IPv6

(Coming Soon To A System Near You)

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U.S. DEPARTMENT OF ENERGY

Fermilab

Outline

- What is IPv6?
- Status of IPv6 Today
- IPv6 Technical Overview
- IPv6 on Systems
- Moving Forward with IPv6

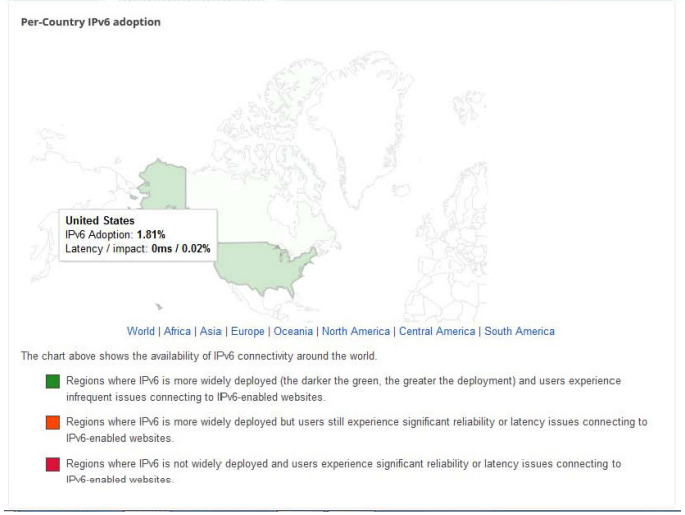
What is IPv6? Why do we want/need it?

- The latest version of the Internet Protocol (IP):
  - Successor to IPv4
- Drafted to alleviate address limitations of IPv4:
  - Internet Registry agencies have essentially run out of IPv4 addresses
- 128 bits of address space:
  - Versus 32 bits for IPv4
  - Provides 340 undecillion addresses
  - Should be viewed as technology-enabling, not just more addresses…

Status of IPv6 Today

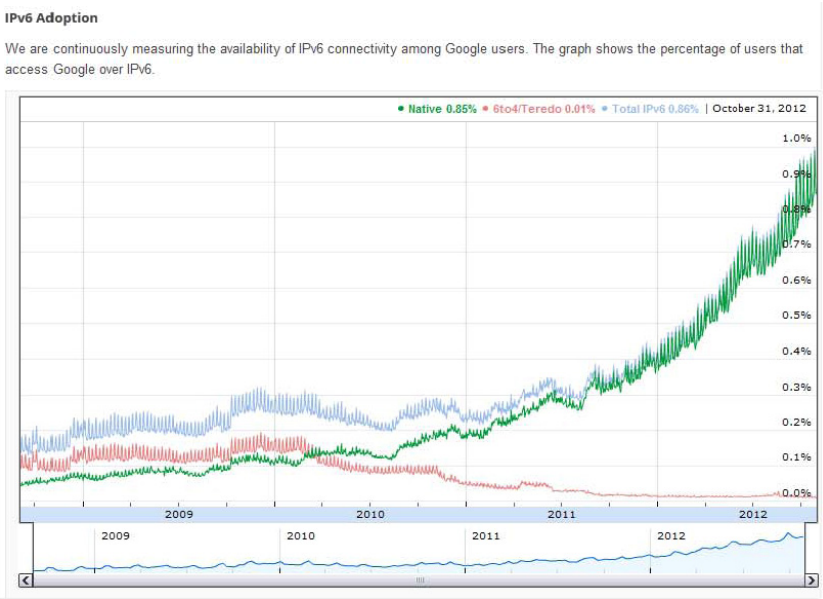
Current status of IPv6 deployment

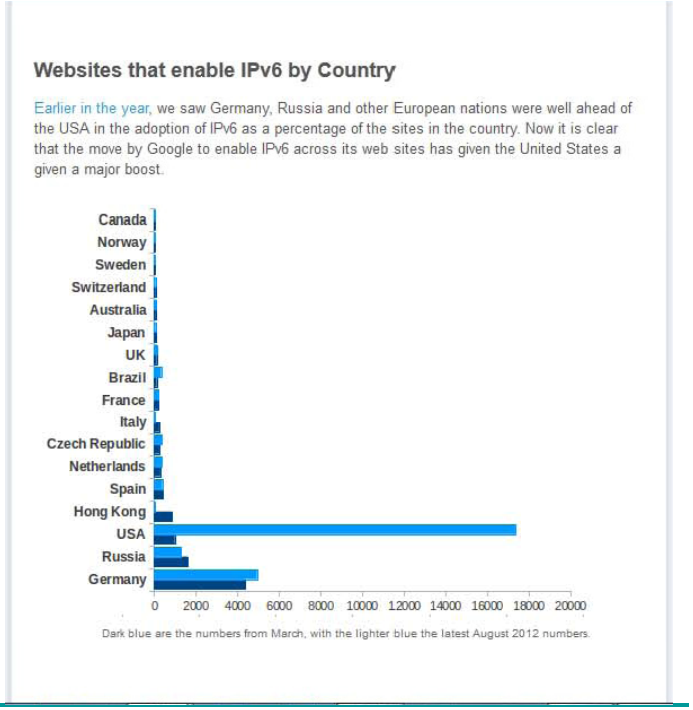
- World-wide IPv6 deployment has been slow
  - Difficult to overcome “IPv4 works; why change?” issue
  - A few countries have established strategic government policies
    - US joined that list
    - European countries looking to emulate US policies



Use of IPv6 Starting To Get Traction

- Google tracks its IPv6 versus IPv4 accesses:
  - Only at 1%, but trend is pretty obvious
  - US has recently emerged as IPv6 deployment leader





