The IPv6 World View
– A global view of IPv6 commercial readiness

Hurricane Electric
IPv6 Native Backbone – Massive Peering!

DREN IPv6 Day 2011

Denver, Colorado, USA – 16th August 2011

Martin J. Levy, Director IPv6 Strategy
Hurricane Electric

IPv6 Global Connectivity – Talk Outline

- IPv6 at Hurricane Electric   *(I'll keep it short and sweet!)*

- ~~Why do we need IPv6?~~   *(Just kidding – I'm assuming that!)*

- Is the IPv6 routing table ready for the real world?

- Can you motivate people to implement IPv6?

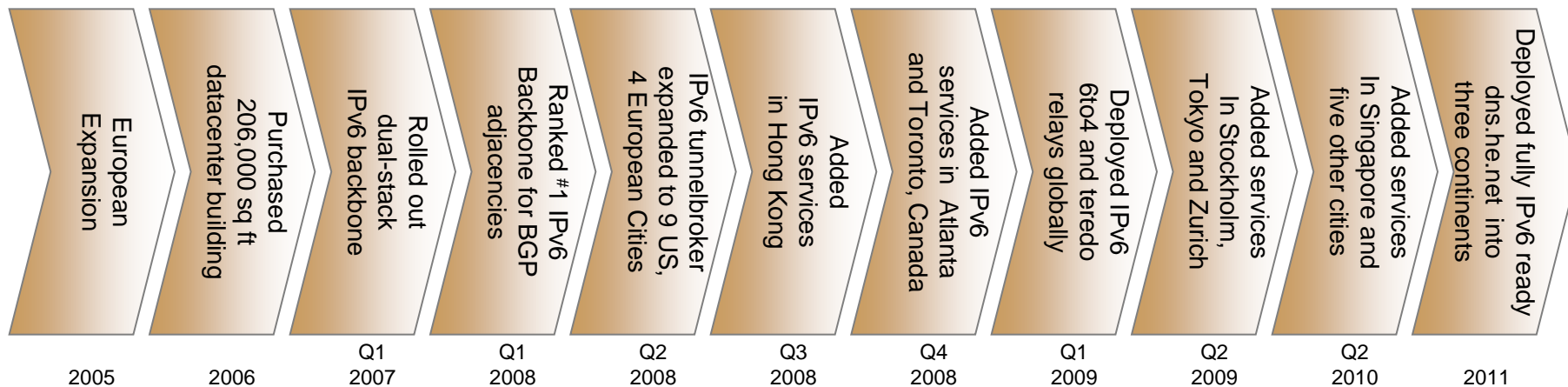- Should we panic or be happy?

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Hurricane Electric – Roots and History

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- Founded 17+ years ago - ISP & datacenter operator

  - 1994 – Roots within the Silicon Valley high-tech community
  - 1999 – Expanded IPv4 network nationwide in the US
  - 2001 – Started IPv6 native and tunnel connectivity (http://tunnelbroker.net)
  - 2006 – Full "technology refresh" enabled native dual-stack IPv6 backbone
  - 2008 – Became largest IPv6 backbone globally (> 1Gbps IPv6 traffic level)

| European Expansion	Purchased 206,000 sq ft datacenter building	Rolled out dual-stack IPv6 backbone	Ranked #1 IPv6 Backbone for BGP adjacencies	IPv6 tunnelbroker expanded to 9 US, 4 European Cities	Added IPv6 services in Hong Kong	Added IPv6 services in Atlanta and Toronto, Canada	Deployed IPv6 6to4 and teredo relays globally	Added services In Stockholm, Tokyo and Zurich	Added services In Singapore and five other cities	Deployed fully IPv6 ready dns.he.net into three continents
2005	2006	Q1 2007	Q1 2008	Q2 2008	Q3 2008	Q4 2008	Q1 2009	Q2 2009	Q2 2010	2011

  - 2009 – Continued expansion into Asia; enabled IPv6 6to4 & Teredo global service
  - 2010 – Added more geographic coverage; expanded IPv6 6to4 and DNS service
  - 2011 – Stop talking about IPv6; just talk about the "Internet"

Hurricane Electric – IPv6 Network Reach

All Hurricane Electric POPs are full IPv6 Native routing and peering
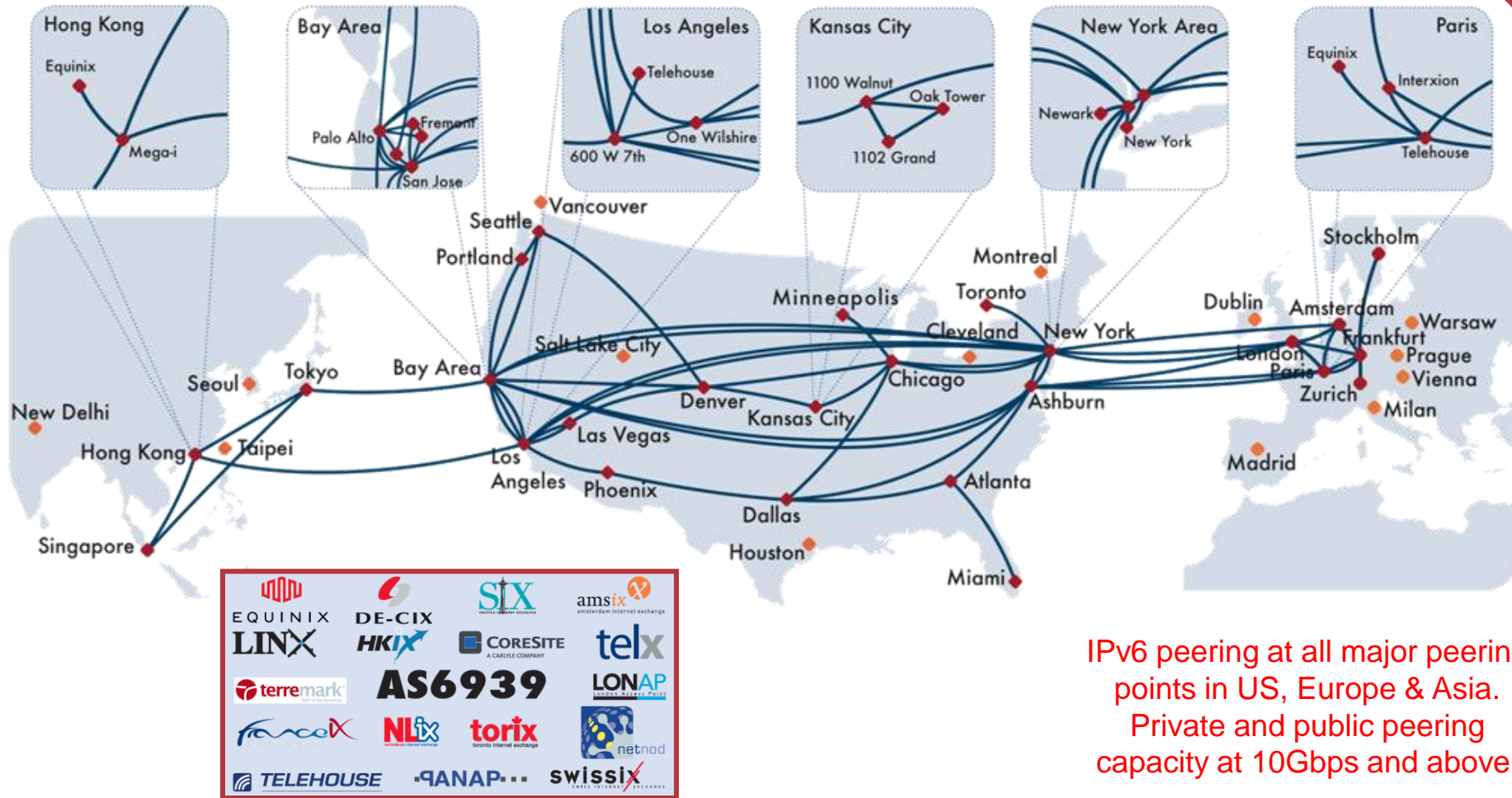
IPv6 peering at all major peering points in US, Europe & Asia. Private and public peering capacity at 10Gbps and above.

Hurricane Electric – IPv6 Native Services

- **Five+ years into native IPv6 network deployment**
  - Touching on 10+ years of IPv6 on the network

- **IPv6 native router platform across all POP's**
  - All IPv6 BGP customer connections are native
  - All IPv6 datacenter customer are native
  - Every customer connection is IPv6 enabled by default!

- **IPv6 dual-stack & native DNS servers**
- **IPv6 dual-stack & native NTP servers**
- **IPv6 & IPv4 public looking glass & route servers**

- **24/7 NOC with IPv6 expertise**

  Not just "Joe" on Thursdays

- **IPv6 hosting services**

Hurricane Electric – IPv6 Native Services

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- Applied for and got IPv6 address allocation from RIR? ✓

- Picked hardware & firmware? ✓

- Enabled IPv6 (dual stack) everywhere? ✓

- IPv6 peering & global connectivity? ✓

- Built IPv6 routing for customer interconnections? ✓

- Reverse-DNS & other backbone IP layer offerings? ✓

- Evangelized IPv6 excessively? ✓ ✓ ✓

- Saw real use from customers? ✓

- ## We're done!

Hurricane Electric mindset – always "yes" to IPv6

- **It's 2011 (and not 2005, 2006, 2007, etc)**
  - IPv6 capable hardware subsystems are available
  - IPv6 capable operating systems are available
  - IPv6 capable open-source software packages are available
  - IPv6 capable service providers are available
  - IPv6 expertise is absolutely available!

- **It's 2011**
  - No reason to say "no" to IPv6 anymore

- **IPv6 in the peering world requires some actions …**
  - … and there's no problem finding the answers!

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Why do we need IPv6?

(Just kidding – I'm assuming that!)

