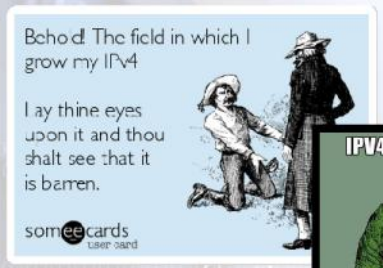
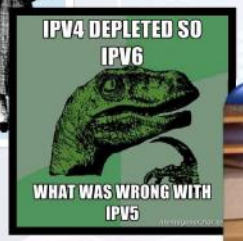
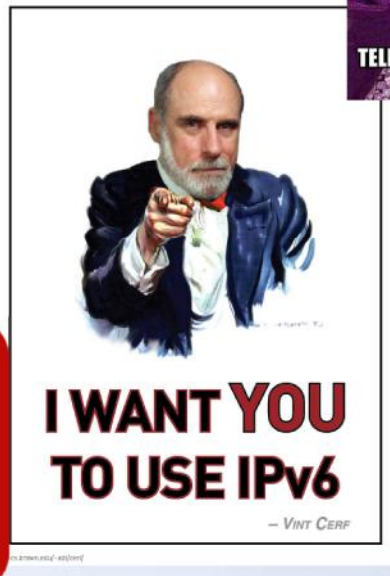
IPv6 Address Planning: A Case-Study

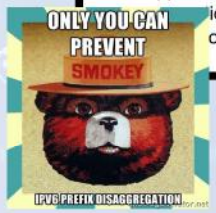




Tom Coffeen, Infoblox



- 2017 North American IPv6 Summit
- April 25-26, 2017
- LinkedIn Headquarters
- Sunnyvale, CA



THERE IS NO PRACTICAL EQUIVALENT TO IPv4 ADDRESS CONSERVATION IN IPv6

THE LIMITS OF THE ADJECTIVE "ASTRONOMICAL"

(VIS-Á-VIS IPv6)

Stars in the Milky Way: 400 billion

Galaxies in the Universe: 2 trillion

$$(4.0\text{x}10^{11}) \cdot (2.0\text{x}10^{12}) = 8.0\text{x}10^{23}$$

$$\frac{(3.4\text{x}10^{38})}{(8.0\text{x}10^{23})} = 4.3\text{x}10^{14}$$

IPv6 offers approximately *430 trillion times more* addresses than there are estimated stars in the Universe…

THE EARLY ENTERPRISE IPv6 ADOPTER

An uncontroversial fact: A /48 (281 trillion Internets) is more than enough address space for any enterprise

But then so is a /64 (4.3 billion Internets)…

Or a /80 (65K Internets)...

Or a /96 – an entire Internet just for your enterprise!

"The Unix philosophy basically involves giving you enough rope to hang yourself. And then a couple of feet more, just to be sure."

-Anonymous

If you're used to "making do" with 10.0.0.0/8 (let's call that one meter of rope).

A /48 gives you enough rope to get to the moon…

…one billion times.

ɔMG!OMG!OMG!OMG!OMG!OMG!OMG!OMG!OMG!OMG!OMG!OMG!C

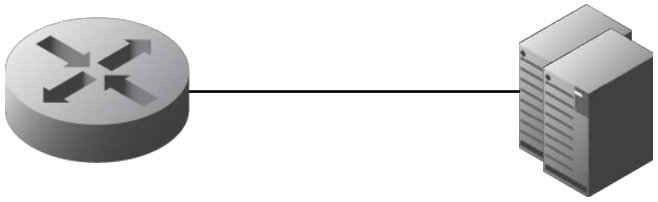
MUST. NOT. WASTE.
IP ADDRESSES!

IPv4 THINKING

- The **single biggest risk** to an effective IPv6 addressing plan

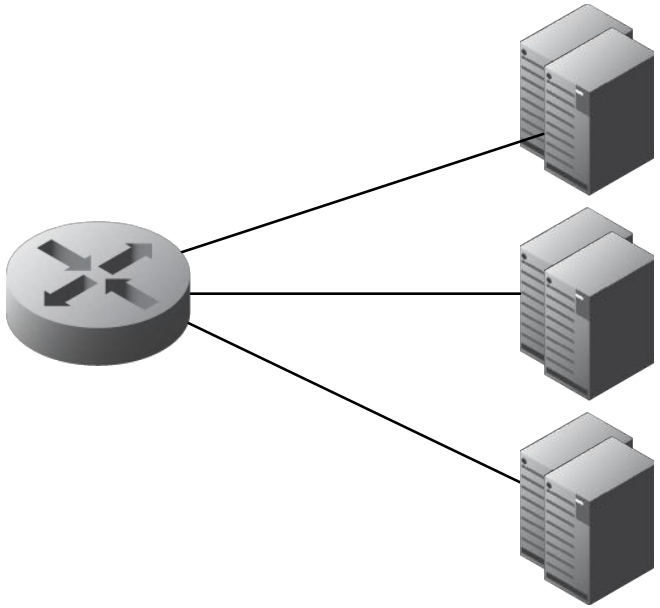
IPv4 Thinking	IPv6 Reality
Must not waste host addresses	No host address conservation required
Must allocate subnets by single bits (see above)	Subnetting done 4 bits at a time (i.e., “nibble boundaries”)
Must make do with initial allocation size from ISP or RIR	An allocation large enough to fit your best design is available

