IT'S THE QUESTION THAT DRIVES US

It's the question that brought you here. You know the question.

James R. Small, Sr. Architect at AT&T

Michigan!/usr/group

mug.org – A Free and Open Source Michigan Community

WHAT IS THE MATRIX?

IPv4 and CGN combined to form a computer generated dream world

A prison for your mind where networking never changes

WHAT IS THE PROBLEM?

Some are claiming IPv4 is not capable of continuing to support the Internet because of insufficient addressing capacity

Is this true?

LETS EXAMINE THE SITUATION

Questions to Answer:

- What exactly is addressing supposed to do?
- Where are we at with IPv4?
- What would merit considering a replacement?
- What happens if we do nothing?

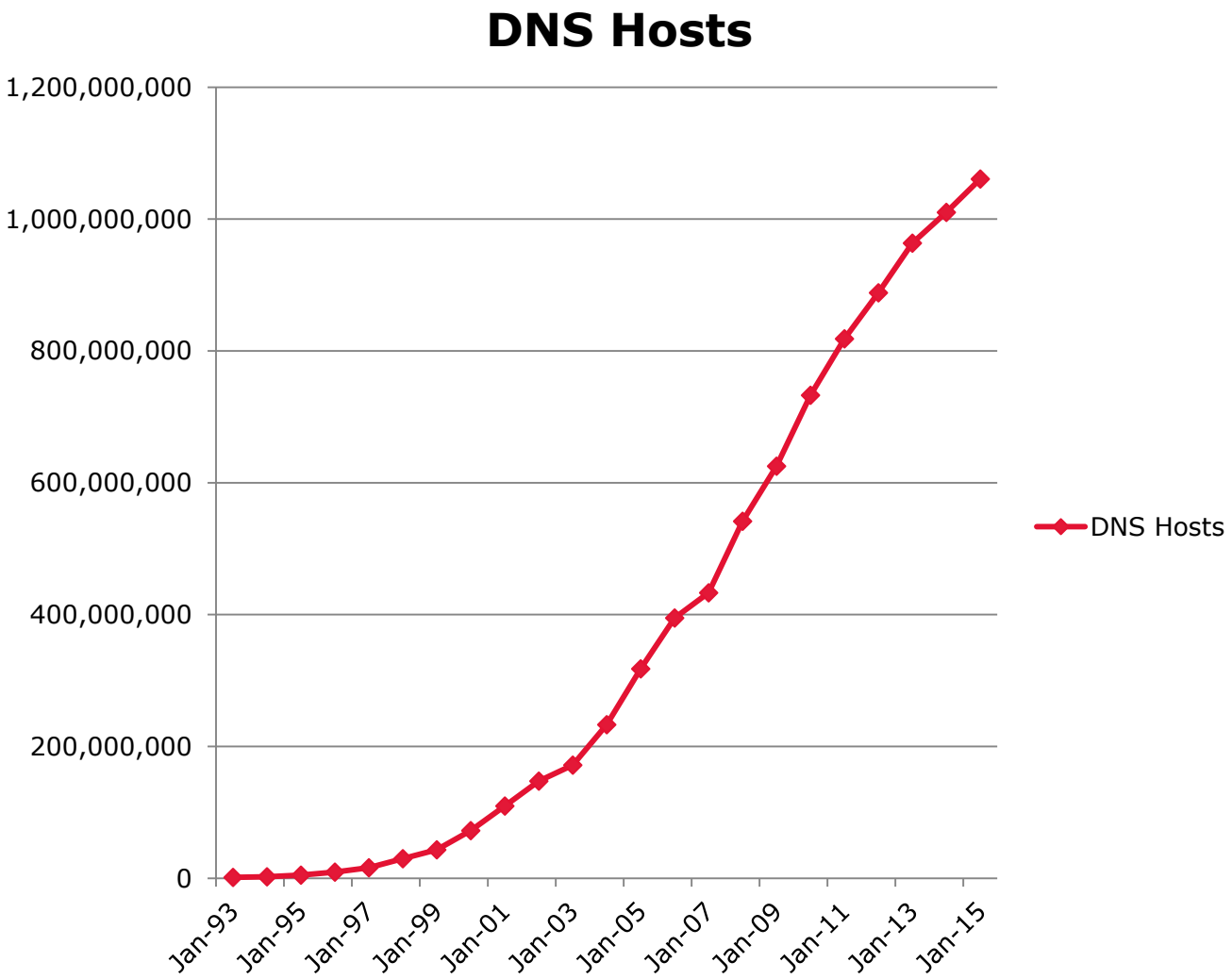
WHAT DOES IP ADDRESSING PROVIDE?

- Uniqueness - uniquely identify endpoints
- Topology - identify the topological location an address may exist in
- Registration - enable identification of party responsible for address (troubleshooting, security, etc.)
- Routability - address may be routed on the Internet (reachable) in a scalable fashion
- Operations - The combination of the above to provide operational simplicity including supporting applications/services

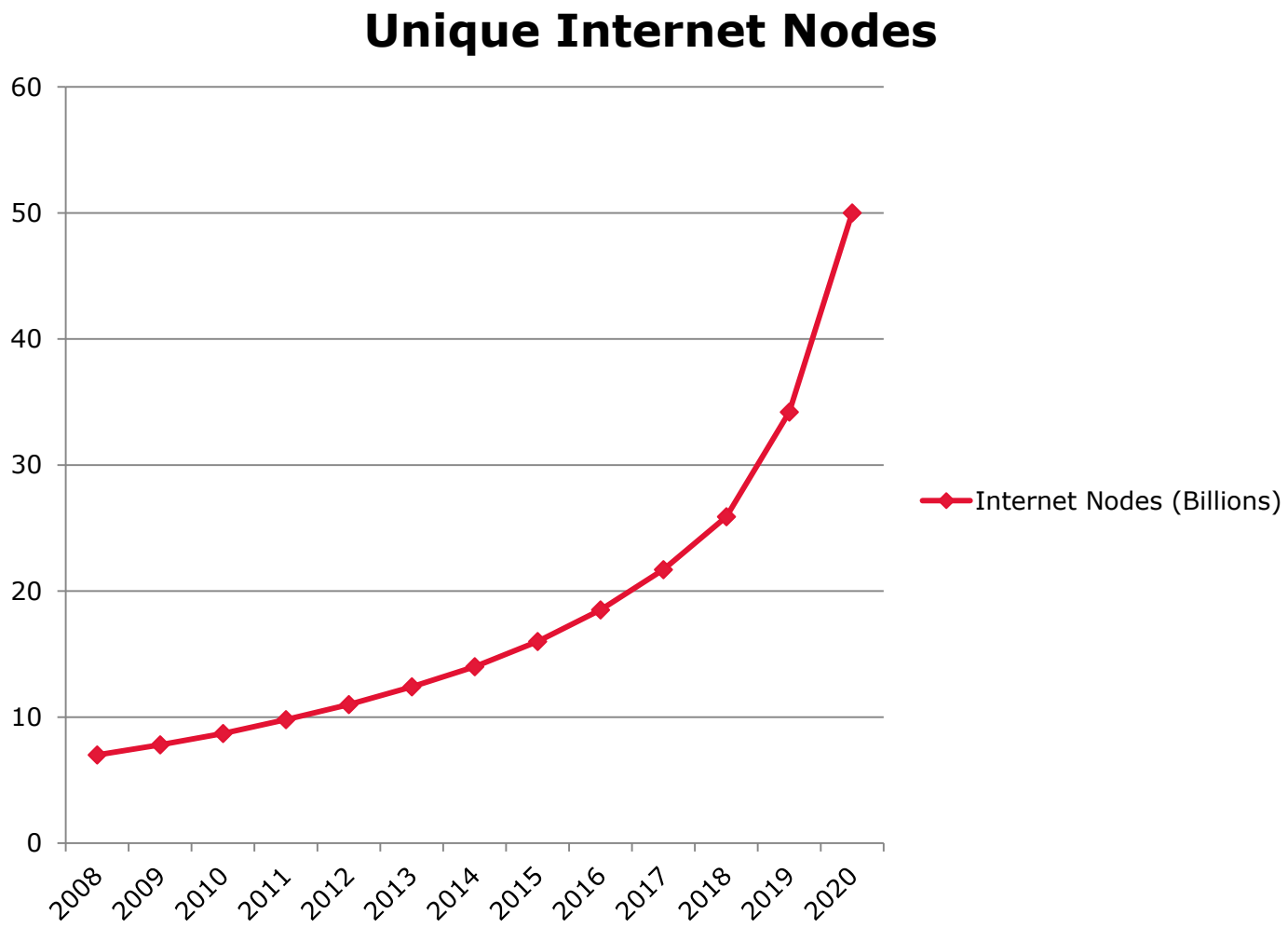
WHAT IS THE CAPACITY OF IPV4?

