MAAWG
Messaging Anti-Abuse Working Group

MAAWG IPv6 Training for Senders and Others

Segment 3 of 3

IPv6 Technology Primer

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MAAWG

Messaging Anti-Abuse Working Group

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MAAWG IPv6 Training – Video Segments

Segment 1 - 21 minutes Basic IPv6 For Senders	Segment 2 – 25 minutes Understanding IPv6 Drivers & Myths	Segment 3 – 21 minutes. IPv6 Technology Primer
1-Do Mail Senders *Really* Need IPv6 Today? 2-IPv6 and SMTP 3-Obtaining Native IPv6 Connectivity and Address Space 4-Enabling IPv6 on Your Servers 5-Enabling IPv6 in Your MTA	Drivers: 6a-IPv4 Address Exhaustion 6b-Regaining Internet Transparency 6c-Controlling Route-Table Bloat 6d-Regulatory Compliance Myths: 7a-Improve “Network Security” 7b-*Everyone’s* Running Out of IPv4 Address Space 7c-IPv6 Will Simplify Renumbering . . . 7d-Access to “Cool New Stuff” 7e-Techies Will Stretch Out What IPv4 Space 7f-Customers Just Aren’t Asking For IPv6	8a-IPv6 Addresses 8b-IPv6 Prefixes 8c-Types of IPv6 Addresses 8d-Addresses and Systems 8e-IPv6 DNS 8f-Enabling IPv6 in Desktop Operating Systems 8g-IPv6 Web Browsers 8h-IPv6 Email Clients 8i-ssh for IPv68. (j): Web Servers

PART III.
IPv6 Technology Primer

8. (a): IPv6 Addresses

Starting With What We Know: IPv4

- IPv4 addresses are 32 bits long
- 2^32=4,294,967,296
- Normally represented in “dotted decimal” format:
  -- four 8 bit octets (0 to 255 decimal)
  -- each octet is seperated from the next by a dot
  -- leading zeroes in each octet may be omitted
- Examples:
  -- 127.0.0.1
  -- 128.223.142.89
  -- 64.170.98.32

Something A Little Different: IPv6

- IPv4 addresses are 128 bits / 32 hexadecimal digits long
- 2^128=340,282,366,920,938,463,463,374,607,431,768,211,456 (e.g., 3.4x10^38 addresses)
- Normally represented in "colon separated" format:
  -- eight sets of four hex digits (0000 to FFFF hex)
  -- chunks are separated with colons (:)
  -- leading zeroes in each chunk may be omitted
  -- for convenience, :: (two successive colons) may replace one or more all-zero chunks, but only once in any addr
- Examples:
  2001:48a8:6880:0095:0000:0000:0000:0021
  ::1
  2001:468:d01:d6::80df:d617
  fe80::203:93ff:fecf:b638

Quick Quiz

- Structurally/superficially valid or invalid?
  If invalid, why?

  A) 2001:468:0d01:003c:0000:0000:80df:3c15
  B) 2001:468:0d01:003c::80df:3c15
  C) 2001:468:d01:3c::80df:3c15
  D) 2001:760:2e01:1::dead:beef
  E) 2001:480:10:1048:a00:20ff:fe9a:58c1:80
  F) 2001:500::4:13::80
  G) 2001:13G7:7002:4000::10
  H) 2607:f278:4101:11:209:5bff:fe8f:6609
  I) fe80::209:3dff:fe13:fcf7
  J) ::

Quick Quiz Answers

- Structurally/superficially valid or invalid?
  If invalid, why?

  A) Valid
  B) Valid
  C) Valid
  D) Valid
  E) Invalid (nine chunks instead of eight)
  F) Invalid (double colons appear more than once)
  G) Invalid (G is not a valid hexadecimal digit)
  H) Valid
  I) Valid
  J) Valid (albeit as the IPv6 “unspecified address”)

8. (b): IPv6 Prefixes

Starting With Something We Know: IPv4 Prefixes

- We originally had class A, class B and class C blocks:

Name	CIDR equiv	Number	Addresses Per Block
Class A	/8	128	16,777,216
Class B	/16	16,384	65,536
Class C	/24	2,097,152	256

- Like Goldilocks, some of those were too large, and some of those were too small.

- We needed something a little more flexible, and that’s what we got from CIDR, or Classless Inter-Domain Routing.

Common IPv4 CIDR Prefix Lengths

/8	==>	16,777,216 addresses
/9	==>	8,388,608
/10	==>	4,194,304
/11	==>	2,097,152
/12	==>	1,048,576
/13	==>	524,288
/14	==>	262,144
/15	==>	131,072
/16	==>	65,536
/17	==>	32,768
/18	==>	16,384
/19	==>	8,192
/20	==>	4,096
/21	==>	2,048
/22	==>	1,024
/23	==>	512
/24	==>	256
/25	==>	128
/26	==>	64
/27	==>	32
/28	==>	16
/29	==>	8
/30	==>	4
/31	==>	2
/32	==>	1

- IPv4 subnets are often /24’s (or maybe /23’s or /25’s)

IPv6 Uses Prefixes, Too

- IPv6 prefixes are just a “little bit” bigger…

Prefix	IPv6 Addresses
/32	2^(128-32) = 79,228,162,514,264,337,593,543,950,336 (that’s like getting 4,294,967,296 /64 subnets)
/48	2^(128-48) = 1,208,925,819,614,629,174,706,176 (that’s like getting 65,536 /64 subnets)
/56	4,722,366,482,869,645,213,696 (that’s like getting 256 /64 subnets)
/64	18,446,744,073,709,551,616 IPv6 addresses each

General Rules for IPv6 Allocations/ Assignments/Subneting

- Local Internet Registries (LIRs), e.g., ISPs, statewide networks, etc., will get one (or more) IPv6 /32 from ARIN, RIPE, APNIC, etc.
- Large sites will get an IPv6 /48 from their LIR's /32
- Small sites needing only a few subnets over 5 years will get an IPv6 / 56 from their LIR's /32 (some LIRs will just always issue /48's)
- If one and only one subnet is needed, that entity gets an IPv6 /64 (some LIRs will just always issue /48's)
- Hosts get one or more IPv6 /128s

- ALL SUBNETS at most sites will normally be /64s (even if they have only one or a small handful of hosts).

- Do NOT try to get clever and do something exotic when it comes to subnetting in IPv6.