IPv4 INTERFACE ASSIGNMENT



- /24 or 255.255.255.0 = 254 host addresses (75% utilization)
  - Assuming you can consistently use /24s, operationally efficient:
    - provides a tidy boundary for ACLs and routing summarization
    - room for growth on the segment

IPv4 INTERFACE ASSIGNMENT

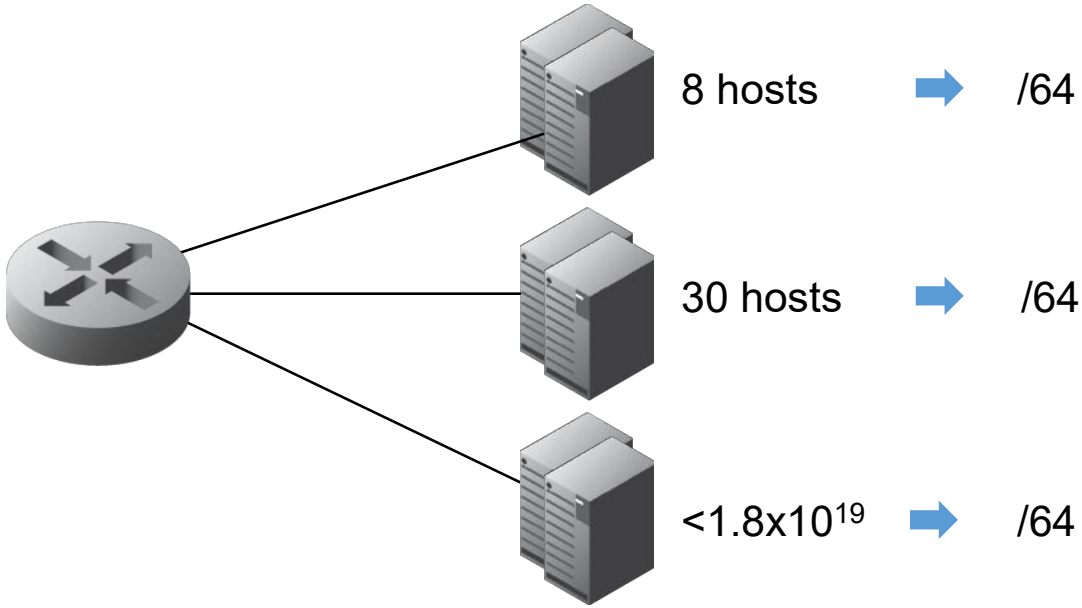


8 hosts → /28 = 14 host addresses (57% utilization)

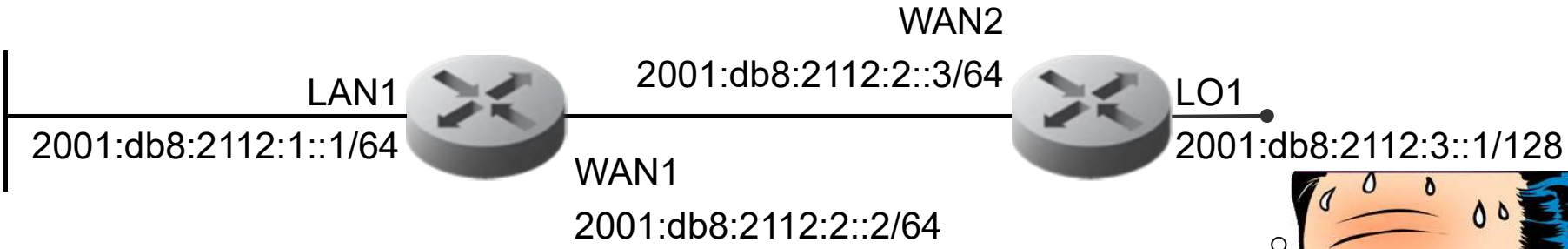
30 hosts →
Option 1:
/27 = 30 host addresses (100% utilization)
Option 2:
/26 = 62 host addresses (48% utilization)

119 hosts →
Option 1:
/25 = 126 host addresses (94% utilization)
Option 2:
/24 = 254 host addresses (47% utilization)

IPv6 INTERFACE ASSIGNMENT



IPv6 INTERFACE ASSIGNMENT



- LAN/VLAN Interfaces: /64
- Point-to-point links: /64
- Loopback interfaces: /128

THE LIMITATIONS OF IPv4 ADDRESS PLANNING (AND HOW IPv6 HELPS)

