IPv6 Address Planning Lab

FOCUS ON LARGE ENTERPRISES / ORGANIZATIONS

MIKE ACKERMANN

BLUE CROSS

MACKERNANN@BCBSM.COM

Collaborative Project

- India Internet Engineering Society (IIESoc) and Industry Network Technology Council (INTC)
- Funding: Grant from ISIF Asia
- Thank you!

https://www.iiesoc.in/

https://industrynetcouncil.org/

Vision

Multi-year project: IPv6 deployment at enterprises.

Collaboration with American Registry for Internet Numbers (ARIN)

- Provide training,
- Analysis of security and application conversion,
- Help enterprises plan their IPv6 deployment.

Classes

- Introduction to IPv6 : Feb 4, 2021 ✓
- Lab: IPv6 basics : Feb 11, 2021 ✓
- Neighbor Discovery: March 4, 2021 ✓
- Lab: Neighbor Discovery: March 18, 2021 ✓
- IPv6 Address Planning: April 8, 2021 ✓
- Lab: IPv6 Address Planning: April 15, 2021
- IPv6 Transition Mechanisms: May 6, 2021
- Lab: IPv6 Transition Mechanisms: May 13, 2021

- DHCPv6: June 3, 2021
- Lab: DHCPv6: June 10, 2021
- IPv6 and Cloud: June 17, 2021
- Lab: IPv6 and Cloud: June 24, 2021
- Introduction to IPv6 Security July 8, 2021

The next sessions are sponsored by a generous grant from ARIN.

- Trace Reading: August 12, 2021
- Troubleshooting: August 19, 2021

Mike Ackermann

- Michael Ackermann is the **Lead Network Engineer of the System Management and Monitoring Team, at Blue Cross Blue Shield of Michigan.**
- He is responsible for all aspects of **planning, engineering, deployment and administration** for all enterprise wide Management, Monitoring and Diagnostic activities.
- Mike also serves as a **chief architect** for all Plan related IT issues. He has been a member of the BluesNet and Network Advisory Group committees since their inception and has served as committee and subcommittee chair on numerous occasions. Mike has also been a member of several advisory boards and is currently **active in the IETF and INTC**.

Agenda

- Topology / characteristics common to large enterprises / organizations
- How this affects IPv6 address planning
- Mapping information into IPv6 addresses
- Impact and/or benefits on operation
- Examples

Nalini's Rules from Last Week

IPv6 Address Planning Presentation

1. Use /48 for site.
2. Use /49 - /63 for subnets.
3. Leave /65 – 128 for IID.
4. Break on nibble boundary.
5. Aggregate routes.
6. Remember security!
7. Use sparse allocation.
8. Avoid reserved addresses.
9. Decide policy for point-to-point links.

Enterprise Topology: General

- Large numbers of EVERYTHING
- Bottom line focused $$$
- Often spanning large geographic area

Enterprise Topology: Logical Structure

Logical geographic structures delineate the large areas. (for both business and technical reasons):

- Continents, countries, regions, states, cities, buildings, floors, etc.
- Usually dictated by business factors, industries, markets, demographics, etc.
- Varies by industry, size, objectives and other requirements

Enterprise IPv6 Address Structure

- IPv6 address structure should support and reflect enterprise logical structure
  - And is flexible enough to do so!

- Mainly pertains to:
  - internal addresses
  - But also, maybe ……
    - Other **"Entities"** such as subsidiaries, divisions, business partners (even customers??)
- Depends on the relationships

Public / Private Addresses

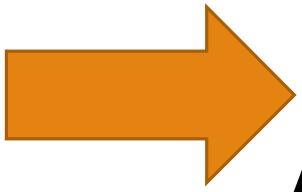
- In the IPv4 world, enterprises usually use both public and private addresses
  - Private: Inside
  - Public: Outside
- How will we do this (and more) in IPv6?

Network Management

- Network management is a huge concern because of the large number and types of devices **managed.**
- Usually have help desk, NOC, SOC, etc. and they are critical functions.
- IP addresses can used as identifiers!
  - IPv6 can enhance this!

How can we design an IPv6 address plan with all these considerations????

Characteristics
Information
Requirements
Data



IPv6 Address

HOW CAN WE POSSIBLY GET FROM HERE TO THERE??

Strategic Business Directions

Talk to business strategic planners and management. Understand directions, priorities and scope changes.

- Will business be expanding to other regions, markets, demographics?
- Will numbers be increasing or decreasing?
- Consider: $$$, customer base, employees, **business partners**.

IT / Technical Directions

Talk to Technical Architects and IT Strategic Management. Determine information such as:

- #'s of clients, servers & networks.
- Amount of data and location(s).
- Performance requirements
- Management issues
- New: Apps, sites, customers vendors
- Cloud or hybrid?