IPv4 Addressing	Addresses	Notes
IPv4 address count	4,294,967,296	Theoretical limit (2^{32})
Reserved addresses	301,989,888	0.0.0.0/8, 127.0.0.0/8, 240.0.0.0/4
Multicast addresses	268,435,456	224.0.0.0/3
Private addresses	17,891,328	RFC 1918 - 10.0.0.0/8, 172.16.0.0/12, 192.168.0.0/16
Shared Address Space (CGN)	4,194,304	RFC 6598 - 100.64.0.0/10
Benchmarking	131,072	RFC 2544 - 198.18.0.0/15
Link Local	65,536	RFC 3927 - 169.254.0.0/16
IANA special purpose	1024	RFC 6890 et. al. - 192.0.0.0/24, 192.31.196.0/24, 192.52.193.0/24, 192.88.99.0/24
Documentation/Test Nets	768	RFC 5737 - 192.0.2.0/24, 198.51.100.0/24, 203.0.113.0/24
Usable addresses	3,702,257,920	Available for general use

WHAT IS THE USAGE FOR IPV4?



WHAT IS THE USAGE FOR IPV4?



WHEN DOES USAGE BECOME A PROBLEM?

- What is a reasonable host density for an addressing system?
- RFC 3194 examines many addressing systems – networking and telecommunications – and reaches the following conclusions:

	Reasonable (HD=80%)	Painful (HD=85%)	Very Painful (HD=86%)	Practical Maximum (HD=87%)
9-digit plan	16,000,000	45,000,000	55,000,000	68,000,000
10-digit plan	100,000,000	316,000,000	400,000,000	500,000,000
32-bit addressing	51,000,000	154,000,000	192,000,000	240,000,000

- HD = Host Density Ratio
- Current Internet HD Ratio: 94.2%

SO WHAT HAPPENS WITH OVERSUBSCRIPTION?

- Not possible to provide unique addressing, overloading (NAT) required
- Topology, Registration and Routability are limited, don’t work or must use scopes
- Operations become more complex
  - » Applications/services require Application Layer Gateways or fixups to work with overloading
  - » Some applications/services are incompatible with overloading

SO WHAT? WE'VE BEEN LIVING WITH IT…

- Network challenges and complexities are fairly well understood
- But…what about the application side?

APPLICATION CHALLENGES WITH NAT

- Simple applications such as basic E-mail and web sites generally work fine with NAT
- Interactive applications or more complex/dynamic services typically require assistance to work through NAT – voice, video, games
- What does it take to support NAT?

APPLICATION COSTS WITH NAT

- Dealing with NAT and frameworks – 30+ RFCs
  - » General approaches include:
    - STUN – Session Traversal Utilities for NAT
    - TURN – Traversal Using Relays around NAT
    - ICE – Interactive Connectivity Establishment
- Approaches are per application/protocol
- Thousands of pages of documentation, rules, suggestions, approaches
- New RFCs/techniques continually appearing
- Entire companies that specialize just in the middleware to support NAT Traversal

LIFE IS TOUGH, HOW DO I MAKE IT WORK?

- IPv4 Addresses are not unique – CGN or cascading NAT is pervasive
- Make sure you don’t use addressing for authentication/authorization or anything else requiring uniqueness
- Logging must include source/destination address/port and transport protocol (UDP/TCP); must also include very accurate time stamp (use NTP) as NAT correlations can change quickly

CAN'T WE EXTEND IPV4 FOREVER WITH NAT?

- With traditional device types – desktops, laptops, servers, tablets, smartphones, printers, etc. – can probably extend IPv4 for some time, years
- What happens when new categories of devices come online?

ONE OF THESE PROTOCOLS HAS A FUTURE, THE OTHER DOES NOT

POLL

How far can we oversubscribe IPv4 before it becomes too painful to use and support?

A) 10x (37 billion Internet nodes)

B) 100x (370 billion Internet nodes)

C) 1,000x (3.7 trillion Internet nodes)

D) 10,000x (37 trillion Internet nodes)

Point of Reference: From RFC 3194, practical maximum usage is 240 million nodes. So 10:1 oversubscription is over 154 times the recommended limit.