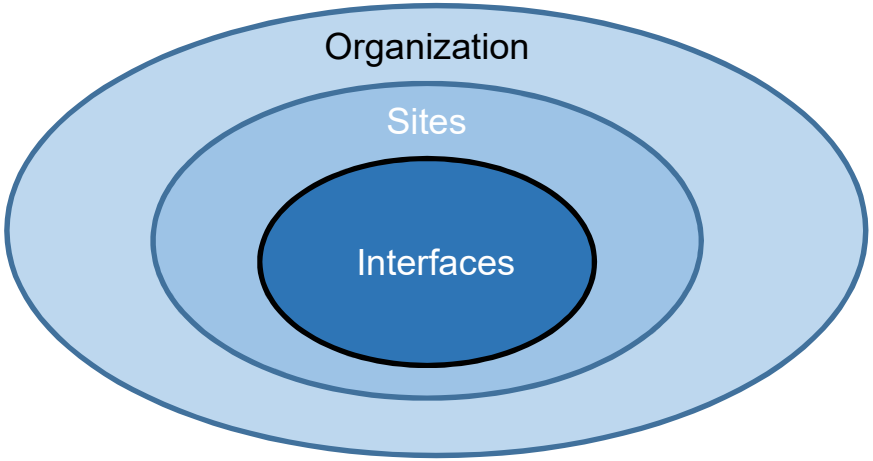
- There are never enough addresses (i.e., *prefixes* and/or *network bits*) with IPv4
  - This makes a consistent address plan much more difficult to accomplish
- IPv4 doesn't easily permit mapping hierarchy and network structure into address plan while also providing for sufficient host addressing
- IPv6, however, provides unlimited host addresses and sufficient bits to accommodate representing network structure

SOME BASIC GUIDELINES FOR IPv6 ADDRESS PLANNING

A PROPER IPv6 ADDRESS PLAN REQUIRES A SUFFICIENTLY LARGE IPv6 ALLOCATION

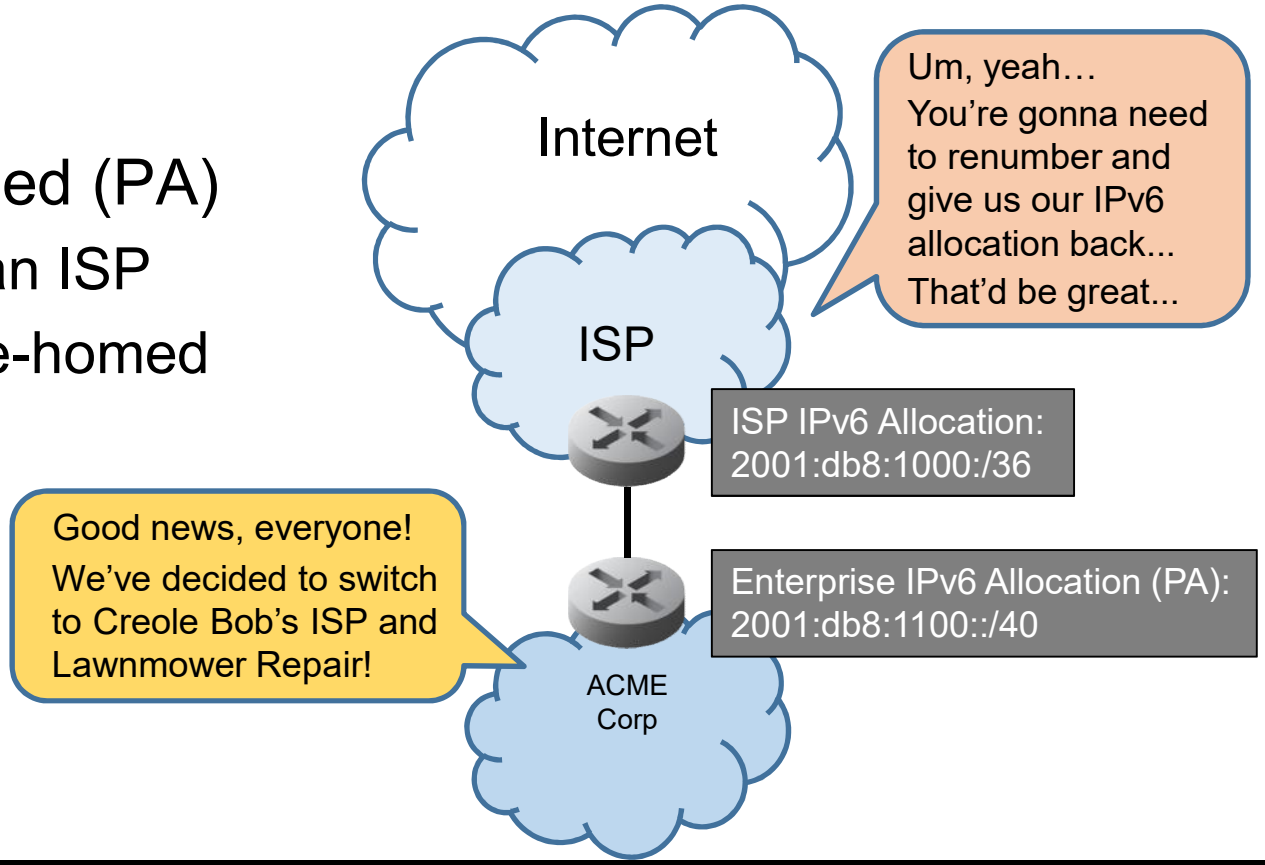
THE 3 MOST IMPORTANT IPv6 SUBNET SIZES WHEN ADDRESS PLANNING

