IPv6 Address Planning

NALINI ELKINS

Industry Network Technology Council

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Collaborative Project

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

Vision

Multi-year project: IPv6 deployment at enterprises.

- 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
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- 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.

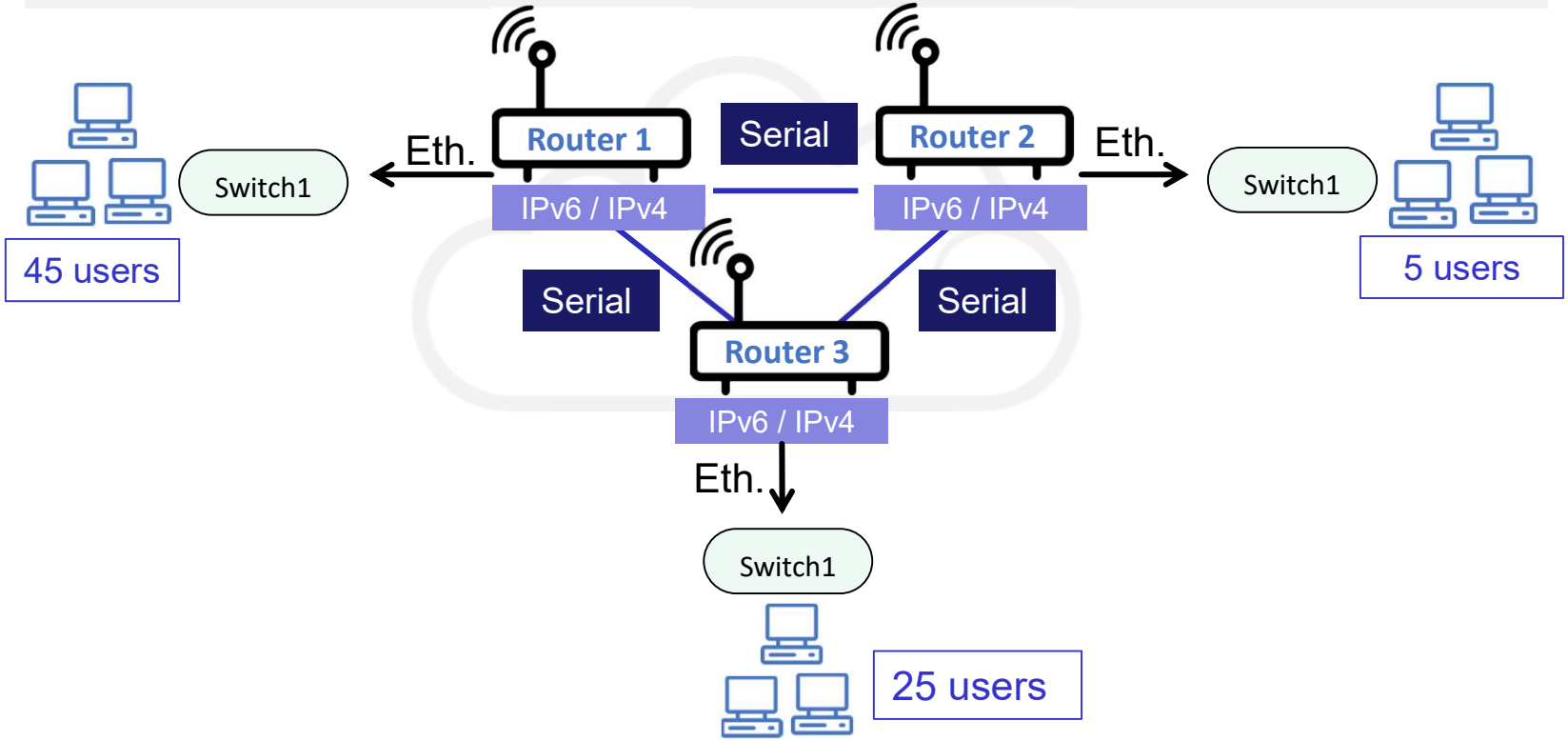
- Trace Reading: August 12, 2021
- Troubleshooting: August 19, 2021

A few words about me

- President: Industry Network Technology Council
- Founder & CEO: Inside Products, Inc.
- Advisory Board: India Internet Engineering Society
- RFCs: RFC8250 (Embedded performance and diagnostics for IPv6) and others
- Product developer (OEMed by IBM and others)
- Working with IPv6 for 15 years
- Working with network management, diagnostic, performance issues at large brick-and-mortar enterprises for over 30 years

What Is Address Planning?

- Break out your address range by ‘subnets’ or regions
- Assign addresses to devices (servers, clients, routers)

