HURRICANE ELECTRIC
INTERNET SERVICES

The State of the Global IPv6 Tables
– A global view of IPv6 routing readiness

Hurricane Electric
IPv6 Native Backbone – Massive Peering!

PLNOG

Warsaw, Poland – 16th March 2011

Martin J. Levy, Director IPv6 Strategy
Hurricane Electric

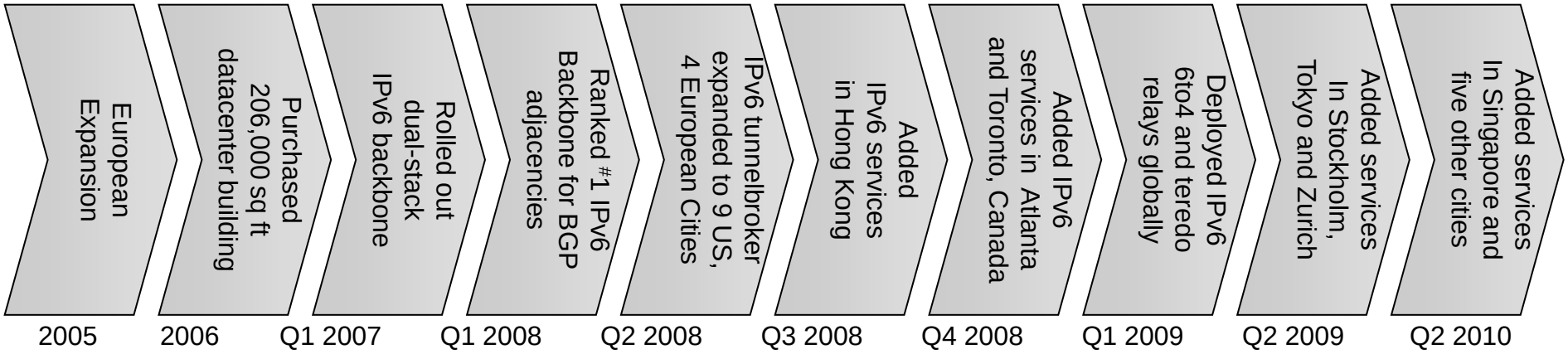
IPv6 Global Connectivity – Talk Outline

- 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?

Hurricane Electric

Hurricane Electric – Roots and History

- Founded 16+ years ago - ISP & datacenter operator
  - Roots within the Silicon Valley high-tech community
  - 1999 – Expanded IPv4 network nationwide
  - 2001 – 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)

