# IPV6 PROSPECTUS

**Current status, projections, example deployment options**

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Michigan!/usr/group

mug.org – A Free and Open Source Michigan Community

# PRESENTATION OBJECTIVES

- **Overview of Current Industry Landscape**
- IPv6 Deployment Considerations

Q&A throughout, I may postpone questions until the end depending on time

# PLANNED IP ADDRESS LIFE CYCLE

ICANN Holds all unassigned global IP addresses (IPv4 and IPv6). Through its IANA function, addresses are issued to RIRs.

**ICANN (IANA)**

Regional Internet Registries (RIRs) issue addresses to LIRs and End-Users

**ARIN** | **RIPE** | **APNIC** | **LACNIC** | **AFRINIC**

Local Internet Registries (LIRs) issue addresses to End-Users

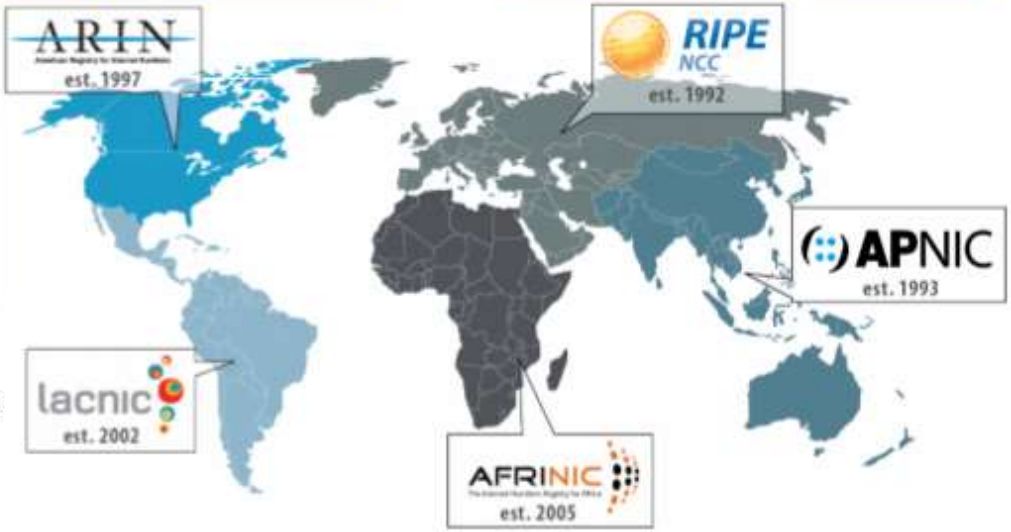
**LIR (e.g. ISP)**

**End-User (e.g. Enterprise)**

Addresses obtained directly from RIR are "Provider Independent" - they are not tied to a particular ISP

**End-User (e.g. Enterprise)**

End-Users are organizations which deploy addresses



# IPV4 ALLOCATION

| | /8s | Number (Billions) |
|---|---|---|
| **Total** | 256 | 4.29 |
| **Usable** | 220.77 | 3.70 |
| **RIR Pool** | 3.64 | 0.06 |
| **Allocated** | 217.13 | 3.64 |
| **Advertised** | 168.11 | 2.82 |

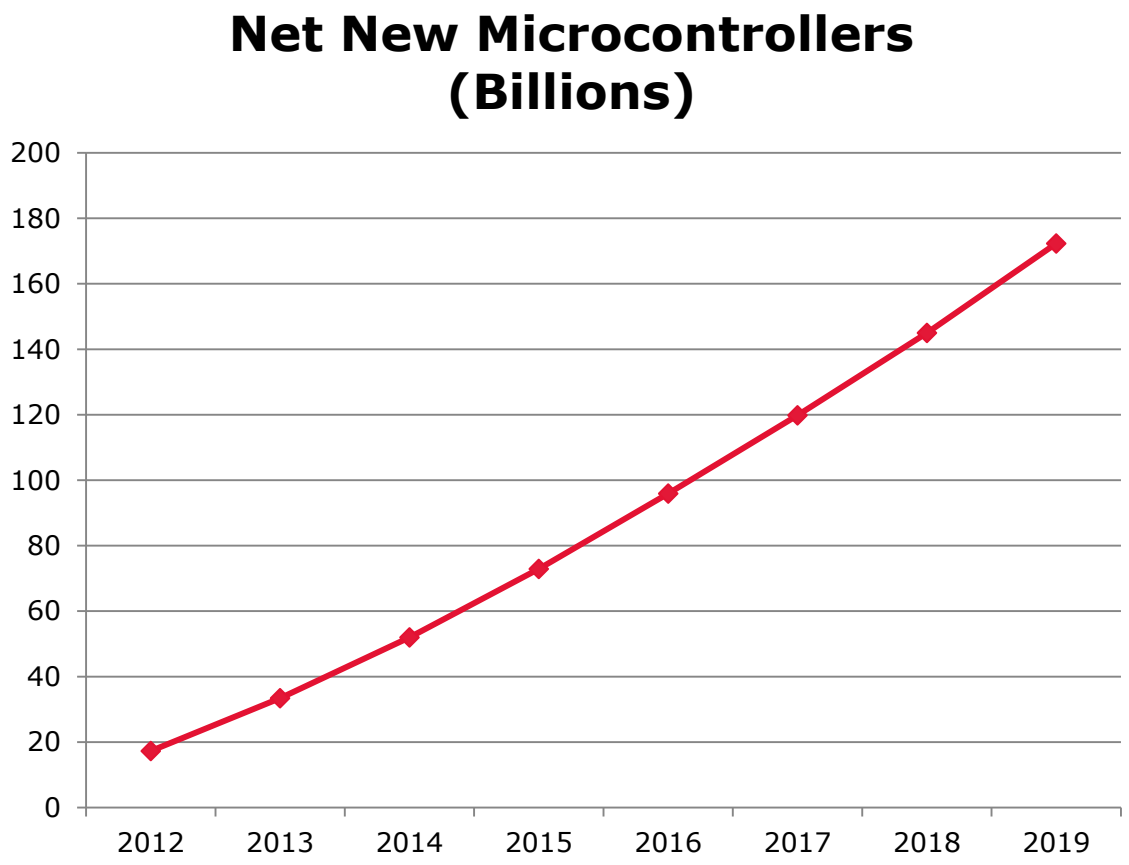
10.0.0.0/8 –or- 10.0.0.0 255.0.0.0 is one /8

# ADDRESS ALLOCATION DRIVERS

- World Population
  - » Almost 7.4 billion and growing
- Global Internet Population Penetration
  - » Over 43% and steadily growing
- Global Cellular/Mobile/M2M Connections
  - » Over 7.6 billion and growing
- The Internet of Things
  - » 4.9 billion as of end of 2015 (Gartner)
  - » 25 billion by 2020 (Gartner)

# IOT DEVICE GROWTH

| Year | Units (Billions) |
|---|---|
| 2012 | 17.3 |
| 2013 | 16.1 |
| 2014 | 18.6 |
| 2015 | 20.9 |
| 2016 | 23.0 |
| 2017 | 23.9 |
| 2018 | 25.2 |
| 2019 | 27.3 |