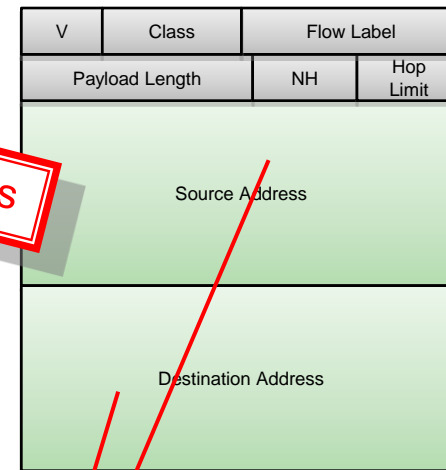# IPv6 – Maybe the one-page history lesson

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IPv4

V	L	TOS	Total Len	
Identification		Flags	Frag' Off	
TTL	Proto		Checksum	
Source Address				
Destination Address				
Options			Pad	
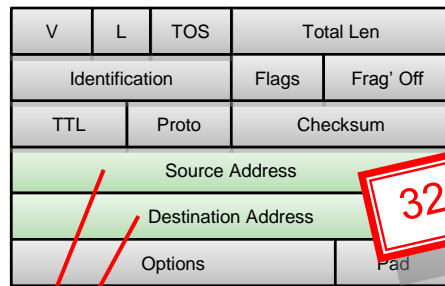
32 bits

```
typedef __uint32_t in_addr_t;

struct in_addr {
 in_addr_t s_addr;
}

struct sockaddr_in {
 __uint8_t      sin_len;
 sa_family_t    sin_family;
 in_port_t      sin_port;
 struct  in_addr sin_addr;
 char           sin_zero[8];
};
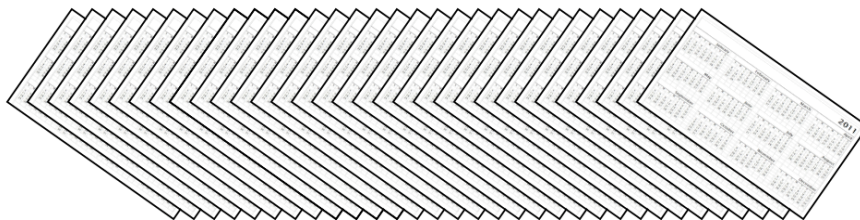```

It's all about address space size

IPv6

| V | Class | Flow Label | |
|---|---|---|---|
| Payload Length | | NH | Hop Limit |
| Source Address | | | |
| Destination Address | | | |

**128 bits**