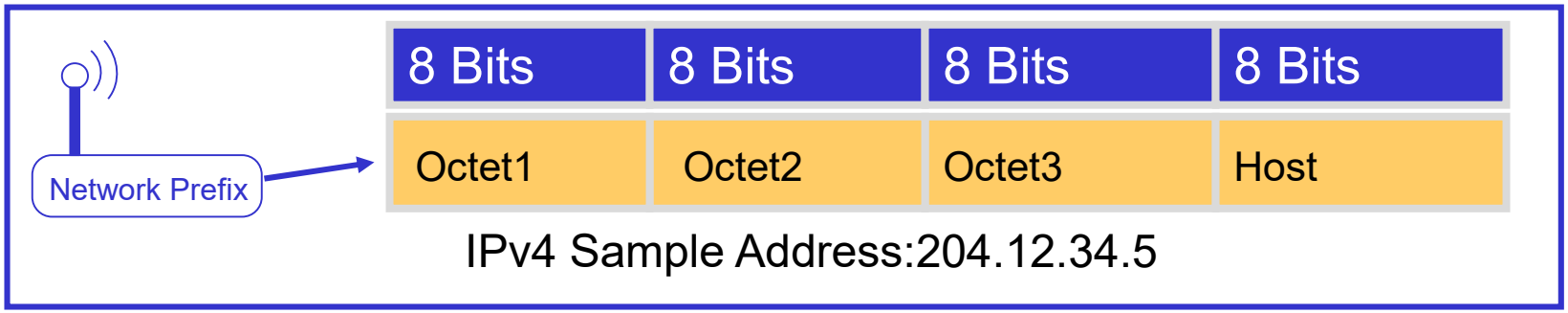


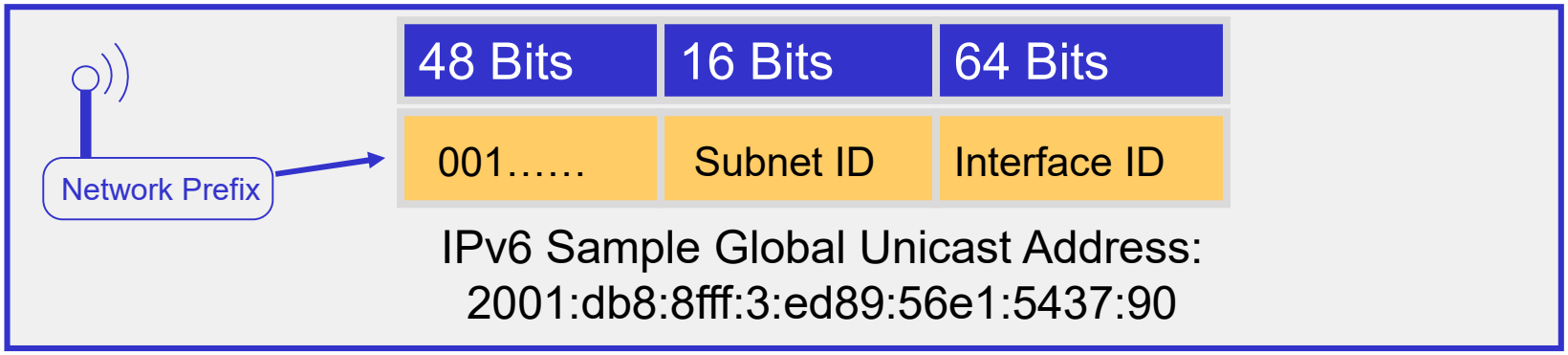
Important IPv6 Address Prefixes

Let's review!

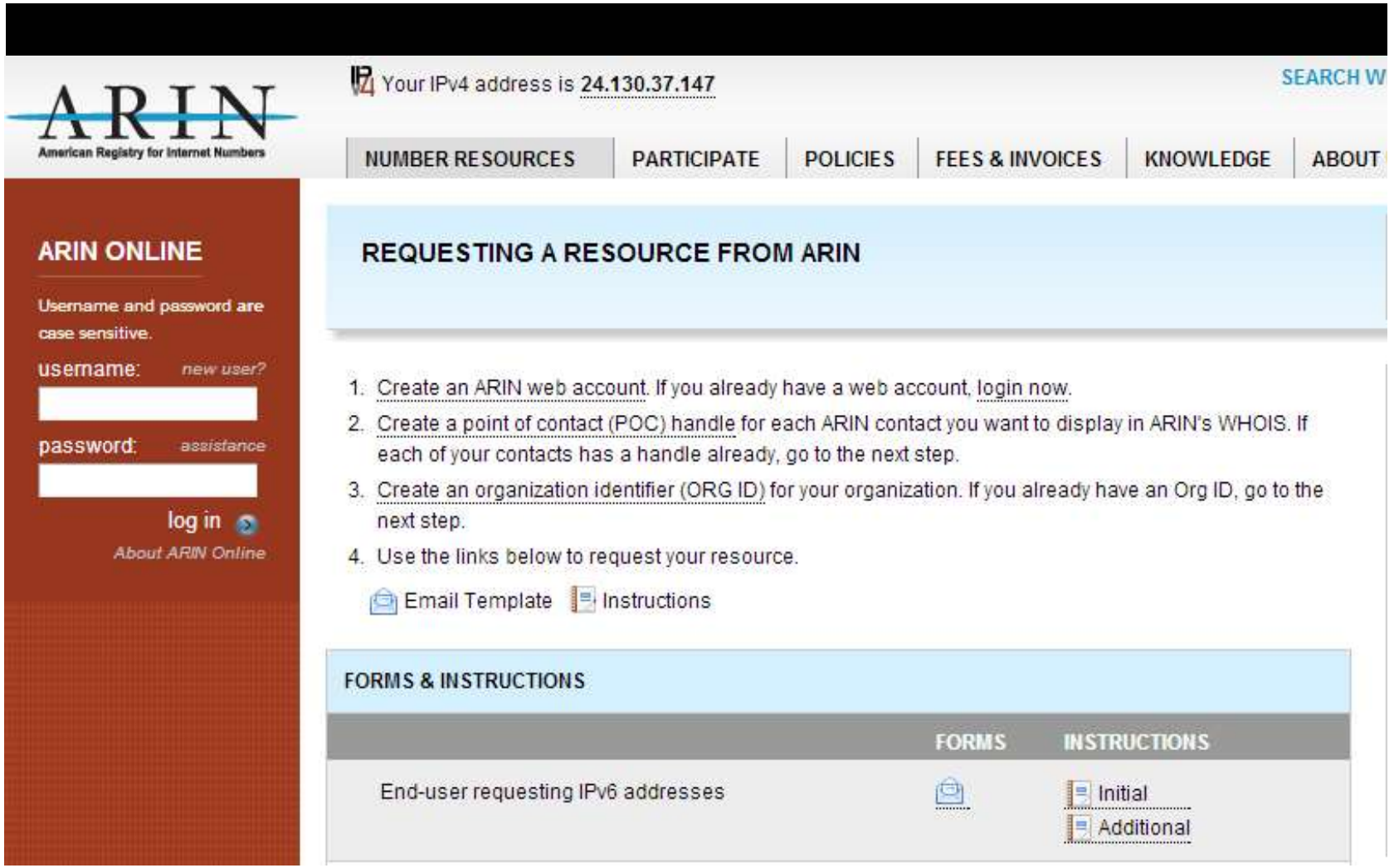
/8	11111111xxxxxxxx.xxxxxxxxxxxxxxxx. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx	00xx:: FFxx::
/16	1111111111111111.xxxxxxxxxxxxxxxx. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx	0000:: FFFF::
/32	1111111111111111.1111111111111111. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx	0000:0000:: FFFF:FFFF::
/48	1111111111111111.1111111111111111. 1111111111111111.xxxxxxxxxxxxxxxx. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx	0000:0000:0000:: FFFF:FFFF:FFFF::
/56	1111111111111111.1111111111111111. 1111111111111111.11111111xxxxxxxx. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx	0000:0000:0000:00xx:: FFFF:FFFF:FFFF:FFxx::
/64	1111111111111111.1111111111111111. 1111111111111111.1111111111111111. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx. xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx	0000:0000:0000:0000:: FFFF:FFFF:FFFF:FFFF::

What Is An Address Range?