8. (c): Types of IPv6 Addresses

Types of IPv6 Addresses

Global Unicast:	**2000::/3**
Link Local Unicast:	**FE80::/1**
Loopback:	**::1/128**
6to4:	2002::/16
Teredo:	2001:0000::/32
Unique Local Unicast:	FC00::/7
Multicast:	FF00::/8
IPv4-Mapped:	::ffff:128.223.214.23

- Deprecated: Site Local addrs and IPv4-Compatible addrs.
- For more on IPv6 addresses, see RFC4291 (+ other RFCs).
- For the most part, we primarily care about global unicast, link local unicast, and loopback addresses

Address Type Discussion

- **Global Unicast** addresses are globally unique, “real” IP addresses. These are the way you’ll normally refer to most IPv6 hosts
- **Link Local Unicast** addresses are used for some purposes local to a particular link; outside the extent of that link, they don’t get used.
- **Loopback** addresses -- just like 127.0.0.1 in IPv4 space, the IPv6 loopback address (::1/128) is an internal virtual address that the server can use to refer to itself.
- **6to4 and Teredo** addresses are special IPv4-to-IPv6 transition mode technologies. As a sender, you won’t be using these.
- **Unique Local Unicast** addresses (RFC4193) are the IPv6 equivalent of RFC1918 IPv4 addresses. Don’t use them.
- **Multicast** addresses are just like multicast in IPv4, except that in IPv6 they’re used extensively on the LAN, but IPv6 multicast traffic rarely appear on the wide area Internet, unlike IPv4 where the exact opposite is largely true.
- **IPv4-Mapped** addresses allow hosts that only bind IPv6 sockets to also accept IPv4 addresses. (largely of interest to programmers)

Anycast

- IPv6 also uses "anycast" addresses. Anycast addresses look just like regular global unicast addresses, however the same prefix gets advertised from multiple locations.

- Through the magic of routing, users automatically connect to the closest anycast instance when accessing a UDP service (such as DNS) hosted on an anycast prefix.

- If one anycast instance goes down, routes adjust, and the other anycast instances seamlessly assume the additional load.

8. (d): Addresses and Systems

Expect Multiple Addresses

- When you look at the interfaces on an IPv6-enabled system, it will be routine for it to have multiple addresses/interface.
- Sometimes this will just be a single globally unique unicast address, plus a link local address, plus some other bits and pieces, other times you may see multiple globally unique unicast addresses.
- Do not let this shake you up.

- Speaking of multiple addresses, most hosts will have both IPv6 AND IPv4 addresses on some interfaces. This is known as being “dual stacked” and is perfectly normal and acceptable.

Looking at Addresses on Interfaces on Linux

```
% ifconfig -a
eth0      Link encap:Ethernet  HWaddr 00:09:3D:13:FC:F7
          inet addr:128.223.142.32  Bcast:128.223.143.255  Mask:255.255.254.0
          inet6 addr: 2001:468:d01:8e:209:3dff:fe13:fcf7/64 Scope:Global
          inet6 addr: fe80::209:3dff:fe13:fcf7/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:1187468996 errors:0 dropped:1805 overruns:0 frame:0
          TX packets:1338373204 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:232065679216 (216.1 GiB)  TX bytes:915094219311 (852.2 GiB)
          Interrupt:185
[snip]
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:8143461 errors:0 dropped:0 overruns:0 frame:0
          TX packets:8143461 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:0
          RX bytes:4295055907 (4.0 GiB)  TX bytes:4295055907 (4.0 GiB)
```

How Addresses Get On Interfaces: IPv4

- Starting with something you know, IPv4, most **end-user workstations** get their IP addresses automatically assigned via DHCP.
- Besides IPv4 addrs, RFC2132 describes additional useful bits that a host can get from a DHCP server, including:
  -- subnet mask
  -- router address(es)
  -- domain name server(s)
  -- the host name
  -- the domain name
  -- MTU information
  -- broadcast address
  -- plus an amazing amount of other bits and pieces
  (check it out if you don't believe me!)

How Addresses Get On Interfaces: IPv4 (2)

- Some sites may use host-specific DHCP entries to configure servers, too, but most IPv4 **servers** tend to be manually configured by a system administrator with a statically assigned IP addresses, host name and domain information, name server information, broadcast address, MTU information, etc.

How Addresses Get On Interfaces: IPv6

- In IPv6 world, most user workstations will get IPv6 addresses from *state-less address auto configuration*, or SLAAC. SLAAC runs on a router (not on a separate DHCP server), and as you might expect from the name, the IPv6 addresses that one gets via SLAAC are not maintained in a table anywhere (no "state" gets created when an IPv6 address is assigned via SLAAC).

- So how does the router know that it won't accidentally give you the same address as someone else (e.g., assign a duplicate address) if it doesn't keep track of who it has given an address to? Answer: it derives the address it gives you from something only you have, namely the MAC (hardware ethernet) address of your NIC

IPv6 Modified EUI-64 Format Identifier

- We need to take the 48 bit globally unique hardware MAC address from your network card, and convert that into a 64 bit dynamically assigned address. We do this by:

  -- Taking the left most 24 bits of the MAC, and using that for the left most 24 bits of the EUI-64 ID
  -- Taking the right most 24 bits of the MAC, and using that for the right most 24 bits of the EUI-64 ID
  -- Cram the constant “FFFE” in the middle 16 bits
  -- Tweak bit 7 (counting from the left) from zero to one (this is the “universal/local” bit)

  The “front half” of the 128 bit address comes from the network (remember our rule that all subnets are /64s!)

“But Joe!” [Pretend You’re A Geek]

- “The whole world will know my unique and unvarying hardware MAC address! Evil marketers will track and correlate my every move wherever I may connect my IPv6 device, based on my invariant MAC address! This is worse than cookies!”

- True.

- This concern spawned another type of IPv6 address, so-called RFC3041 “Privacy Addresses.” These addresses effectively use a random address for the low order 64 bits of the IPv6 address, instead of a value derived from the host’s MAC address. Systems may also periodically change those addresses from time to time.