Vendors & Service Providers IPv6 Support

- Network OEMs provide full IPv6 support now
  - In US, all federal network procurements must be IPv6 compliant
  - CPE vendors now supporting IPv6 on home routers as well
  - Implementations now in ASICs
- Operating systems:
  - Windows 7 & MacOS 10.6 support IPv6 by default
  - Linux has had IPv6 support for 5+ years (but not by default)
- Tablets & smart phones generally have IPv6 support
- Internet service providers:
  - Comcast targeting 100% IPv6 availability to homes by end of year
  - AT&T, Verizon, Time-Warner, & others are also deploying
- Content service providers:
  - Google, Facebook, Yahoo, Youtube, Wikipedia support IPv6 natively

OMB IPv6 "Mandates" for 2012 & 2014

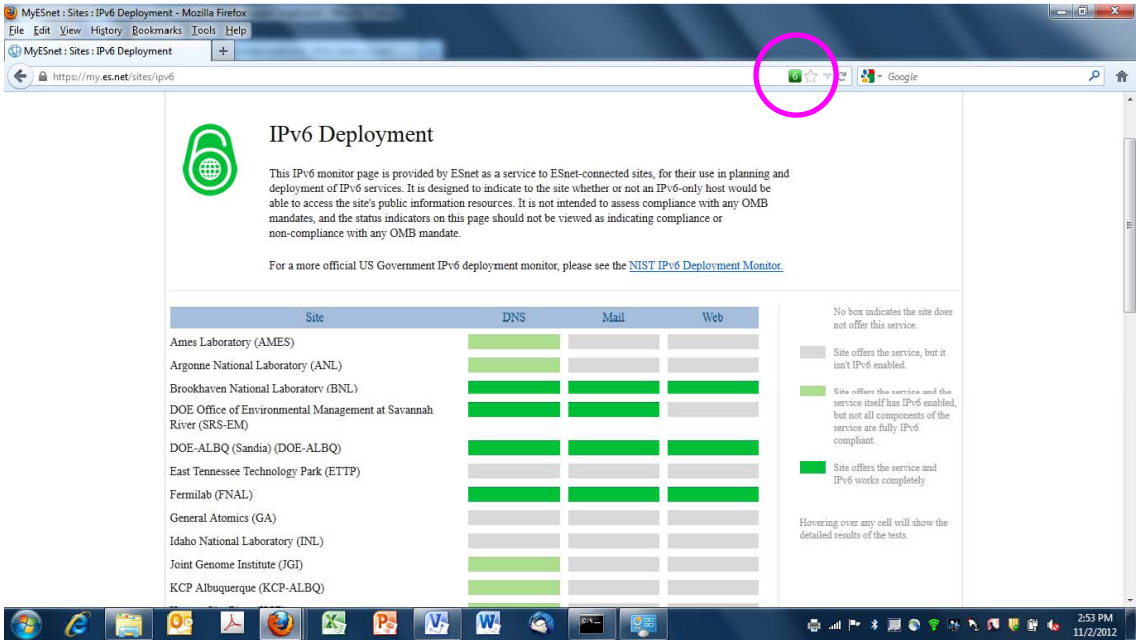
- End of FY12: Public-facing servers to support native IPv6
  - For DOE, this means e-mail, DNS, & web services
  - "Public-facing" interpreted as "intended for the general public"
- End of FY14: Internal client systems to support IPv6
  - Essentially, this means all desktops
- No OMB IPv6 transition mandate for all USG systems
  - Scientific computing systems are not within scope
- Labs are **not** included in DOE IPv6 compliance reporting
  - Current DOE interpretation: Labs aren't bound to OMB mandate
- "Mandate" lacks enforcement element
  - NIST dashboard for agency compliance:

http://fedv6-deployment.antd.nist.gov/cgi-bin/generate-gov

FNAL & the OMB 2012 IPv6 Milestones

- We're done:
  - DNS in March '12
  - Email in Aug. '12
  - Central web in Oct. '12
- Only 3 Labs are "all green"