```
struct in6_addr {
 union {
  __uint8_t   __u6_addr8[16];
  __uint16_t  __u6_addr16[8];
  __uint32_t  __u6_addr32[4];
 } __u6_addr; /* 128-bit IP6 address */
};
```

1980 ——————— IPv4's 30 Year Lifespan ———————> 2011 ———————————————————> ????

IPv6 Deployment with tons of space (no end in sight)
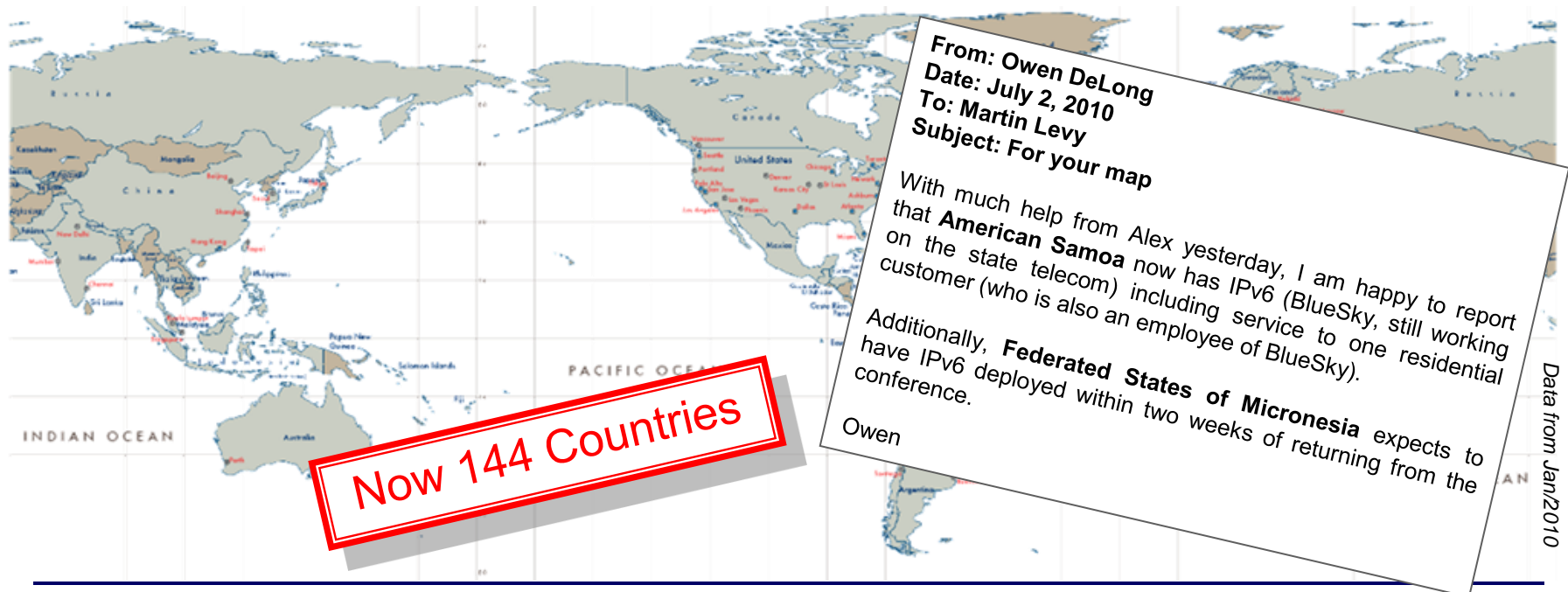
IPv4 Deployment – but no additional space

HE

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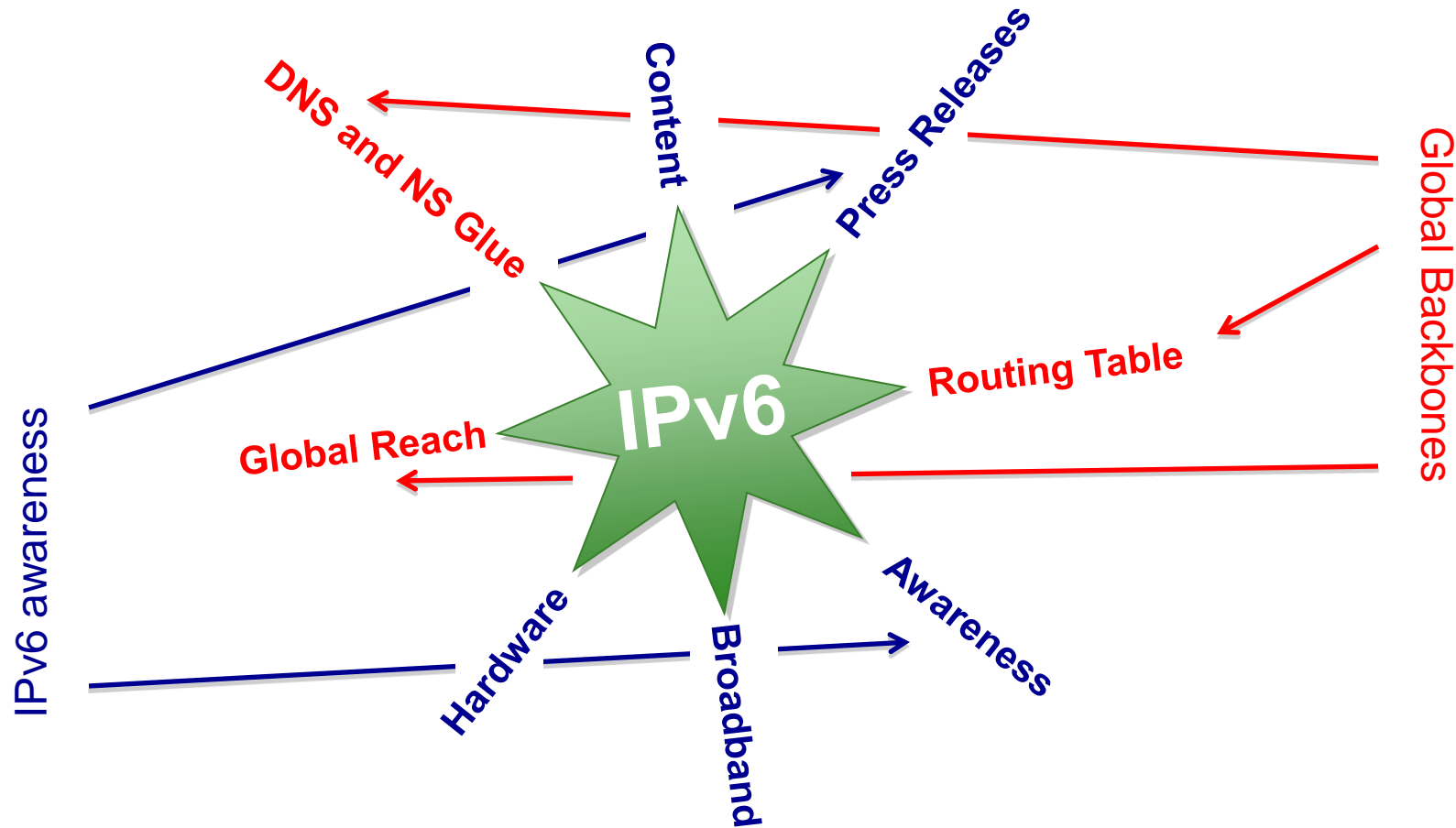# Does IPv6 have global coverage?

IPv6 and global deployment worldwide

- **IPv6 deployment is everywhere**
  - ❑ 90+ countries had a "live" IPv6 presence in Jan 2010
  - ❑ IPv6 active at nearly all global Internet peering points

Now 144 Countries

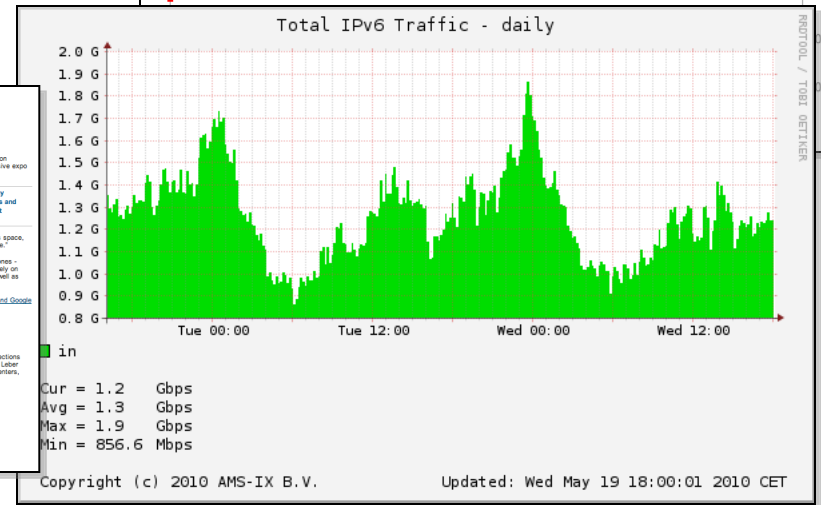From: Owen DeLong
Date: July 2, 2010
To: Martin Levy
Subject: For your map

With much help from Alex yesterday, I am happy to report that **American Samoa** now has IPv6 (BlueSky, still working on the state telecom) including service to one residential customer (who is also an employee of BlueSky).

Additionally, **Federated States of Micronesia** expects to have IPv6 deployed within two weeks of returning from the conference.

Owen

Data from Jan/2010

IPv6 and the global backbone story

Hurricane Electric - DREN IPv6 Day 2011 - Denver Colorado -
Martin J. Levy - Director IPv6 Strategy

Measurement methods …

- ❑ … via peering?
- ❑ … via bandwidth?
- ❑ … via press releases?

IPv6 questions to check on global deployment

- **Is IPv6 supported? (the basic questions)**

  - ❑ Is IPv6 native on all backbones?

  - ❑ Is IPv6 interconnections/peering prevalent?

  - ❑ Is IPv6 part of the standard product mix?

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Is the IPv6 routing table ready for real world use?

Basic question: Is IPv6 routing ready?

- ## Theory #1: It's been ready for years…
  - ❑ Plenty of backbones running v6 routing
  - ❑ Plenty of v6 inter-backbone peering
  - ❑ Plenty of v6 talks at conferences

- ## Theory #2: We are not ready yet; but close…
  - ❑ Still a few gaps in the routing tables
  - ❑ Still some spotty cleanup's here-and-there

Checking global IPv6 routing – graphically!

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Showing IPv4/IPv6 route propagation in a graphical form

http://bgp.he.net/

Caveat:

- This tool is only as good as its source data.