LOOK WHO'S COMING TO DINNER…

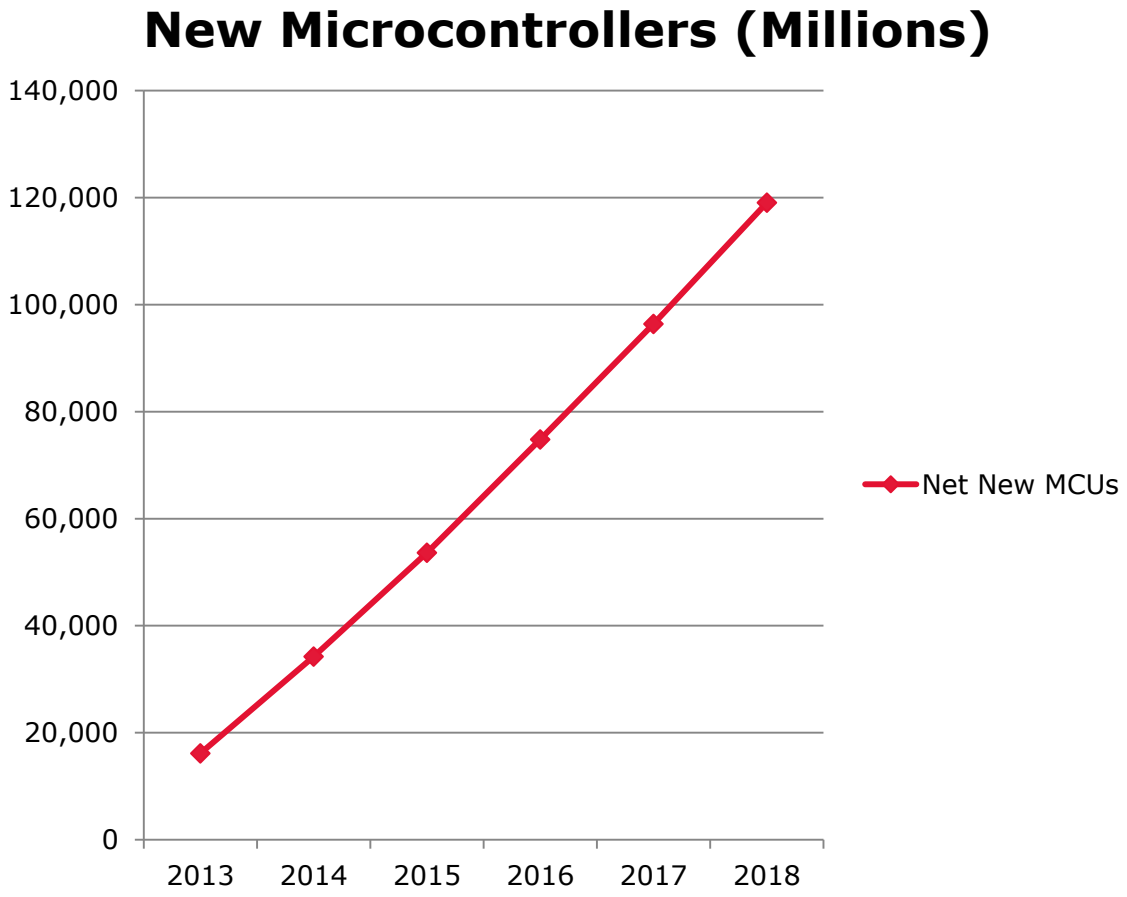
The Internet of Things (IoT)

- Devices designed to monitor, interact and react to surrounding environment (microcontrollers, sensors, actuators, etc.)
- Many come with built-in networking, but not all…yet
- By 2020, integrated networking will be ubiquitous due to plummeting costs
- How many of these devices are there/will there be?

IOT DEVICE GROWTH

Net new microcontrollers (assuming steady state, not accounting for increased demand, new products, etc.):

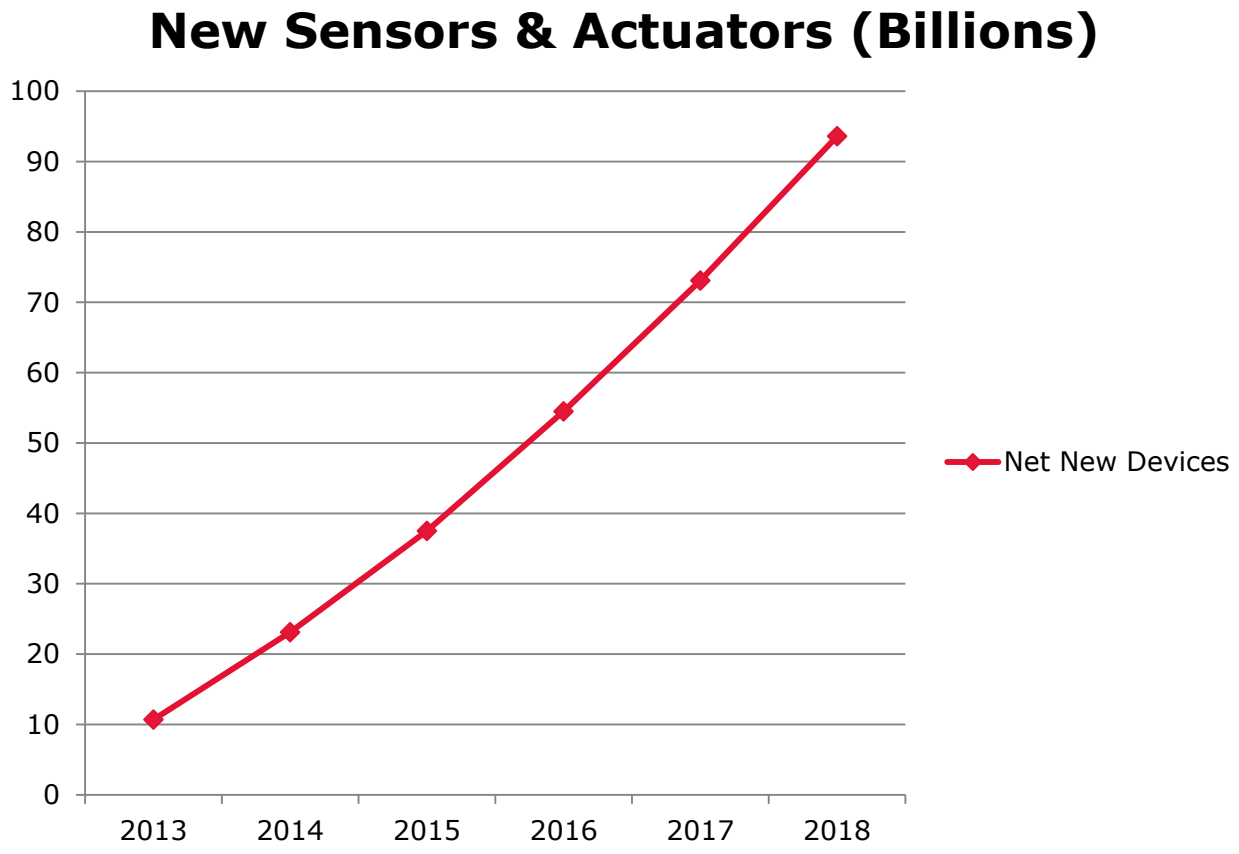
Year	Units (Millions)
2013	16,131
2014	18,100
2015	19,417
2016	21,158
2017	21,585
2018	22,675