Firefox Sixornot Add-on

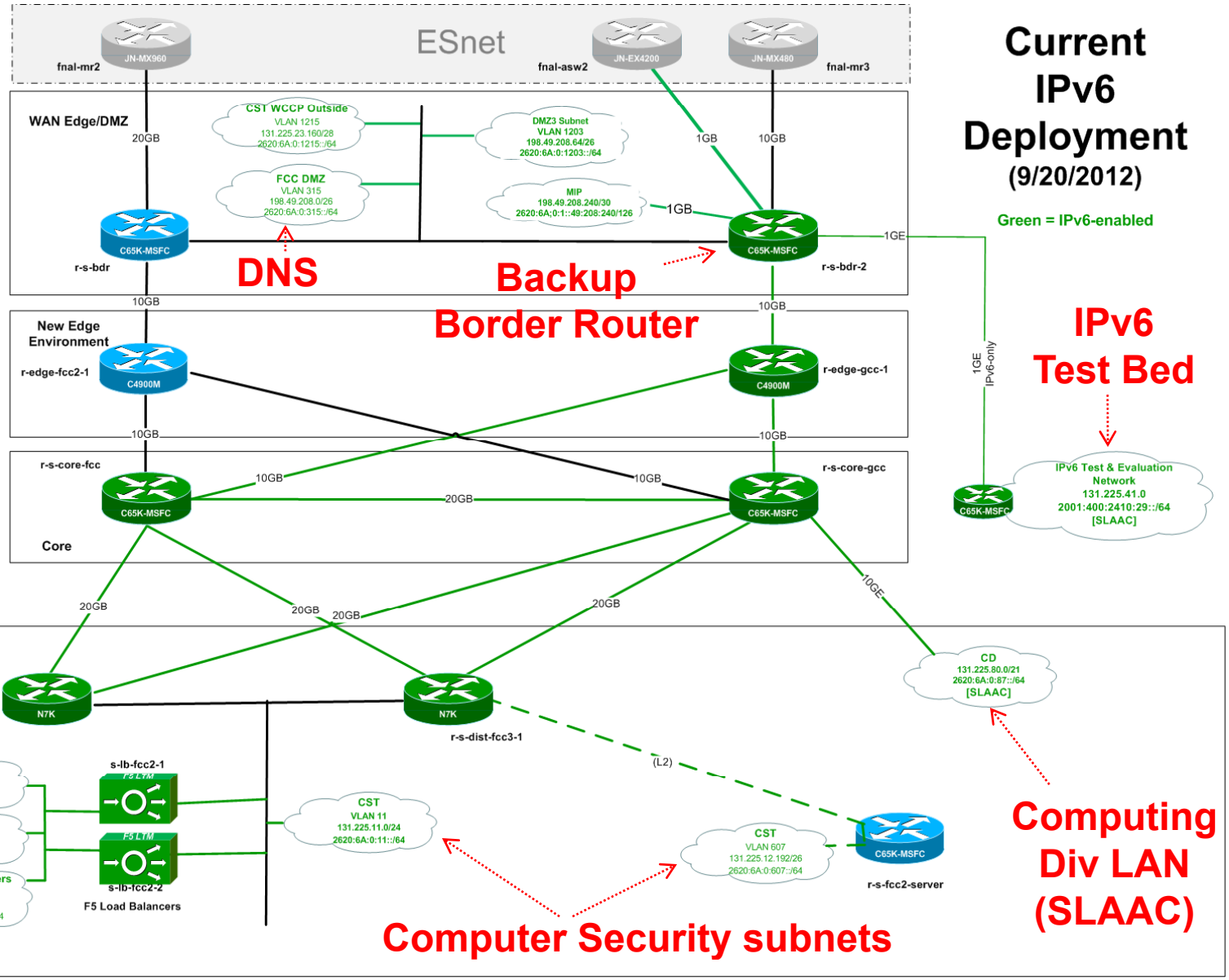


ESnet IPv6 Dashboard:
https://my.es.net/sites/ipv6

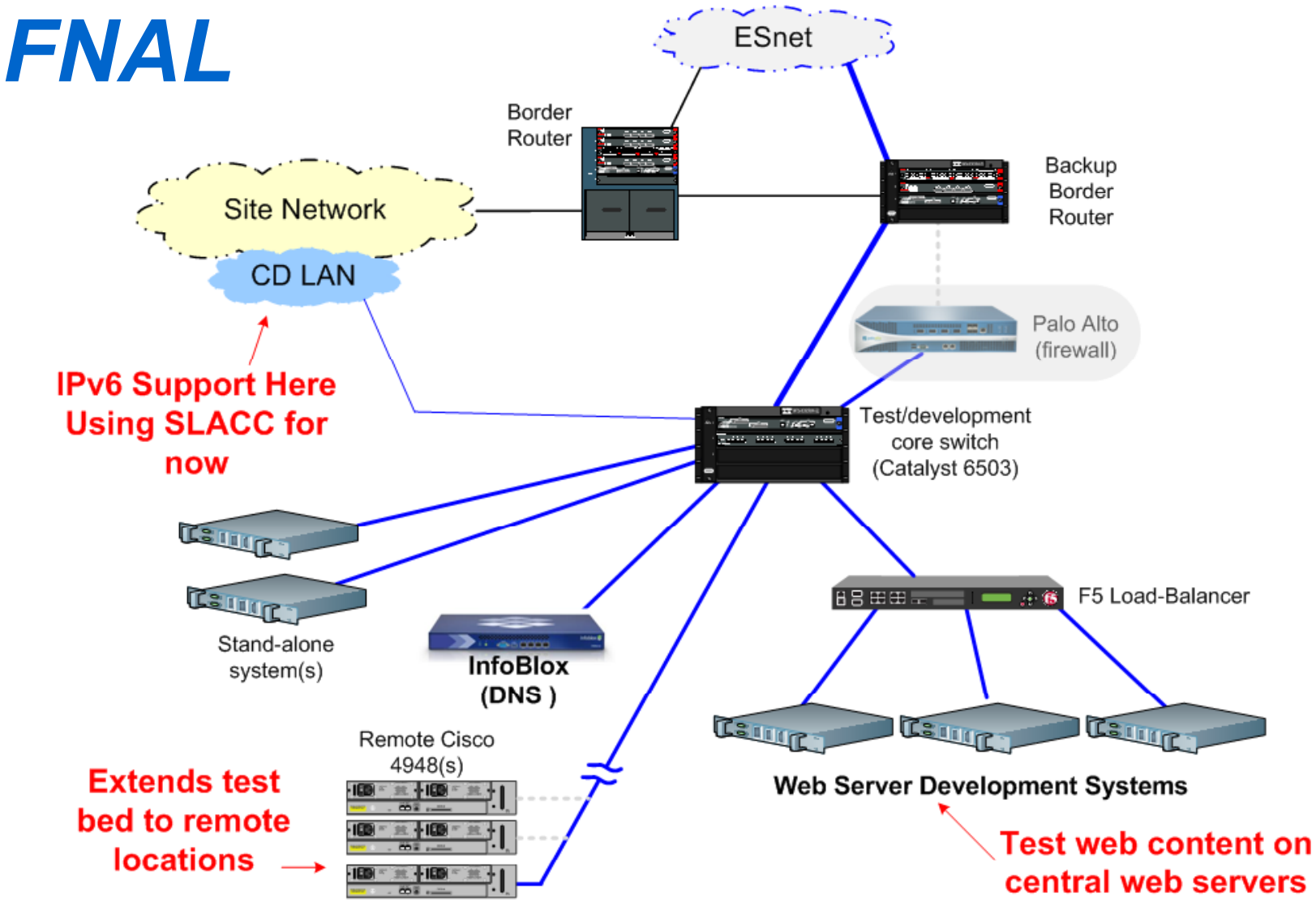
IPv6 in FNAL Core Network

Current IPv6 Deployment (9/20/2012)

Green = IPv6-enabled



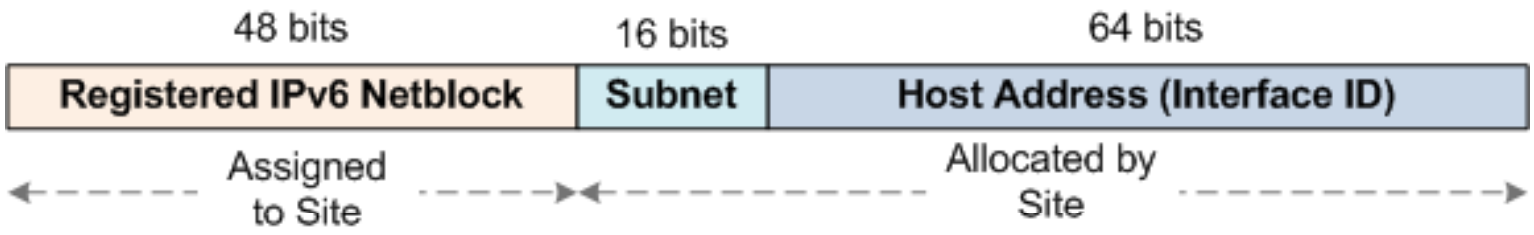
IPv6 Test / Development Network Today



IPv6 High-Level Technical Overview

IPv6 Addressing (I) - IPv6 Address Format

- Default IPv4 address block allocation is /48
  - Host ID is normally left at 64bits
  - Leaving 16 bits for the IPv6 subnet



- FNAL has two IPv6 /48 address blocks:

ARIN-assigned (PI) block: **2620:006A:0000::/48** **<production network>**

ESnet-assigned (PA) block: **2001:0400:2410::/48** **<used in IPv6 test bed>**

IPv6 Addressing (II) - Types of Addresses

- IPv6 interfaces use multiple types of addresses
  - Global addresses:
    - Used for internet communications

  - Link-Local addresses
    - Used for communications within the local subnet

  - Unique local addresses (ULAs):
    - Rough equivalent of IPv4 RFC1918 addresses
    - Not clear if they will be supported here
  - Privacy address extensions:
    - Global address that doesn't use MAC address to derive host field
    - Configurable option

Auto-Configuration

- IPv6 can be statically or dynamically configured on systems
- Two types of dynamic configuration for global addresses
  - Stateless address auto-configuration (SLAAC)
    - End systems configure their own address based on exchange of information with neighboring IPv6 router