- IP information is uploaded from RIPE RIS & Oregon routeviews.
- Some views are missing; not all routes and paths are visible.

- <u>NOT</u> based on the Hurricane Electric routing tables.

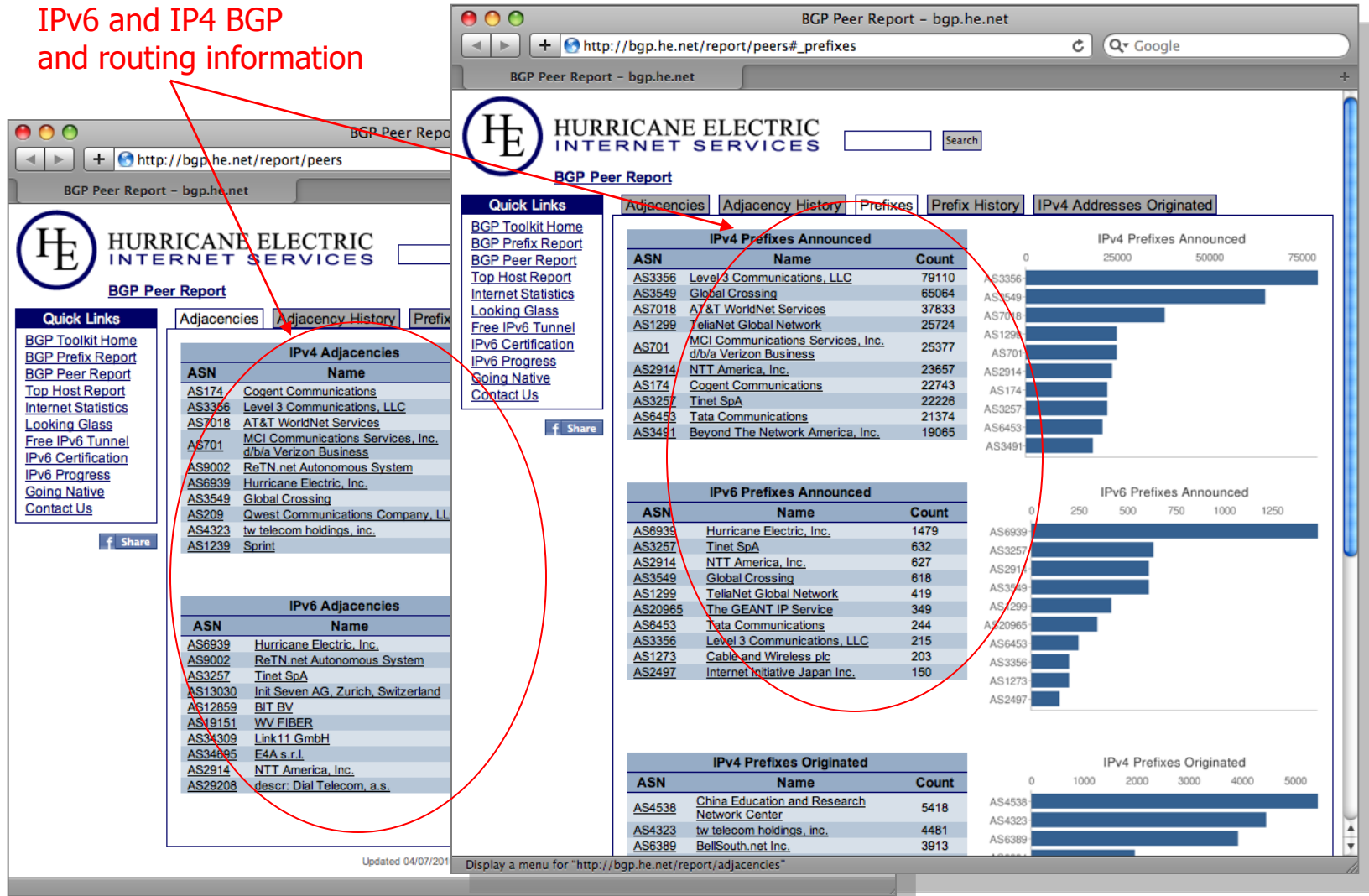# http://bgp.he.net/ - Searching on ASN, IP, etc.

NATIVE IPv6 EVERYWHERE
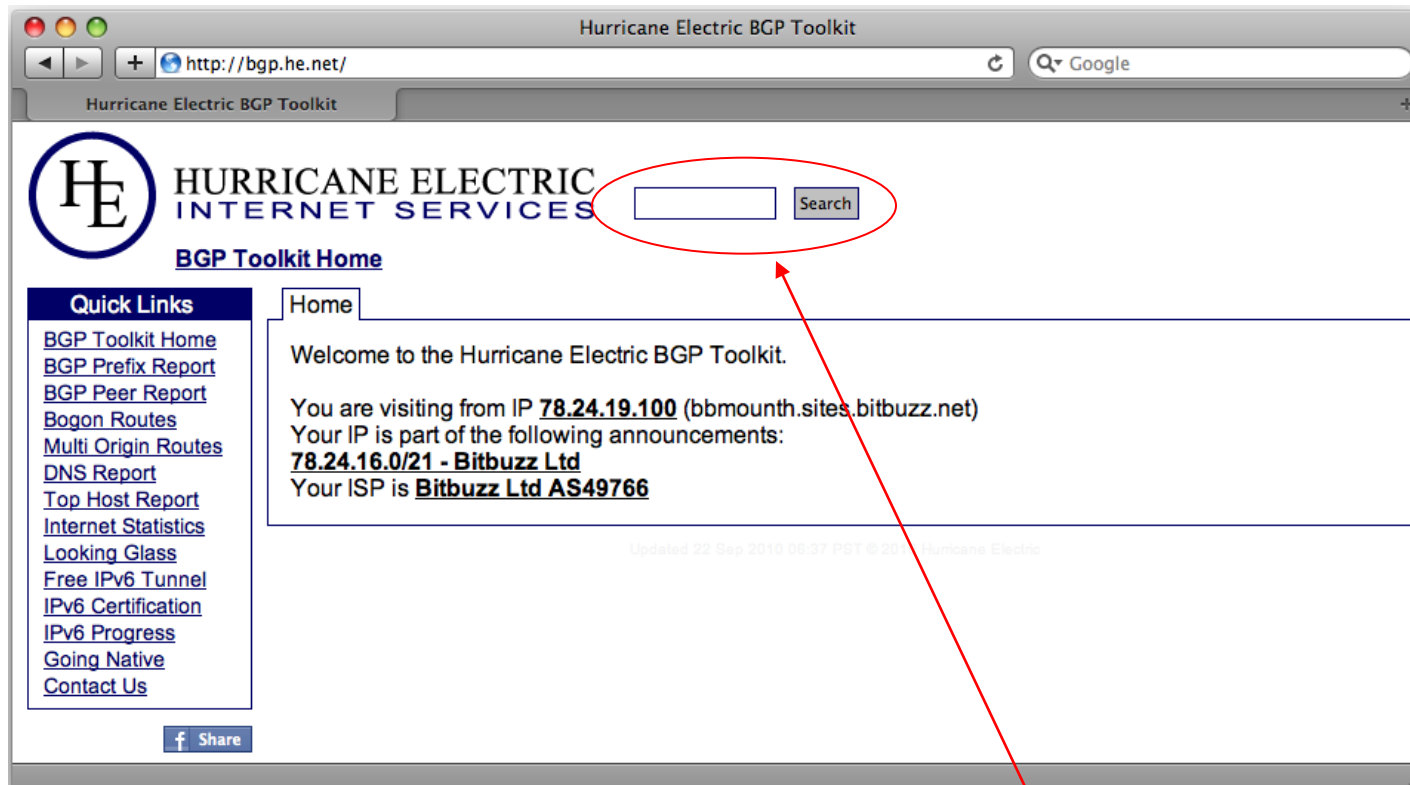
Search command

ASN   AS2128
IPv4 address   193.242.111.1
IPv4 block   194.88.240.0/23
IPv6 address   2001:7f8:18:2::4
IPv6 block   2001:7f8:18::/48
...etc ...

Example of BGP tools – IPv4/IPv6 statistics

IPv6 and IP4 BGP and routing information

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http://bgp.he.net/

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http://bgp.he.net/ – Available information

- **BGP Prefix Report**
  - Prefixes, Networks, Distribution
    - IPv4/IPv6 Prefixes Originated (90 Days)
    - ASN's with IPv4/IPv6 Announcements (90 Days)
    - IPv4/IPv6 Announced Prefix Count by CIDR
- **BGP Peer Report**
  - Adjacencies, Adjacency History
    - IPv4/IPv6 Adjacencies
    - IPv4/IPv6 Adjacency Count (90 Days)
  - Prefixes, Prefix History
    - IPv4/IPv6 Prefixes Announced
    - IPv4/IPv6 Prefixes Announced (90 Days)
  - IPv4 Addresses Originated
    - IPv4 Addresses Originated
- **Top Host Report**
  - Top Hosts
- **Internet Statistics**
  - Internet Statistics
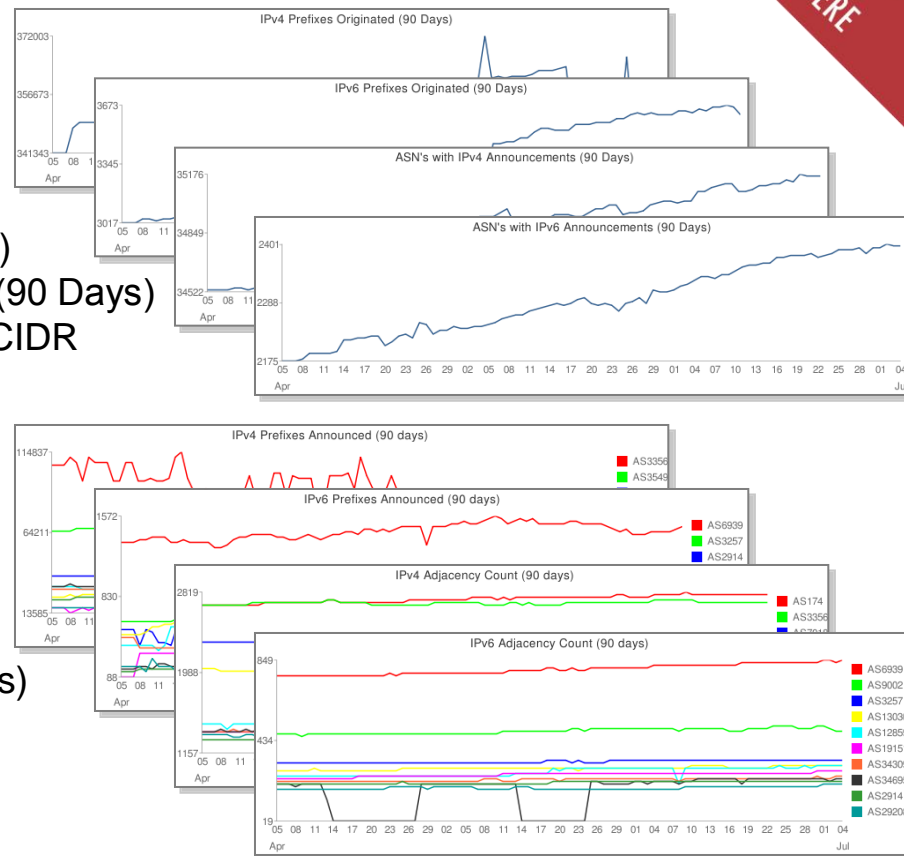
http://bgp.he.net/ – Route propagation graphs
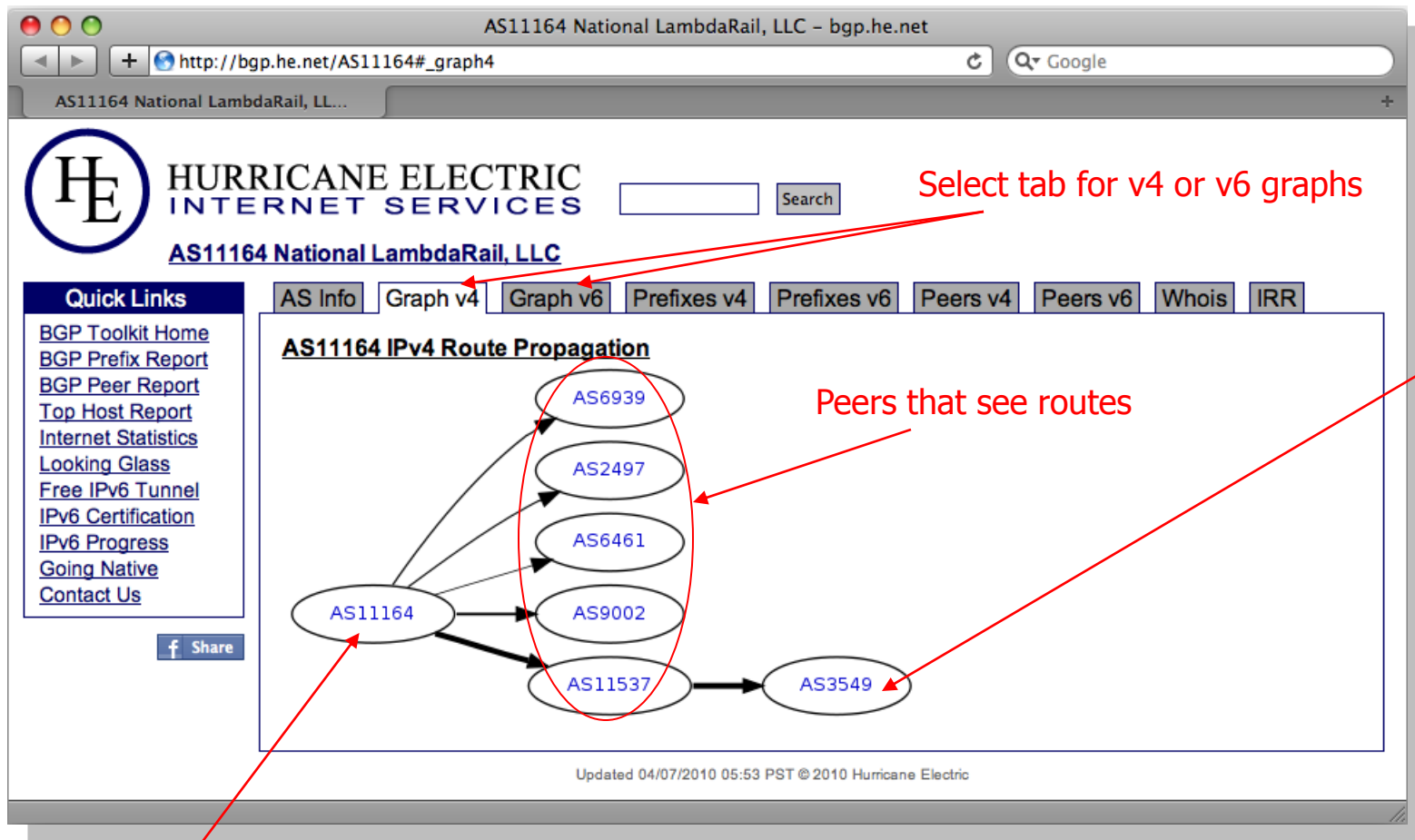
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Is IPv6 routing/interconnect/peering prevalent?

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IPv6 Prefixes Originated (240 Days)

66% increase in 8 months!

http://bgp.he.net/report/prefixes#_prefixes

ASN's with IPv6 Announcements (240 Days)

53% increase in 8 months!

http://bgp.he.net/report/prefixes#_networks

Simple conclusion #1 – "up and to the right"

Is IPv6 native on all backbones? (globally)

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NTT · Telia · Level3 · TATA · Sprint · TInet · Cogent · AT&T · HE.NET · GBLX

Simple conclusion #2 – global routing seems to exist on nearly every tier1 backbone

IPv6 routing on backbones (the summary)

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- **Classic backbones have (finally) got IPv6**
  - This is not news to a savvy IPv6 crowd!
  - One Tier1 backbone only completed this step 12 months ago!