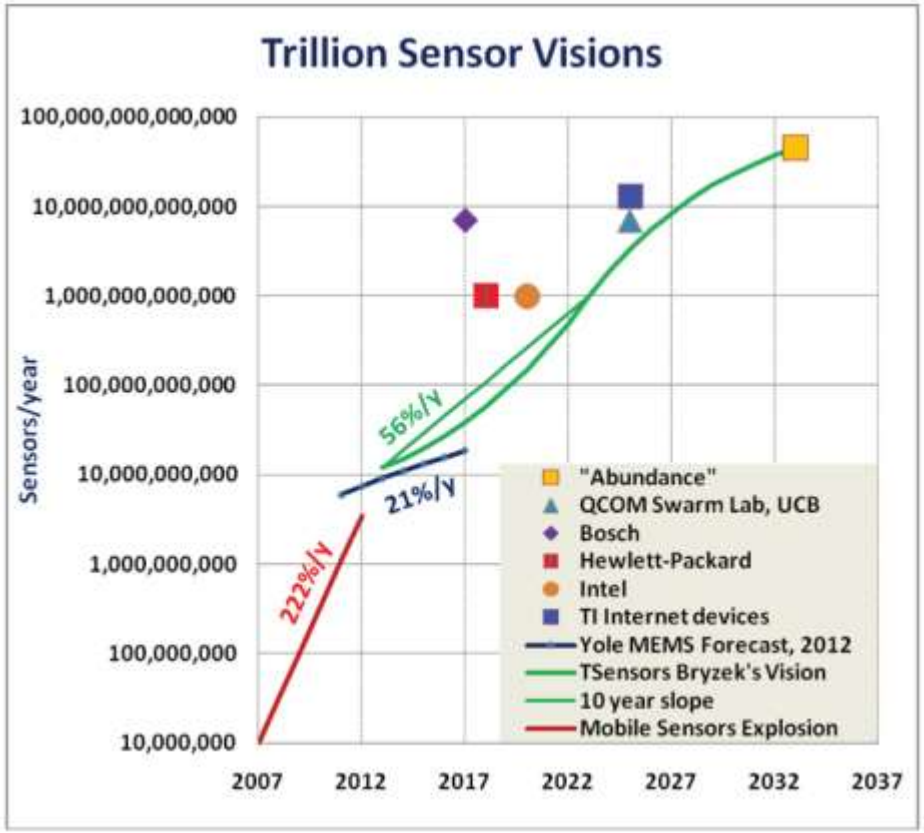
IOT DEVICE GROWTH

Net new sensors/actuators (assuming steady state, not accounting for increased demand, new products, etc.):

Year	Units (Billions)
2013	10.7
2014	12.4
2015	14.4
2016	17
2017	18.6
2018	20.5



STANFORD UNIVERSITY'S PREDICTION



WHAT DOES IOT NEED?

IoT Network Requirements

- Must have low power demands
- Must support lossy (unreliable) networks
- Must be operationally simple

	IPv4	IPv6
Low Power?	No, protocol not designed for this	Yes – 6LoWPAN
Lossy Networks?	No, protocol not designed for this	Yes – 6LoWPAN
Simple Operations?	No, protocol not designed for this	Yes - Autoconfiguration

HOW DOES THE INDUSTRY SEE IT?

IoT Networking Path

- IETF – IPv6/6LoWPAN/6Lo
- IEEE – IPv6
- ACM – IPv6
- Universities/Researchers – IPv6
- Analysts (Gartner et. al.) – IPv6
- Silicon Valley – IPv6
- Home IoT (Zigbee) – IPv6 (6LoWPAN)
- Bluetooth SIG – IPv6 (6LoWPAN)
- ISPs/Carriers – IPv6
- Networking Companies – IPv6
- Operating Systems – IPv6

DOES IOT HAVE PRACTICAL USES TODAY?

Solution Areas	Example Applications
Energy and Utilities	Smart Meters, SmartGrids
Building Automation	Demand Response, HVAC, Lighting, Surveillance, Security
Transportation	Connected Vehicles, Public Transportation, Freight & Containers, Logistics & Tracking
Retail	Vending Machine, PoS, Scanners, Kiosks
Healthcare	Medical Equipment, Remote Monitors, EHR Access, eOutpatient Care, Assisted Living, eHospital
Manufacturing	Industrial Process Control, PLC, Diagnostics, Energy Use Management

CONSUMER ELECTRONICS SHOW 2015

- "…everything in your home is getting a chip or a sensor in the near future, even if the industry hasn't quite figured out how to tie it all together yet."
- Fashionable wearables with sophisticated health monitoring
- Self-driving/parking cars – many demos
  - » Advanced Driver Assistance Systems
- Autonomous robots, drones and bots
- Automation leveraging cloud-based analytics

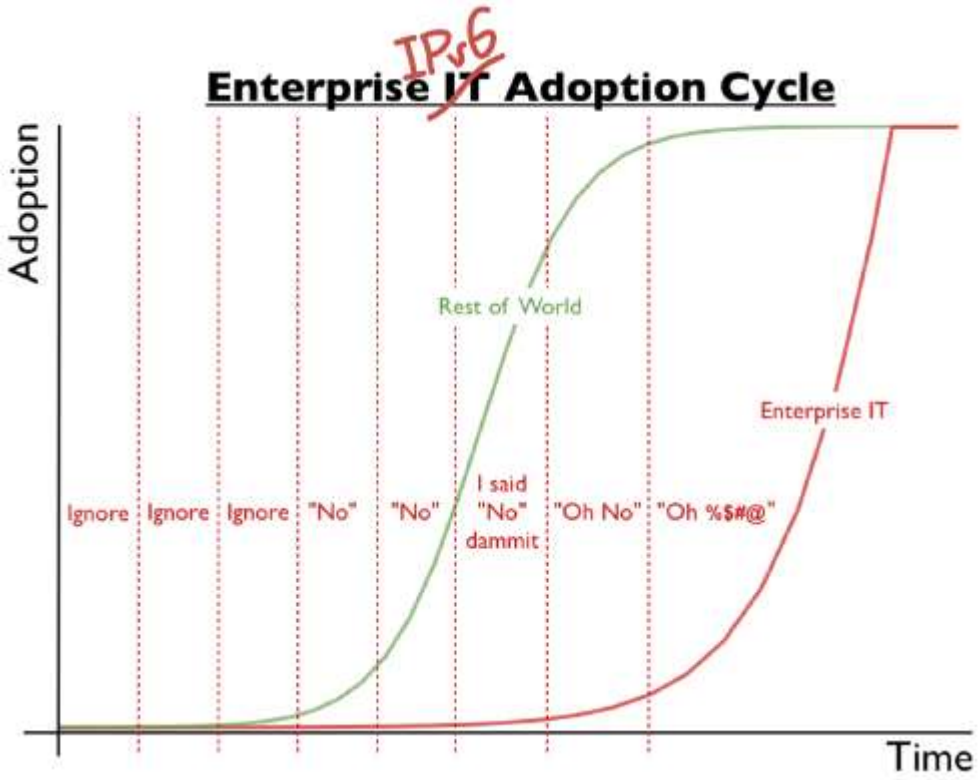
BENEFITS – MONEY/TIME/SAFETY/EFFICIENCY

- Buildings are single largest consumer of power
  - » Facilities energy management can save up to 40% of costs
- Connected and Autonomous Vehicles
  - » Logistics and Transportation Management
  - » Real time parking assistance
  - » Real time scheduling (book/swap/track)
  - » Adaptive tracking/assistance (construction/traffic/legally parked)
  - » Remote control
  - » Real time EV charging station locator
- Manufacturing Intelligence
- Healthcare monitoring and assistance

WHO'S DRIVING THIS?