- Organizational allocation
- Site assignment
- Interface subnets



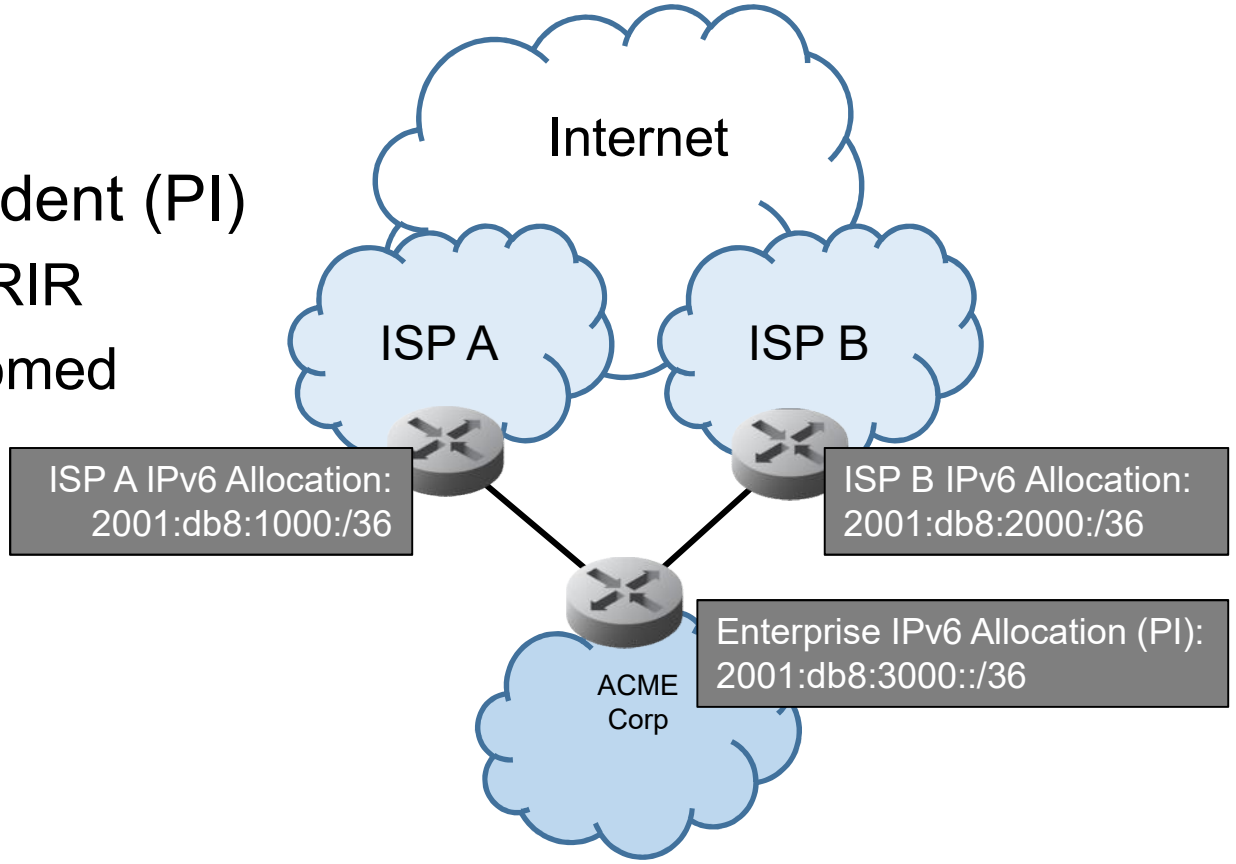
IPv6 ALLOCATION TYPE: PI vs. PA

- Provider Assigned (PA)
  - Assigned by an ISP
  - Best for single-homed networks
  - *Non-portable*

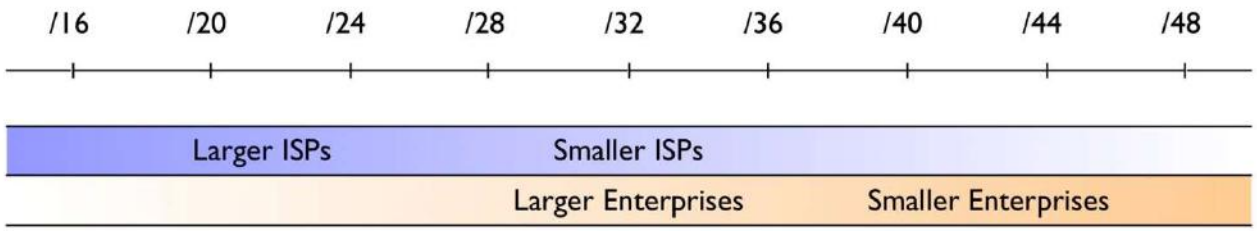


IPv6 ALLOCATION TYPE: PI vs. PA

- Provider Independent (PI)
  - Assigned by a RIR
  - Best for multihomed networks
  - *Portable*



HOW BIG SHOULD AN ORGANIZATIONAL IPv6 ALLOCATION BE?



- Most enterprises receive a /32 to a /44
- A /48 is assigned per *site* within the organization

WHAT CONSTITUTES A SITE?