Get IP Addresses from ISP or RIR

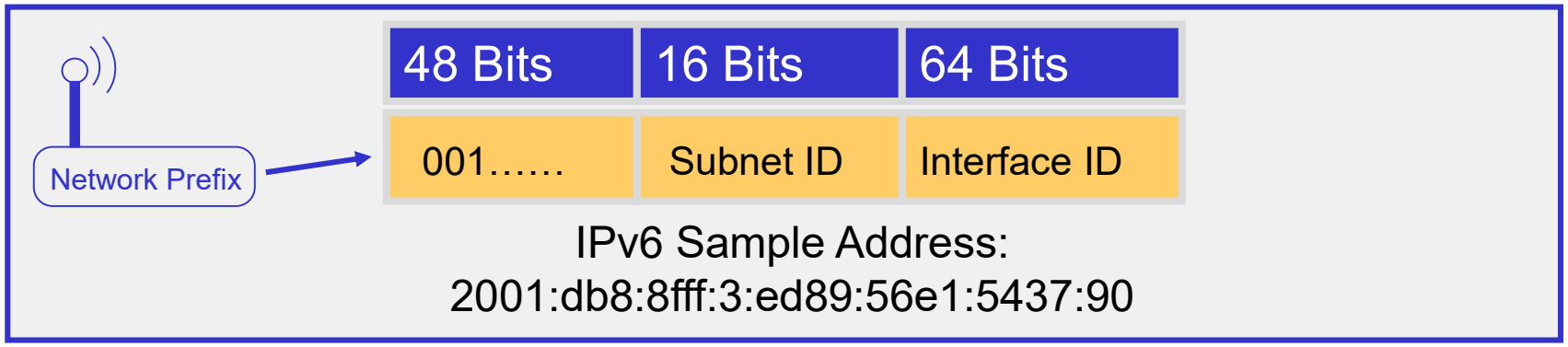


What Do You Get?

- From ISP, one /48 per site
  - 2^{16} or 65,536 subnets/LAN segments
  - 2^{64} hosts per subnet
- From ARIN, by default
  - For an ISP/LIR, at least one /32

- For an enterprise:
  - More than 1 but less than or equal to 12 sites justified, receives a /44 assignment;
  - More than 12 but less than or equal to 192 sites justified, receives a /40 assignment;
  - More than 192 but less than or equal to 3,072 sites justified, receives a /36 assignment;
  - More than 3,072 but less than or equal to 49,152 sites justified, receives a /32 assignment; etc…

Is This Enough?



- Network Prefix from ISP/ARIN (48 bits)
- Subnets ID: 16 bits = 2^{16} = 65,536 network segments
- Interface ID: 64 bits = 2^{64} = 18,446,744,073,709,551,616 hosts

Exponential Growth (Powers of 2)

20	1048576	104.9 x 10**-3	quarter of the Sears tower (440m)
25	33554432	3.4 x 10**0	past the Matterhorn
30	1073741824	107.4 x 10**0	outer limits of the atmosphere
35	34359738368	3.4 x 10**3	
40	1099511627776	109.9 x 10**3	
45	35184372088832	3.5 x 10**6	
50	1125899906842624	112.5 x 10**6	~ distance to sun (95 million miles)
55	36028797018963968	3.6 x 10**9	
60	1152921504606846976	115.3 x 10**9	size of the solar system?
65	36893488147419103232	3.7 x 10**12	one-third of a light year
70	1180591620717411303424	118.1 x 10**12	11 light years
75	3777893186295716170956	3.8 x 10**15	377 light years
80	1208925819614629174706176	120.9 x 10**15	12,000 light years
85	38685626227668133590597632	3.9 x 10**18	4x the diameter of our galaxy
90	1237940039285380274899124224	123.8 x 10**18	12 million light years
95	39614081257132168796771975168	4.0 x 10**21	
100	1267650600228229401496703205376	126.8 x 10**21	(12 billion light years) approx. radius of the known universe?

What to Do Once You Have It

- Network planning
  - Divide address range by subnets or regions
    - A subnet is defined by a prefix, a bit string with a length. Often associated with a LAN.
    - Prefixes often assigned to buildings, campuses, or other regions.
  - Assign addresses from that prefix to attached interfaces (servers, clients, routers, etc.)

- Changes from IPv4
  - No broadcast address
  - Many more hosts per subnet, or freer use of the interface (host) identifier
  - No NAT

Simple IPv6 Address Plan

- Given: 2001:db8:56::/40
- Nationwide company:
  - 50 regions,
  - 100 offices per region,
  - 100 departments per office
- Initial allocation:

More than 12 but less than or equal to 192 sites justified, receives a /40 assignment;

/40

1111111111111111.1111111111111111.
11111111xxxxxxxx.xxxxxxxxxxxxxxxx.
xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx.
xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx

2001:db8:56::/40

Define Regions

- Make regions /48
- Range: 2001:db8:5600:: to 2001:db8:56**FF**::
- 256 possible regions
- Only need 50

/48

```
1111111111111111.1111111111111111.
1111111111111111.xxxxxxxxxxxxxxxx.
xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx.
xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx
```

- For example:
  - Alabama: 2001:db8:56**00**::/48
  - Alaska: 2001:db8:56**01**::/48
  - Arizona: 2001:db8:56**02**::/48
  - California: 2001:db8:56**03**::/48

Define Offices

- Make offices each /56
- The range is: 2001:db8:56nn:**00**::/56 to 2001:db8:56nn:**FF**::/56
- 256 offices per region
- Need only 100 per region

/56

1111111111111111.1111111111111111.
1111111111111111.11111111xxxxxxxx.
xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx.
xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx

0000:0000:0000:0000::
FFFF:FFFF:FFFF:FFFF::