    - By default, systems & devices will use SLAAC
  - Stateful auto-configuration:
    - Essentially an IPv6 version of DHCP
    - Implementations of DHCPv6 are sparse right now
- Currently, SLAAC is being used within CD wired LAN
  - Strategic decisions need to be made on where to use SLAAC

Dual Stack for IPv6 & IPv4

- IPv6 and IPv4 address formats are incompatible:
  - An IPv6 system and an IPv4 system can not communicate directly
  - IPv4 systems expected to be around for a long time
- Transition strategy to supporting IPv6 is to run both network stacks on the system (called dual stack)
- Typical sequence:
  - IPv6 system requests an A (IPv4) record from DNS for a remote system, and also a AAAA (IPv6) record
  - If a AAAA record is returned, the system will normally try IPv6 first:
    - Falling back to trying IPv4 if the IPv6 connection fails
  - Preference of which stack to try first may be configurable, but varies by O/S

Tunnels

- IPv6 has native tunneling capabilities to work across IPv4-only networks:
  - Regarded as a transition tool, particularly to assist islands of IPv6
  - Intended to work automatically & transparently
- IPv6 tunnels come in many flavors:
  - Router-to-Router
  - Host-to-Router
  - Router-to-Host
  - Host-to-Host
- Currently, the most common IPv6 tunnels are being blocked at the border:
  - Your IPv6 system may encounter performance delays if it tries to use a tunnel and waits for the timeout

IPv6 on Systems

Ifconfig on IPv6-enabled Laptop (WinXP)