- Characteristics of sites in IPv6
  - Logical construct
  - Definition that makes operational sense
    - Based on network topology, routing and security policy, etc
    - Based on what best maximizes operational efficiency
  - Often assigned a /48
    - Sites can receive larger or smaller allocations depending on what makes operational sense
    - Address conservation generally not a concern
  - Not enough /48s? Back to the RIR or ISP…
    - RIRs hold contiguous bits in reserve

IPv6 SITE ASSIGNMENT

Corporate HQ campus

Data center

Regional office

Home network

Laptop at the end of an HE 6to4 tunnel

German fire truck

SUBNETTING IN IPv6 SHOULD BE DONE ON NIBBLE BOUNDARIES

NIBBLE BOUNDARIES IN IPv6 (ORGANIZATIONAL ALLOCATION)

Prefix	Subnet groups per /32	/48 subnets per group
/32	1	65,536
/36	16	4,096
/40	256	256
/44	4,096	16
/48	65,536	1

NIBBLE BOUNDARIES IN IPv6 (SITE ASSIGNMENT)

Prefix	Subnet groups per /48	/64 subnets per group
/48	1	65,536
/52	16	4,096
/56	256	256
/60	4,096	16
/64	65,536	1

NIBBLES MAKE IPv6 PREFIXES MORE LEGIBLE

Subnet bits a multiple of 4	
Prefix:	2001:db8:1::/48
Range:	2001:db8:1:0000:0000:0000:0000:0000 2001:db8:1:ffff:ffff:ffff:ffff:ffff

Subnet bits not a multiple of 4	
Prefix:	2001:db8:1::/49
Range:	2001:db8:1:0000:0000:0000:0000:0000 2001:db8:1:7fff:ffff:ffff:ffff:ffff 2001:db8:1:8000:0000:0000:0000:0000 2001:db8:1:ffff:ffff:ffff:ffff:ffff

MAPPING LOCATION OR FUNCTION INTO IPv6 ADDRESS PREFIXES

2001:db8:1:LXXX::[/52 - /64]

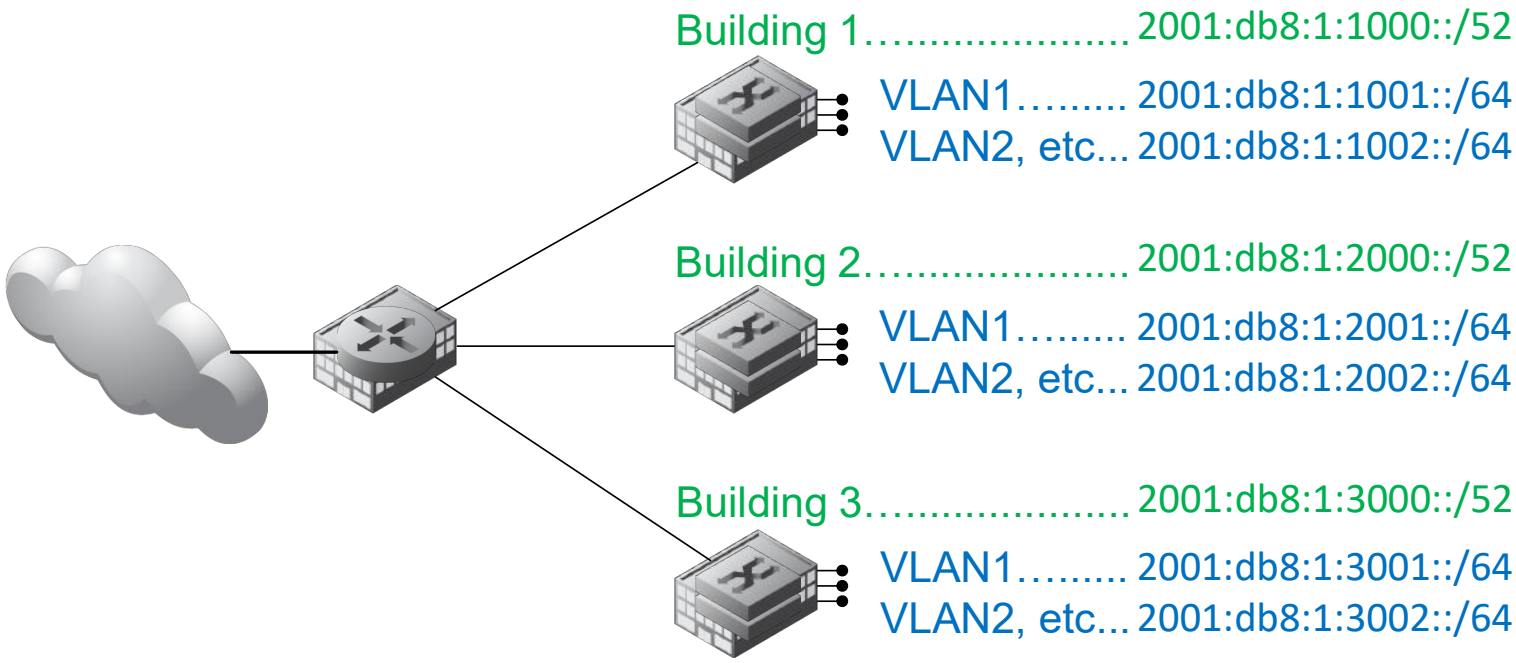
Location (16 sites)
2001:db8:1:[0-f]nnn::/52