- For example, in California:
  - Oakland: 2001:db8:5603:**01**::/56
  - Carmel Valley: 2001:db8:5603:**02**::/56
  - Moraga: 2001:db8:5603:**03**::/56
  - San Diego: 2001:db8:5603:**04**::/56

Define Departments

- Make departments each /64
- Range: 2001:db8:56nn:nn**00**:: to 2001:db8:56nn:nn**FF**::
- 256 possible departments per office
- Need only 100

/64

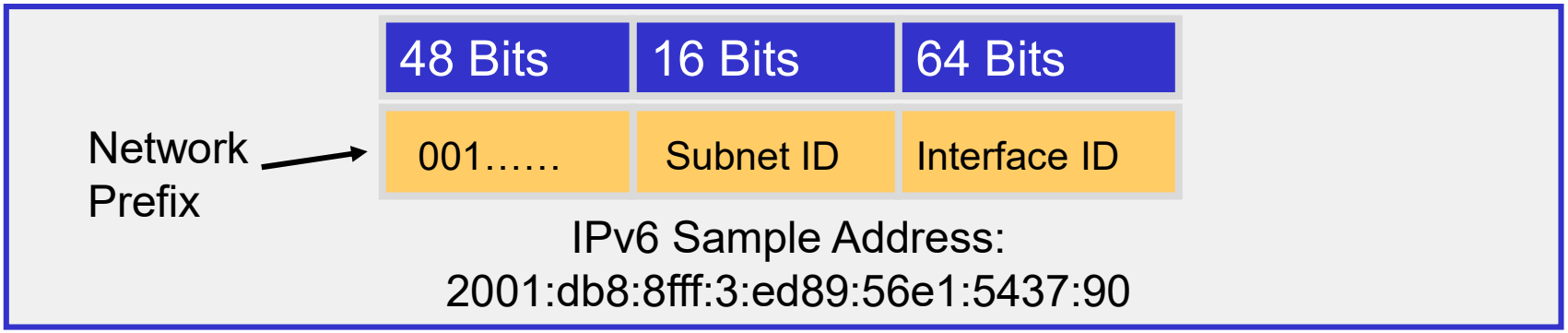
1111111111111111.1111111111111111.
1111111111111111.1111111111111111.
xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx.
xxxxxxxxxxxxxxxx.xxxxxxxxxxxxxxxx

0000:0000:0000:0000::
FFFF:FFFF:FFFF:FFFF::

- For example, the Carmel Valley office:
  - Payroll: 2001:db8:5603:02**00**::/64
  - Engineering: 2001:db8:5603:02**01**::/64
  - Shipping: 2001:db8:5603:02**02**::/64
  - Sales: 2001:db8:5603:02**03**::/64

Remember! 64-bit Interface ID

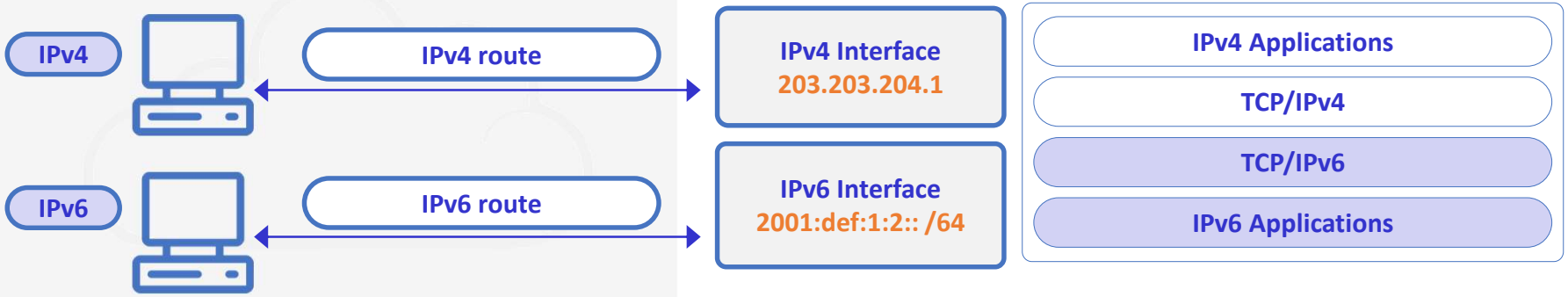
- Format of a Global Unicast Address!
- Save 64 bits for the Interface ID.



Let's Make Some Rules

1. Use /48 for site.
2. Use /49 - /63 for subnets.
3. Leave /65 – 128 for IID.

Dual Stack



Dual Stack: Running both IPv4 and IPv6 stacks on the same device/network

SOME THINGS OTHERS HAVE DONE IN ADDRESS PLANNING

Using VLAN Number

- Use VLAN number in subnet number
- Use IPv4 address (if any) as host address

```
interface vlan201
    ip address 192.0.201.1 255.255.255.0 1
    ipv6 address 2001:db8:5678:201::192:0:5:1/64
```

- Note that 2001:db8:5678:201::192:0:5:1 != 2001:db8:5678:201::192.0.5.1
- If you're strict about this embedding, you limit possible addresses to IPv4 space

Reuse IPv4 Host ID

- Host ID **123**
- IPv4: 129.150.201.**123**
- IPv6: 2001:db8:5678:201::**123**

Other Conventions

- Use first 48 bits of IPv6 host ID
- 2001:db8:5678:201:**xxxx**:**xxxx**:**xxxx**:**hhhh**
- Examples
  - DHCP assigned: 2001:db8:5678:201:**xxxx**:**xxxx**:**Dxxx**:**hhhh**
  - IP Printers 2001:db8:5678:201:**xxxx**:**xxxx**:**Bxxx**:**hhhh**

Security note: using the full 64 bits of address space makes a network scan harder.