- Companies through new products
- Consumers
- Operations/Engineering/Facilities
- Supported by Telecommunications Companies
- But…Not IT!

HOW DOES IT VIEW IPV6?



WHY DOES IT IGNORE IPV6?

Gartner sums it up nicely:

- IPv6 current phase: Trough of Disillusionment
- IPv6 business value/benefit: Low*

**But…needed for IoT initiatives and recommended for Internet access because of CGN problems*

DISCONNECT

- Facilities – Evaluating energy management solutions which may require IPv6
- Engineering – Testing new systems/solutions using state of the art microcontrollers, sensors and actuators; expects universal connectivity
- Operations – Looking at new manufacturing capabilities leveraging state of the art microcontrollers, sensors…

Common problem:

"What do you mean I can't just use it (IPv6)? Why not? So can you have that fixed by tomorrow?"

CHALLENGE

IT: "No one is asking for IPv6, therefore we don't need it."

Problem: Does your family ask for IPv4 or IPv6? Do they care? What if Facebook were only available via IPv6?

Many companies and industries see IoT initiatives as key parts of their strategy. This will require IPv6; but, are you sure this is understood?

THE INTERNET HAS ALWAYS BEEN IPV4…

Hasn’t the Internet always used IPv4?

Is it possible to transition to a new protocol (IPv6)?

Let’s examine history.

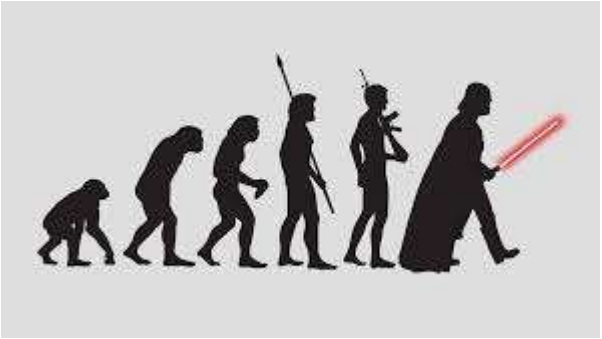
INTERNET EVOLUTION

- 1969 – Inception, First for nodes brought online
- 1970 – ARPANET switches to Network Control Protocol (NCP)
- 1974 – Vint Cerf and Bob Kahn public the initial design of TCP
- 1975 – Operation of Internet transferred to DCA (now DISA)
- 1978 – TCP split into TCP and IP; first SPAM message sent!
- 1981 – RFC 801 published, NCP/TCP Transition Plan
- 1982 – DCA standardizes Internet on TCP/IP
- 1983 – NCP “turned off”, Internet now IP only

INTERNET EVOLUTION

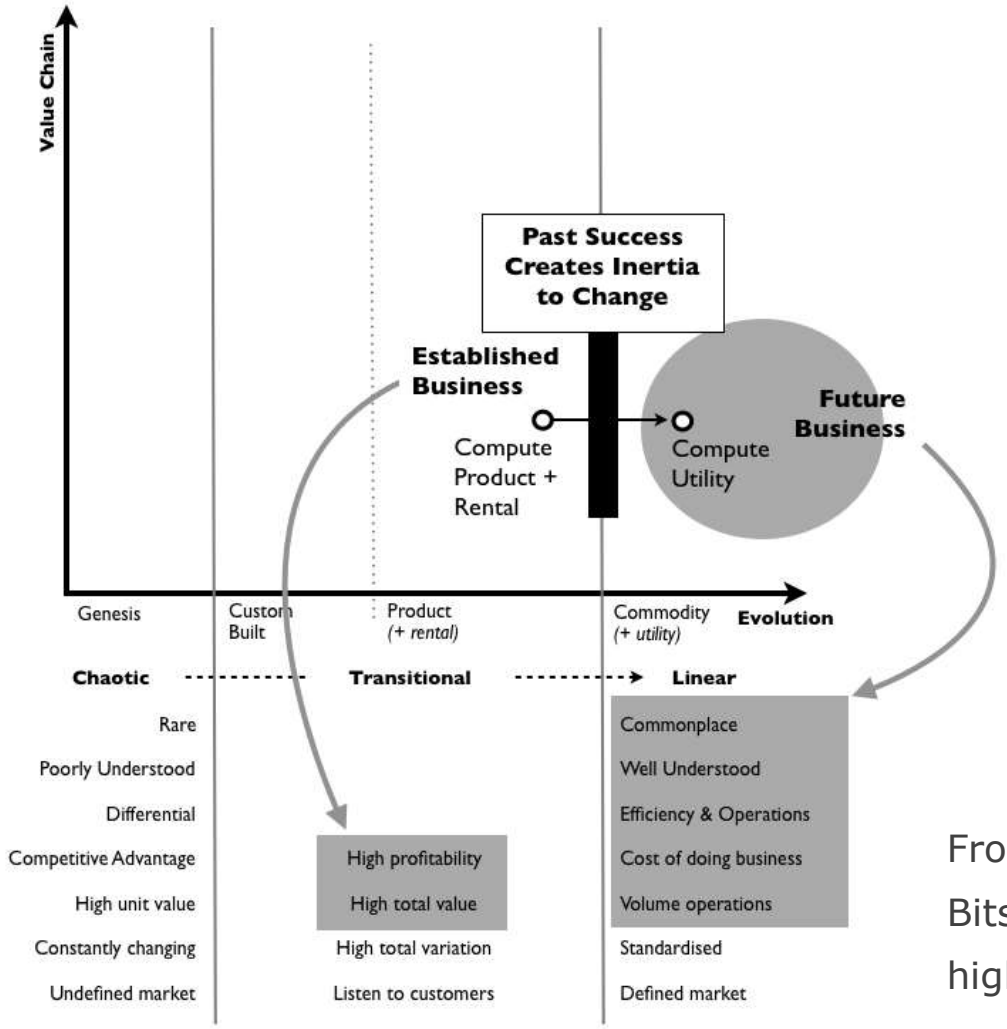
- Question: What drove the migration from NCP to TCP/IP?
- Answer: Applications

- Question: Since NCP had many limitations which TCP/IP solved, were users/IT happy to switch?
- Answer: No! Many resisted the change. DCA forced it. Users oblivious as long as their applications work.