Wireless Interface

Hardwire Interface

Command Prompt

```
Wireless LAN adapter Wireless Network Connection:

   Connection-specific DNS Suffix  . : dhcp.fnal.gov
   Description . . . . . . . . . . . : Intel(R) Centrino(R) Advanced-N 6205
   Physical Address. . . . . . . . . : 8C-70-5A-87-A4-F8
   DHCP Enabled. . . . . . . . . . . : Yes
   Autoconfiguration Enabled . . . . : Yes
   Link-local IPv6 Address . . . . . : fe80::d46d:5958:345b:2a06%16(Preferred)
   IPv4 Address. . . . . . . . . . . : 131.225.173.28(Preferred)
   Subnet Mask . . . . . . . . . . . : 255.255.252.0
   Lease Obtained. . . . . . . . . . : Thursday, November 01, 2012 10:53:31 AM
   Lease Expires . . . . . . . . . . : Thursday, November 01, 2012 5:23:30 PM
   Default Gateway . . . . . . . . . : 131.225.172.1
   DHCP Server . . . . . . . . . . . : 1.1.1.1
   DHCPv6 IAID . . . . . . . . . . . : 529297498
   DHCPv6 Client DUID. . . . . . . . : 00-01-00-01-17-AB-15-44-24-B6-FD-FA-A8-B4

   DNS Servers . . . . . . . . . . . : 131.225.0.254
   Primary WINS Server . . . . . . . : 131.225.9.1
   Secondary WINS Server . . . . . . : 131.225.110.15
   NetBIOS over Tcpip. . . . . . . . : Enabled

Ethernet adapter Bluetooth Network Connection:

   Media State . . . . . . . . . . . : Media disconnected
   Connection-specific DNS Suffix  . :
   Description . . . . . . . . . . . : Bluetooth Device (Personal Area Network)
   Physical Address. . . . . . . . . : D0-DF-9A-40-DB-44
   DHCP Enabled. . . . . . . . . . . : Yes
   Autoconfiguration Enabled . . . . : Yes

Ethernet adapter Local Area Connection:

   Connection-specific DNS Suffix  . : dhcp.fnal.gov
   Description . . . . . . . . . . . : Intel(R) 82579LM Gigabit Network Connecti
on
   Physical Address. . . . . . . . . : 24-B6-FD-FA-A8-B4
   DHCP Enabled. . . . . . . . . . . : Yes
   Autoconfiguration Enabled . . . . : Yes
   IPv6 Address. . . . . . . . . . . : 2620:6a:0:87:71b5:7aba:7a5f:b7e5(Preferre
d)
   Temporary IPv6 Address. . . . . . : 2620:6a:0:87:68fc:c6c:2783:d537(Preferred
)
   Link-local IPv6 Address . . . . . : fe80::71b5:7aba:7a5f:b7e5%12(Preferred)
   IPv4 Address. . . . . . . . . . . : 131.225.82.200(Preferred)
   Subnet Mask . . . . . . . . . . . : 255.255.248.0
   Lease Obtained. . . . . . . . . . : Monday, October 22, 2012 8:50:52 AM
   Lease Expires . . . . . . . . . . : Friday, November 02, 2012 12:18:26 PM
   Default Gateway . . . . . . . . . : fe80::20b:45ff:feb0:7c80%12
                                       131.225.87.200
   DHCP Server . . . . . . . . . . . : 131.225.8.120
   DNS Servers . . . . . . . . . . . : 131.225.0.254
   Primary WINS Server . . . . . . . : 131.225.9.1
   Secondary WINS Server . . . . . . : 131.225.110.15
   NetBIOS over Tcpip. . . . . . . . : Enabled
```

Link-Local IPv6 Address

Global IPv6 Addresses

IPv6 Default Gateway

IPv6 on MacOS & Linux Looks Pretty Similar…

Linux system with hardwire connection:
Ifconfig command

vyto@thunderbird:~ - Shell - Konsole

Session Edit View Bookmarks Settings Help

```
[vyto@thunderbird ~]$ /sbin/ifconfig
eth0      Link encap:Ethernet  HWaddr 00:06:5B:15:04:97
          inet addr:131.225.82.165  Bcast:131.225.87.255  Mask:255.255.248.0
          inet6 addr: 2620:6a:0:87:206:5bff:fe15:497/64 Scope:Global
          inet6 addr: fe80::206:5bff:fe15:497/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:8746494 errors:0 dropped:0 overruns:81 frame:0
          TX packets:11837 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:902030854 (860.2 MiB)  TX bytes:1165364 (1.1 MiB)
          Interrupt:11 Base address:0xcc00

lo        Link encap:Local Loopback
          inet addr:127.0.0.1  Mask:255.0.0.0
          inet6 addr: ::1/128 Scope:Host
          UP LOOPBACK RUNNING  MTU:16436  Metric:1
          RX packets:3036 errors:0 dropped:0 overruns:0 frame:0
          TX packets:3036 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:0
          RX bytes:3624469 (3.4 MiB)  TX bytes:3624469 (3.4 MiB)
```

MacOS system with hardwire & wireless connections:
Ifconfig command

```
cd-117052m:~ vyto$ ifconfig
lo0: flags=8049<UP,LOOPBACK,RUNNING,MULTICAST> mtu 16384
        inet6 ::1 prefixlen 128
        inet6 fe80::1%lo0 prefixlen 64 scopeid 0x1
        inet 127.0.0.1 netmask 0xff000000
gif0: flags=8010<POINTOPOINT,MULTICAST> mtu 1280
stf0: flags=0<> mtu 1280
en0: flags=8863<UP,BROADCAST,SMART,RUNNING,SIMPLEX,MULTICAST> mtu 1500
        ether c4:2c:03:3c:9a:4f
        inet6 fe80::c62c:3ff:fe3c:9a4f%en0 prefixlen 64 scopeid 0x4
        inet6 2620:6a::87:c62c:3ff:fe3c:9a4f prefixlen 64 autoconf
        inet 131.225.82.156 netmask 0xfffff800 broadcast 131.225.87.255
        media: autoselect (100baseTX <full-duplex,flow-control>)
        status: active
en1: flags=8863<UP,BROADCAST,SMART,RUNNING,SIMPLEX,MULTICAST> mtu 1500
        ether 60:33:4b:2a:15:4c
        inet6 fe80::6233:4bff:fe2a:154c%en1 prefixlen 64 scopeid 0x5
        inet 131.225.170.203 netmask 0xffffc00 broadcast 131.225.171.255
        media: autoselect
        status: active
fw0: flags=8863<UP,BROADCAST,SMART,RUNNING,SIMPLEX,MULTICAST> mtu 4078
        lladdr 78:ca:39:ff:fe:0f:92:72
        media: autoselect <full-duplex>
        status: inactive
cd-117052m:~ vyto$
```