Other Ways to Assign

- Geographical Boundaries
- Organizational Boundaries
- Security policy
- Service Type
  - VoIP,
  - Wireless,
  - Internet Access,
  - Security zones

Breaking on Nibble Boundary

- Nibble is half of a byte. (A byte is 8 bits. So, a nibble is 4 bits)

2001:db8:5678:1201:DF89:783C:2590:67ED

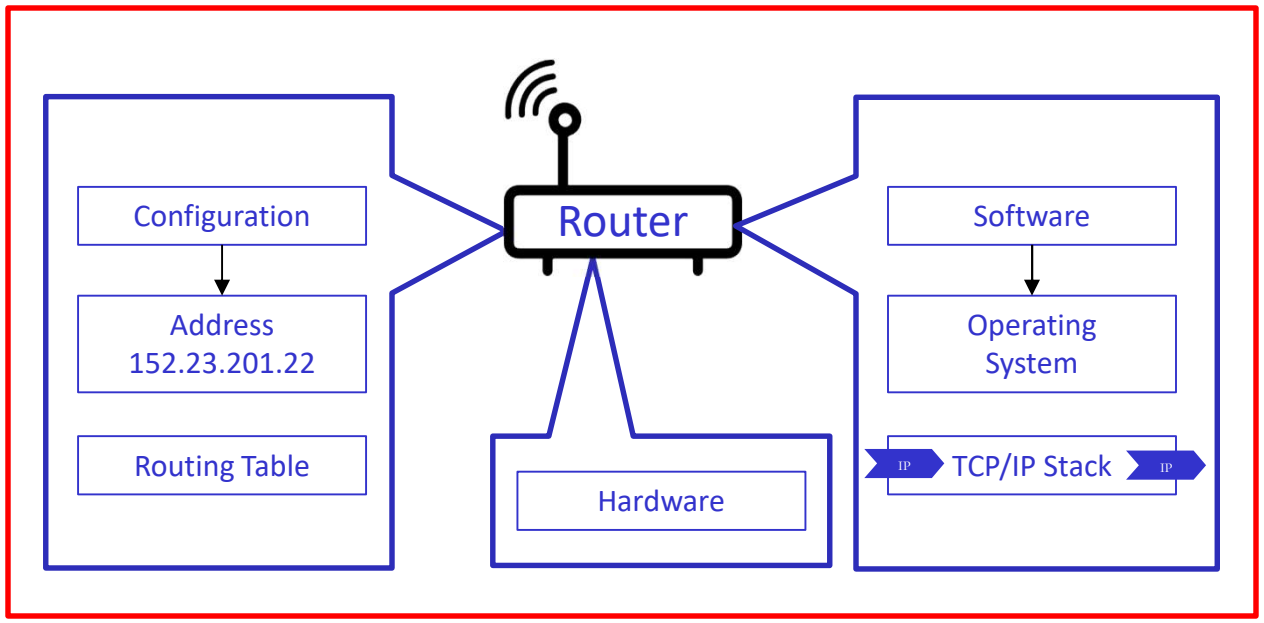
XXXX:XXXX:XXXX:XXXX:XXXX:XXXX:XXXX:XXXX

- X marks nibble boundary
- Break at bit 4, 8, 12, 16, etc. (All the multiples of 4)

New Rule

1. Use /48 for site.
2. Use /49 - /63 for subnets.
3. Leave /65 – 128 for IID.
4. Break on nibble boundary.

Route Aggregation

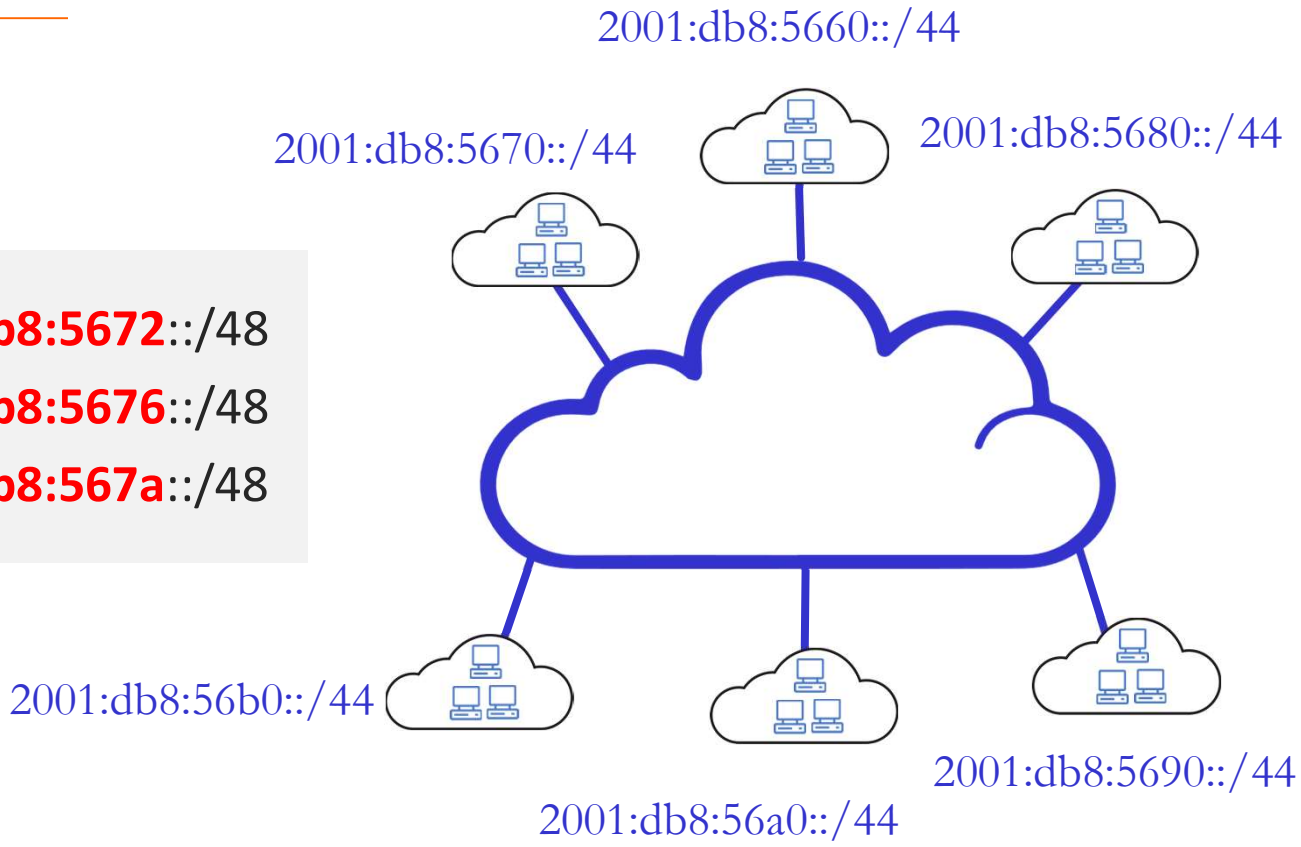


- IP – routes packets
- IPv6 routing table size
- Mirror topology

Good Aggregation

Prefix : **2001:db8:5670**::/44

Chicago, IL :	**2001:db8:5672**::/48
Bloomington, IL :	**2001:db8:5676**::/48
Normal, IL :	**2001:db8:567a**::/48