IOT WILL DRIVE IPV6

Most will resist – the following may help illustrate:



From Simon Wardley's Bits or Pieces blog, highly recommended!

WHY ARE WE RESISTING IPV6?

- Why did an online book reseller capture the cloud market? How can that company now dominate this market space with all the "established" players scrambling to try to catch up?
- Because we're a victim of our own success. TCP/IP and specifically IPv4 is so successful and so commonplace that it literally is the Matrix. We can't even see it any more.
- Only people outside the industry who don't understand "the rules" can see the need for something new and don't care if it's inconvenient.

WHO IS DRIVING IPV6?

IoT component producers (engineers)

- Almost 20 billion net new units/year, increasing exponentially for several different categories (microcontrollers, sensors, actuators, etc.)
- Need to support universal connectivity
- "Those Internet/Networking People" have two standards, IPv4 and IPv6
- IPv4 supports around 4 billion unique nodes
- IPv6 supports virtually unlimited nodes
- For an engineer who doesn't understand "the rules", the choice is obvious – IPv6
- Decision has been made

SO WHEN DO I NEED TO SUPPORT IPV6?

Confession:

I can’t predict the future.

Really irritates my clients…

LET'S LOOK AT IPV6 ADOPTION

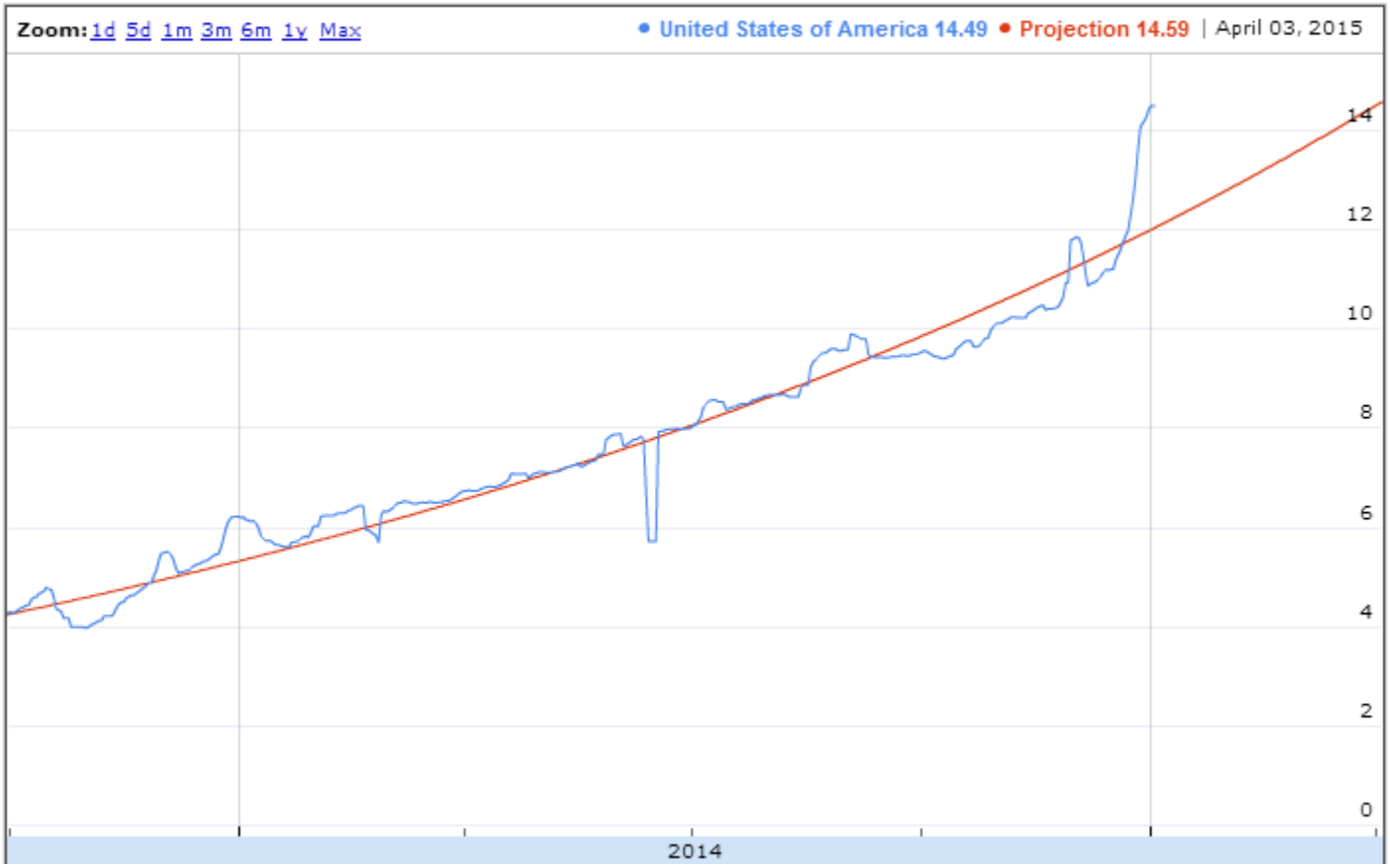
How to measure IPv6?

- How much traffic uses IPv6?
- How many connections use IPv6?
- How many routes are IPv6 routes?
- How many service providers offer IPv6?
- How many domain names have AAAA RRs?
- How many domain NS's use AAAA's?
- How many DNS queries are for AAAA RRs?
- How many DNS queries are made over IPv6?
- How many end devices have IPv6?
- How many end devices use IPv6?

(and many more!)