From the McClean Report 2015, IC Insights' analysis of IC industry

# 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 |

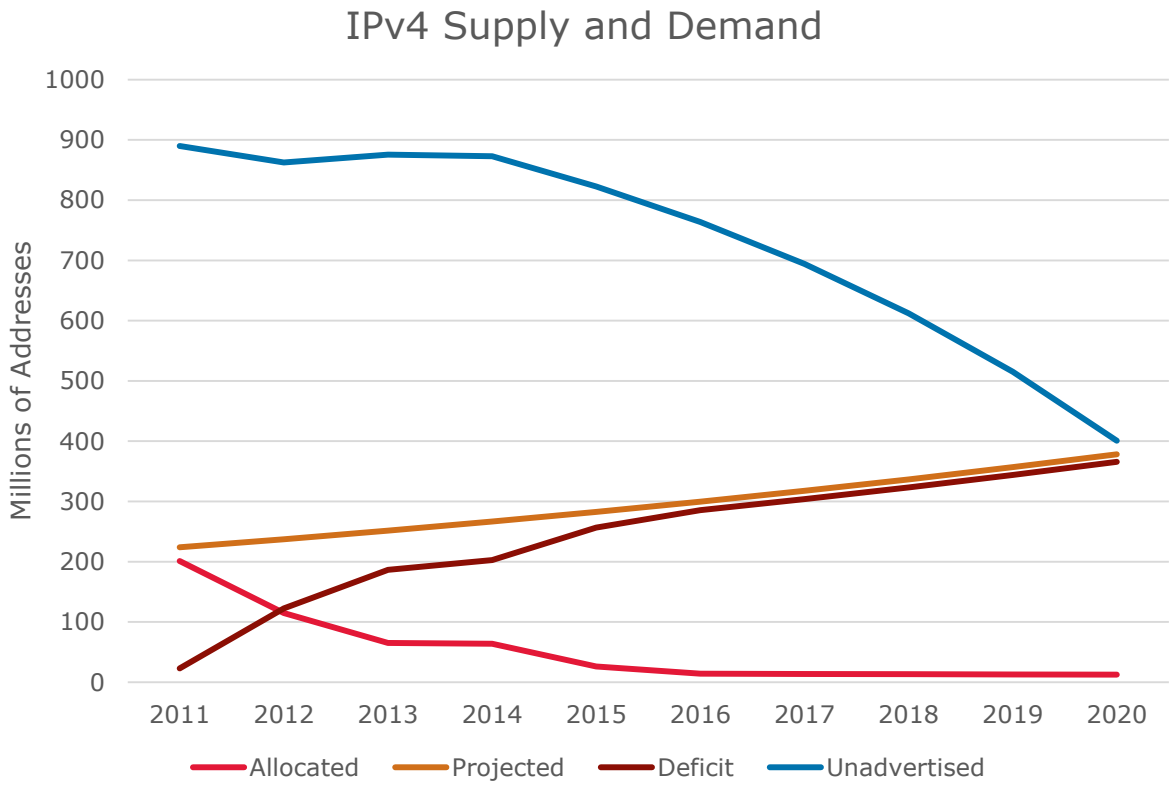
# BUT…

| Registry | Depletion Date | Available /8s | Status |
|---|---|---|---|
| IANA | Feb-2011 | 0 | Exhausted |
| APNIC | Apr-2011 | 0.6284 | Depleted |
| RIPE NCC | Sep-2012 | 0.9520 | Depleted |
| LACNIC | Jun-2014 | 0.1144 | Depleted |
| ARIN | Sep-2015 | 0 | Exhausted |
| AFRINIC | Jul-2017 (Est) | 1.9496 | Normal |

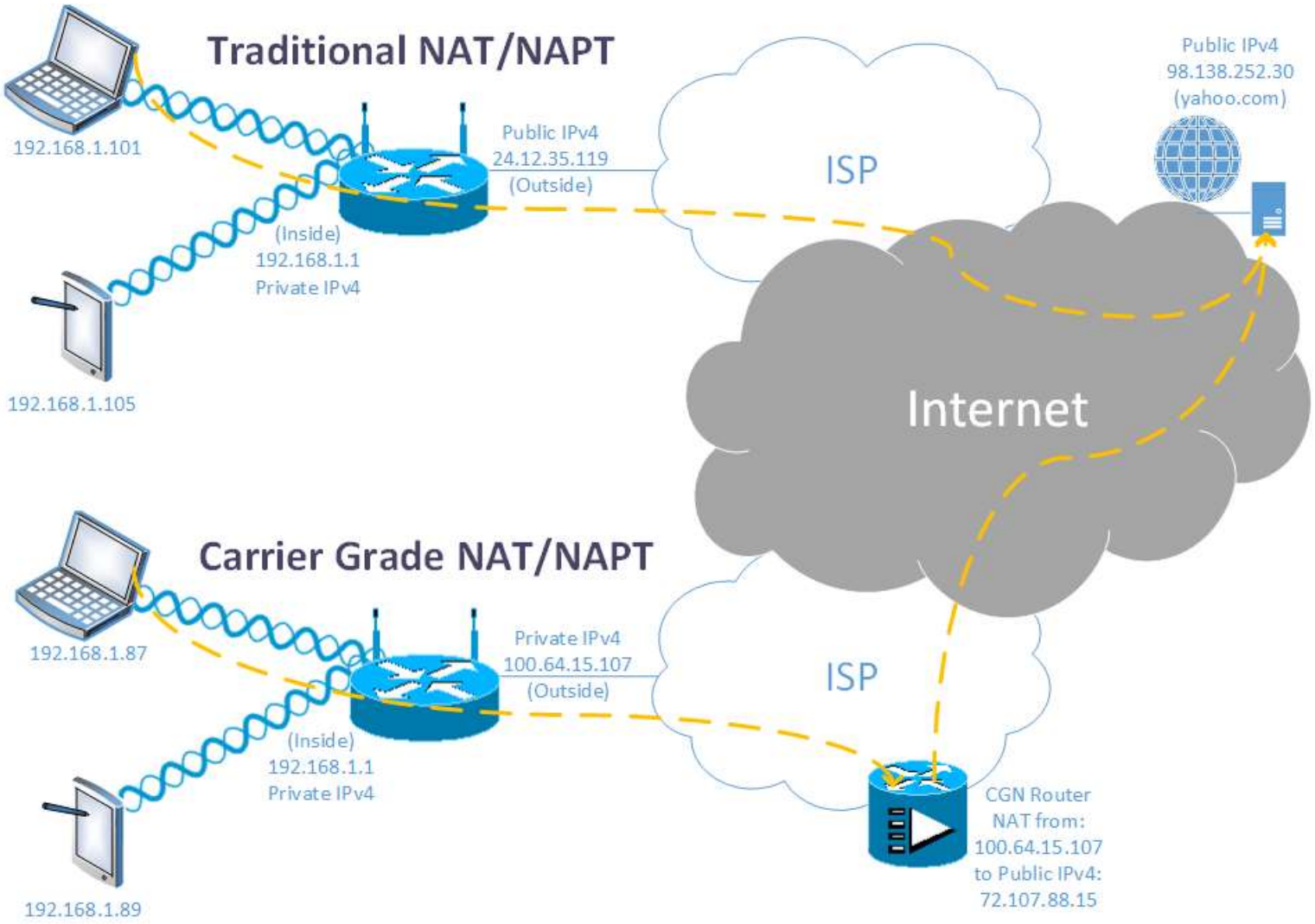
One /8 is 16,777,216 IPv4 addresses

# CONTEXT

| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|
| Allocated (millions) | 174.4 | 168.1 | 203.9 | 203.3 | 189.4 | 248.8 | 201 |
| Alloc /8s | 10.4 | 10 | 12.2 | 12.1 | 11.3 | 14.8 | 12.0 |