Bad Aggregation

Prefix : **2001:db8:5678:9**000::/52

Locations

- Chicago, IL : **2001:db8:5678:9**aaa::/64
- New York, NY : **2001:db8:5678:9**bbb::/64
- San Jose, CA : **2001:db8:5678:9**ccc::/64

Routes : **2001:db8:5678:9aaa**::/64,
2001:db8:5678:9bbb::/64,
2001:db8:5678:9ccc::/64

Address by Department

Prefix : **2001:db8:5678:9**xxx::

Locations

- **Payroll**: Chicago, IL: **2001:db8:5678:9**aaa::/64
- **Payroll**: New York, NY: **2001:db8:5678:9**bbb::/64
- **Payroll**: San Jose, CA: **2001:db8:5678:9**ccc::/64

Routes : 2001:db8:5678:9aaa::,
2001:db8:5678:9bbb::,
2001:db8:5678:9ccc::

If you embed "payroll" or department type in the prefix portion of the IPv6 address, you may get into trouble

ARIN - Aggregation

6.3.4. Aggregation

- Wherever possible, address space should be distributed in a hierarchical manner, **according to the topology of network infrastructure**. This is necessary to permit the **aggregation of routing** information by ISPs, and to limit the expansion of Internet routing tables.
- This goal is particularly important in IPv6 addressing, where the size of the total address pool creates significant implications for both internal and external routing.
- IPv6 address policies should seek to avoid fragmentation of address ranges.
- Further, RIRs should apply practices that maximize the potential for subsequent allocations to be made contiguous with past allocations currently held. However, there can be no guarantee of contiguous allocation.

Let's Add To Our Rules

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.

Sparse Allocation

Chicago, IL : **2001:db8:5672**::/48

Bloomington, IL : **2001:db8:5676**::/48

Normal, IL : **2001:db8:567a**::/48

To leave room for:

Chicago2, IL : **2001:db8:5674**::/48

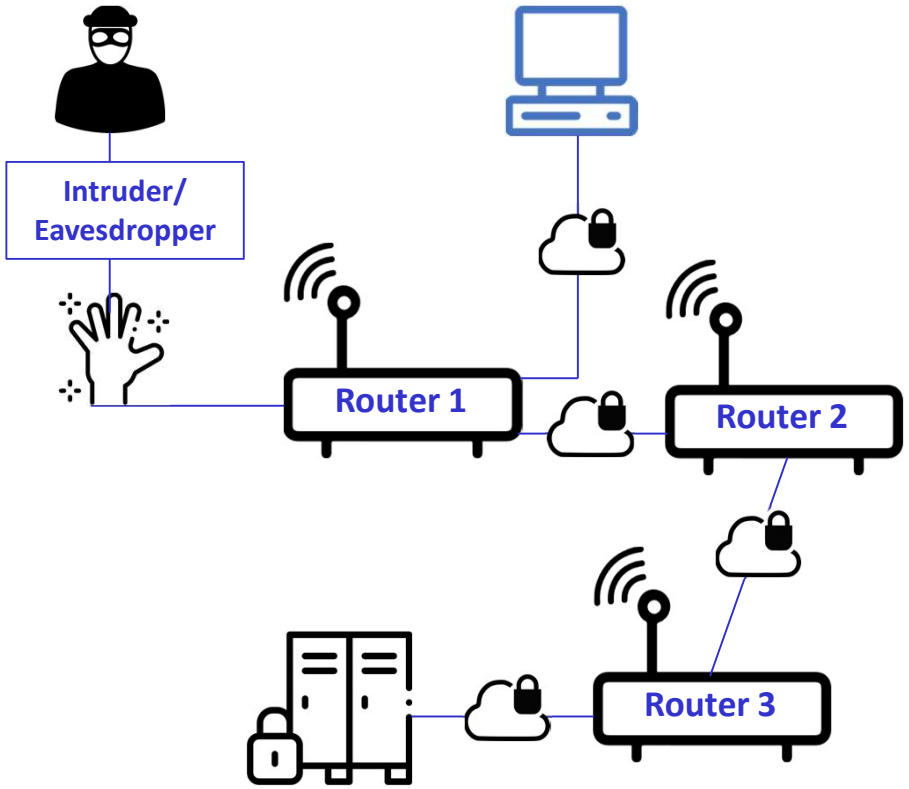
Springfield, IL : **2001:db8:567c**::/48

One More Rule

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. Use sparse allocation.

Privacy and Security

- Recon attacks
- DoS attacks
- Privacy addressing
- Internet access



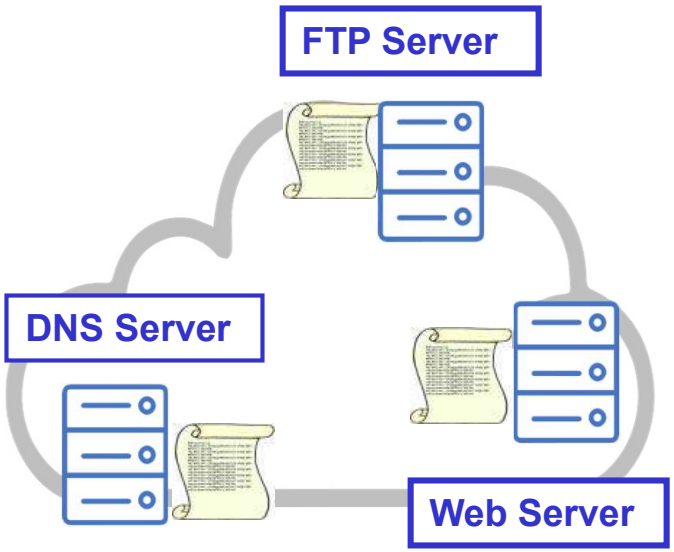
Recon Attacks

```
FTP Server 1: 2001:db8:5678:03df::22
FTP Server 2: 2001:db8:5678:04df::22
DNS Server 1: 2001:db8:5678:03aa::53
DNS Server 2: 2001:db8:5678:04aa::53
Web Server 1: 2001:db8:5678:0322::80
Web Server 2: 2001:db8:5678:0422::80
```