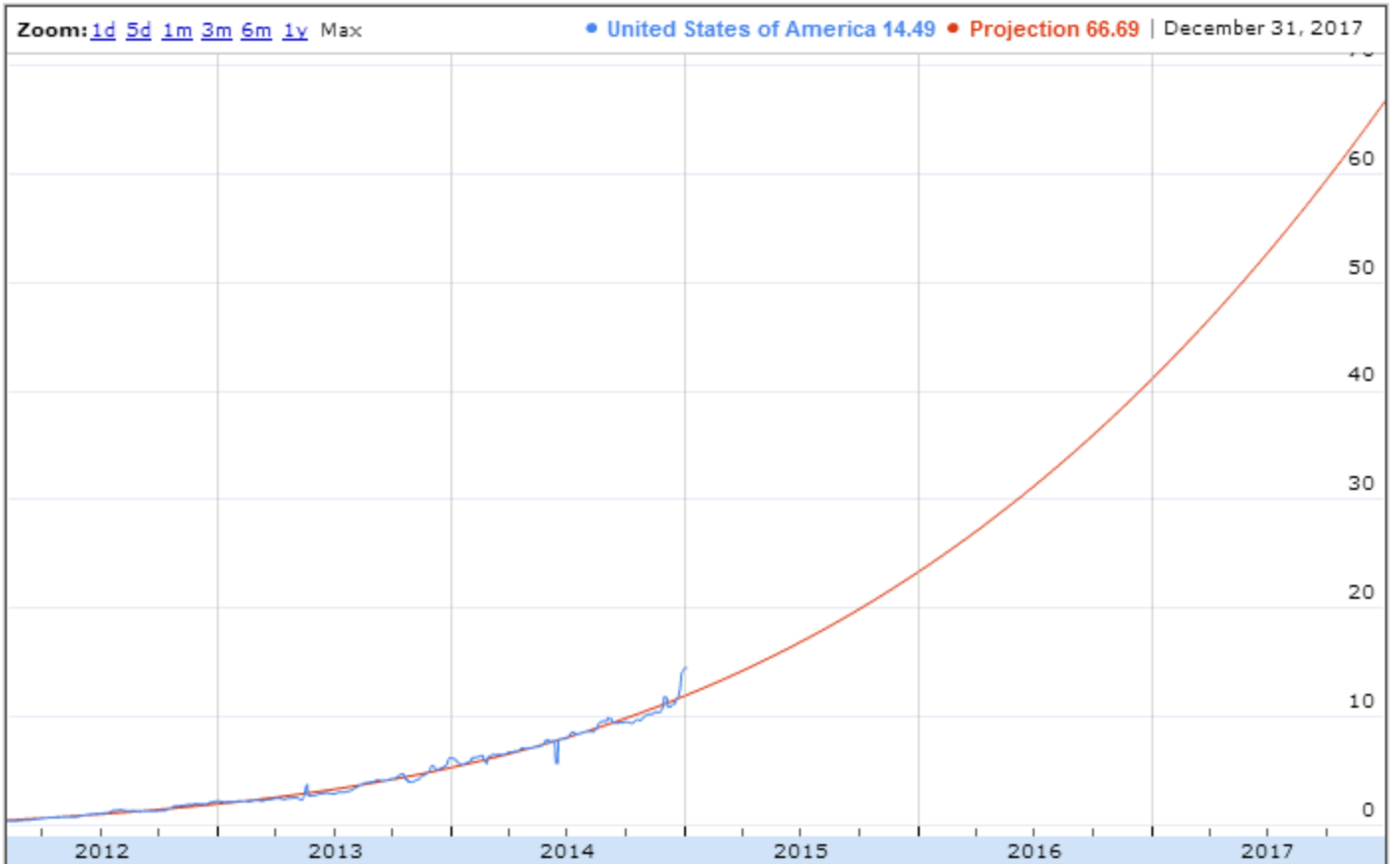
LET'S LOOK AT IPV6 ADOPTION

Best way is to measure end to end capability - can a user/endpoint connect to IPv6 site/service/app?
This requires all the previously mentioned points…



WHERE HAVE WE BEEN/ARE WE GOING?

Data from last 3 years; projection for next 3 years based on that:



WHAT CONSTITUTES CRITICAL MASS?

- Aggressive: 10% penetration
- Moderate: 15% penetration
- Conservative: 20% penetration

Current penetration in US:

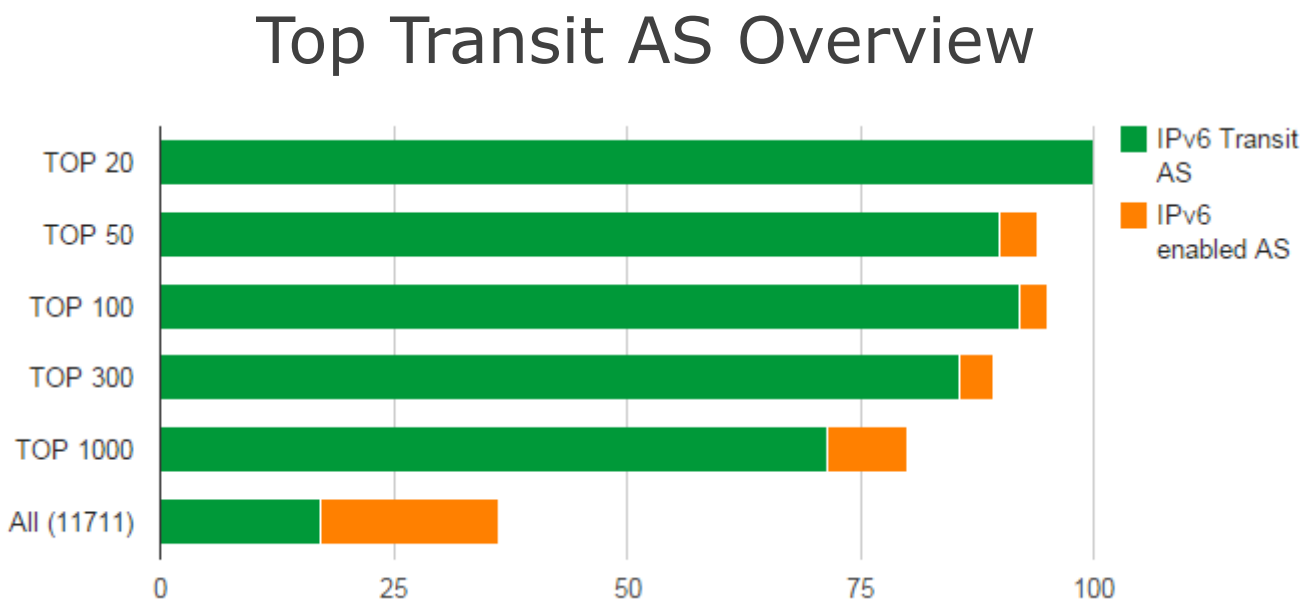
- Approaching 15%
- Will pass 20% well before the end of the year

Current number of IPv6 Internet Users in US:

34,083,812

MARKET INDICATORS

- What are Internet Service Providers doing?



MAJOR US PROVIDERS AND IPV6 STATUS

ISP/Service Provider	Traffic% which is IPv6
Google Fiber	74.2%
Verizon Wireless	63.2%
T-Mobile USA	46.1%
Comcast	30.3%
AT&T	27.1%
CloudFlare	21.6%
Hughes Network Systems	21.3%
Hurricane Electric	16.8%
Time Warner Cable	12.4%

WHAT ABOUT IPV4 ADDRESS EXHAUSTION?

Registry	Depletion Date	Available /8s	Status
IANA	Feb-11	0	Exhausted
APNIC	Apr-11	0.7624	Depleted
RIPE NCC	Sep-12	0.9711	Depleted
LACNIC	Jun-14	0.2022	Depleted
ARIN	Apr-15	0.4196	Stage 4
AFRINIC	Apr-19	2.7922	Normal

DO I REALLY NEED IPV6?

Recommended because:

- IoT will drive IPv6 – monitor this space carefully
- Mobility moving to IPv6
  - » Largest US Wireless Carrier – Verizon, majority of their traffic is IPv6, all 4G handsets must support IPv6
  - » T-Mobile USA – New Android handsets are IPv6-only with 464XLAT for backwards compatibility with IPv4, but doesn't work with everything
  - » AT&T and Sprint have fully deployed IPv6 core; M2M networks are IPv6-only; only a matter of time before migrate to IPv6

DO I REALLY NEED IPV6?