Determine ALL areas involved and get their input & support (not just IT).

*** IPv6 Address Plan Document ***

1. IPV6 ADDRESSING OBJECTIVES
2. ADDRESS SPACE DETAILS
3. ADDRESS TYPES AND GLOBAL NETWORK PREFIX
4. ADDRESS SPACE - PREFIX ASSIGNMENTS
5. ADDRESS PREFIX ROUTING DEFINITIONS
6. SUBNET ALLOCATION AND LOCATION DEFINITION
7. HOST ADDRESSES

Have at least these 7 sections!

- Use as a framework.
- Adapt to your situation.
- **And do this first!**

IPv6 Addressing Objectives

What do I want this for and how much IPv6 address space do I need? (/xx)

- What **"Entities"** should have their own sub networks?
  - Examine requirements: Geographical/Organizational characteristics, location, segmentation, Business Partners, etc.
- How big does each subnetwork need to be? (/yy of the /xx)
  - And how many you need, will determine the /xx
- Does each subnetwork have its own sub subnetwork requirements? (regions, cities, buildings, floors, divisions, departments, etc.)
  - Per Rule #1, lets allocate a large amount of /48's for each. (e.g. 4k).
- Determine what is likely to be the largest subnetwork and work backwards from there.

IPv6 Addressing Objectives

How much IPv6 address space do I need? The yy of the (/xx)

- **Example thought process:**
- The enterprise has 100 such entities today (some smaller).
  - E.G. US, Europe, China, Singapore, Government, Insurance, Sales…
  - Lets say US-Sales subsidiary is the biggest and has sub requirements for 4k (or less) /48's. (rule #1).
    - Assume US-S has 20 locations in every state.
  - But all sub entities, should have the same size or /yy, for consistency.

- Business expects growth of 100% in 3-5 years. (200).
- Add room for expansion (Rule #6) and stay on a "Nibble" (Rule #4) boundary, and we arrive at 256!
- And aim high! Out of respect for Internet Routing Tables. ☺
  - So, if anything, go higher than 256 in this planning process.

IPv6 Addressing Objectives

How much IPv6 address space do I need? (/xx)

Based on above, we forecast the need for 256 subnetworks. This requires 8 bits, leaving 28 bits for a prefix. So, to accommodate our projected business and networking requirements, we think we need a /28, subdivided into 256 /36s!!!

The above is illustrative of the type of information and math needed to project IPv6 addressing objectives.

With this type of effort, information and results, the RIR/NIR will be much more likely to grant such a request and the enterprise will be much better prepared to utilize the address space in a much more effective fashion. DO THIS FIRST!

Address Space Details

How do I break down the bits of my /28 IPv6 address space?

OBJECTIVE: Create a logical mapping between the IPv6 Address space (/28 in this example), and the present & future networking requirements of the organization(s), it will support.

Proposed breakdown of the 128 bits in a /28 IPv6 address, sub divided to accommodate 256 /40's.

nnnnnnnnnnnnnnn:nnnnnnnnnnnnaaaa:aaaaxxxxxxxxxxxx:ssssssssssssssss:
hhhhhhhhhhhhhhh:hhhhhhhhhhhhhhh:hhhhhhhhhhhhhhh:hhhhhhhhhhhhhhh

Where:

n = / 28 Network Bits as assigned by the RIR.

a = /36 Allocated network Bits as assigned by internal IPAM staff. (256 /36's).

x = Sub Allocated bits for each /48 in each /36 to be utilized internally or externally. (4K /48's per /36).

s = Sub Net Bits utilized as appropriate internally or externally.

h = Host Bits utilized as appropriate internally or externally.

Address Space Details

How do I break down the bits of my IPv6 address space? (/xx = /28 EXAMPLE)

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x, s, and h bits can be used as determined appropriate by the enterprise. Standard setup being discussed provides 256 /36's. Every /36 will have 4096 /48's, and each /48 will have 64K subnets and 18 quintillion (10 **18) hosts per subnet.

Example : 2600:1500:1001:0002:0000:0000:0000:0001

OR **2600:150**0:1001:0002::1

IPv6 Network /28 = **2600:150** /36 = 2600:150**0:1**

/48 = 2600:1500:1**001** Subnet = 0002 Host = ::0001

Summary

- Previous example assumes that organization with the /28, will have 256 internal or external entities, for which IP connectivity is required.
- Each entity has a /36 dedicated to them and be used by that entity.
- Accommodate current and projected growth.
- Each entity can break down their /36, into /48s, for their needs (ex. divisions, regions, cities, buildings, environments or other.

This does not apply to me!