# IPV4 TACTICS AND STRATEGY

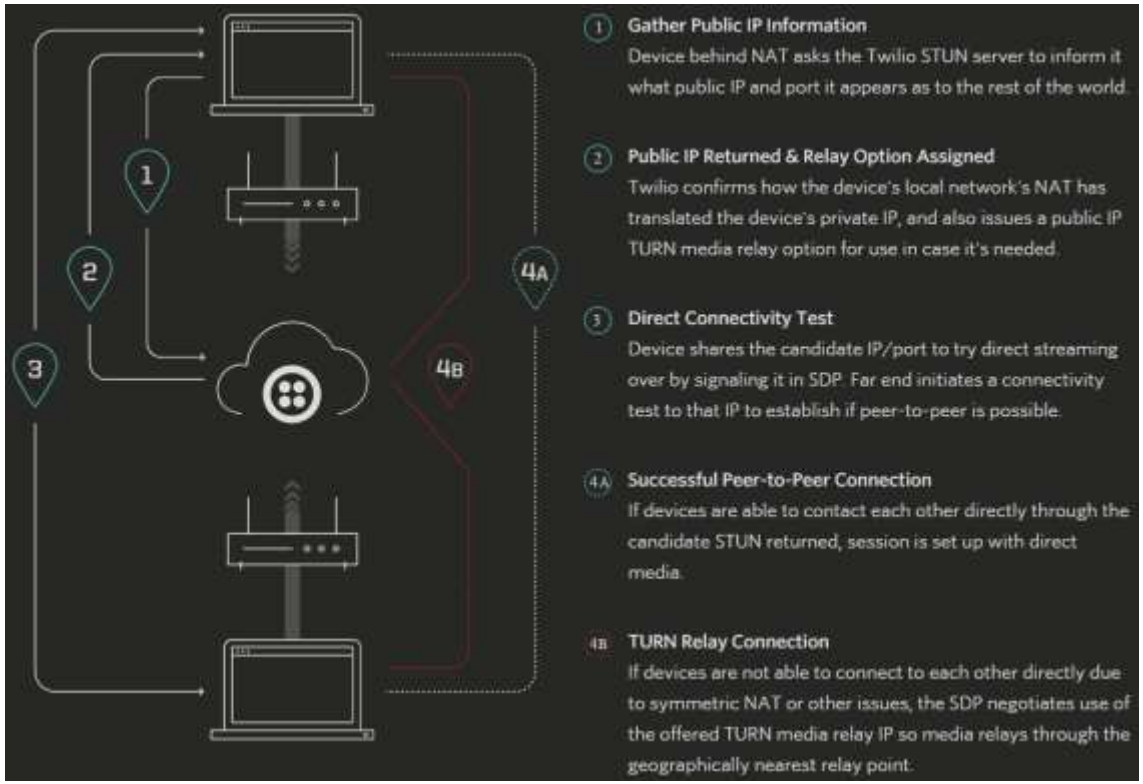



Short Term - Preserve IPv4 with CGN

# IMPACT OF IPV4 EXHAUSTION

- Wide spread CGN Deployment
  - » Security challenges – One IPv4 address no longer maps to a user/location, could be an entire neighborhood/area
  - » Makes some communications challenging – Generally doesn't work with online gaming

Twilio STUN/TURN Service



# IPV4 TACTICS AND STRATEGY

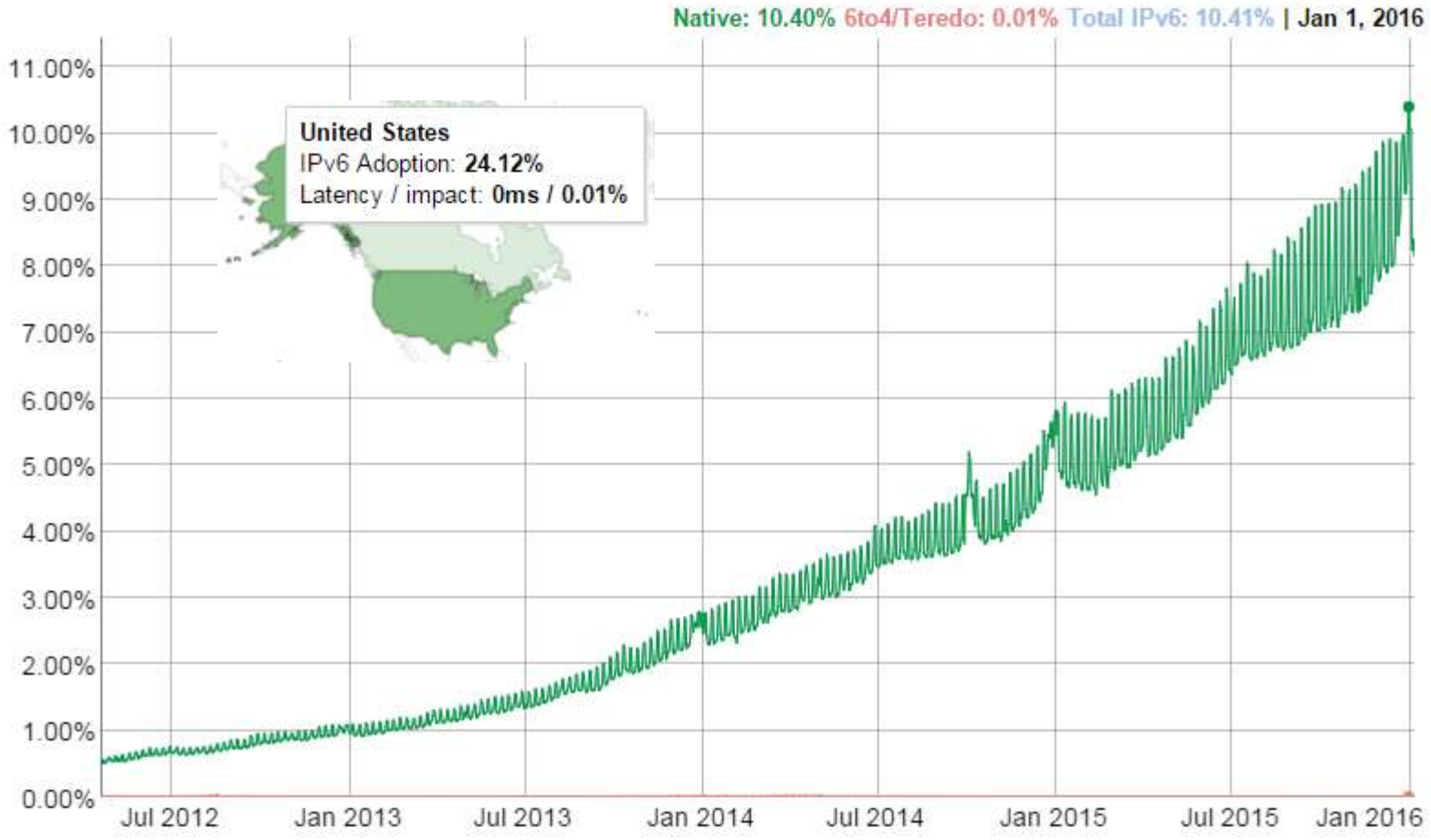
- Short Term - Maintain Adequate IPv4 Reserve
  - » New IPv4 blocks through Address Markets