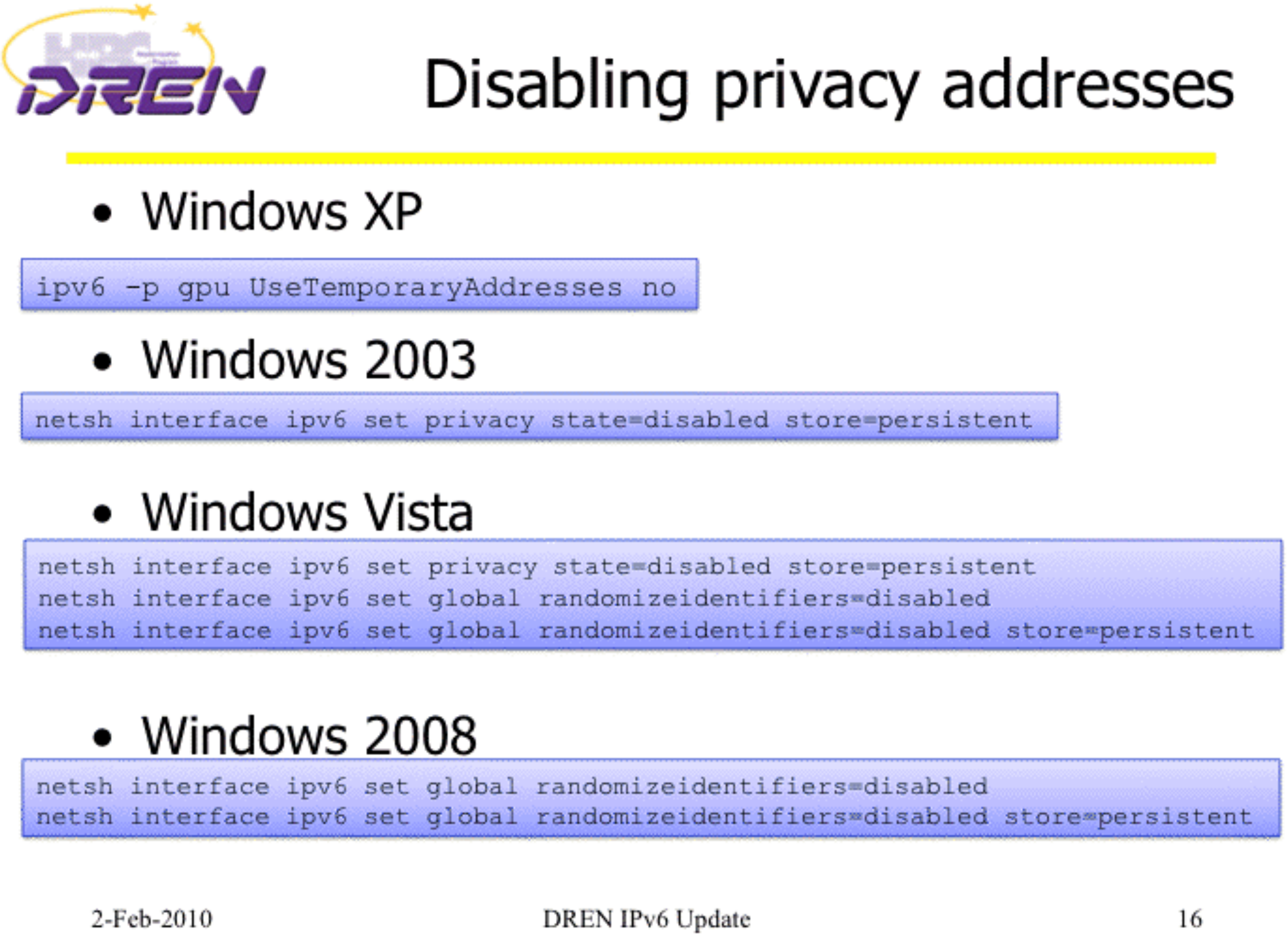
"BUT JOE!!!!!"

- "That's NOT what I wanted! If we give users random network addresses, how will we be able to track down abusers??? The same user may have one IPv6 address now, and another completely different IPv6 address later, and I don't see how we'd keep track of who's got what address when!!! What a pain!"
- One bit of potential happiness: NDPmon (think of this as "arpwatch for IPv6"). See ndpmon.sourceforge.net
- Another potential option: control network access just as you currently control network access for wireless networks (e.g., use 802.1x or a homegrown authentication solution)

Selecting/Deselecting Privacy Addresses

- **Windows:** privacy addresses are **enabled** by default when IPv6 is enabled on Windows XP. To disable them, see the next slide.
- **Macs:** privacy addresses are **disabled** by default.
  To enable them:
  ```
  # sysctl net.inet6.ip6.use_tempaddr=1
  ```
- **Linux:** like Macs, privacy addresses are disabled by default. To enable them:
  ```
  # sysctl net.ip6.conf.all.use_tempaddr=2
  # sysctl net.ip6.conf.default.use_tempaddr=2
  ```
- Periodically recheck your assigned addresses if this is a big deal for you, and remember, this is NOT life-and-death privacy, it is just "something-to-make-life- hard (er)-for-intrusive-marketers"-grade privacy.

Disabling IPv6 Privacy Addresses



Disabling privacy addresses

- Windows XP

```
ipv6 -p gpu UseTemporaryAddresses no
```

- Windows 2003

```
netsh interface ipv6 set privacy state=disabled store=persistent
```

- Windows Vista

```
netsh interface ipv6 set privacy state=disabled store=persistent
netsh interface ipv6 set global randomizeidentifiers=disabled
netsh interface ipv6 set global randomizeidentifiers=disabled store=persistent
```

- Windows 2008

```
netsh interface ipv6 set global randomizeidentifiers=disabled
netsh interface ipv6 set global randomizeidentifiers=disabled store=persistent
```

2-Feb-2010 DREN IPv6 Update 16

http://www.internet2.edu/presentations/jt2010feb/20100202-broersma.pdf

A Stateful Alternative to SLAAC: DHCPv6

- An alternative to SLAAC for workstations is DHCPv6, much like DHCP for IPv4.
- One critical difference: while DHCPv6 is well supported by IPv6ified versions of Microsoft Windows, **at least some important vendors (read that as “Apple”) do not support DHCPv6 at this time (and may never do so).**
- If you’re using a Mac OS X box and you want or need to do DHCPv6, you will need to run a third party DHCPv6 client (Dibbler is a commonly suggested option, see http://klub.com.pl/dhcpv6/ , but note the comment there that “Due to work on my Ph.D, the Dibbler project is in the maintenance mode. Active development and non-critical bug fixing is on hold, until I finish my dissertation. Sorry.”)

8. (e): IPv6 DNS

If You Run Your Own Name Servers: Make Those Name Servers IPv6 Aware

- You'll need to think about making your name servers IPv6 aware. By this I mean your recursive resolvers and your authoritative name servers should both "know about" AAAA records.
- Your ***access*** to your name servers need not change -- you can continue to access them over IPv4 -- you just need to make sure that they understand AAAA records.
- Recent versions of BIND from ISC, the most common name server, are fully able to support IPv6
- If you have off site secondary name servers, make sure that those secondary name servers are also IPv6 aware
- A new option for folks is to outsource recursive DNS to Google -- 8.8.8.8 and 8.8.4.4 are already IPv6 aware

IPv6 DNS Is Fairly Similar to IPv4 DNS

- In IPv4 world, servers and other hosts use “A” records to map fully qualified domain names to IP addresses:

  ```
  % dig www.uoregon.edu a +short
  128.223.142.89
  ```

- In IPv6 world, we use “AAAA” (“quad A”) records instead of A records to map fully qualified domain names to IPv6 addresses:

  ```
  % dig network-services.uoregon.edu aaaa +short
  2001:468:d01:3c::80df:3c15
  ```

Inverse Address Records Are Also Similar

- IPv4 world:

```
% dig -x 128.223.142.89 +short
www.uoregon.edu.
```

- IPv6 world:

```
% dig -x 2001:468:d01:3c::80df:3c15 +short
network-services.uoregon.edu.
```

- If you need a web-accessible IPv6 dig interface, try http://www.digwebinterface.com/

Complication: IPv6 Inverse Address Records

- There aren't a lot of good solutions for IPv6 inverse address record creation (other than manually creating them for servers, publicly visible network links, etc.).