- **Some backbones still missing some routes**
  - Uninteresting to multi-homed networks

- **Expect the trickle-down effect to other networks**

Simple conclusion #3 – it took till 2010 for some Tier1 backbones to get v6 ready!

IPv6 measured at via BGP ASNs with IPv6

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http://bgp.he.net/ipv6-progress-report.cgi

Networks Running IPv6
We can measure the percentage of networks running IPv6 by comparing the
set of ASes in the IPv6 routing table to those in the combined set of IPv4 and IPv6.
IPv4 and IPv6 RIBs Last Parsed: Mon Aug 8 01:08:26 PDT 2011

IPv4 ASes: 38604
IPv6 ASes: 4471
ASes using only IPv4: 34227
ASes using only IPv6: 94
ASes using IPv4 and IPv6: 4377
ASes using IPv4 or IPv6: 38698

Percentage of ASes (IPv4 or IPv6)
running IPv6: 11.6%

11.6%

3.6%

IANA Runout

Date

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HE
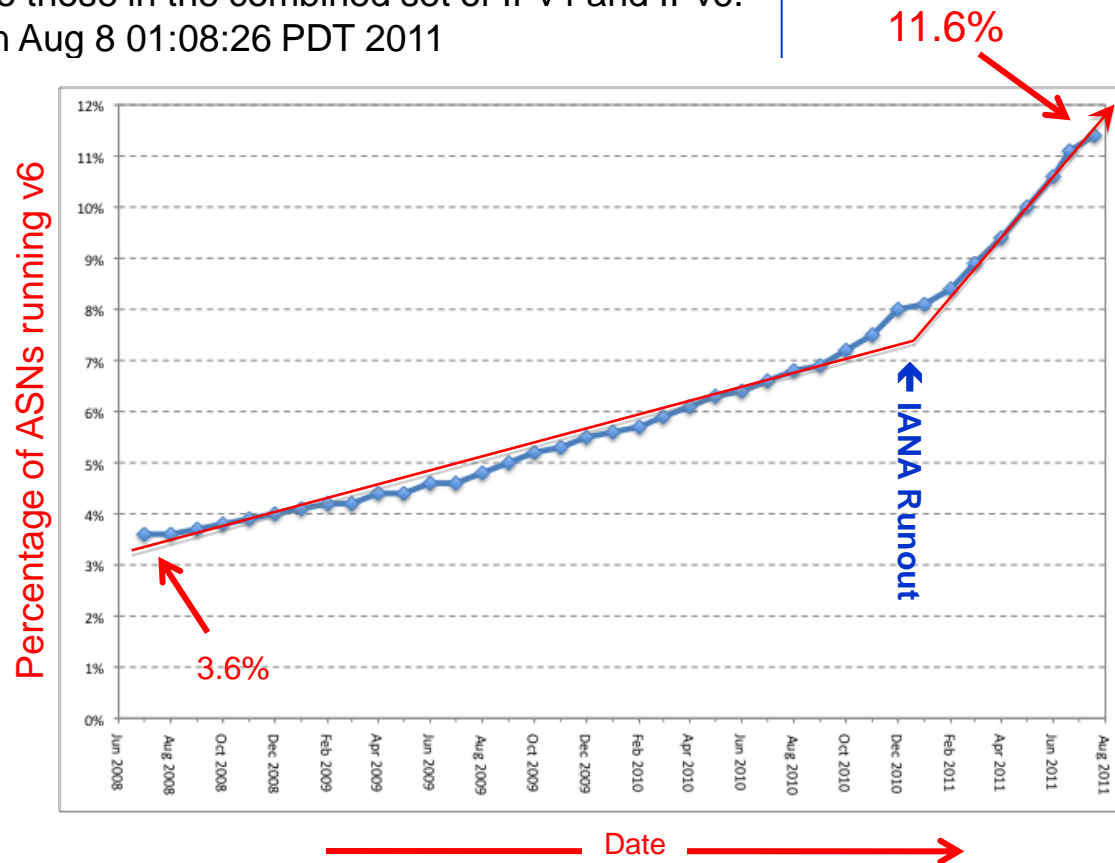
World IPv6 Day

(Not just IPv6 Day, World IPv6 Day)
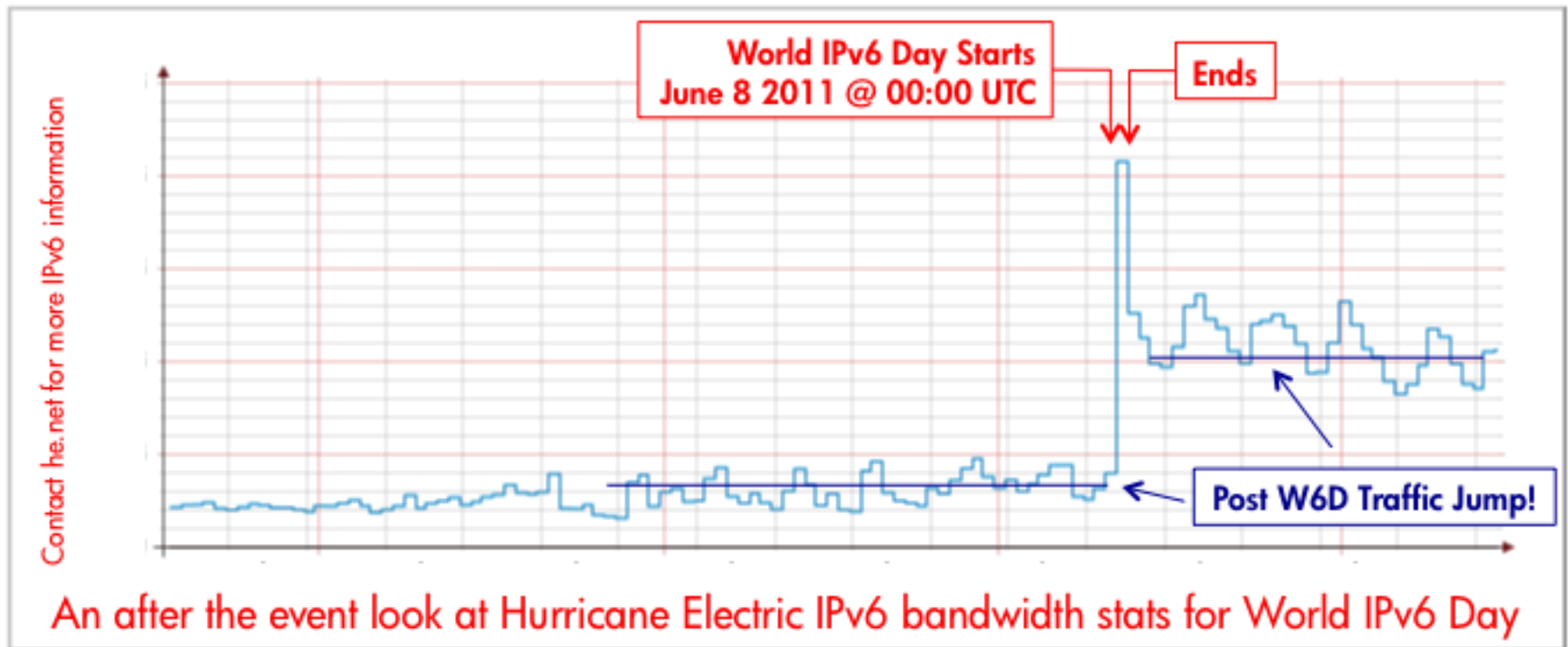
World IPv6 Day and real IPv6 traffic

- **World IPv6 Day was about enabling web-based traffic for IPv6**
    - Focus on content providers
    - Web (port 80 & 443 TCP traffic) plotted below

An after the event look at Hurricane Electric IPv6 bandwidth stats for World IPv6 Day
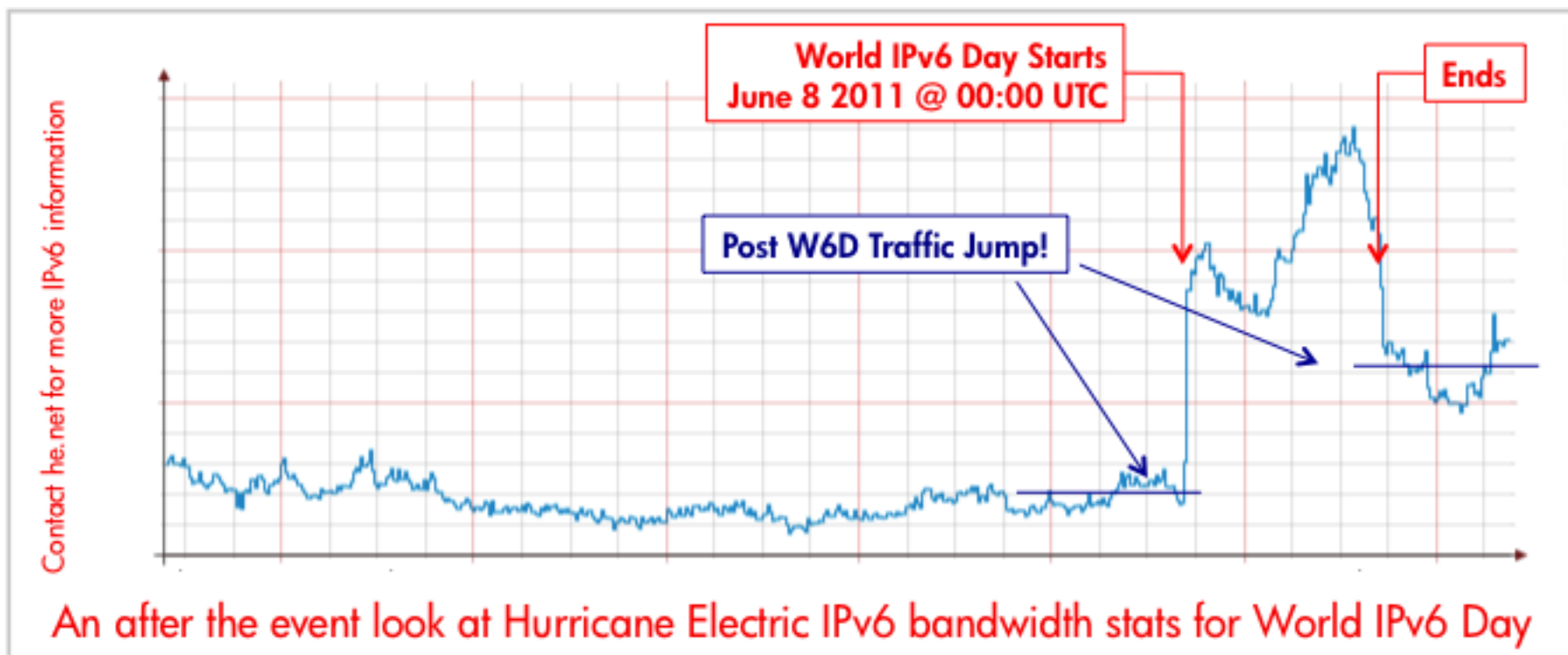
World IPv6 Day and real IPv6 traffic

- **Long term win since W6D in IPv6 traffic levels**
    - That means there are both content and eyeballs in play

World IPv6 Day Starts June 8 2011 @ 00:00 UTC

Ends

Post W6D Traffic Jump!

Contact he.net for more IPv6 information

An after the event look at Hurricane Electric IPv6 bandwidth stats for World IPv6 Day

Hurricane Electric W6D and translation traffic

- Yes – there is 6to4 traffic
    - Lots of traffic on Hurricane Electric's backbone!
- Measured on the largest 6to4 global deployment (with Teredo included)
    - AMS ASH CHI FMT FRA HKG LAX LON MIA NYC PAO PAR SEA SIN SJC STO TYO

6to4 IPv6 bandwidth stats for World IPv6 Day
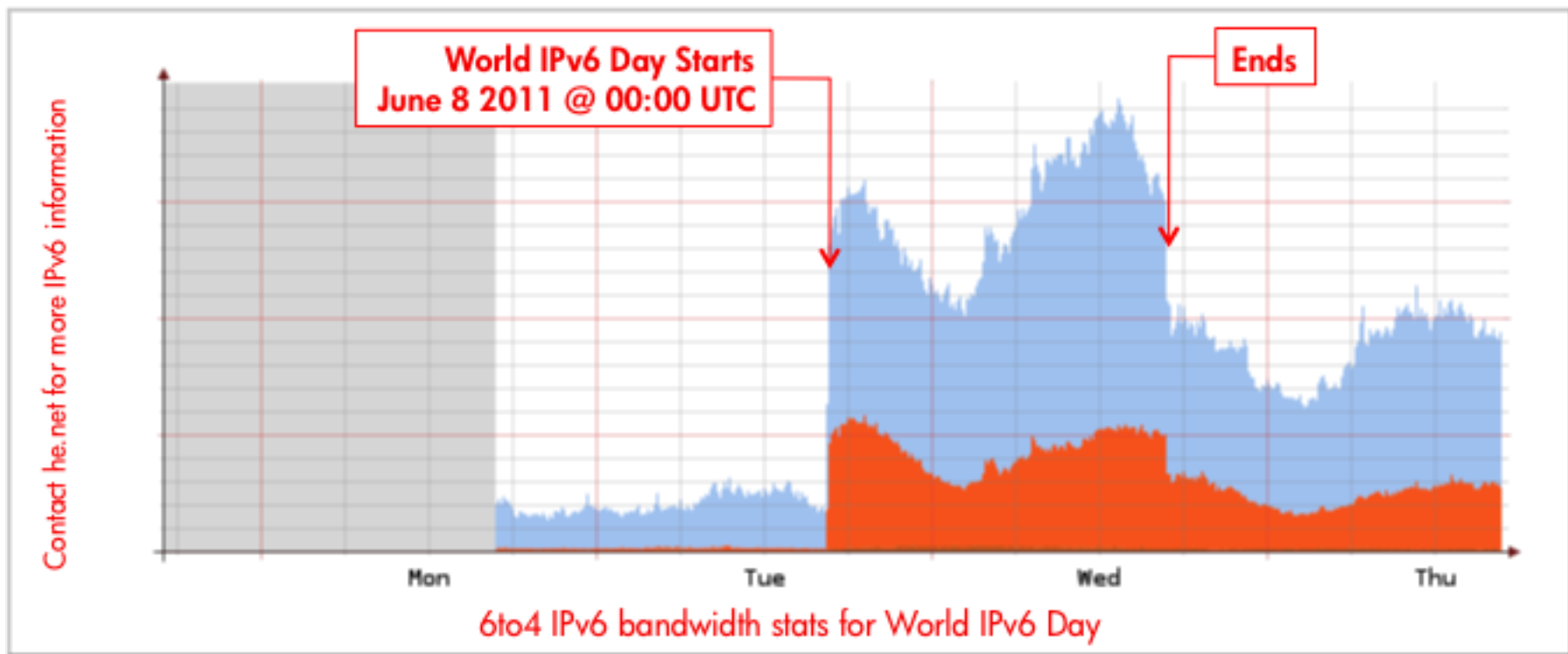
World IPv6 Day – tunnelbroker.net users

Large jump in interest in IPv6 on W6D

Accounts Signed Up Last 20 Days
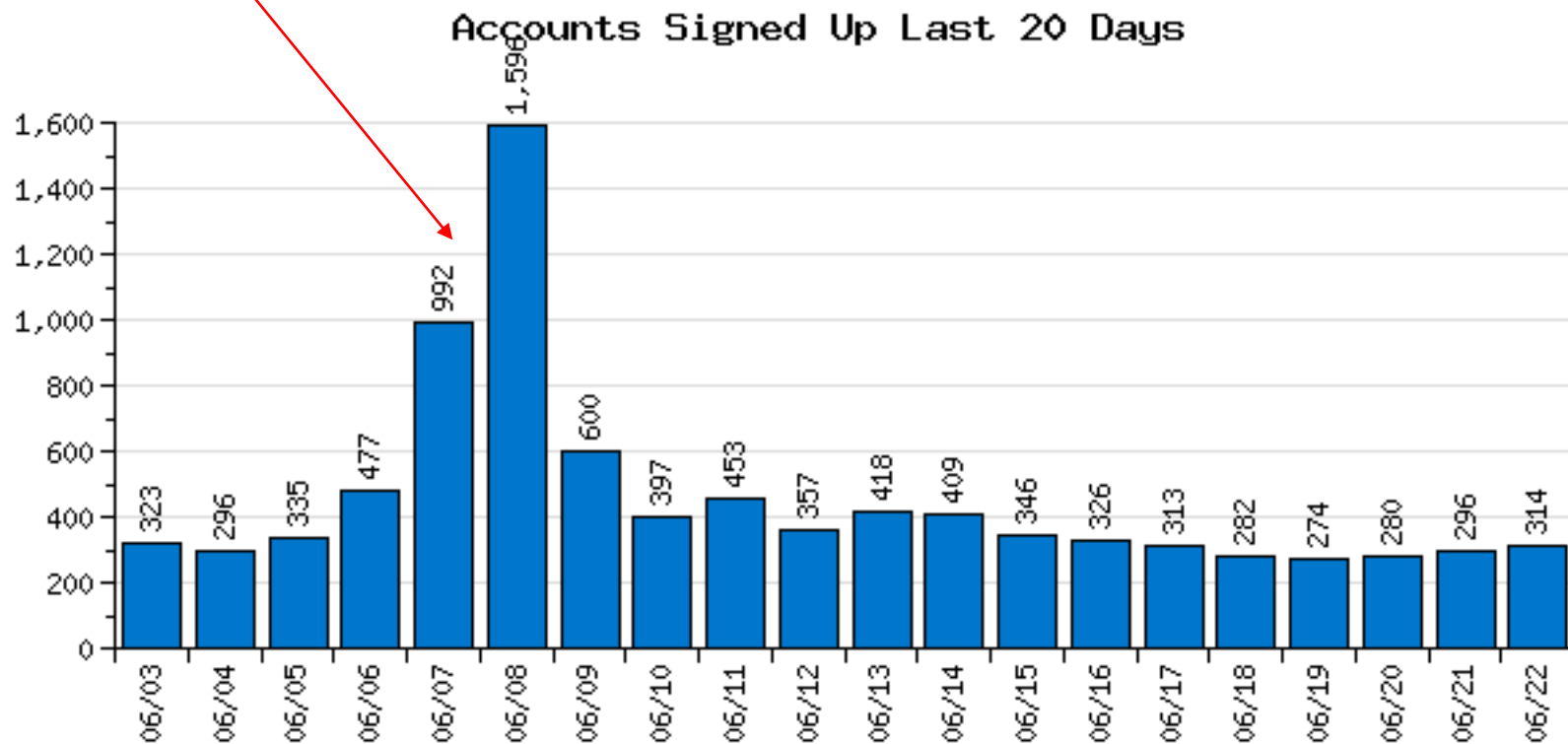
Hurricane Electric W6D – Observed issues

- **PMTU & ICMP6 blocking**
  - Heard again and again all over the net
  - Enabling IPv6 (for the first time) with too-aggressive filtering