RECENTLY CLOSED AUCTIONS

| BLOCK | SOLD DATE | PRICE | PRICE PER ADDRESS |
|---|---|---|---|
| /24 Block Registered in ARIN | 1/08/16 | $2,816.00 | $11.00 |
| /23 Block Registered in ARIN | 1/07/16 | $6,176.00 | $12.06 |
| /21 Block Registered in ARIN | 1/07/16 | $16,384.00 | $8.00 |
| /24 Block Registered in ARIN | 1/07/16 | $2,816.00 | $11.00 |
| /24 Block Registered in ARIN | 1/06/16 | $2,916.00 | $11.39 |
| /24 Block Registered in ARIN | 1/04/16 | $2,816.00 | $11.00 |
| /21 Block Registered in ARIN | 12/31/15 | $16,434.00 | $8.02 |
| /23 Block Registered in ARIN | 12/31/15 | $5,760.00 | $11.25 |
| /24 Block Registered in ARIN | 12/30/15 | $2,816.00 | $11.00 |
| /24 Block Registered in ARIN | 12/29/15 | $2,560.00 | $10.00 |
| /23 Block Registered in ARIN | 12/29/15 | $5,120.00 | $10.00 |
| /22 Block Registered in ARIN | 12/29/15 | $9,216.00 | $9.00 |
| /20 Block Registered in ARIN | 12/29/15 | $30,720.00 | $7.50 |
| /19 Block Registered in ARIN | 12/29/15 | $61,440.00 | $7.50 |

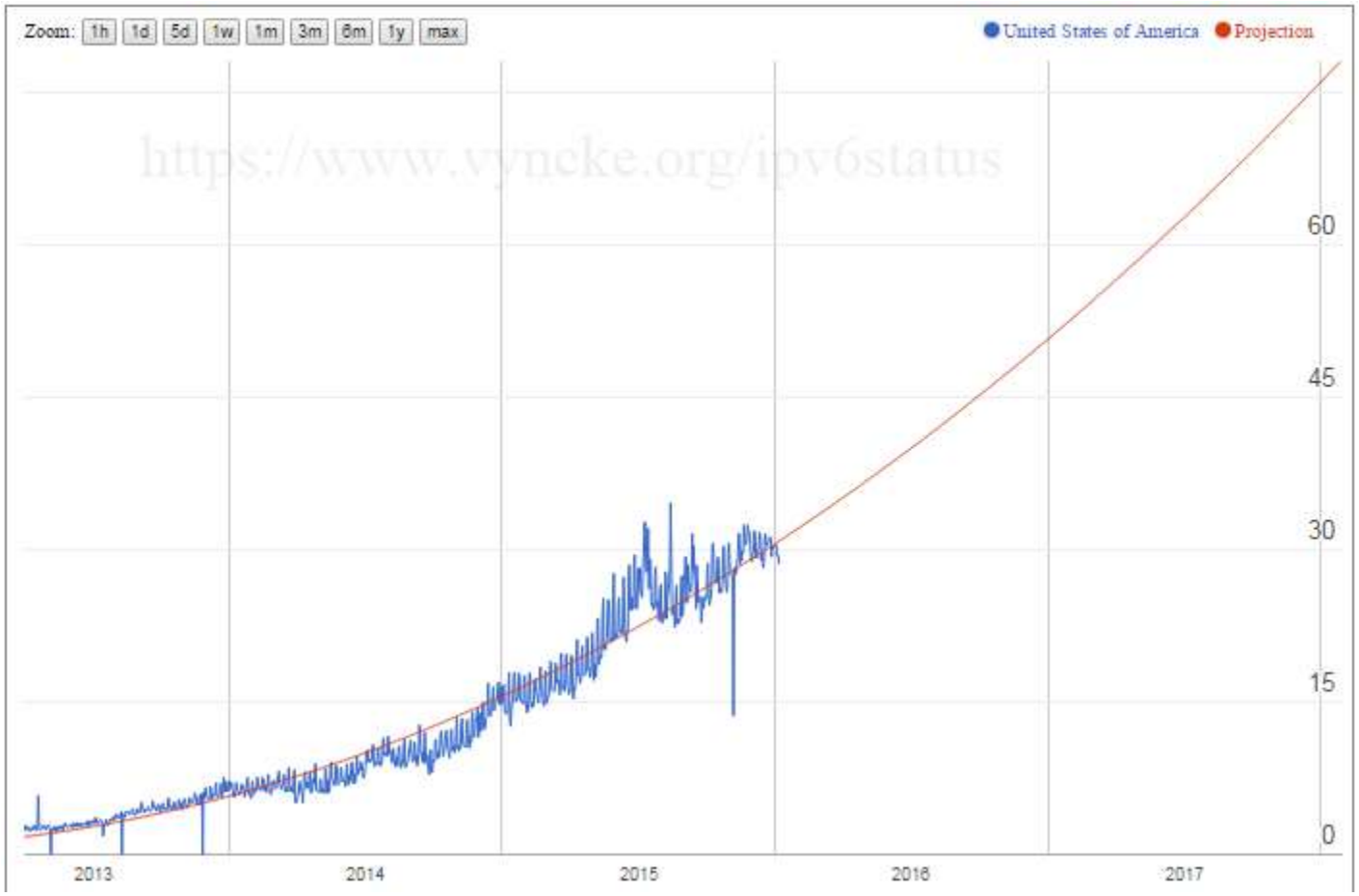
IPv4Auctions.com

# IPV6 STORY – GOOGLE




Evaluating IPv6 Adoption in the Internet

# IPV6 STORY – US (APNIC LABS)




[APNIC Labs IPv6 Measurement System Changes to the Way We Measure IPv6]

# IPV6 STORY – AKAMAI VS. APNIC LABS

| Rank | IPv6% | Country |
|---|---|---|
| 1 | 37.5 | Belgium |
| 2 | 22.2 | Switzerland |
| 3 | 21.4 | Portugal |
| 4 | 20.4 | Greece |
| 5 | 20.2 | Germany |
| 6 | 18.2 | Peru |
| 7 | 16.7 | US |
| 8 | 15.6 | Luxembourg |
| 9 | 12.3 | Ecuador |
| 10 | 10.8 | France |

| Rank | IPv6% | Country |
|---|---|---|
| 1 | 49.8 | Belgium |
| 2 | 29.7 | US |
| 3 | 29.1 | Switzerland |
| 4 | 28.8 | Germany |
| 5 | 24.8 | Portugal |
| 6 | 20.8 | Greece |
| 7 | 20.2 | Luxembourg |
| 8 | 17.3 | Estonia |
| 9 | 16.8 | Peru |
| 10 | 16.4 | Japan |