Interface subnets (4096 per location)
2001:db8:1:n[0-f][0-f][0-f]::/64

Prefix	Assignment
2001:db8:1:0000::/52	Reserved
2001:db8:1:1000::/52	Building 1
2001:db8:1:2000::/52	Building 2
…	…
2001:db8:1:f000::/52	[Location 16]

Prefix	Assignment
2001:db8:1:1000::/64	Reserved
2001:db8:1:1001::/64	VLAN1
2001:db8:1:1002::/64	VLAN2
…	…
2001:db8:1:1fff::/64	[Subnet 4096]

MAPPING LOCATION OR FUNCTION INTO IPv6 ADDRESS PREFIXES

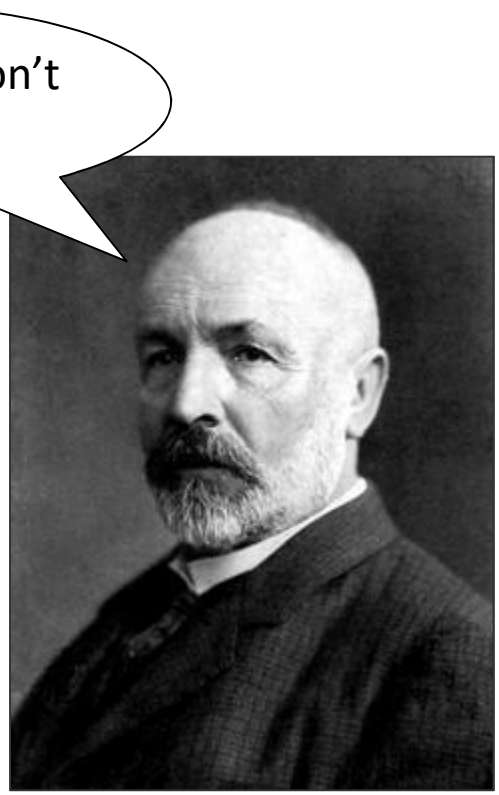


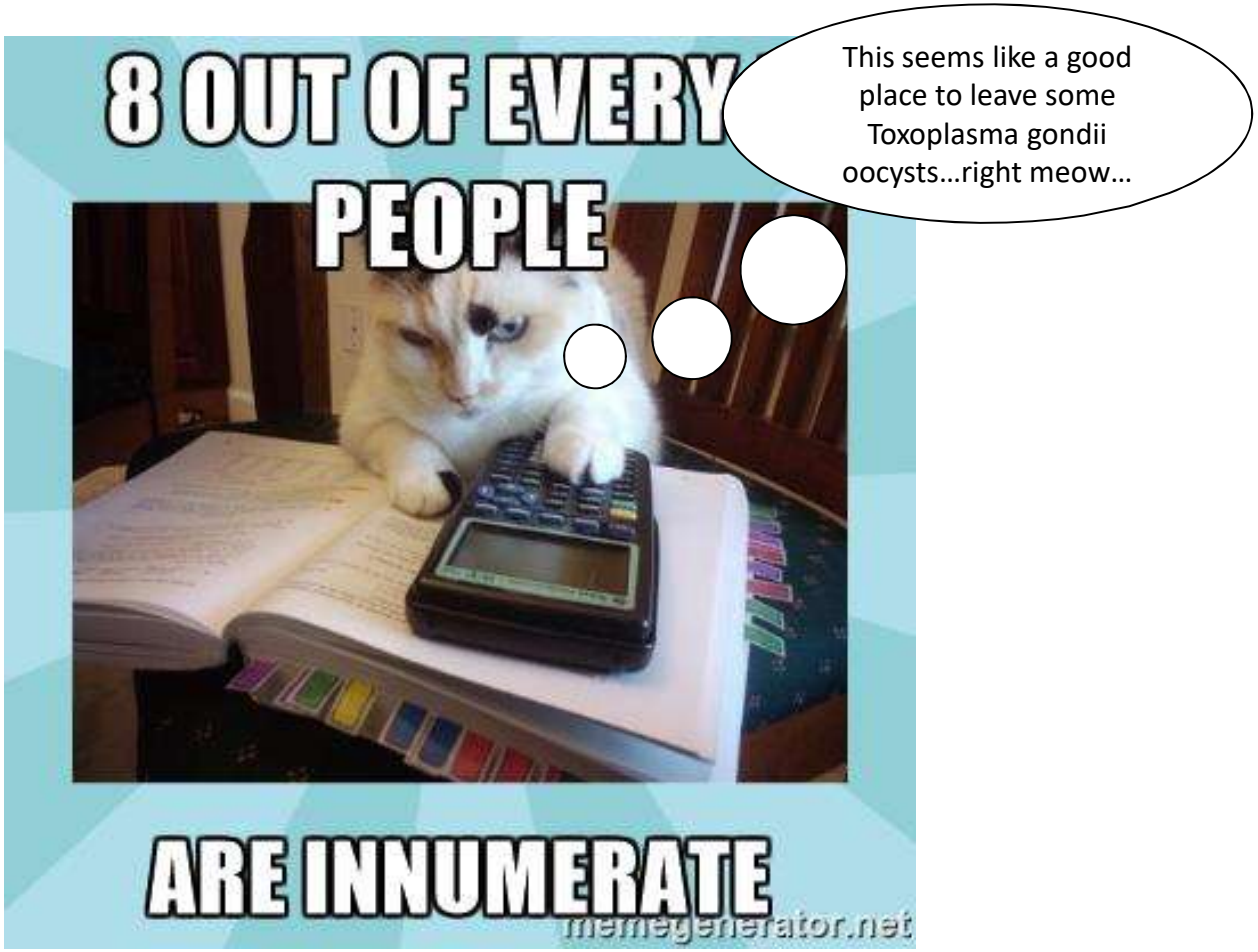
- /64 per interface
- /48 per site
- Nibble boundaries
- PI space