Hardwire Interface

Wireless Interface

Adding IPv6 Address (static…) to Solaris

- **# cat /etc/hostname6.bge0**
  addif 2620:6a:0:70::70:30/64 up

  → **ADDS THE ADDRESS TO THE SERVER'S CONFIGURATION**

  To make default/gateway route persistent.
  # route -p add -inet6 default 2620:6a:0:70::70:1

  → **ADDS AWARENESS TO THE SERVER'S EXTERNAL ENVIRONMENT (ROUTE)**

  # ifconfig -a6
  bge0:1: flags=2000841<UP,RUNNING,MULTICAST,IPv6> mtu 1500 index 2
  inet6 2620:6a:0:70::70:30/64

  → **A VIEW OF THE FUNCTIONING ADDRESS**

  # netstat -rnf inet6

  → **A VIEW OF THE FUNCTIONING ENVIRONMENT (ROUTE)**

  Routing Table: IPv6

Destination/Mask	Gateway	Flags	Ref	Use	If
2620:6a:0:70::/64	2620:6a:0:70::70:30	U	1	9	bge0:1

<Paul Lauss>

Adding IPv6 to Apache

Listen [2620:6a:0:70::70:30]:80
Listen [2620:6a:0:70::70:30]:443

→ THESE LINES NEEDED TO BE ADDED TO THE APACHE WEBSERVER CONFIGURATION FOR THE SERVER TO LISTEN FOR NEW CONNECTIONS

order deny,allow
deny from all
allow from 131.225
allow from 2620:6a::/48

→ ANY LIMITATIONS SPECIFIED IN .HTACCESS FILES NEEDED TO BE UPDATED TO INCLUDE THE NEW IPV6 RANGE SO THAT USERS COULD STILL ACCESS THEM AS IPV6 ROLLS OUT SITE WIDE

nslookup -query=AAAA www.fnal.gov
Server: 131.225.0.254
Address: 131.225.0.254#53

→ MAKES SURE THAT DNS (DOMAIN NAME SERVICES) FOR IPV6 (AAAA OR QUAD A RECORD) IS UPDATED

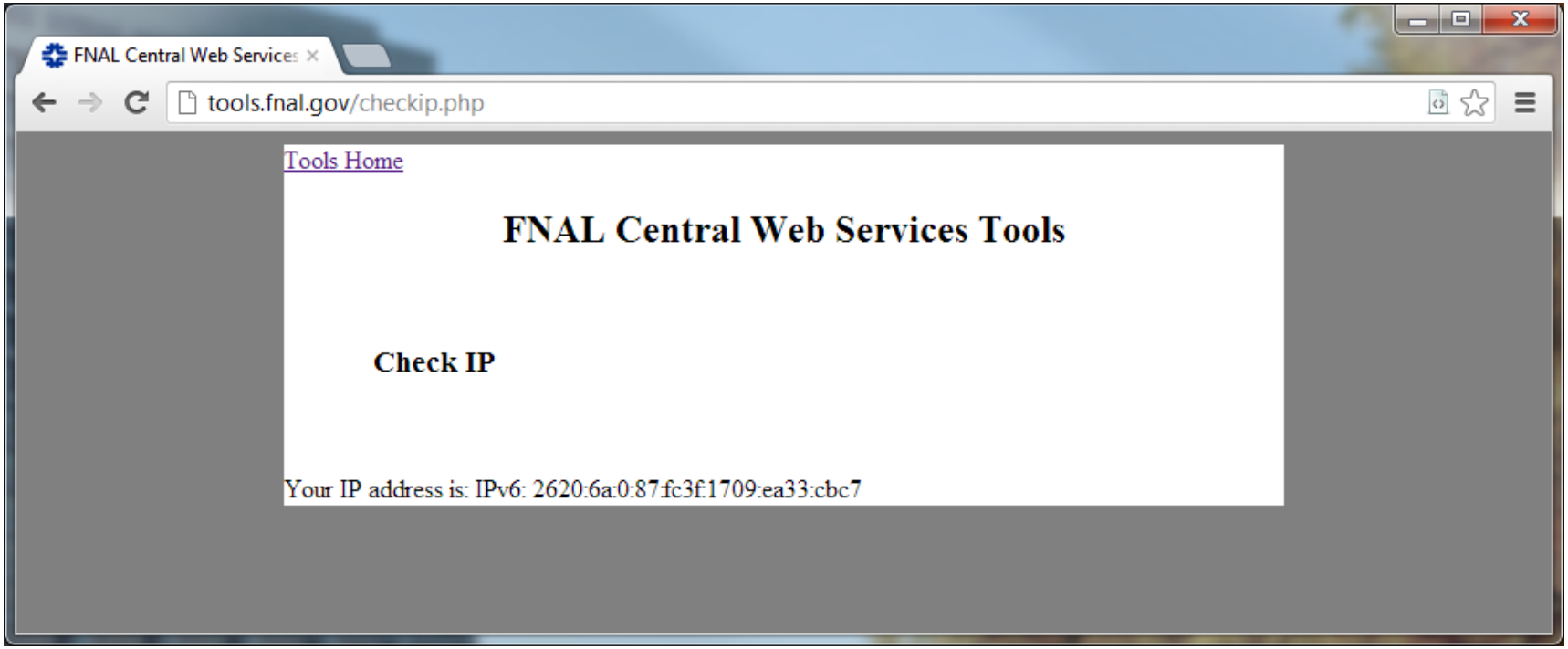
www.fnal.gov has AAAA address 2620:6a:0:70::70:30