# WHAT CONSTITUTES CRITICAL MASS?

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

Penetration in US (APNIC Labs):

| | |
|---|---|
| Today | 30% |
| December, 2016 | 50% |

| | |
|---|---|
| August, 2017 | 67% |
| February, 2018 | 80% |

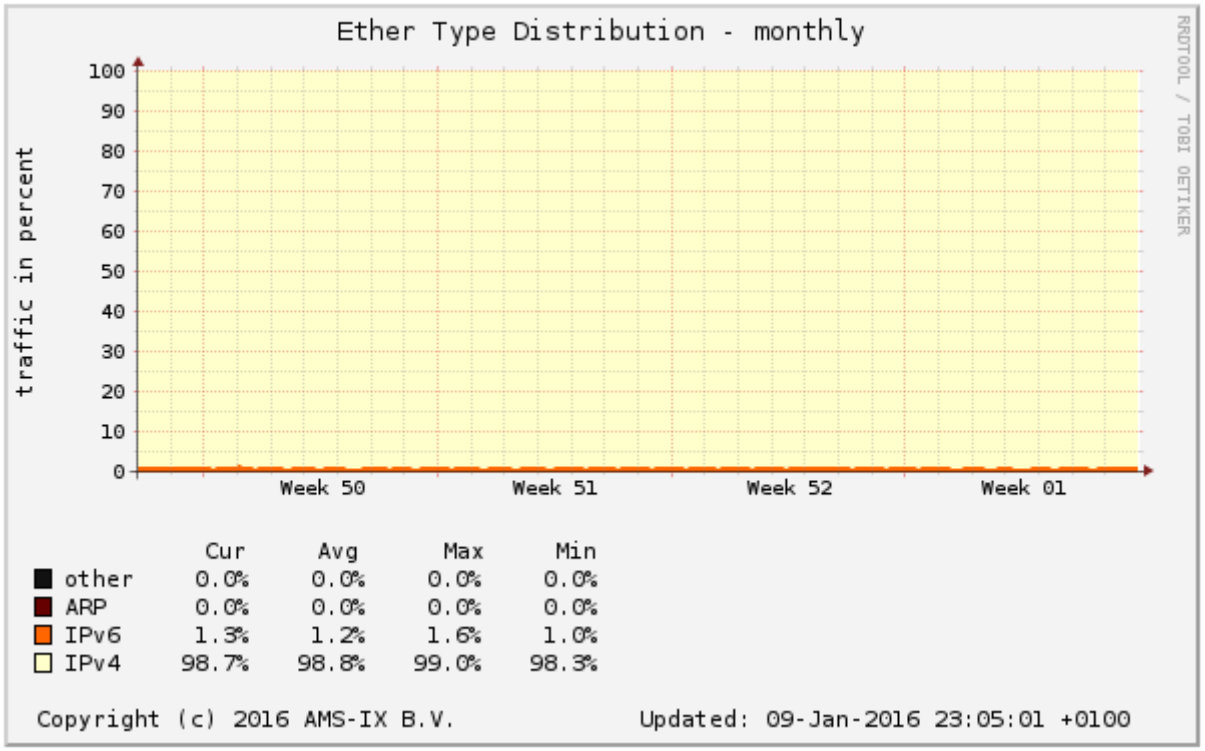
Current number of (est.) IPv6 Internet Users in US:
84,414,764

(Est. US Internet Users: 280,687,714)

(Est. US Population: 323,000,822)

# PENETRATION DIFFERENT FROM VOLUME

Ether type - monthly




Amsterdam Internet Exchange – One of the world's largest

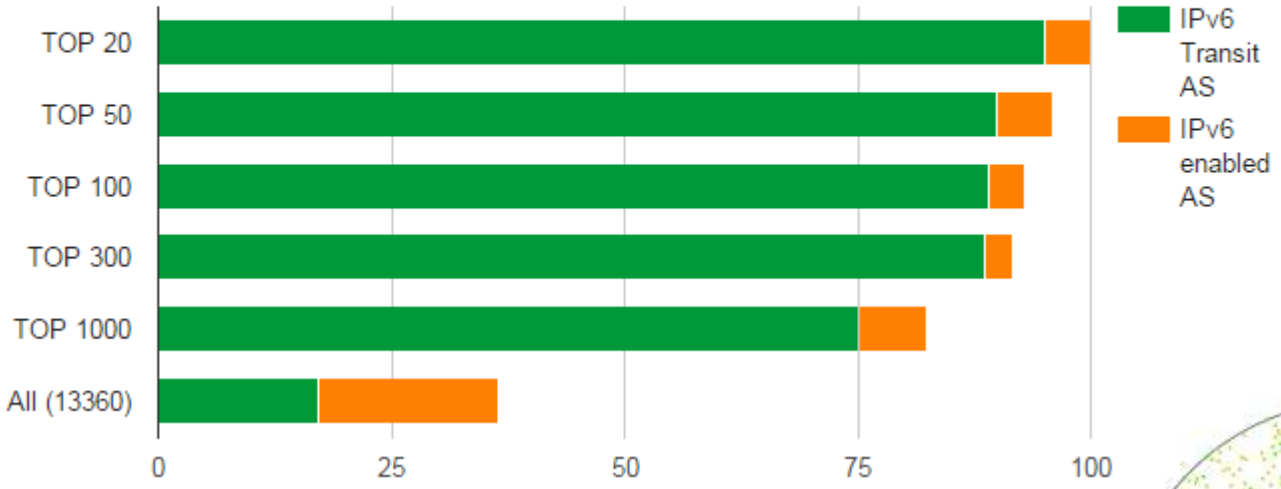
# IPV6 STORY – MAJOR US ISPS (USERS)

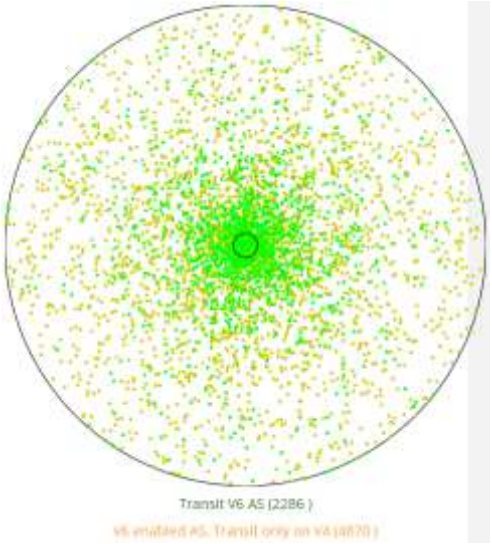
| US Broadband Rank | ISP | IPv6 Deployment % |
|---|---|---|
| 1 | Comcast | 41.9 |
| 2 | AT&T | 52.4 |
| 3 | Time Warner Cable | 23.6 |
| 4 | Verizon | ? |
| 5 | CenturyLink | 0.1 |

| US Cellular Rank | ISP | IPv6 Deployment % |
|---|---|---|
| 1 | Verizon Wireless | 71.4 |
| 2 | AT&T Wireless | 6.1 |
| 3 | T-Mobile USA | 53.2 |
| 4 | Sprint Wireless | 9.7 |
| (Satellite) | Hughes Network Systems | 24.9 |