Enterprise administrators don't have a history of getting addresses directly from RIRs.

$$
\begin{aligned}
p_1 &= 0\,1\,0\,1\,0\,1\,0\,1\,\ldots \\
p_2 &= 1\,0\,1\,0\,1\,0\,1\,0\,\ldots \\
p_3 &= 0\,0\,1\,1\,0\,0\,1\,1\,\ldots \\
p_4 &= 1\,1\,0\,0\,1\,1\,0\,0\,\ldots \\
p_5 &= 0\,0\,0\,0\,1\,1\,1\,1\,\ldots \\
p_6 &= 1\,1\,1\,1\,0\,0\,0\,0\,\ldots \\
p_7 &= 0\,0\,0\,0\,0\,0\,1\,1\,\ldots \\
p_8 &= 1\,1\,1\,1\,1\,1\,0\,0\,\ldots \\
\vdots &\quad \vdots\ \vdots\ \vdots\ \vdots\ \vdots\ \vdots\ \vdots\ \vdots\ \ddots
\end{aligned}
$$

$$
p = 1\,1\,0\,1\,0\,1\,0\,1\,\ldots
$$





DIGRESSION:

- Observation: Toxoplasma gondii infections rewire mammalian brains to make cats irresistible to them
- Observation: The Internet exists primarily to propagate cat videos
- Conclusion: Toxoplasma gondii is cybernetic malware and the Internet is infected with it

IPv6 CASE STUDY: RADIA

- The Business:
  - USA-based
  - Manufacturing (Industrial machinery)
  - Founded: 1955
  - Fortune 500
  - 150 facilities on 6 continents
  - 65K employees
  - $75B USD revenue

IPv6 CASE STUDY: RADIA

- The Network:
  - HQ campus (in US)
  - 18 data centers
  - 60 manufacturing plants
  - 300 regional offices
  - MPLS enterprise WAN
  - Regional Internet connectivity

RADIA: IPv6 ALLOCATIONS

Region	Registry	Allocated Prefix
Africa	AFRINIC	2c0f:[redacted]::/32
Asia Pacific	APNIC	2400:[redacted]::/32
Europe/Middle East	RIPE	2a02:[redacted]::/29
Latin America	nic.br (Brazil)	2804:[redacted]::/32
North America	ARIN	2620:[redacted]::/31

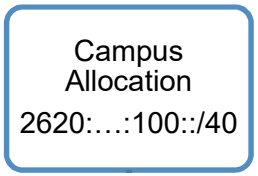
RADIA: IPv6 SUBNETS

Usage	Prefix	No. of /48 Networks	No. of /64 Networks
Regional Block	/32	65,536	4,294,967,29
--	/36	4,096	268,435,456
--	/38	1,024	67,108,86
Large Site Block	/40	256	16,777,216
--	/44	16	1,048,576
Site Block	/48	1	65,535
--	/56	--	256
Segment	/64	--	--
P2P	/127	--	--
Loopback	/128	--	--