<Paul Lauss>

Address Verification Service

IPv6 or IPv4 verification is located at:

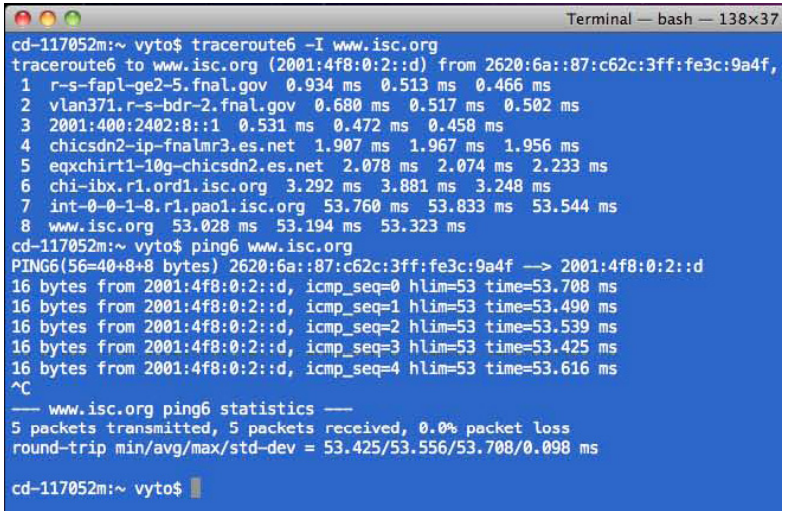
http://tools.fnal.gov/checkip.php



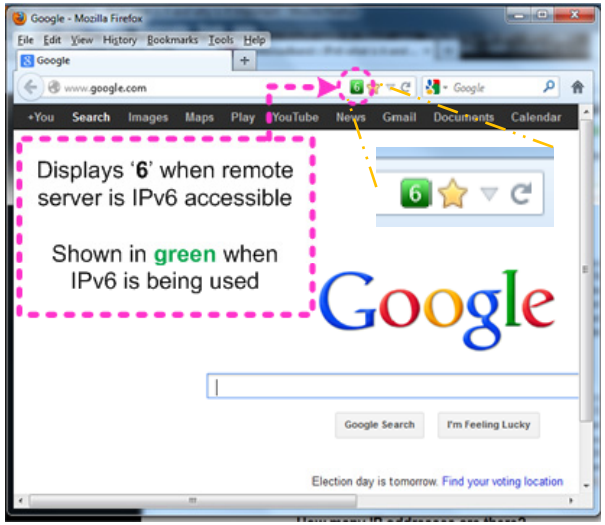
IPv6 Tools

- Ping & Traceroute:

O/S	Ping	Traceroute
Windows XP	**Ping6**	**Tracert6**
Windows 7	**Ping** *<-4;-6 >*	**Tracert** *<-4;-6>*
MacOS	**Ping6**	**Traceroute6**
Linux	**Ping6**	**Traceroute6**



- Firefox Sixornot is a nice add-on that will indicate IPv6 accessibility and use within your browser:
  - Haven't found counterparts for IE or other browsers yet…