- **What if your organization's business and networking needs are completely different?**
- Many ways to use a flexible and strategic resource as an IPv6 address space!

Address Space Details

Alternative bit breakdown examples

As an alternative, a /28 could be sub divided into over a million /48's, each of which has 64K subnets and 18 Quintillion hosts per subnet.

nnnnnnnnnnnnnnn:nnnnnnnnnnnnxxxx:xxxxxxxxxxxxxxxx:ssssssssssssssss:
hhhhhhhhhhhhhhh:hhhhhhhhhhhhhhh:hhhhhhhhhhhhhhh:hhhhhhhhhhhhhhh

Or as a final alternative, a /28 could be utilized to provide over 1 Nonillion host addresses. (2 **100 or a 1 followed by 30 zeros!).

nnnnnnnnnnnnnnn:nnnnnnnnnnnnhhhh:hhhhhhhhhhhhhhh:hhhhhhhhhhhhhhh:
hhhhhhhhhhhhhhh:hhhhhhhhhhhhhhh:hhhhhhhhhhhhhhh:hhhhhhhhhhhhhhh

Address Types and Global Network Prefix

RECOMMENDATIONS

- Use Provider Independent(PI) vs Provider Dependent (PD)
  - From RIR vs ISP. $$$?
  - Flexibility when doing multihoming or switching ISPs
- Use **Global Unique Addresses** that begin with your Global Network Prefix, granted by the RIR
- GUA's should be the primary addresses used for most all IPv6 traffic.
- GUAs, will start with the **Global Network Prefix**, granted by the RIR or ISP.
  - /28 in our examples.
  - In our examples the Global Network Prefix is: 2600:150

Address Types

- **Link Local Addresses** will be automatically generated by the OS on all IPv6 Interfaces.
  - All LLAs start with fe80:
  - LLAs used by all OS's and IP stacks for core IPv6 functions and most intra subnet connectivity.
- **Temporary or Privacy addresses** are available on most OS's and may be useful in certain situations
  - Temporary address change automatically
  - Detailed discussions and specifics needed to determine if/when they may be appropriate

Address Types

- **Unique Local Addresses** (ULA's) are also available on most all OS's.
  - May be useful to replace Private or RFC1918 addresses. (if needed).
  - Detailed discussions and specifics needed to determine if/when ULAs may be appropriate

Can have multiple of each IPv6 address type on a given interface.

In general, it is recommended to (at least initially) keep things simple and keep the number of IPv6 addresses per interface to the lowest number required. Frequently this will be one LLA (which is always needed), and one GUA, with your Global Network Prefix. This should provide all the local and global scope connectivity required, for most situations.

ADDRESS SPACE - PREFIX ASSIGNMENTS

HOW TO "SUB DIVIDE" YOUR IPV6 ADDRESS SPACE

In the mapping of business requirements, the projected need was for 256 /36s

- Values need to be assigned to these /36 prefixes.
  - Values would correspond to sub "Entities"
- In much the same way the RIR will assign a value to the Global Network Prefix (e.g. 2600:150), internal IPAM staff will need to assign values to as many as 256 /36's. (the "a" bits in the Address Space Detail section.
- Intent is to utilize some of these /36's for Internal (and subsidiary) networks.
- The remainder would be designated for partner organizations and future use.

Address Space Prefix Assignments

How to "subdivide" your IPv6 address space

000------031 Internal /36 Networks

- 000 ..... Production
- 001 ..... Non Production
- 002 ..... Lab
- 003 ..... Cloud

004----- 009 ..... BGP/ISP Multi-Homing

032------063 Corporate External

- 032 ..... Disaster Recovery
- 033 ..... Subsidiary #1

064------192 Business Partners

- 064 ..... Partner Network #1
- 065 ..... Industry Association #1
- 066 ..... Government Agency #1

193------255 Reserved

Example Mapping: Can be changed as business and network requirements evolve.

Address Prefix Routing Definitions

How to “route” within your IPv6 address space

- Thought: “subdividing” the /28 into /36s, best supports the organizations business model.
- So, makes sense to use /36 as the routing prefix and aggregate IPv6 routes to that level.
- Please note: not recommended to use prefixes longer than /64, as many common IPv6 functions may not work.

Address Prefix Routing Definitions

IP route aggregation

- IP routing aggregation is a very good practice and IPv6 deployment is an excellent opportunity to revisit or improve IP routing. (Rule #5).
- Currently, mainly focused on geographic network information, but may make sense to consider traffic patterns and other factors as well.
- Many IPv6 implementations and end points will default to /64. So, make the extra effort to customize & optimize for your environment!