Recommended because:

- All major US ISPs are deploying IPv6
- Most major ISPs are also deploying CGN to conserve IPv4 address space
- CGN breaks/degrades many applications – the content provider (read – you) will be blamed for problems
- IPv4 Exhaustion increases pressure to migrate to IPv6
- Silicon Valley/Technology leaders have long since deployed IPv6
  - » Facebook moving to IPv6 only network
  - » Start expecting enhanced features requiring IPv6

REMEMBER, ALL I'M OFFERING IS THE TRUTH

WHERE DO I START?

- Lab – Unless you enjoy learning in production…
- No lab budget? Home lab works too.
- Goals:
  - Connectivity to IPv6 Internet
  - Allow remote access from IPv6 Internet
  - Allow option of making applications/services available from IPv6 Internet
  - Allow access to IPv6 Internet

PROFICIENCY REQUIRES PRACTICE

CONNECTIVITY TO IPV6 INTERNET

Talk to your ISP about provisioning IPv6

- Will require patience
- 15% of people having IPv6 means 85% don't…
- Much of ISP staff have little or no IPv6 experience
- Not uncommon to hear:
  - "What's that?"
  - "Why do you want that?"
  - "No one is using it."

CONNECTIVITY TO IPV6 INTERNET

Expectations for ISPs:

- All Tier 1 and the vast majority of mid-range ISPs have deployed IPv6
  - » If your ISP doesn't offer IPv6 service you should look at switching providers
  - » You may be able to find cheaper service which also includes IPv6
- If your ISP talks about a surcharge for IPv6 you should look at switching providers, see above points
  - » Exception – You may have to pay one time provisioning fees

CONNECTIVITY TO IPV6 INTERNET

Expectations for ISPs:

- Provision for native service
  - » Try to avoid tunneled service – this is grounds for shopping
  - » If your Internet access is through MPLS, 6PE or 6VPE is fine

CONNECTIVITY TO IPV6 INTERNET

Deployment:

- Single connection to ISP, assuming default route
  - » Configuring IPv6 address and default route is easy
  - » Make sure all your IPv4 security/controls are equivalent or acceptable for IPv6 – watch out for management access
  - » Possible to do on your own but watch out for the above; make sure IPv6 configuration, features and functionality of equipment clearly understood
- Multi-homed
  - » Recommend getting help, even if it's just to review your configuration and talk through it

CONNECTIVITY TO IPV6 INTERNET

Equipment:

- All major network/security vendors have long supported IPv6
- Your equipment may not support IPv6 because:
  - » Software upgrade needed
  - » Hardware upgrade needed
  - » Legacy solution, needs to be replaced
- Solution:
  - » Equipment under support contract, no additional costs for upgrade. Plan and execute.
  - » Costs involved
    - Budget available – plan and execute
    - Budget not available – get in next year's plan

ALLOW REMOTE ACCESS FROM IPV6 INTERNET

Once connected to IPv6 Internet, look at setting up remote access

- User Remote Access (VPN)
- Site Remote Access (VPN)

More and more common for SOHO sites to be unable to obtain a public IPv4 address. This can be a problem for remote management. Solution – use IPv6.

Note: IPv6 VPN access still allows using IPv4 for the "inside" connection. This is the easy button for IPv6 remote access.

ALLOW PUBLISHING TO IPV6 INTERNET

Full support of IPv6 for applications will take years, perhaps decades:

- Operating system must support (all major ones do but requires configuration/testing)
- Application platform/components must support (most major ones do but requires configuration/testing)
- Application typically requires re-work (coding) to support IPv6
  - » Database fields (32 bit → 128 bit fields)
  - » User input/forms
  - » Dealing with IPv6 DNS records
  - » Address normalization, etc…

ALLOW PUBLISHING TO IPV6 INTERNET

While application teams starting thinking about migrating to IPv6, an interim solution is required. Options:

- NAT64
  - » Appears to be easy button but complex to troubleshoot, limited flexibility, MTU problems difficult to solve/diagnose
- Reverse Proxy
  - » Workable solution for “proxyable” applications, performance/scale is the limiting factor
- SLB64
  - » Generally the best solution – supported by all major load balancer (ADC) solutions

ALLOW ACCESS TO IPV6 INTERNET

For testing, development and potentially some Internet sites/applications/services. Options include:

- Dual stack intranet
  - » Ideal but typically a major project
- Proxy
  - » Good solution for "proxyable" applications (e.g. many web sites), as with reverse proxy – performance/scale is the bottleneck

ALLOW ACCESS TO IPV6 INTERNET

For testing, development and potentially some Internet sites/applications/services. Options include:

- Tunneling (e.g. ISATAP)
  - » Can be a good solution for intranet lab access; more problematic for general use – can be difficult to troubleshoot/monitor; Reduced MTU can be an issue
- VPN/Reverse VPN
  - » Provide in-house or use service provider; similar issues to ISATAP; also potential loss of control depending on solution setup

QUESTIONS

@netsec14

My IPv6 Blogs:
Packet Pushers

Appendix

EXAMPLE SOFTWARE PROXY

HAPROXY

Example configuration (/etc/haproxy.cfg):

```
frontend http-in
        bind :::80
        acl is_example hdr_end(host) -i example.com
        use_backend example.com if is_example
        default_backend localhost

backend example.com
        balance roundrobin
        cookie SERVERID insert nocache indirect
        option httpchk HEAD /check.txt HTTP/1.0
        option httpclose
        option forwardfor
        server B2 192.0.2.1:8080 cookie B2
```

From Andrew Yourtchenko's Cisco Live Preso (BRKRST-2304)

EXAMPLE SOFTWARE PROXY

HAPROXY – Connection Timeouts:

```
ayourtch@Ubuntu-1204:~$ telnet localhost 80
Trying 127.0.0.1...
Connected to localhost.
Escape character is '^]'.
HTTP/1.0 408 Request Time-out
Cache-Control: no-cache
Connection: close
Content-Type: text/html

<html><body><h1>408 Request Time-out</h1>
Your browser didn't send a complete request in time.
</body></html>
Connection closed by foreign host.
ayourtch@Ubuntu-1204:~
```

From Andrew Yourtchenko's Cisco Live Preso (BRKRST-2304)

EXAMPLE SOFTWARE PROXY

HAPROXY – Connection Timeouts, test the defaults!

```
global
        log 127.0.0.1   local0
        maxconn 4096
        user haproxy
        group haproxy
        daemon
defaults
        log     global
        mode    http
        option  dontlognull
        retries 3
        option redispatch
         contimeout       50000
        clitimeout      50000
        srvtimeout      50000
```

From Andrew Yourtchenko's Cisco Live Preso (BRKRST-2304)