- Dynamic DNS isn't such a hot idea, nor is building an inverse address record for millions of IPv6 addresses which may never get used!

- Ron Broersma from DREN described one potential approach in a talk he did at Joint Techs, see: http://www.internet2.edu/presentations/jt2010feb/20100202-broersma.pdf
  but it is unclear if the code he mentions there will be available for others to also use. (I hope it will be!)

Complications: IPv6 AND IPv4 Domain Names

- If a fully qualified domain name is bound to both IPv4 and IPv6 addresses, which one gets used? Which one should be "preferred?" The IPv6 one or the IPv4 one?
- This may be determined by the application (e.g., it may ask for both, and then use its own internal precedence information to determine which it will use), or by the DNS server (if it can give you an IPv6 address for a host, it will, and it will then stop; this is a problem if you advertise an IPv6 address for a host but then don't actually offer IPv6 connectivity for that domain name!)
- One sort of kludgy solution: put the IPv6 address in a subdomain. E.g., www.example.com (IPv4 only) might also have a related domain www.ipv6.example.com (IPv6 only)

What Address Do I Appear to Be Using?

- Sometimes you just want to know what address your system appears to be using.

- When that's the case, try:

  http://whatismyv6.com/

- If you find yourself routinely curious about whether you're connecting to a site via IPv4 or IPv6, you can install the ShowIP Firefox addon available from

  https://addons.mozilla.org/en-US/firefox/addon/590

  It will then report the IP address that it is using for each web site you visit, green for IPv6 and red for IPv4

Protocol Precedence More Generally

- Assume you have IPv4 connectivity as well as IPv6.
- If a host is available via both IPv4 and IPv6, what's the "right" order (or "precedence") with which traffic to that dual stack host should be tried? Should traffic go over IPv4 whenever possible, or over IPv6 whenever possible? Obviously IPv4 is the old-and-proven familiar/safe/production-quality choice, but the object of this whole exercise is to eventually move to IPv6, right?
- On the other hand, some IPv6 connectivity may be less direct/more circuitous than production IPv4 connections, with greater latency and maybe even some packet loss. Do we really want to force as much traffic as possible over that sort of "disadvantaged" connection?
- Thoughts?

8. (f): Enabling IPv6 in Desktop Operating Systems

Most Desktop OS's Will Autoconfigure (Except XP)

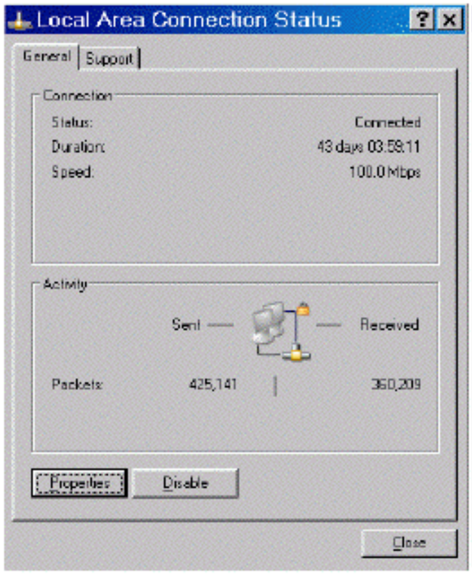
To enable IPv6, begin by putting up a Windows command prompt terminal window

```
Start ==> Programs ==> Accessories ==> Command Prompt
C:\> netsh interface ipv6 install                                    (if you ever want to remove, change install to uninstall)
C:\> netsh interface ipv6 set teredo client     (member of a domain? use enterpriseclient not client) (to disable, use disabled, not client)
C:\> ping ipv6.google.com                                  (no reply? you probably need to configure an alternative IPv6 aware name server)
```

Configuring An IPv6 Aware Name Server, If Needed

Windows XP Service Pack 2 needs to one or more IPv6-**aware** name servers defined (an IPv6-aware name server is one which can return AAAA records for IPv6-connected fully qualified domain names). Note that Windows XP does **not** support name servers **accessible** only via IPv6. You may already have received a suitable name server as part of your existing IPv4 configuration, but if not, you will want to add an IPv6-aware name server. To manually configure an IPv6-aware name server, do:

Start ==> Settings ==> Control Panel ==> Network Connections ==> Local Area Connection

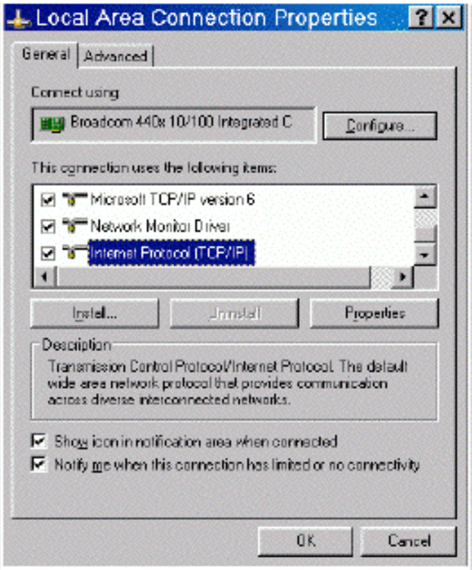


Local Area Connection Status

Connection
Status: Connected
Duration: 43 days 03:59:11
Speed: 100.0 Mbps

Activity
Packets: Sent 425,141 | Received 360,209

Click Properties.



Local Area Connection Properties

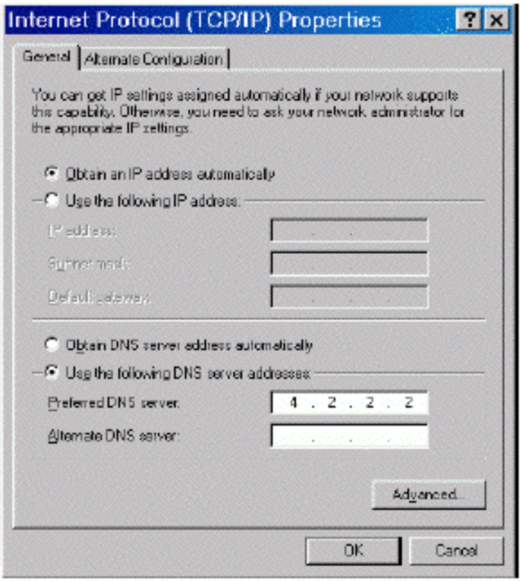
Connect using: Broadcom 440x 10/100 Integrated C

This connection uses the following items:
☑ Microsoft TCP/IP version 6
☑ Network Monitor Driver
☑ Internet Protocol (TCP/IP)

Description
Transmission Control Protocol/Internet Protocol. The default wide area network protocol that provides communication across diverse interconnected networks.

