  – Required for SLAAC
  – Anycast problems are not significant on PtP links
    • Subnet-Router Anycast
    • MIPv6 Home Agent Anycast
Point-to-Point Subnets

• Reasons for using /127:
  – RFC 6164
  – Ping-pong vulnerability
    • This is an issue with older version of ICMPv6 (RFC 2463)
    • Issue is corrected in newer version of ICMPv6 (RFC 4443)
    • Vendors: Upgrade your code!
  – Neighbor cache exhaustion vulnerability
Point-to-Point Subnets

• Don’t use /126
  – This is IPv4 thinking
  – “Subnet number” is meaningless in IPv6
  – IPv6 does not use broadcast addresses

• Potential compromise:
  – Assign /64 per PtP subnet
  – Address /127 out of the /64
What About Provider Independence?

- There is (currently) no NAT66
- PI address assignment rules (varies by RIR):
  - Must not be an LIR
  - Must be an end site
  - Must have previously justified a PI IPv4 assignment; or
  - Must currently be multihomed with IPv4; or
    - And have an assigned ASN
    - Proposals to end this requirement
  - Will make active use of 2000 IPv6 addresses within 12 months; or
  - Will make active use of 200 /64s within 12 months; or
  - Technical justification why cannot use assignment from LIR
- PI assignment: One or more /48s
  - Larger based on number of sites
- Micro-allocations available for critical Internet infrastructure
Link Local vs Global Unicast

- Some conflict of interpretation
  - Static route next hops
  - BGP peering
- IPv6 says use link local for direct connections
- Accepted practice is to use global unicast
- Recommendation: Stick with accepted practice
  - Link-local harder to manage
  - Interface changes can change link-local address
Other Issues

• DNS design and management is critical
  – DNS issues are well documented

• IP Address Management is critical
  – IPv6 design is not easy to manage via spreadsheets
  – Good luck finding integrated DNS and DHCPv6 management

• Stateful vs Stateless Address Configuration

• Abandon IPv4 thinking!
Questions?

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