# IPV6 STORY – TOP GLOBAL ISPS (INTERNET)

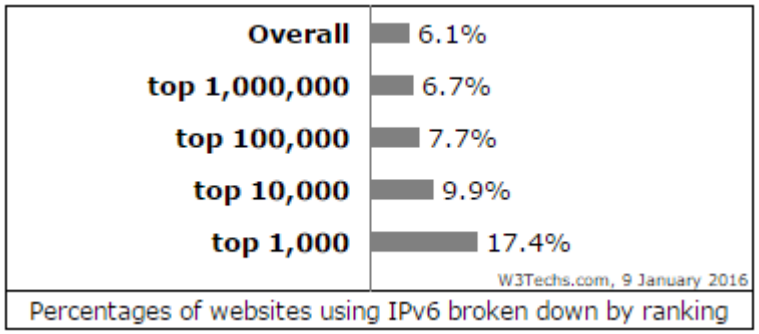
Top transit AS overview



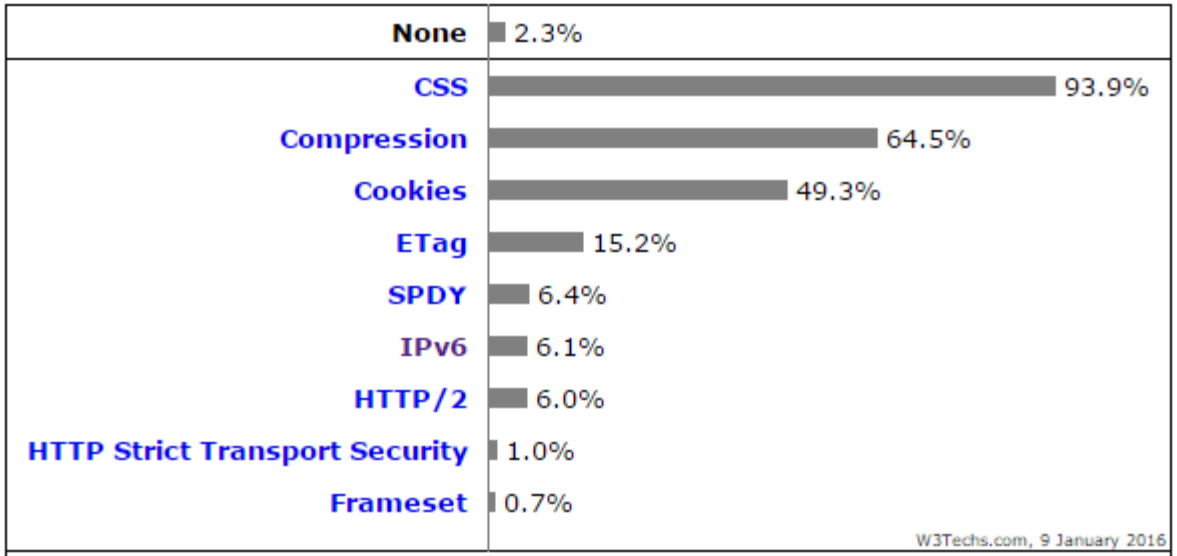




Cisco 6lab

# IPV6 VIEW FROM THE WEB (CONTENT)



Percentages of websites using IPv6 broken down by ranking



Percentages of websites using various site elements
Note: a website may use more than one site element

W3Techs Web Technology Surveys – Site Elements

# WHO IS DEPLOYING IPV6?

Silicon Valley/Technology leaders have long since deployed IPv6, also:


Operating System Vendors


Networking Vendors


Security


Common Sites and Services

# WHO IS NOT DEPLOYING IPV6?

But Missing…

Cloud




Compute





Storage




Mainstream Sites





Service Sites





Smaller sites

# WHY THE RELUCTANCE WITH IPV6?

- Interface change
- Invisible infrastructure (electric grid)
- Inertia
- Limited short term benefits

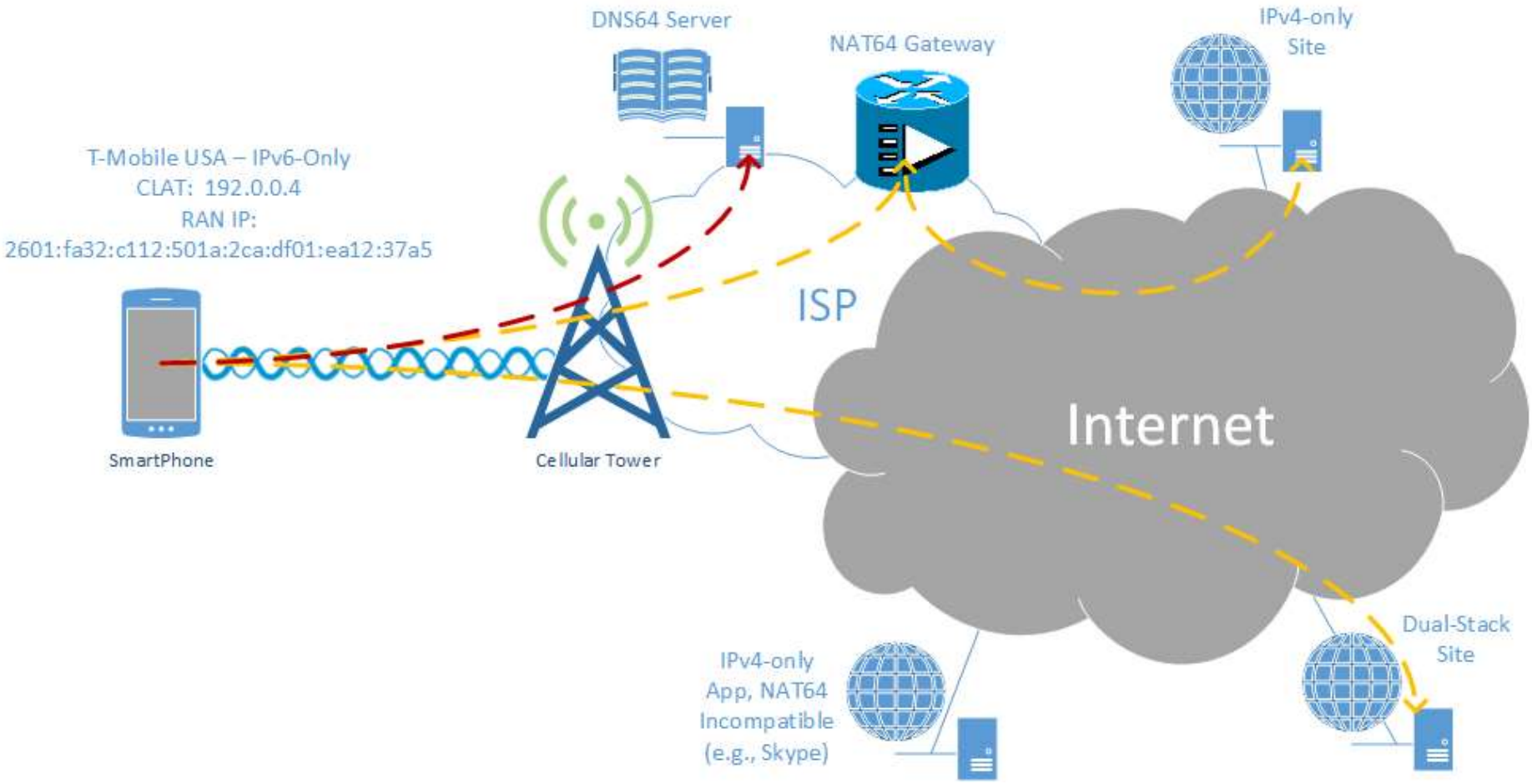
# IPV6 DRIVERS

- The Internet of Things

- Mobility - Facebook findings from their @Scale Conference (September, 2015)
  - 10% of global users connect to them with v6
  - 23% of US users connect with v6
  - 33% of Mobile US users connect with v6
  - 45% of 4G Mobile US users connect with v6
  - » With client instrumented A/B testing (mobile focus), IPv6 is consistently about 15% faster than IPv4 across carriers
    - Analysis done by Facebook data scientist
    - Two sample sizes of over 155,000
  - » More than 1/3 of US Mobile Traffic is IPv6 and still growing…