☑ Show icon in notification area when connected
☑ Notify me when this connection has limited or no connectivity

Come down to Internet Protocol (TCP/IP) and select that item. Now click Properties.



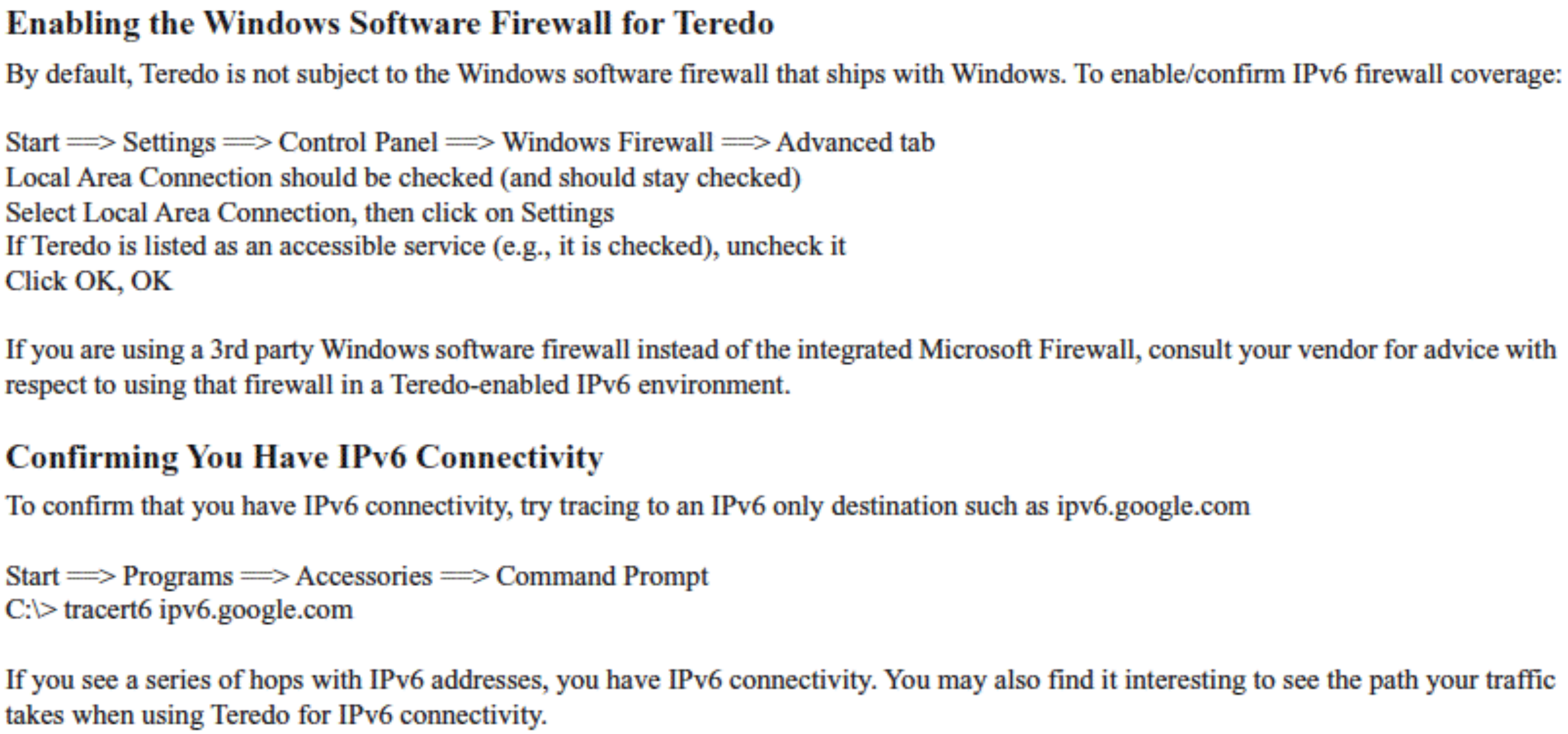
Internet Protocol (TCP/IP) Properties

You can get IP settings assigned automatically if your network supports this capability. Otherwise, you need to ask your network administrator for the appropriate IP settings.

● Obtain an IP address automatically
○ Use the following IP address:
IP address: . . .
Subnet mask: . . .
Default gateway: . . .

○ Obtain DNS server address automatically
● Use the following DNS server addresses:
Preferred DNS server: 4 . 2 . 2 . 2
Alternate DNS server: . . .

Click Use the following DNS server address and enter the name of the IPv6 aware name server you want to use (such as 4.2.2.2).



Enabling the Windows Software Firewall for Teredo

By default, Teredo is not subject to the Windows software firewall that ships with Windows. To enable/confirm IPv6 firewall coverage:

Start ==> Settings ==> Control Panel ==> Windows Firewall ==> Advanced tab
Local Area Connection should be checked (and should stay checked)
Select Local Area Connection, then click on Settings
If Teredo is listed as an accessible service (e.g., it is checked), uncheck it
Click OK, OK

If you are using a 3rd party Windows software firewall instead of the integrated Microsoft Firewall, consult your vendor for advice with respect to using that firewall in a Teredo-enabled IPv6 environment.

Confirming You Have IPv6 Connectivity

To confirm that you have IPv6 connectivity, try tracing to an IPv6 only destination such as ipv6.google.com

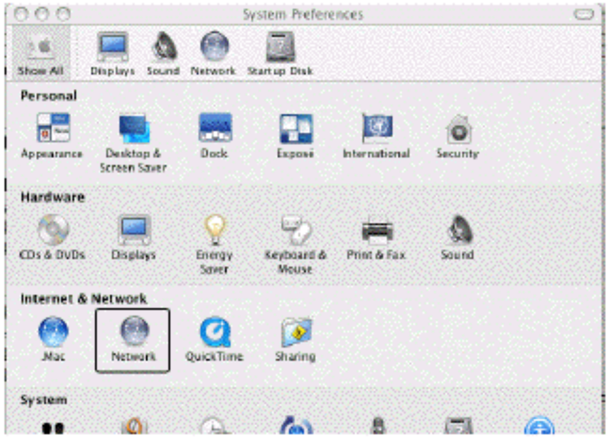
Start ==> Programs ==> Accessories ==> Command Prompt

```
C:\> tracert6 ipv6.google.com
```