- **Two failure modes**
  - Pre W6D testing – normally on "ipv6.example.com"
  - During W6D – affected "www.example.com"

- **Trigger points?**
  - Testing from Teredo or 6to4 enabled end-nodes
  - Real-world tunnels

- **ICMP6 re-explained**
  - Teredo requires end-node to respond to a ping to initiate protocol
  - This breaks classic enterprise firewall/filter setups
  - Consensus is that elements ahead of server perform this function

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Hurricane Electric's IPv6 Tunnel Broker

http://tunnelbroker.net/

(IPv6 Tunnels Exist! – sometimes it's the only way)

Hurricane Electric – IPv6 tunnelbroker.net

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Geographically diverse locations allowing customers best routing – coincident with IP peering

AVAILABLE
AVAILABLE
AVAILABLE
BGP
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BGP
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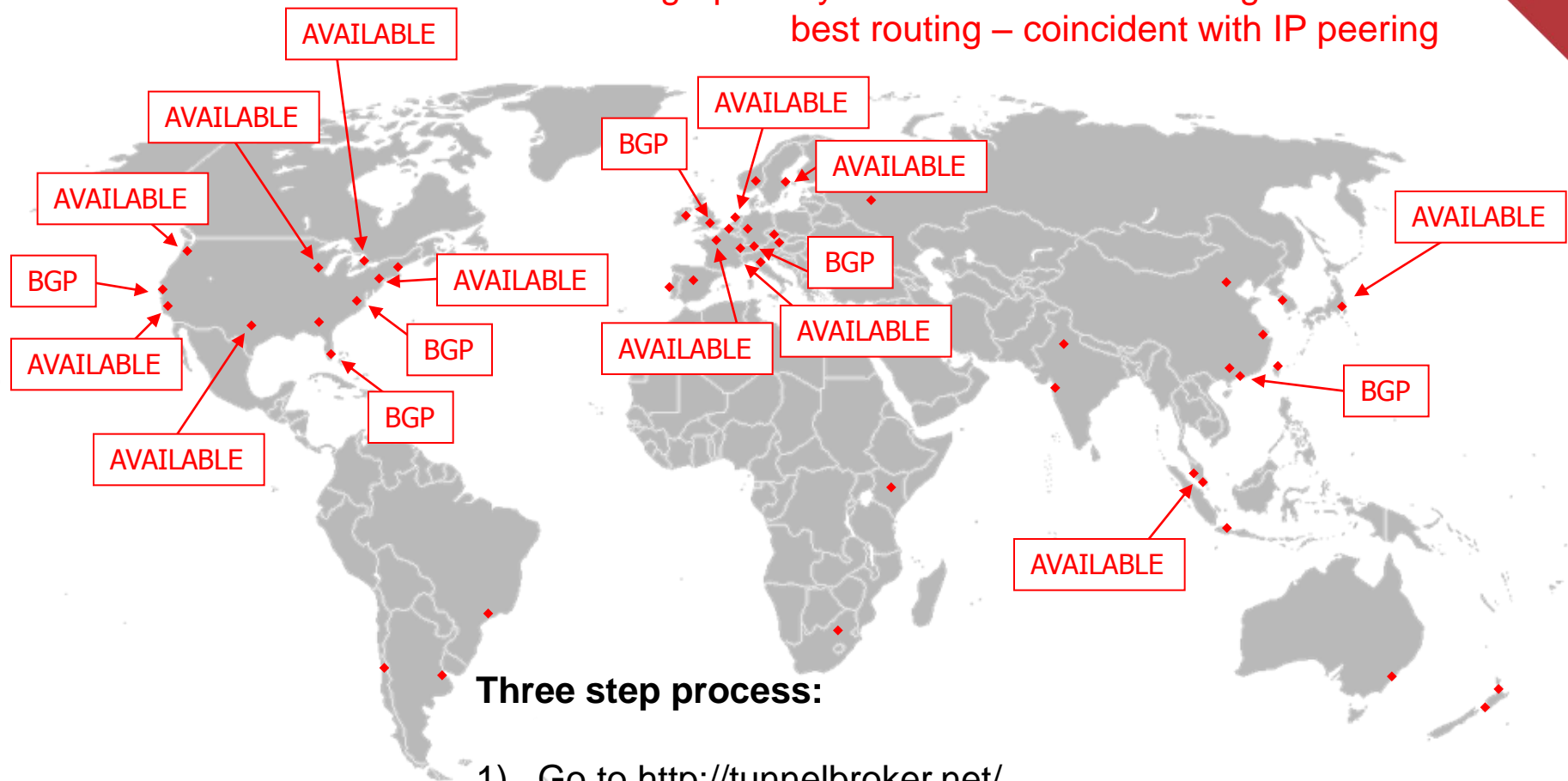
Three step process:

1) Go to http://tunnelbroker.net/
2) Setup an account – choose a location
3) Setup your own host or router to allow tunnels

Hurricane Electric – IPv6 tunnelbroker.net setup

Setup Regular IPv6 Tunnel

You currently have 1 of 4 allowed tunnels configured.

- If you are trying to reclaim a tunnel simply enter your last IPv4 address here. If you have any issues please email ipv6@he.net.
- If you have an official ASN and wish to setup a full BGP feed, please use **this form** instead.

IPv4 endpoint:
(your side of the tunnel)

You are viewing from IP: 216.218.214.2

We recommend you use: Fremont, CA, US [72.52.104.74]

Which Server Is Closest to you?:

Asia
- Tokyo, JP [74.82.46.6]
- Hong Kong, HK [216.218.221.6]

Europe
- Amsterdam, NL [216.66.84.46]
- Stockholm, SE [216.66.80.90]
- Paris, FR [216.66.84.42]
- Zurich, CH [216.66.80.98]
- London, UK [216.66.80.26]
- Frankfurt, DE [216.66.80.30]

North America
- Seattle, WA, US [216.218.226.238]
- Fremont, CA, US [72.52.104.74]
- Ashburn, VA, US [216.66.22.2]
- Miami, FL, US [209.51.161.58]
- Chicago, IL, US [209.51.181.2]
- Dallas, TX, US [216.218.224.42]
- Toronto, ON, CA [216.66.38.58]
- Los Angeles, CA, US [66.220.18.42]
- New York, NY, US [209.51.161.14]

Submit

Select Global Location

Hurricane Electric – IPv6 tunnelbroker.net setup

Hurricane Electric – IPv6 tunnelbroker.net setup

Windows XP