- Maximum control of user experience

# IPV6-ONLY, NAT64, 464XLAT

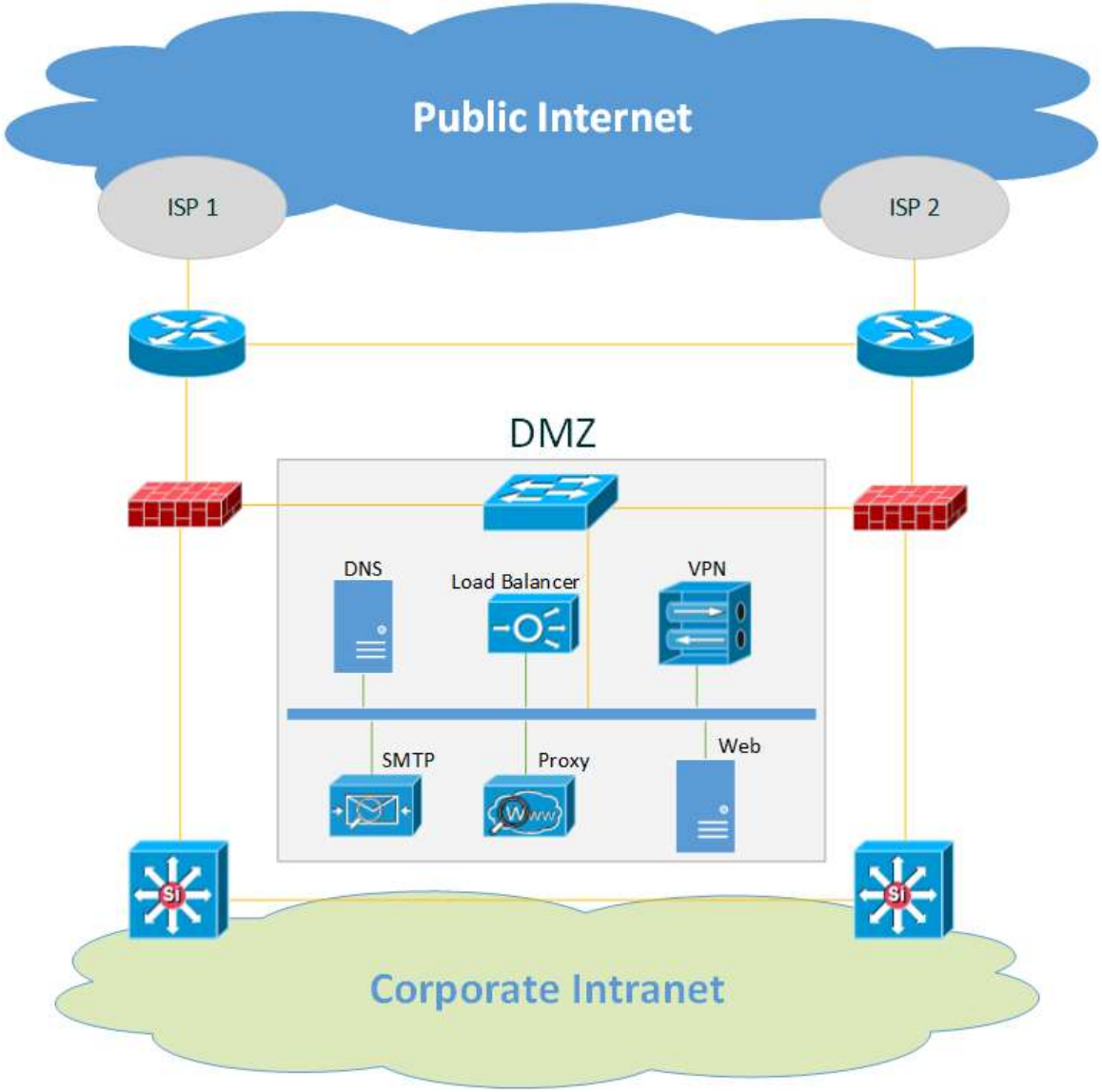



The User Experience – Control, Visibility, Performance

# PRESENTATION OBJECTIVES

- Overview of Current Industry Landscape
- **IPv6 Deployment Considerations**

# EXAMPLE ORGANIZATION PERIMETER



# A WORD OF CAUTION

- When you enable IPv6 – most modern services will automatically listen on all IPv4 and IPv6 addresses

- Often times your network services are restricted by address-based access control:
  - SNMP (network management)
  - VTY (telnet/ssh access)
  - HTTP/HTTPS (web/REST/API)
  - FTP (file transfers)
  - NTP (time synchronization)


- By default, these services will accept connections from anywhere on the IPv6 Internet which may not be what you want…

# SHIPS IN THE NIGHT

Remember – IPv4 and IPv6 are ships in the night!

- They are completely independent protocols
- Blocking all IPv4 has no effect on IPv6 and vice versa.

# IPV6 EASY BUTTON

- Need to publish your content via IPv6 but don't want to do anything?
- Use a CDN!  (Content Distribution Network)
- Many companies use CDNs for IPv6
- Popular CDNs offering IPv6 to IPv4 translation:
  - Akamai
  - Limelight Networks
  - CloudFlare
  - Edgecast




# LINUX/OPEN SOURCE IPV6 TOOLS

- Routing (BGP/OSPF) – Quagga (used by Cumulus)
  - » GoBGP, ExaBGP, BIRD, OpenBGDd, BaGPipe BGP
- Load Balancing (Application Delivery Control) – HAProxy
  - » Nginx, LVS, Balance, Varnish
- Proxy – Squid (Forward/Reverse/Caching/Security/Content Filter/Authentication)
  - » Varnish, Nginx, IPFire, Apache, Artica


- Others
  - » DNS – BIND, PowerDNS
  - » E-mail – Postfix or Exim (Extra time – sendmail ;-)
  - » Firewall – IPTables (IP6Tables)
  - » VPN – OpenVPN