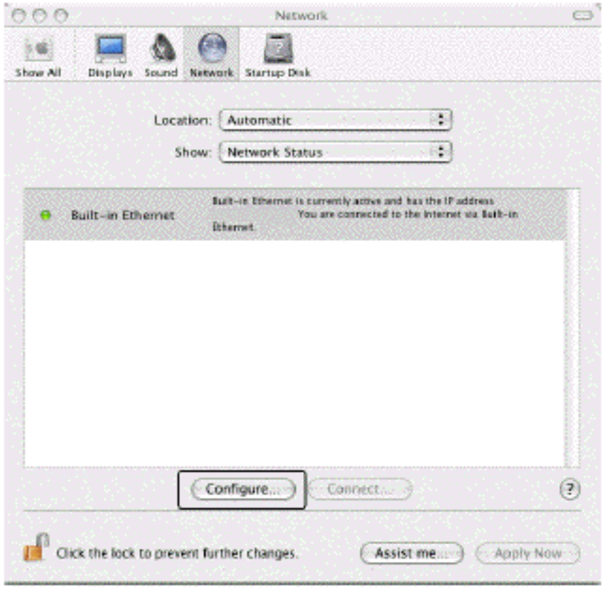
If you see a series of hops with IPv6 addresses, you have IPv6 connectivity. You may also find it interesting to see the path your traffic takes when using Teredo for IPv6 connectivity.

http://www.uoregon.edu/~joe/ipv6/windows-xp-ipv6-with-teredo.pdf

Mac OS X



Apple Menu ==> System Preferences ==> Network



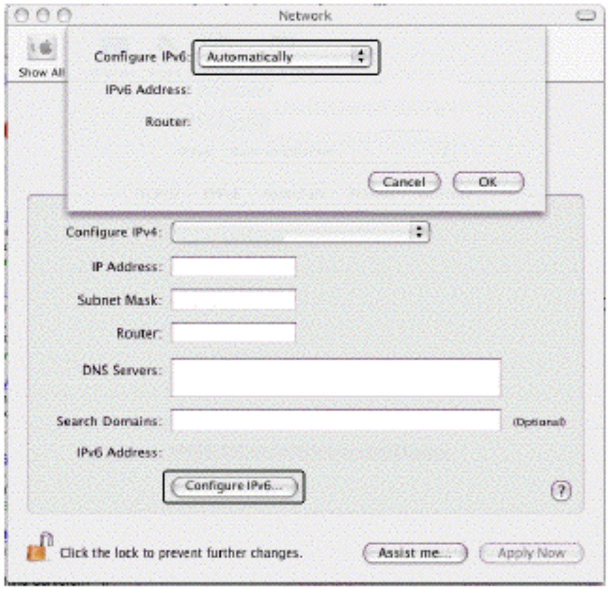
Location: Automatic

Show: Network Status

Built-in Ethernet — Built-in Ethernet is currently active and has the IP address You are connected to the Internet via Built-in Ethernet.

Click the lock to prevent further changes.

On the network preferences screen, choose the drop down item: Network Status
Select the interface to be configured (e.g., wireless, built-in ethernet, etc.)
Click Configure



Configure IPv6: Automatically

On the TCP/IP tab
Click on Configure IPv6 near the bottom of the pane
When the Configure IPv6 panel comes up, select Automatically
Click OK to close the Configure IPv6 panel

Click Apply Now
Close the Network Preferences window by clicking the red X button in the upper left corner
You should now have IPv6 enabled on your Mac

8. (g): IPv6 Web Browsers

Enabling IPv6 in Firefox for the Web

- If you don't already have Firefox, download it from: http://www.mozilla.com/firefox/
- Firefox is IPv6 aware, but may need to be tweaked the first time you use it (it will remember this setting after that):
  -- Launch Firefox
  -- In the address bar, enter about:config and hit return
  -- Filter on ipv6
  -- Make sure network.dns.disableIPv6 is set to false
  -- If it isn't, double click on it to toggle it to false
- Now try going to http://ipv6.google.com/

A Somewhat Random Selection of IPv6-Accessible Web Sites

Google	**http://ipv6.google.com/**	**2001:4860:b005::68**
AFRINIC	http://www.afrinic.net/	2001:42d0::200:80:1
APNIC	http://www.apnic.net/	2001:dc0:2001:b:4608::115
Arctic Regional Supercomputer Center	http://www.arsc.edu/	2001:480:150:75::109
Argonne National Lab Public Software Mirror	http://mirror.anl.gov/	2620::dc0:1800:214:4fff:fe7d:1b9
ARIN	http://www.arin.net/	2001:500:4:13::80 and 2001:500:4:13::81
Berkeley	http://www.ipv6.berkeley.edu/	2607:f140:ffff:ffff::80
DANTE	http://www.dante.net/	2001:798:2:284d::60
deepspace6.net (Linux IPv6 portal)	http://www.deepspace6.net/	2001:760:2e01:1::dead:beef
DREN	http://www.ipv6.dren.net/	2001:480:10:1050::5
ESNet	http://www.es.net/	2001:400:14:3::d
Fort Scott Community College	http://www.fortscott.edu/	2001:49d0:2c02::214:22ff:fe0f:38f4
Hexago	http://www.hexago.com/	2001:5c0:1000:10::2
HPCMO	http://www.hpcmo.hpc.mil/	2001:480:430:dddd:68b0:bff:fed5:f128
Hurricane Electric	http://ipv6.he.net/	2001:470:0:64::2
IANA	http://www.iana.org/	2620:0:2d0:1::193
ICANN	http://www.icann.org/	2620:0:2d0:1::103
IETF	http://www.ietf.org/	2001:1890:1112:1::20
Internet2	http://www.ipv6.internet2.edu/	2001:468:1420::151
Iowa State University	http://www.iastate.edu/	2610:130:101:100::7
IPv6.org	http://www.ipv6.org/	2001:6b0:1:ea:202:a5ff:fecd:13a6
IPv6 Portal	http://www.ipv6tf.org/	2a01:48:1::2e0:81ff:fe05:4658
IPv6 Task Force	http://www.ipv6.eu/	2001:690:1fff:200::226
ISC	http://www.isc.org/	2001:4f8:0:2::d
KAME Project	http://www.kame.net/	2001:200::8002:203:47ff:fea5:3085
KANREN	http://www.kanren.net/	2001:49d0:3c00:1:209:6bff:fe7f:6c06
Kenya NIC	http://www.kenic.or.ke/	2001:43f8:10:50::2655
LACNIC	http://www.lacnic.net/	2001:13c7:7002:4000::10