- DNS scan
- Predictability = memorability
- NAT won't help: need a proper stateful firewall

Methods To Harvest Addresses

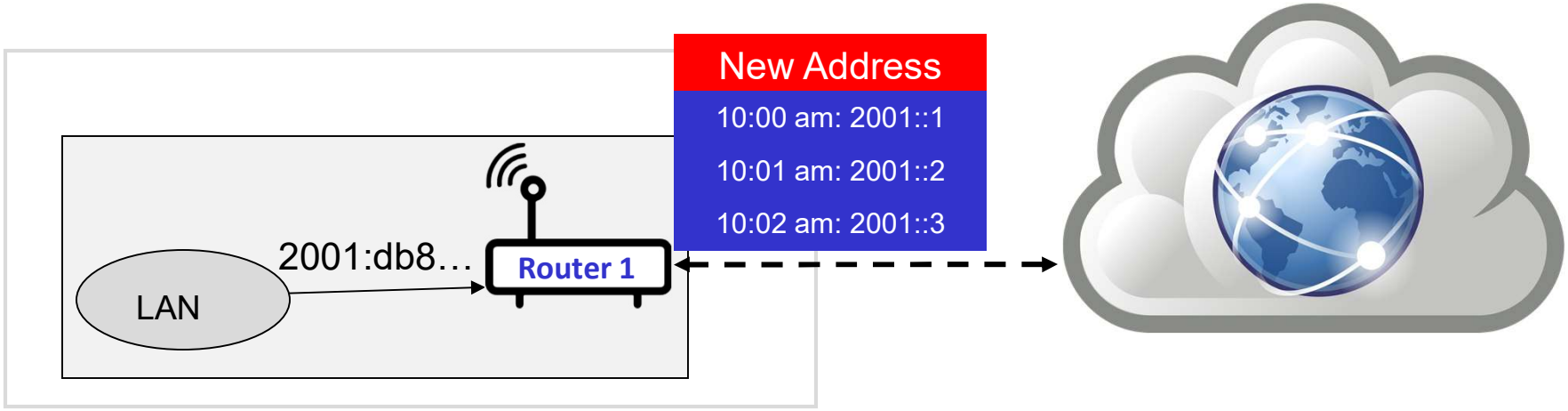
- SMTP envelopes, Web or FTP server logs.
- Email headers
- Client or p2p harvesting
- Guessing SLAAC addresses by OUI
- Trying low numbers (::1 - ::1024)



Facebook Packet

```
Domain Name System (Response)
        Transaction ID : 0x2c4b
        DNSflags: 0x8180(Standard Query)
        Q/R flag : 1
        Opcode : 0x0
        Authoritative Answer Flag : 0
        Truncation Flag : 0
        Recursion Desired Flag : 1
        Recursion Available Flag : 1
        Answer Authenticated Flag : 0
        Reply code : 0 (No Error)
Questions : 1
Answer RRS : 1
Authority RRS : 0
Additional RRS : 0
        Queries :
        Name : www.facebook.com
        Type : AAAA (IPv6 Address)
        Class : 0x1 IN
        -------------------------
        Answers :
        Name : www.facebook.com
        Type : AAAA (IPv6 Address)
        Class : 0x1 IN
        Time to live : 0 Hours 0 Minutes, 9 Seconds.
        Data Length : 16
        IPv6 Addr : 2620:0000:1c00:0000:face:b00c:0000:0002
        zCompressed IPv6 Address: 2620::1c00:0:face:b00c:0:2
        -------------------------
```

IPv6 Privacy Addresses



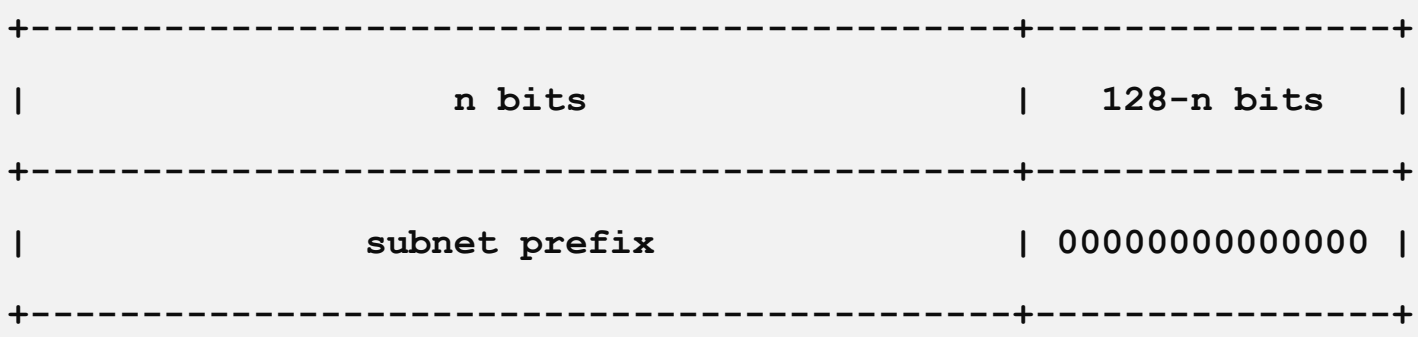
- RFC4941 "**Privacy Extensions for Stateless Address Autoconfiguration in IPv6"**
- RFC7217 "**Semantically Opaque Interface Identifiers with SLAAC"**
- Change address frequently
- How to diagnose problems?
  - Prefix doesn't change, but IID does
- Implementation differences

Another Rule

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. Use sparse allocation.
7. Remember security!