Moving Forward with IPv6

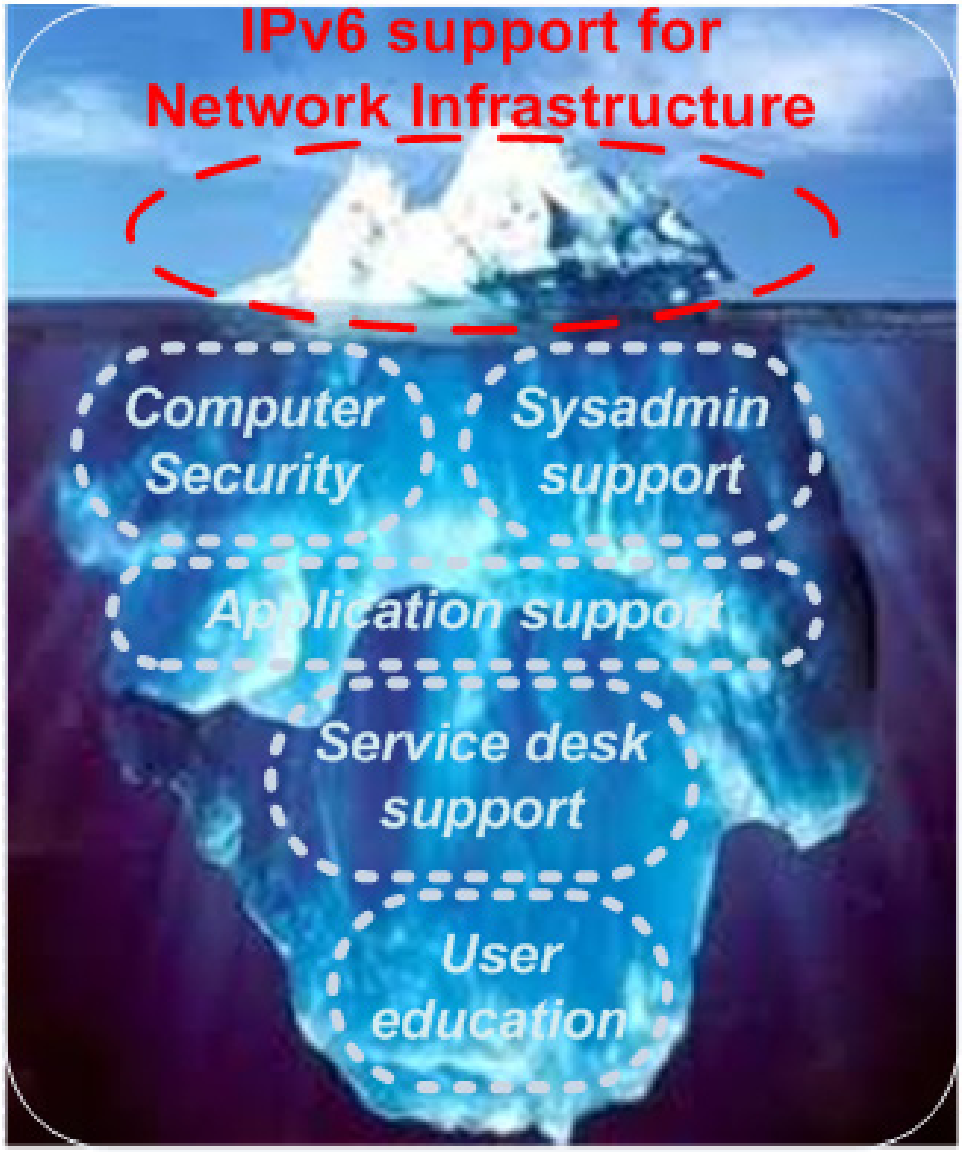
FNAL IPv6 Directions (I)

- First of all, what's already been done with IPv6:
  - Addressing model adopted
    - Will overlay IPv4 addressing that's in place
  - Test bed environment deployed
  - Routing in place within core network
  - Production support in DNS, central web, & e-mail
  - Flow data collection adapted for IPv6
  - Quasi-production evaluation with real users (CD wired LAN)
- All of this activity lays groundwork for wider IPv6 support

IPv6 Planning: Strategic view

What you see shouldn't sink your ship

What you don't see might…


IPv6 support for
Network Infrastructure
Computer Security
Sysadmin support
Application support
Service desk support
User education

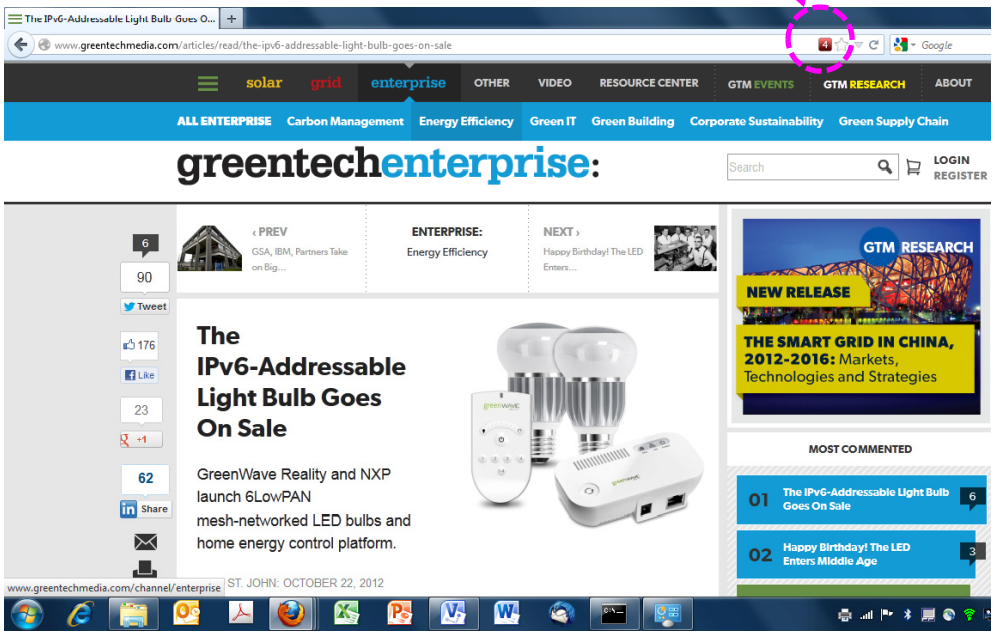
FNAL IPv6 Directions (II)

- Likely direction: limited deployment of production-quality IPv6 user support, consistent with OMB directives
  - Probably based on CD wired LAN and maybe some wireless
  - Still need review & approval to pursue this path
- Specifically, what would this translate to?
  - Develop:
    - Appropriate addressing configuration mechanisms
    - IP address management (IPAM) support comparable to IPv4
    - IPv6 configuration guidance for common platforms
    - IPv6-based monitoring capabilities
  - Adapt existing networking & computer security tools and utilities to support IPv6 addresses
- Not looking for additional subnets to develop IPv6 support

Problems Holiday Shopping for the Person with Everything?

A little irony here…

- IPv6-addressable light bulb (LED)
  - Uses 6LoWPAN over IEEE 802.15.4
  - $200 for the kit
  - $30/light bulb



- In case you were wondering why we might need an undecillion addresses…

?

Questions

(And Don’t Forget to Vote…)