Linkopings University	http://www.liu.se/	2001:6b0:17:f005::148
MAGPI	http://www.magpi.net/	2001:468:1802:101::805b:22c
Michigan Tech	http://www.ipv6.mtu.edu/	2001:48a8:0:2::1:22
NANOG	http://www.nanog.org/	2001:48a8:6880:95::21
Nederlandse IPv6 Task Force	http://www.ipv6-taskforce.nl/	2001:610:512::1000
NREN	http://www.nren.nasa.gov/	2001:4d0:8102:8:198:10:138:131
NTT	http://www.nttv6.net/	2001:fa8::80
Peter Bieringer	http://www.ipv6.bieringer.de/	2001:a60:9002:1::186:6
RIPE	http://www.ripe.net/	2001:610:240:11::c100:1319
Sauk Valley Community College	http://www.svcc.edu/	2001:470:c10b::214:5eff:fe28:7878
Space and Naval Warfare Systems Command	http://www.spawar.navy.mil/	2001:480:10:1048:a00:20ff:fe9a:58c1
SURFNet	http://www.ipv6.surfnet.nl/	2001:610:510::192:42:113:60
SWITCH	http://www.switch.ch/	2001:620:0:1b::b
TERENA	http://www.terena.org/	2001:610:148:dead::6
Tsinghua University	http://www.tsinghua.edu.cn/	2001:da8:200:200::4:100
UCLA	http://www.ucla.edu/	2607:f010:3fe:301:101d:9ff:fe32:a7db (etc)
University of Hawaii	http://www.ipv6.hawaii.edu/	2607:f278:4101:11:209:5bff:fe8f:6609
University of Oregon video archive	http://limestone.uoregon.edu/	2001:468:d01:103::80df:9d0c
Virginia Tech	http://www.ipv6.vt.edu/	2001:468:c80:210f::173:2bc6:4145
WPI	http://www.wpi.edu/	2001:468:616:824::31
3ROX	http://www.3rox.net/	2001:5e8:0:1000::fa
6TAP	http://www.6tap.net/	2001:400:14:3::9

Track the IPv6-ification of some of your favorite web sites at http://www.mrp.net/IPv6_Survey.html

Access most any IPv4-only web site via IPv6 using sixxs.org s IPv4-to-IPv6 gateway by just appending sixxs.org to the normal IPv4 only domain name. For example, to access www.cnn.com via IPv6, you d go to http://www.cnn.com.sixxs.org/

What About Other GUI Web Browsers?

- Opera (http://www.opera.com/) is ready to use IPv6 as shipped with no tweaking required, likewise Internet Explorer 8.
- Safari is IPv6 enabled, but some versions of Safari may prefer IPv4 to IPv6 when both are available. To reverse that preference for dual stack sites:
  1) In a Mac terminal window (Applications --> Utilities --> Terminal) enable the Safari Debug menu by entering:
  defaults write com.apple.Safari IncludeDebugMenu 1
  You can then close the terminal window.
  2) Launch Safari, then go to Safari's Debug Menu (on the far right side of the main Safari menu), and come all the way down to Supported Protocols and **uncheck** http: (Simple Loader). You only need to do this once.

8. (h): IPv6 Email Clients

Modern Mail User Agents Support IPv6

- Apple Mail.App
- Opera Mail client
- Outlook 2007
  (see http://support.microsoft.com/kb/924469)
- Thunderbird: (see the next slide)
- Other MUAs?

Enabling IPv6 in Thunderbird for Email

- Thunderbird (Mozilla's graphical email client, sibling application to the Firefox web browser) may ship with IPv6 DNS queries disabled by default.

- Enabling IPv6 DNS queries requires you to:
  -- Start Thunderbird
  -- Go to Thunderbird --> Preferences
  -- Go to Advanced (the "sprocket" or "gear" at the top)
  -- Click the "Config Editor" button near the bottom
  -- In the about:config window's Filter: box, enter **ipv6**
  -- You should see:
  network.dns.disableIPv6 [etc] false
  -- If, however, that setting is true, double click true to toggle it to false

Public IPv6-Accessible Web Email

- As another example of IPv6 email lagging relative to where it should be, consider web-based email, one of the most popular and widely used applications on the Internet today.
- To the best of my knowledge, there is currently only ONE (1) public web email provider which has even an experimental web email service accessible via IPv6, and that's http://ipv6.rollernet.us/
- Technically, if you're able to manipulate your local hosts file, you can also access Google's Gmail via IPv6, see http://jeremy.visser.name/2008/11/25/how-to-access-gmail-and-google-reader-over-ipv6/ (URL wrapped due to length), but that's hardly the sort of thing that a typical user should be expected to be able to do.
- **If you're aware of any additional IPv6-accessible public web email service providers, I'd love to know about them.**

8. (i): ssh for IPv6

ssh and IPv6

- ssh supports IPv6. To get OpenSSH (5.5p1 was released 4/15/2010!) go to www.openssh.com/portable.html (be sure you're also running the latest OpenSSL -- 1.0.0 was released 3/29/2010 -- see www.openssl.org/ and don't forget to set a sane installation prefix!)

- To force ssh to use IPv6, use:

  ```
  % ssh –6 joe@example.com
  ```

- To force ssh to use IPv4, use:

  ```
  % ssh –4 joe@example.com
  ```

8. (j): Web Servers

What About Your Web Site?

- **Is your web site IPv6 accessible?** If not, why not? The most popular web servers, e.g., Apache and Microsoft IIS, both support IPv6 these days! So what's the "holdup," eh?
- One potential roadblock to explore is whether hardware load balancers are IPv4 only. Hardware load balancers commonly sit in front of multiple physical computers, making a pile of systems act as if they were one computer. Some popular hardware load balancers know how to do IPv6, but license IPv6 functionality separately from IPv4.
- Other times the issue may be the use of outsourced content delivery networks (CDNs) which may not be IPv6-enabled (previously discussed)
- Lastly, at least sometimes, no one may every have asked, "Hey, why isn't our web site IPv6 accessible?" Perhaps that's a question that YOU should ask once you're done with this training?