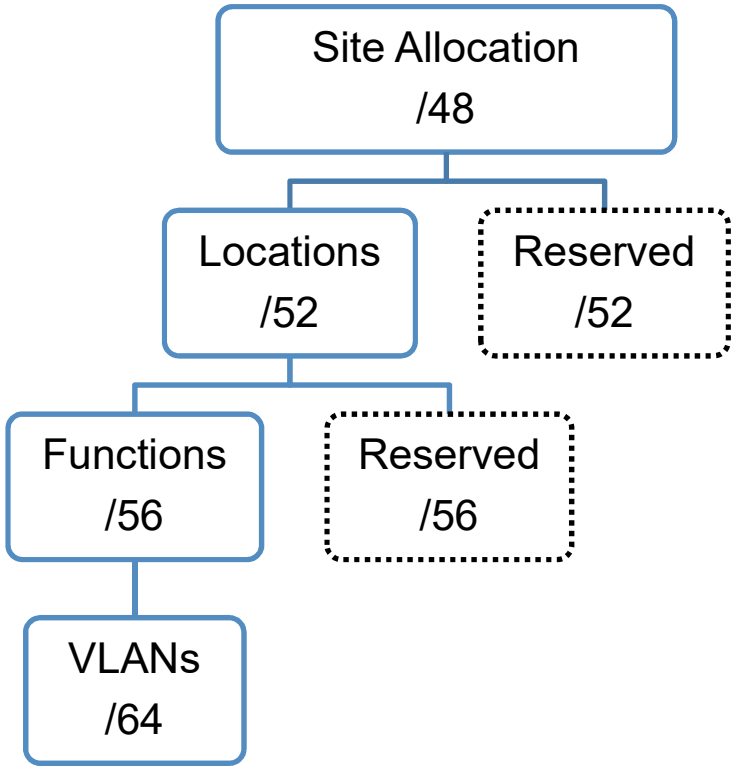
RADIA: SITE ALLOCATIONS

Regional
/32

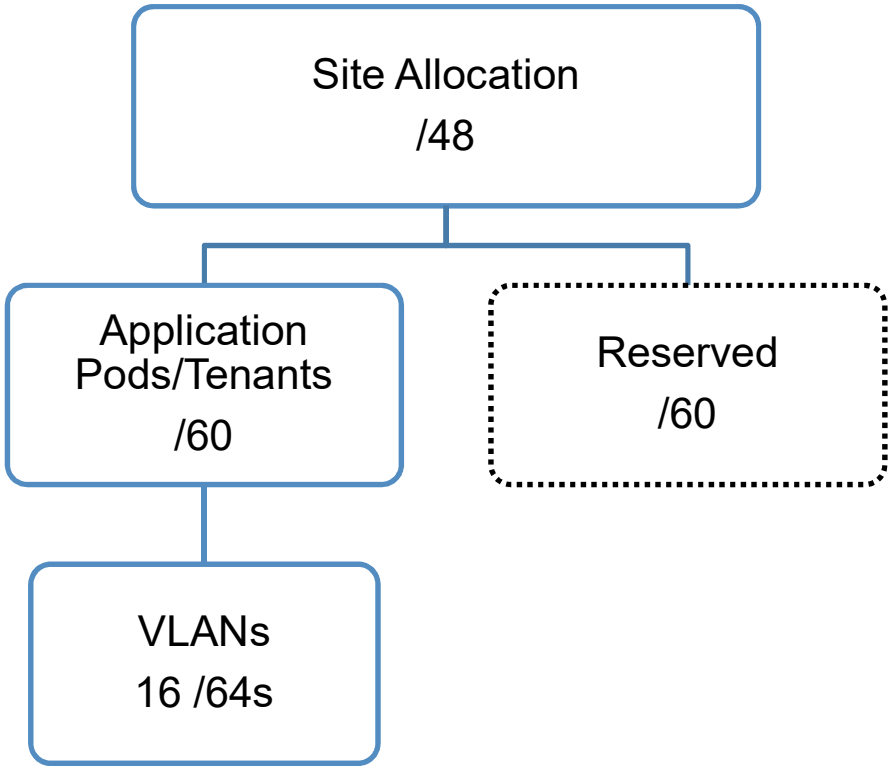
RADIA: SITE ALLOCATIONS (NORTH AMERICA)



RADIA: CORPORTATE CAMPUS SITE TEMPLATE



RADIA: DATA CENTER SITE TEMPLATE



A SIMPLE PLAN

- 5 RIRs with IPv6 (three /32s, one /31, and one /29)
  - Each region gets a /32
    - Extra-large sites (containing a corporate campus, data centers and/or manufacturing facilities) receive a /40
    - Standard sites (stand-alone campuses, data centers, regional offices, manufacturing facilities) receive a /48
    - Site templates provide hierarchy for campuses, data centers, regional offices, and manufacturing facilities
      - A /52 will be reserved at locations not using a site template and /64s may be assigned monotonically until such time as a hiearchical scheme is defined

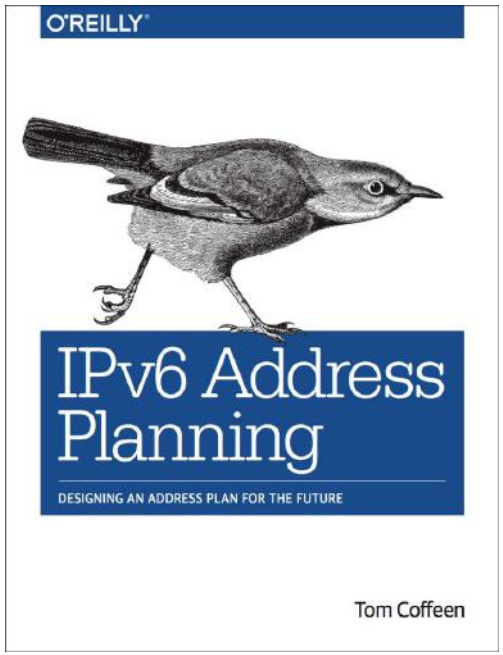
A SIMPLE PLAN – GUIDING PRINCIPLES

- An operations view of the network relies on well-defined organizational entities tied to location and role
- These entities will receive two consistently sized allocations (a /40 or a /48)
- The decision to use a larger allocation for the largest of the network entities drove the need for a larger allocation
  - Note that this is the opposite of choosing to use smaller prefixes to accommodate a smaller initial allocation and still provide a sufficient number of prefixes for the operationally defined entities

RECENT DEVELOPMENTS IMPACTING FUTURE ADDRESS PLANNING

- IoT deployments
- IPv6 addressing for containers
- IETF Draft: Unique IPv6 Prefix Per Host
  - Conceived for IPv6-only wifi deployment
- Homenet
  - /48 per CPE

IPv6 ADDRESS PLANNING, O'REILLY



- For IT network architects, engineers, and administrators
- Comprehensive overview and current best-practices for designing, deploying, and maintaining an effective IPv6 addressing plan

Questions?

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