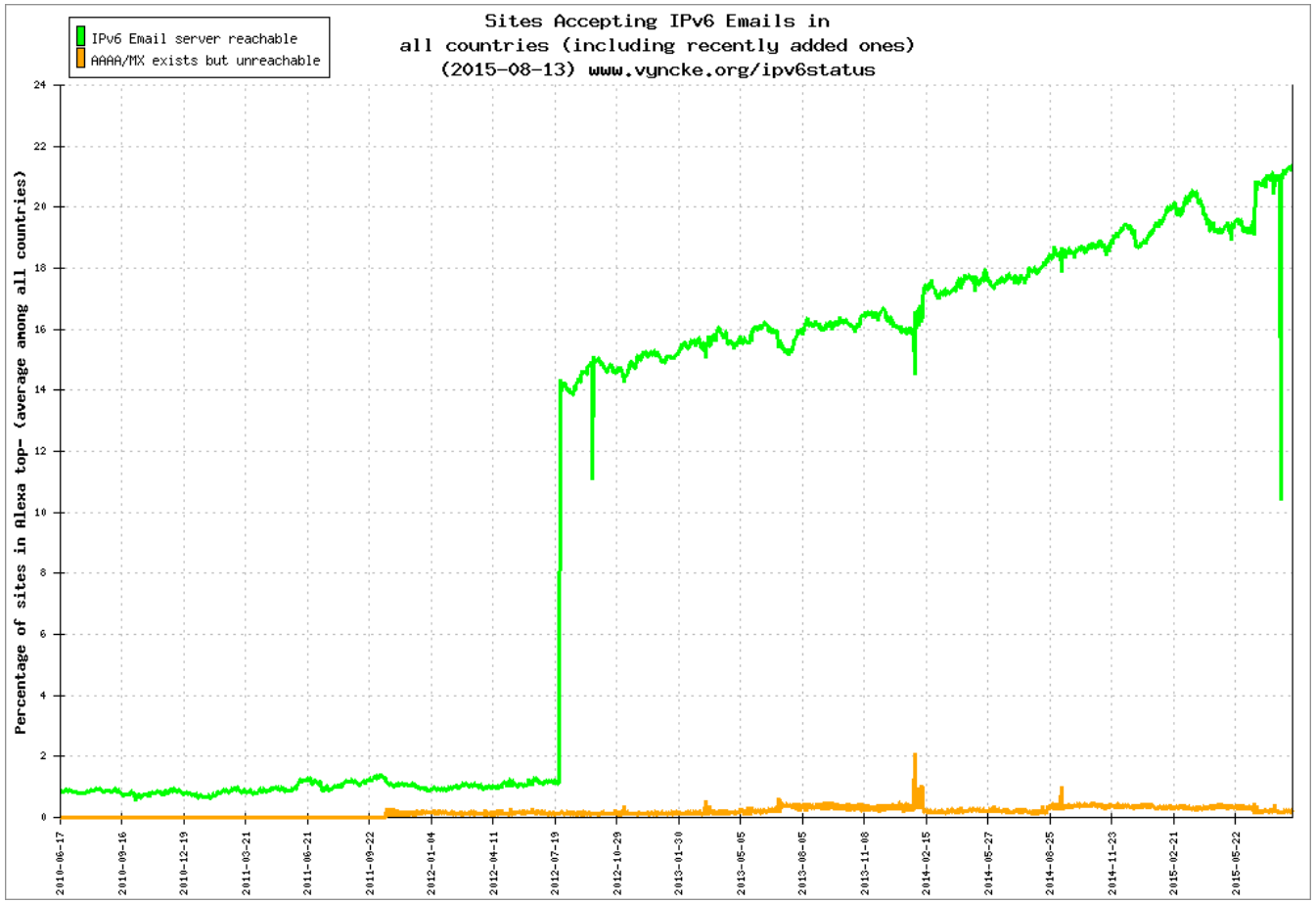
# DEMO

- IPv4-only Web Site/Application
  - » Using NGINX in Docker Container for example

- Translate from IPv6 to IPv4 (SLB64) using HAProxy

- Utility of IPvFoo (Chrome)
  - » Also IPvFox for Firefox

# STATE OF IPV6 INTERNET EMAIL




From the Alexa top 500 Internet sites, approximately 21% of them support inbound IPv6 E-mail

# CAN'T NAT FIX EVERYTHING?

| # | Source | Destination | Stateful | Stateless | Use Case |
|---|---|---|---|---|---|
| 1 | IPv6 Network | IPv4 Internet | Yes | Yes | SmartPhone |
| 2 | IPv4 Internet | IPv6 Network | Static Mappings | Yes | IPv6-only Lab Access |
| 3 | IPv6 Internet | IPv4 Network | Yes | No | SLB64 Preferred |
| 4 | IPv4 Network | IPv6 Internet | No | No | * |
| 5 | IPv6 Network | IPv4 Network | Yes | Yes | Intra-Org |
| 6 | IPv4 Network | IPv6 Network | Static Mappings | Yes | Intra-Org |
| 7 | IPv6 Internet | IPv4 Internet | No | No | |
| 8 | IPv4 Internet | IPv6 Internet | No | No | |

RFC 6144 – Framework for IPv4/IPv6 Translation

# WHAT ABOUT THE APPLICATION SPACE?

- Network challenges and complexities are fairly well understood

# IP SOCKET CODE

Legacy, IPv4-Only Code:

```
import socket, sys

if len(sys.argv) != 2:
    print >>sys.stderr, 'usage: www_ping4 <hostname>'
    sys.exit(2)

hostname = sys.argv[1]
port = 80

# IPv4-only call:
ipv4_addr = socket.gethostbyname(hostname)
# AF_INET = IPv4 Address Family
mysock = socket.socket(socket.AF_INET,socket.SOCK_STREAM)
try:
    mysock.connect((ipv4_addr,port))
except socket.error, e:
    print 'Network failure: ', e.args[1]
else:
    print 'Success: ', hostname, '(' + str(ipv4_addr) +
        ') is listening on port 80'
```


Dual-Stack Code:

```
import socket, sys

if len(sys.argv) != 2:
    print >>sys.stderr, 'usage: www_ping6 <hostname>'
    sys.exit(2)

hostname = sys.argv[1]
port = 80
mysock = None

# Dual-Stack call - use getaddrinfo vs. gethostbyname
# AF_INET6 = IPv6 Address Family
# AF_UNSPEC = Could be IPv4 or IPv6
for res in socket.getaddrinfo(hostname,port,
        socket.AF_UNSPEC,socket.SOCK_STREAM):
    # Address Family, Socket Type, Protocol,
    # Canonical Name, Socket Address Tuple
    af, socktype, proto, canonname, sa = res
    # Only use IPv6 addresses for this program
    if af == 2:
        print 'Skipping IPv4 address (' + sa[0] + ')'
        continue
    try:
        mysock = socket.socket(af, socktype, proto)
    except socket.error as msg:
        mysock = None
        continue
    try:
        mysock.connect(sa)
    except socket.error as msg:
        mysock.close()
        mysock = None
        continue
    break

if mysock is None:
    print 'could not open socket'
    sys.exit(1)
else:
    print 'Success: ', hostname, '(' + str(sa[0]) +
        ') is listening on port 80'
```

# APPLE'S AUDIT FOR IPV4-ONLY CODE

- iOS apps must support IPv6-only connections as of version 9

- What causes apps to be IPv4-only?
  - » IPv4-only storage objects:
    - uint32_t, in_addr, sockaddr_in
  - » IPv4-only APIs:
    - inet_aton, gethostbyname
  - » IPv4-only usage of an API:
    - gethostbyname2(hostname,AF_INET)
  - » Pre-flight checks before connecting:
    - Checking if device has an IPv4 address
    - Checking for reachability to 0.0.0.0


- Note: This is also why iOS doesn't and won't support 464XLAT – instead Apple forces you to support IPv6 or NAT64

# APPLE'S RECOMMENDATIONS TO SUPPORT IPV6

- Create address-family agnostic code

- Connect without pre-flight check:
  - » If connection succeeds, great
  - » If connection fails, handle gracefully
- Use higher-layer networking frameworks
  - » NSURLSession and CFNetwork-layer APIs
- See RFC 4038, Application Aspects of IPv6 Transition
- Connect-by-Name APIs

# QUESTIONS

# 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)