Route Aggregation

- IP Routing is a very big and important topic all by itself. Significant enough to require separate efforts from the address planning initiative.
- For now, the takeaway should be, that routing is crucial, and aggregation should be incorporated wherever possible for some very important reasons, including performance, availability and management.
- Probably even more important in IPv6

Route Aggregation Example

/36 ADDRESS PREFIX ROUTING AGGREGATION EXAMPLES:

2600:1500:0000/36 …….. PRODUCTION
2600:1500:1000/36 …….. LAB
2600:1506:4000/36 …….. PARTNER NETWORK #1

WITHOUT AGGREGATION EXAMPLES? …….. NONE, RIGHT? ☺

Address Prefix Routing Definitions

HOW NOT TO "ROUTE" WITHIN YOUR IPV6 ADDRESS SPACE

WITHOUT AGGREGATION EXAMPLES:

2600:1500:0000:/64 …… 2600:1500:0fff:/64 (4k /48's each have a route table entry)

OR WAIT! IT COULD GET WORSE !!!!

2600:1500:0000:0000/64 …… 2600:1500:0fff:ffff/64 (4k /48's and 64K subnets in each have a route table entry) 270 million entries in routing tables!

☹ ☹ ☹

SO ONCE AGAIN IT IS LIKELY WELL WORTH THE EXTRA EFFORT TO ADDRESS AGGREGATION AND OPTIMIZE ROUTING!

Why Subnets?

- Allow addresses to provide more information to users, apps, tools and management functions.
- Enhance routing efficiency
- Better understanding and usage of geographical characteristics.
- Extended security, segmentation and control

Subnet Allocation and Location Definition

- Frequently used to designate locations, which can provide valuable diagnostic data (Help Desk, etc.), self-documenting information and even enhance network performance.
- Subnetting can provide value to both IPv4 and IPv6.
- Primarily applies to internal network.

Subnet Allocations : Historical (IPv4)

- Most organizations already have an IPv4 subnet framework.
- Usually, it is well thought out and reflects years of organizational experiences.
  - Geographical information and related controls.
  - Departmental, security and VLAN controls. (e.g. limit how big a subnet should be)
  - Enhance traffic flow

Moving to IPv6

- Makes sense to adopt similar approach for IPv6
- Particularly effective in dual stack environments.
- How to do this?

- In general, (at least initially) keep things simple and keep the number of IPv6 addresses per interface to the lowest number required.
- Frequently this will be one LLA (which is always needed), and one GUA, with your Global Network Prefix.
- This should provide all the local and global scope connectivity required, for most situations.

Subnet Example: Private IPv4

10.rrr.ccc.hhh

Where

rrr = Region or Country

ccc = City or Building

hhh = host

an example could be:

10.65.141.001

Where

65 = United States

141 = Chicago

- Many organizations use private / RFC1918 IPv4 addresses internally.
- Use the middle octet to identify location.
- Sample schema on the left.

!

Subnet Allocation IPv6 Example

Compatible IPv6 schema below. Use the subnet bits (s bits) in hex.

Example:

IPv4 address in Chicago, US 10.**65**.**141**.001

IPv6 address in Chicago, US 2600:1500:1001:**418d**::1

DON'T RE INVENT THE WHEEL, IF YOU DON'T HAVE TO!

Host Addresses

1. Stateless auto configuration (SLAAC).
2. Stateful DHCPv6
3. DHCPv6 – PD
4. Stateless DHCPv6
5. Manual – Static.
6. CGA.
7. Combinations of above.

- Host bits (H bits) or the IID, occupy the right most 64 bits of the IPv6 address.
- Several methods for assigning these 64 bits.

Host Addresses

- Each method will have various ways to assign specific bits
- Many use some form of EUI-64, which uses the MAC address to compute the Host Bits.
  - Industry research is ongoing to determine if this method possesses drawbacks such as security issues
  - Privacy or Security Addresses are potential alternatives, if the above is considered an issue.
- SLAAC is very low maintenance and requires little or no manual effort
  - Particularly appropriate where access is difficult, or numbers are large (e.g., IOT devices)

Static and DHCPv6

- DHCPv6 may provide the management, configuration and control, that large organizations are accustomed to for most clients.

- Manual – Static may continue to be appropriate for long standing servers.

Host Addresses: Large Topic!

How to determine and define Host addresses is a large and important subject all by itself.

- More detail to follow on this crucial topic. (and maybe even a lab!).
- For now, please be aware that there are numerous good alternatives, and the best method will usually vary, based on the role of the device and its location in the network.
- Good idea to plan for expansion or growth. (Rule #7).
- Great idea to assure that ANY method interfaces with DNS and IPAM.

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Questions?

Contact:

mackermann@bcbsm.com

nalini.elkins@insidethestack.com

president@industrynetcouncil.org

info@iiesoc.in

More webinars at:

industrynetcouncil.org