```
ipv6 install
ipv6 rtu ::/0 2/::72.52.##.## pub
ipv6 adu 2/2001:470:##:##::2
```

Linux

```
modprobe ipv6
ip tunnel add he-ipv6 mode sit \
    remote 72.52.##.## local ##.##.##.## ttl 255
ip link set he-ipv6 up
ip addr add 2001:470:##:##::2/64 dev he-ipv6
ip route add ::/0 dev he-ipv6
ip -f inet6 addr
```

MacOS X

```
ifconfig gif0 tunnel ##.##.##.## 72.52.##.##
ifconfig gif0 inet6 2001:470:##:##::2 2001:470:##:##::1 prefixlen 128
route -n add -inet6 default 2001:470:##:##::1
```

Windows Vista

```
netsh interface ipv6 add v6v4tunnel IP6Tunnel ##.##.##.## 72.52.##.##
netsh interface ipv6 add address IP6Tunnel 2001:470:##:##::2
netsh interface ipv6 add route ::/0 IP6Tunnel 2001:470:##:##::1
```

Juniper JunOS

```
interfaces {
    ip-0/1/0 {
        unit 0 {
            tunnel {
                source ##.##.##.##;
                destination 72.52.##.##;
            }
            family inet6 {
                address 2001:470:##:##::2/64;
            }
        }
    }
}
routin
    rib
        s