Subnet Router Anycast Address (Reserved)

- RFC4291 provides a definition for the required Subnet Router Anycast Address as follows:



- This is an address such as: 2001:db8:5678:0000:0000:0000:0000:0000 (2001:db8:5678::)

Other IPv6 Reserved Ranges

Interface Identifier Range	Description
0000:0000:0000:0000-0000:0000:0000:0000 [RFC4291]	Subnet Router Anycast
fdff:ffff:ffff:ff80-fdff:ffff:ffff:fffd [RFC2526]	Reserved Subnet Anycast
fdff:ffff:ffff:ffff-fdff:ffff:ffff:ffff [RFC2526]	Reserved Subnet Anycast
fdff:ffff:ffff:fffe-fdff:ffff:ffff:fffe Anycast [RFC2526]	MobileIPv6 Home Agents

Hidden slide: see notes before “un-hiding”

Still Another Rule…

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. Use sparse allocation.
7. Remember security!
8. Avoid reserved addresses.

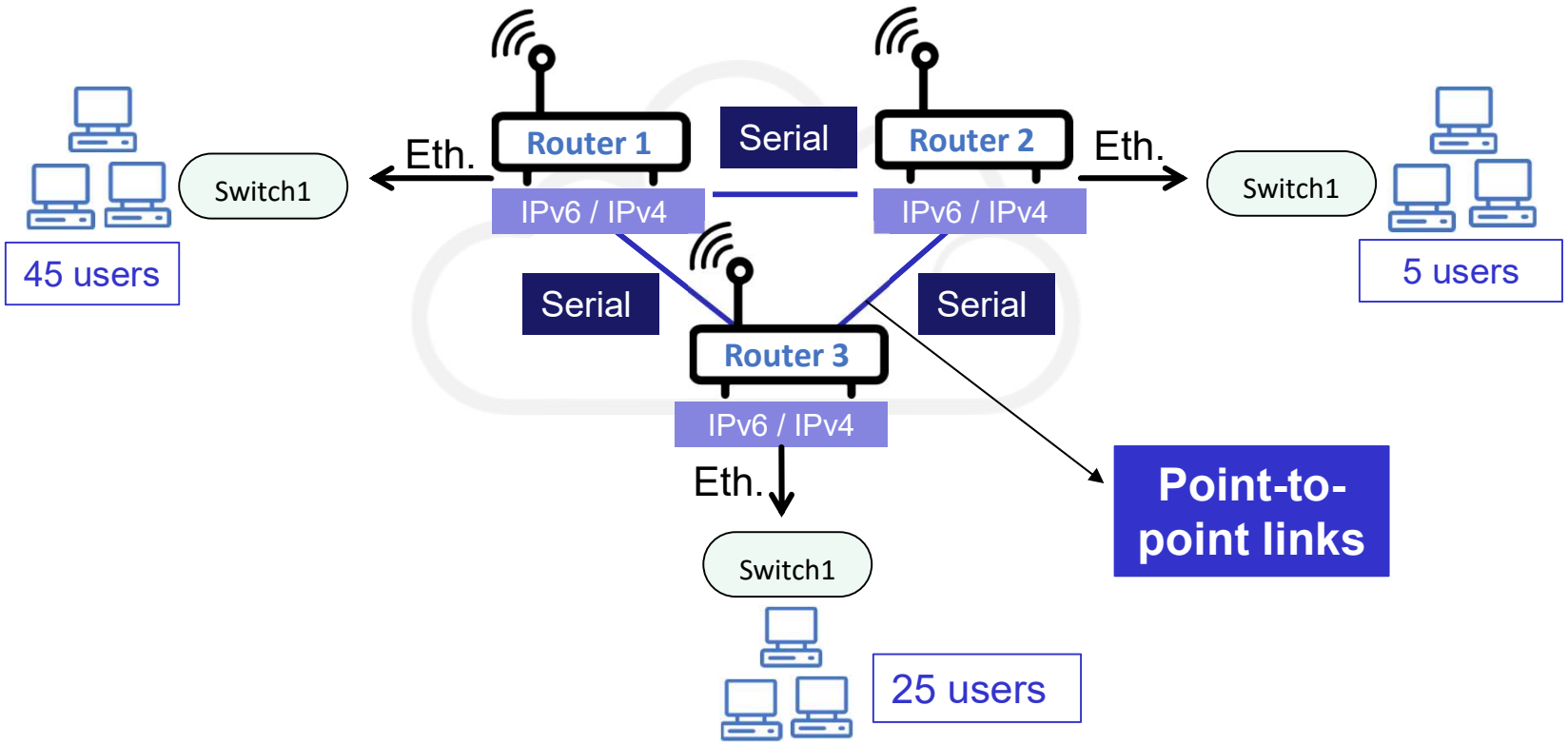
Each rule

- Tradeoffs: pros and cons
- No mistakes – only learning opportunities.

IPv4 /30 Allocation

IP Space available: 195.25.7.0 /24

11111111.11111111.11111111.00000000 /24 (255.255.255.0) 256 addresses



IPv6 /126 Prefix

- **So, what does a /126 look like?**

/126

```
1111111111111111.1111111111111111.
1111111111111111.1111111111111111.
1111111111111111.1111111111111111.
1111111111111111.111111111111111xx
```

How many addresses are we talking about?

4 addresses – none used for network or broadcast.

```
0000:0000:0000:0000:0000:0000:0000:000x
FFFF:FFFF:FFFF:FFFF:FFFF:FFFF:FFFF:FF0x
```

- **Let's look at an example**

2001:db8:5678:1234:5678:90AB:CDEF:0000 –
2001:db8:5678:1234:5678:90AB:CDEF:0003

IPv6 /127 Prefix

The usage of the /127 addresses is discouraged as documented in RFC3627 (Use of /127 Prefix Length Between Routers Considered Harmful).

/127

```
1111111111111111.1111111111111111.
1111111111111111.1111111111111111.
1111111111111111.1111111111111111.
1111111111111111.111111111111111x
```

```
0000:0000:0000:0000:0000:0000:0000:000x
FFFF:FFFF:FFFF:FFFF:FFFF:FFFF:FFFF:FFFx
```

How many addresses are we talking about?

2 addresses – none used for network or broadcast.

- **Let's look at an example**

2001:db8:5678:1234:5678:90AB:CDEF:0000 –
2001:db8:5678:1234:5678:90AB:CDEF:0001

Last Rule…

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.

Summary

- You can get an IPv6 address range directly from your RIR, or from an ISP.
- What to do once you have it is the biggest issue.
- IPv6 address planning is different from IPv4 address planning.

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Questions?

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More webinars at:

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