Apache Web Server and IPv6

- Get Apache 2.2.15 (or whatever's the latest stable version) from http://httpd.apache.org/
- Review httpd.apache.org/docs/2.2/bind.html#ipv6 but otherwise build, install and configure as normal
- When configuring for IPv6, in /etc/httpd/httpd.conf, bind to an appropriate static IPv6 address:

  ```
  BindAddress [2001:468:d01:d6::80df:d617]   <-- example only!
  ```

- Check your config and start httpd; typically:

  ```
  /usr/local/apache2/bin/apachectl configtest
  /usr/local/apache2/bin/apachectl start
  ```

- Confirm that you can connect OK to your IPv6 httpd:

  ```
  % telnet 2001:468:d01:d6::80df:d617 80     <-- example only!
  GET /                       (note: case matters, GET, not get)
  ```

- Problems? Likely a firewall thing, as "always!" :-;

Don't Forget About IPv6 Addrs in Log Files

```
# cd /usr/local/apache2/logs
# cat access_log
[...]
2001:468:d01:d6::80df:d617 - - [23/Apr/2010:10:20:29 -0700]
"GET / HTTP/1.1" 200 54
[etc]
```

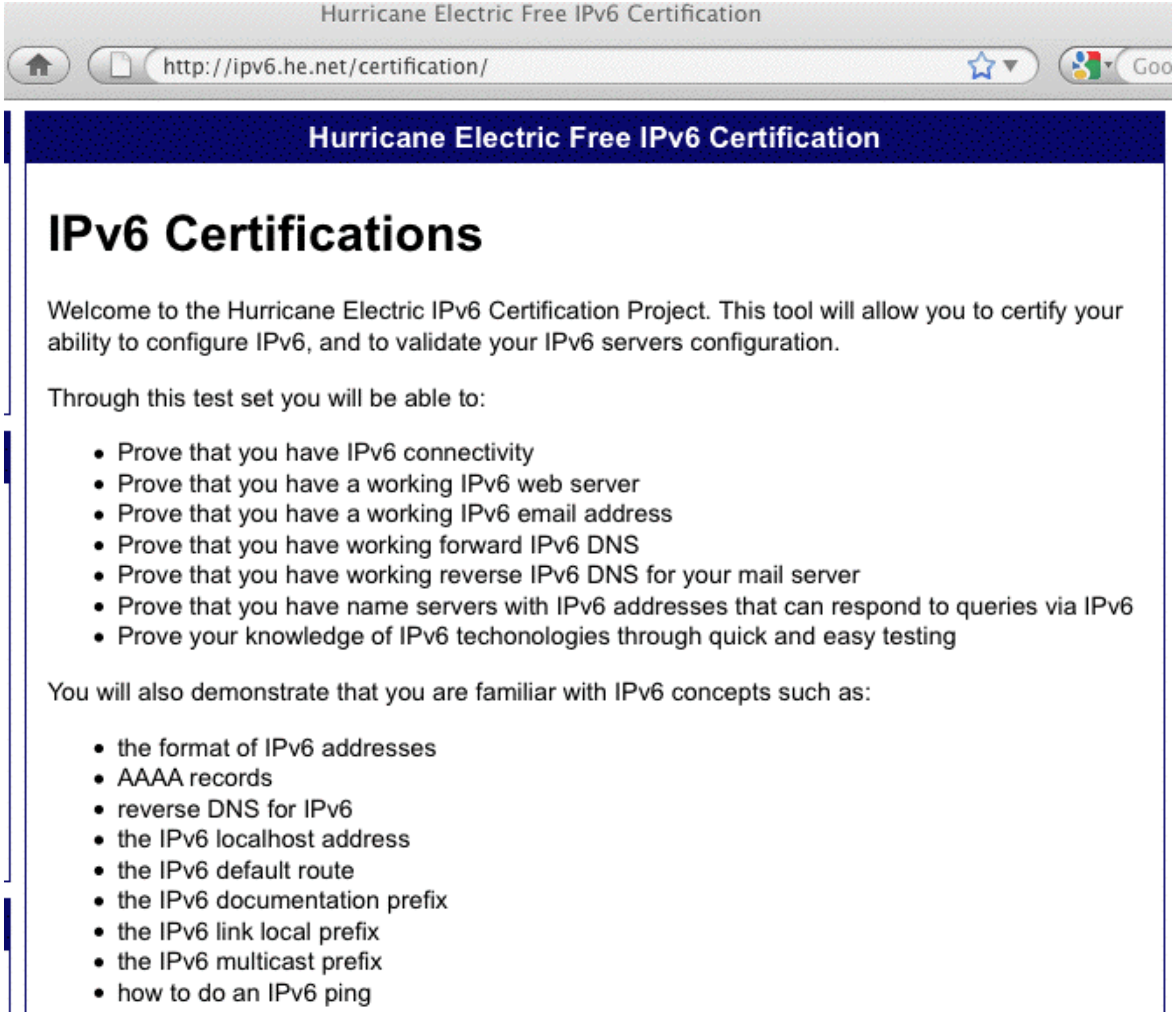
Does *your* log file analyzer product support IPv6 addresses? Some, like AWStats from http://awstats.sourceforge.net/ require a separate plugin to enable some IPv6 functionality; other functionality, like mapping addresses to geographic locations, may simply not be available for IPv6

Conclusion

Learning More About IPv6: Books

- A nice online reference: 6Net IPv6 Cookbook, www.6net.org/publications/deliverables/D3.1.2v2.pdf
- Traditional printed books about IPv6 are also available. If you go to Amazon's book section and search for IPv6, for example, you get 873 hits. That's a bit better than it was in the old days. :-)
- When considering which of those books might work for you, recognize that some are written for specific audiences (like programmers), and those sort of books may not meet your particular needs (unless you're a coder and you're trying to come up to speed for IPv6).
- Also recognize that IPv6 is rapidly evolving, so beware of any books that haven't been recently updated.

Hurricane Electric's IPv6 Certification



Hurricane Electric Free IPv6 Certification
http://ipv6.he.net/certification/
Goo

Hurricane Electric Free IPv6 Certification

IPv6 Certifications

Welcome to the Hurricane Electric IPv6 Certification Project. This tool will allow you to certify your ability to configure IPv6, and to validate your IPv6 servers configuration.

Through this test set you will be able to:

- Prove that you have IPv6 connectivity
- Prove that you have a working IPv6 web server
- Prove that you have a working IPv6 email address
- Prove that you have working forward IPv6 DNS
- Prove that you have working reverse IPv6 DNS for your mail server
- Prove that you have name servers with IPv6 addresses that can respond to queries via IPv6
- Prove your knowledge of IPv6 techonologies through quick and easy testing

You will also demonstrate that you are familiar with IPv6 concepts such as:

- the format of IPv6 addresses
- AAAA records
- reverse DNS for IPv6
- the IPv6 localhost address
- the IPv6 default route
- the IPv6 documentation prefix
- the IPv6 link local prefix
- the IPv6 multicast prefix
- how to do an IPv6 ping

This video is presented by the
Messaging Anti-Abuse Working Group

MAAWG IPv6 Training for Senders and Others

can be viewed in three segments from the training pages at www.MAAWG.org.
This has been part 3 of 3.

Our thanks to MAAWG Senior Advisor Joe St Sauver, Ph.D.,
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and allowing MAAWG to videotape it
for the benefit of professionals worldwide.