    }
}
```

Cisco IOS

```
configure terminal
interface Tunnel0
 description Hurricane Electric IPv6 Tunnel Broker
 no ip address
 ipv6 enable
 ipv6 address 2001:470:##:##::2
 tunnel source ##.##.##.##
 tunnel destination 72.52.##.##
 tunnel mode ipv6ip
ipv6 route ::/0 Tunnel0
end
write
```
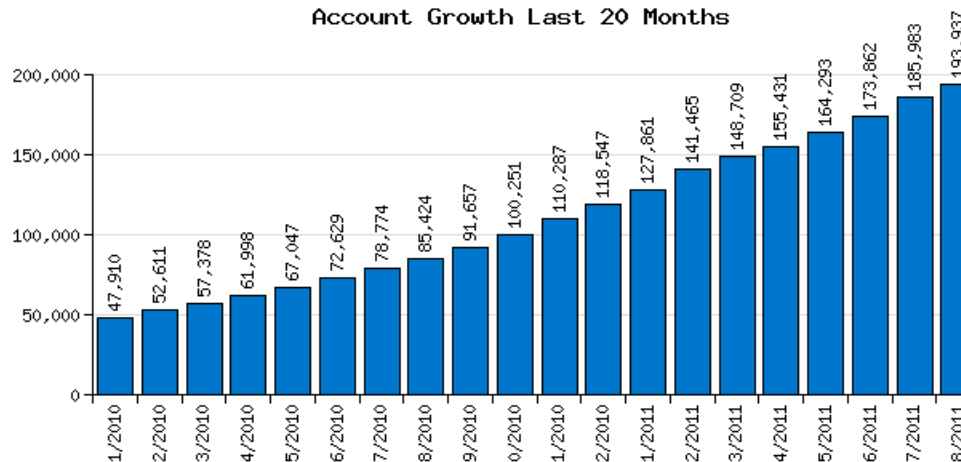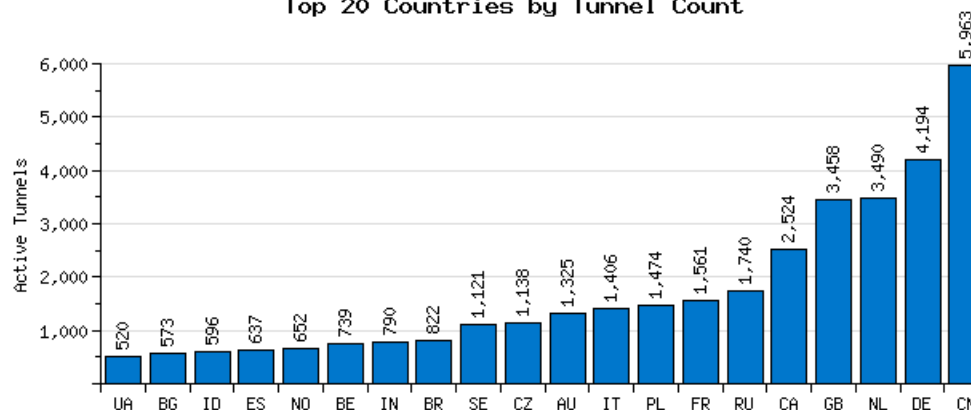
Hurricane Electric – IPv6 tunnelbroker statistics

Country	Users	%
United States	28,523	39.15%
China	5,963	8.18%
Germany	4,194	5.76%
Netherlands	3,490	4.79%
United Kingdom	3,458	4.75%
Canada	2,524	3.46%
Russian Federation	1,740	2.39%
France	1,561	2.14%
Poland	1,474	2.02%
Italy	1,406	1.93%
Australia	1,325	1.82%
Czech Republic	1,138	1.56%
Sweden	1,121	1.54%
Brazil	822	1.13%
India	790	1.08%
Belgium	739	1.01%
Norway	652	0.89%
Spain	637	0.87%
Indonesia	596	0.82%
Bulgaria	573	0.79%
Ukraine	520	0.71%

Account Growth Last 20 Months

47,910 (1/2010), 52,611 (2/2010), 57,378 (3/2010), 61,998 (4/2010), 67,047 (5/2010), 72,629 (6/2010), 78,774 (7/2010), 85,424 (8/2010), 91,657 (9/2010), 100,251 (10/2010), 110,287 (11/2010), 118,547 (12/2010), 127,861 (1/2011), 141,465 (2/2011), 148,709 (3/2011), 155,431 (4/2011), 164,293 (5/2011), 173,862 (6/2011), 185,983 (7/2011), 193,937 (8/2011)

Top 20 Countries by Tunnel Count

Active Tunnels: 520 (UA), 573 (BG), 596 (ID), 637 (ES), 652 (NO), 739 (BE), 790 (IN), 822 (BR), 1,121 (SE), 1,138 (CZ), 1,325 (AU), 1,406 (IT), 1,474 (PL), 1,561 (FR), 1,740 (RU), 2,524 (CA), 3,458 (GB), 3,490 (NL), 4,194 (DE), 5,963 (CN)

More stat's available at: http://tunnelbroker.net/

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Hurricane Electric's Free IPv6 Certification Program

http://ipv6.he.net/certification/

Hurricane Electric – IPv6 Certification (learning?)

- 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 technologies through quick and easy testing
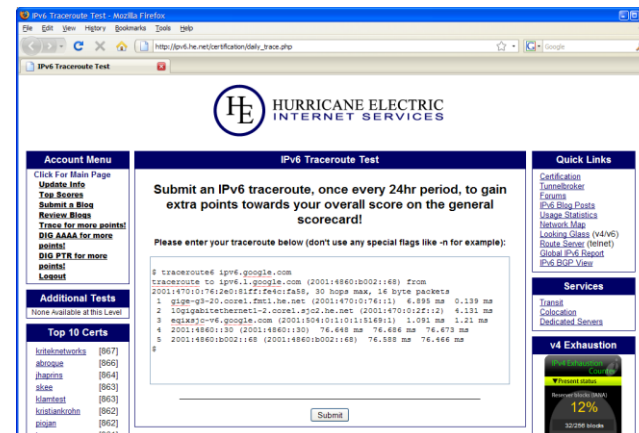
- the format of IPv6 addresses
- AAAA records
- reverse DNS for IPv6
- the IPv6 localhost address
- the IPv6 default route
- the IPv6 documentation prefix
- the IPv6 link local prefix
- the IPv6 multicast prefix
- do an IPv6 ping
- do an IPv6 traceroute
- common IPv6 prefix
- and more!

http://ipv6.he.net/certification/
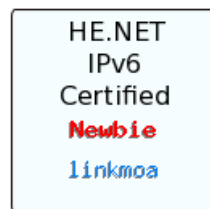
36,500++ Certifications!

NATIVE **IPv6** EVERYWHERE

http://ipv6.he.net/certification/

The test – to send and receive IPv6 emails

Administrator

Congratulations, you are an IPv6 Enthusiast! The next step after geting your website online is to make it so you can receive email via IPv6. What you will need is:

- An IPv6 enabled mail system
- Note: If you have "Greylisting" enabled, either whitelist ipv6@he.net or: send, wait for your greylist timer to expire and then reset and send again. We are working on a better solution to this issue.

[Reset Test]

Step	Description	Data
1	Generate a New User Code	Generated
2	Tell us what your IPv6 capable email address is (Including the domain):	
3	Schedule a test, and we will email you your new User Code	Send It!
4	Tell us what the code was:	–>

Hurricane Electric – IPv6 Certification Levels

Newbie Test
> This is a basic level test of the information here. With this primer at hand these questions should be a snap for you.

Enthusiast Test
> This test validates that you have an IPv6 capable machine setup that can browse the web via IPv6, as well as the fact that you have a web server setup that can serve files via IPv6.

Administrator Test
> This test validates that your SMTP server is able to accept mail over IPv6

Professional Test
> This test validates that Reverse DNS for the IPv6 address of your SMTP server is properly configured.

Guru Test
> This test validates that your nameservers have AAAA records for themselves and that these nameservers can be queried over IPv6 for your domain.

Enthusiast Questionnaire
> These are a few questions to gauge interest and usage level for IPv6 and gather data as to your experiences with IPv6 deployments.

Administrator Questionnaire
> These are a few questions to gauge interest and usage level for IPv6 and gather data as to your experiences with IPv6 deployments.

Professional Questionnaire
> These are a few questions to gauge interest and usage level for IPv6 and gather data as to your experiences with IPv6 deployments.

Guru Questionnaire
> These are a few questions to try to gauge interest and usage level for IPv6 and gather data as to your experiences with IPv6 deployments.

Enthusiast Technical Test
> This test covers technical knowledge of ping and traceroute commands on Linux and Windows.

Administrator Technical Test
> This test covers technical knowledge of DNS and general IPv6 topics.

Professional Technical Test
> This test covers technical knowledge of well known IPv6 prefixes and expands on your understanding of IPv6 related Linux and Windows commands.

Guru Technical Test
> This test covers technical knowledge of IPv6 routing and IPv6 related protocols.

Explorer Test
> This test validates that you have Native or Tunneled IPv6.

Sage Test
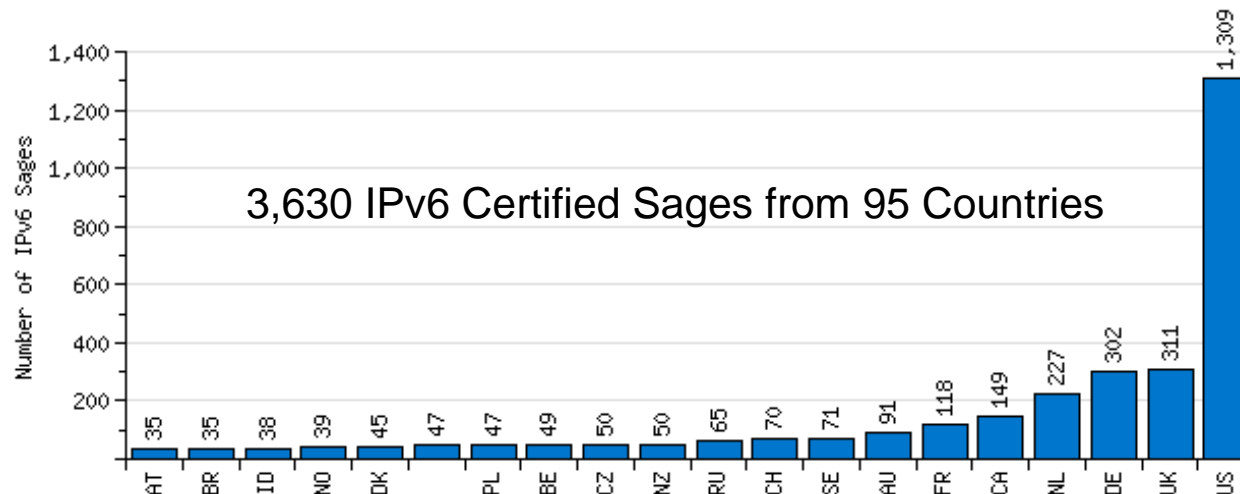> This test validates that you have IPv6 Glue at your registrar

Hurricane Electric – IPv6 Certification – Sages

EU (European Union)	1,474
United States	1,309

Europe	1,684
North America	1,471
South America	61
Asia	207
Africa	16
Oceania	155
Unknown	36
TOTAL	**3,630**

Sage level is the highest level obtainable.

Top 20 IPv6 Sage Countries

3,630 IPv6 Certified Sages from 95 Countries

AT	BR	ID	NO	DK		PL	BE	CZ	NZ	RU	CH	SE	AU	FR	CA	NL	DE	UK	US
35	35	38	39	45	47	47	49	50	50	65	70	71	91	118	149	227	302	311	1,309

http://tunnelbroker.net/usage/sages_by_country_and_state.php

NATIVE IPv6
EVERYWHERE

IPv6 Certification (on a lighter note) …

Motivating people to think about IPv6

… maybe t-shirts will help?

Hurricane Electric – IPv6 and t-shirts?

Hurricane Electric sends email saying "free IPv6 t-shirt" for sage-level users

Certification Tests Taken Last 20 Days

From: <ipv6@he.net>
Date: Thu, May 27, 2010 at 11:32 PM
Subject: Hurricane Electric IPv6 Update

…
* Attention Sages!

Hurricane Electric would like to send you an "IPv6" T-shirt!

Please log into http://ipv6.he.net/certification/, and verify your address information which will only be used for shipping out this T-shirt.

After making certain it is correct (remember to click "Update Info" if you made changes, before validating), you will see T-shirt size selections for S/M/L/XL/XXL, and a button that will submit your preferred shirt size and log that you have validated your address.

This is optional, and will only be sent to validated addresses.

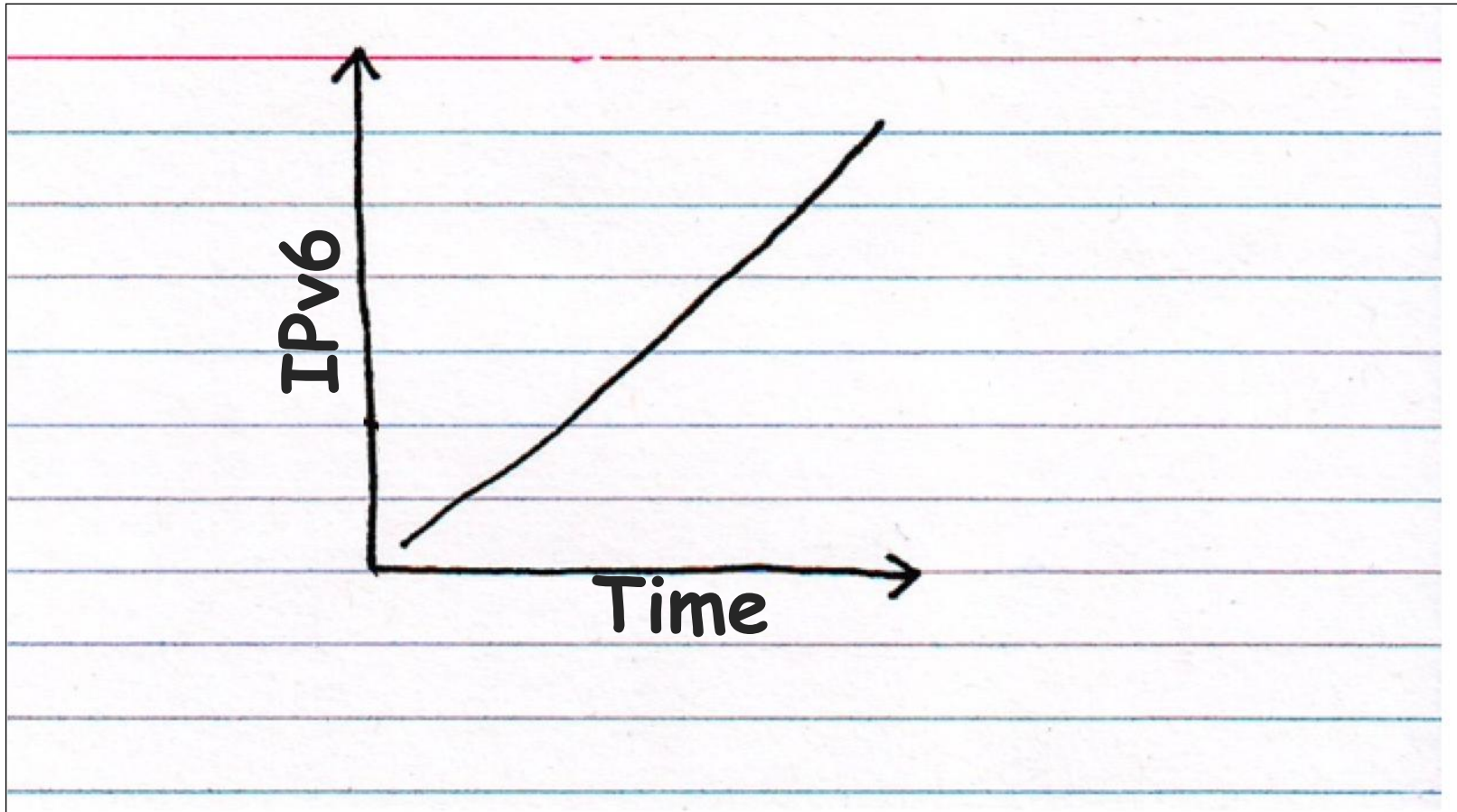We'll be adding on some points to your score for Sages that want to get a T-shirt!

We are looking to get the t-shirts out around the end of June. We need make sure to get enough of each size before sending them out to all of you. …

Hurricane Electric
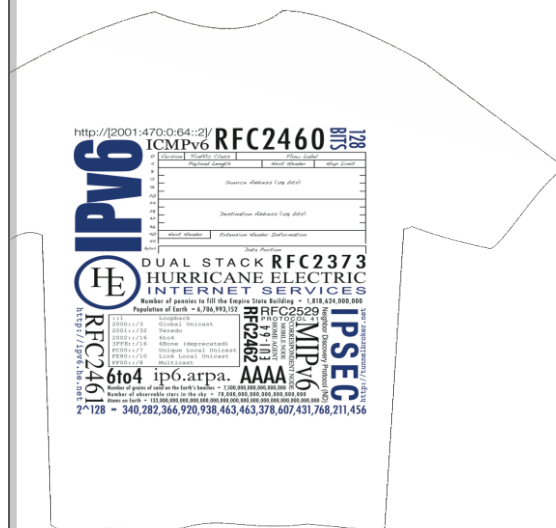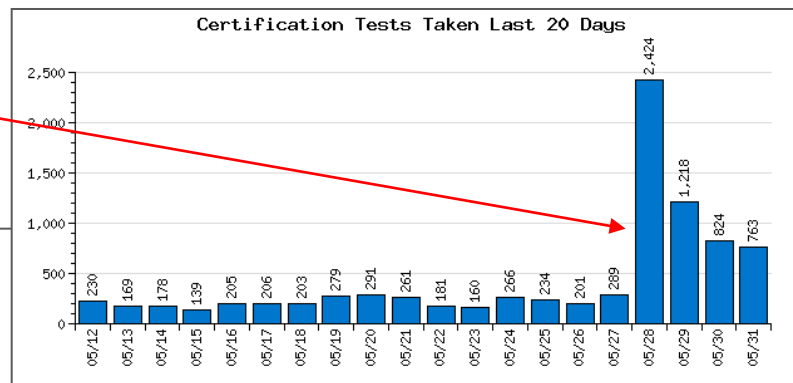
Final thought …

Summary – Have a positive IPv6 mindset

Q&A

?

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