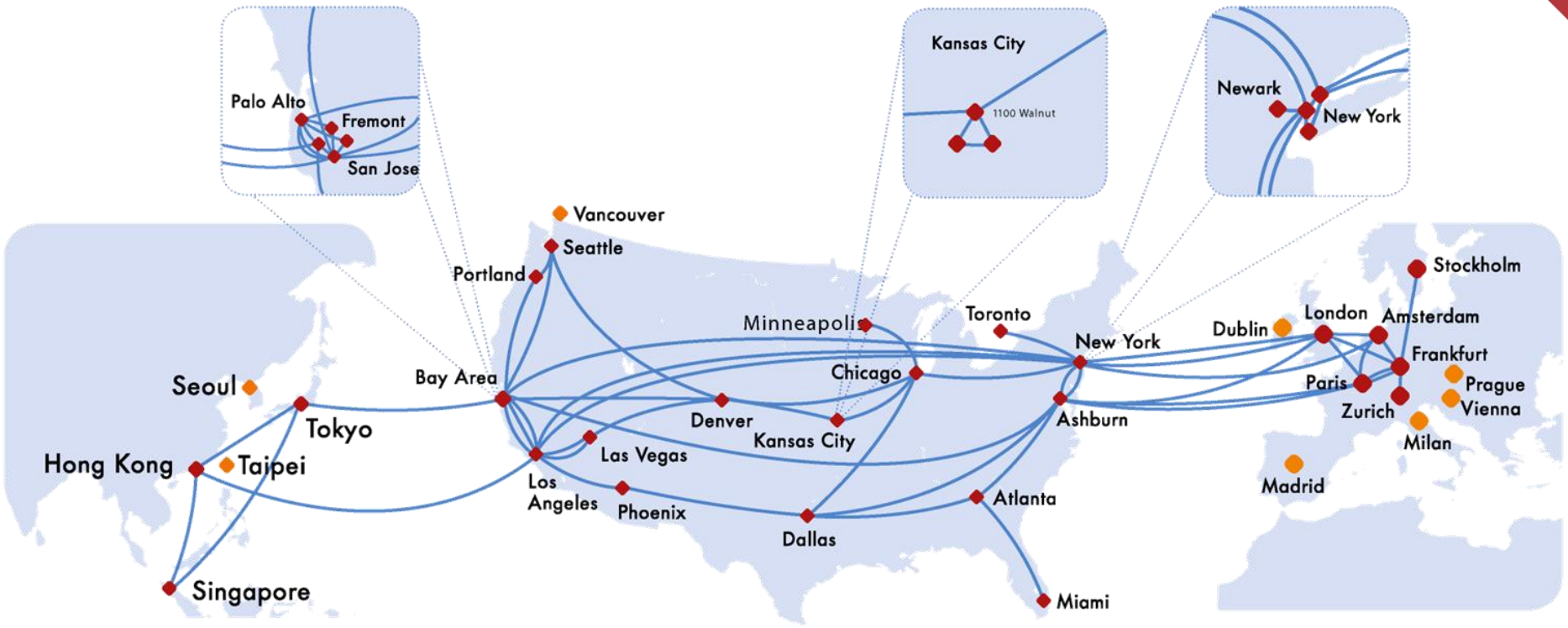


  - 2009 – Continued expansion into Asia; enabled IPv6 6to4 & Teredo service
  - 2010 – Added more geographic coverage; expanded IPv6 6to4 service
  - 2011 – Stop talking about IPv6; just talk about the “Internet”

Hurricane Electric – IPv6 Network Reach

NATIVE IPv6 EVERYWHERE

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

- Four+ years into native IPv6 network deployment
  - Nine+ 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
- IPv6 hosting services

Not just "Joe" on Thursdays

Hurricane Electric – IPv6 Native Services

- 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!

~~Why do we need IPv6?~~

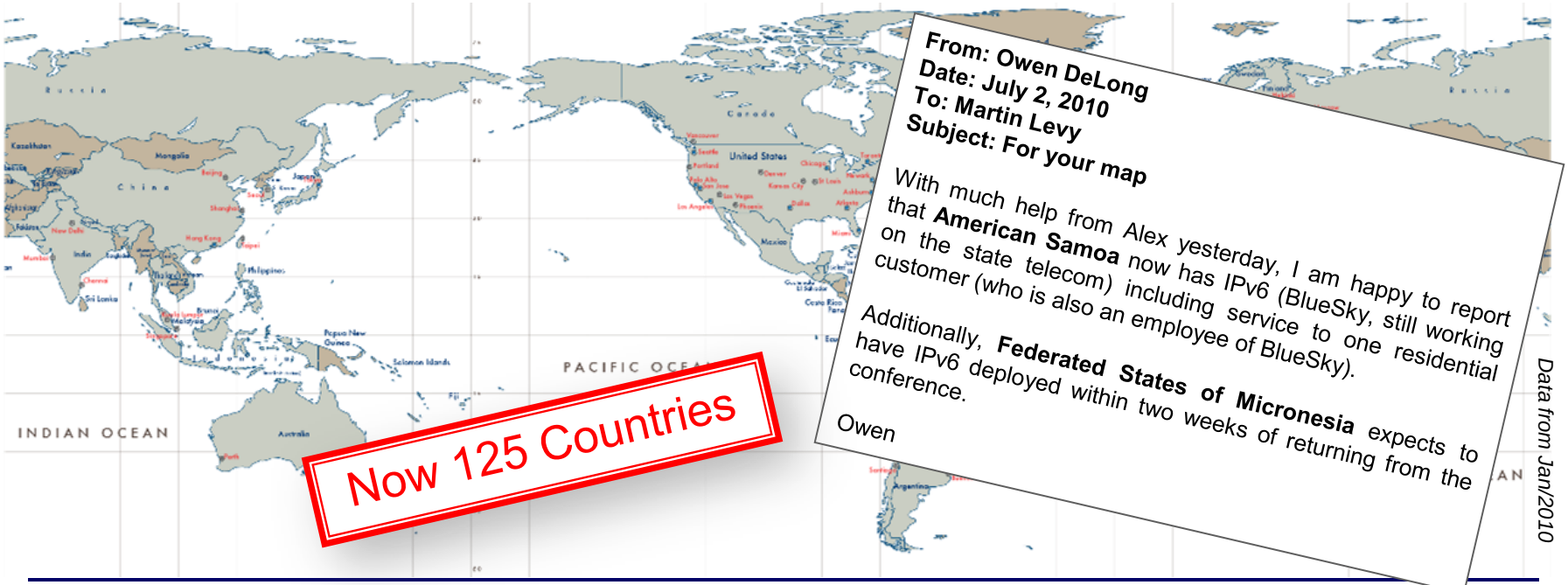
(Just kidding – I'm assuming that!)

Does IPv6 have global coverage?

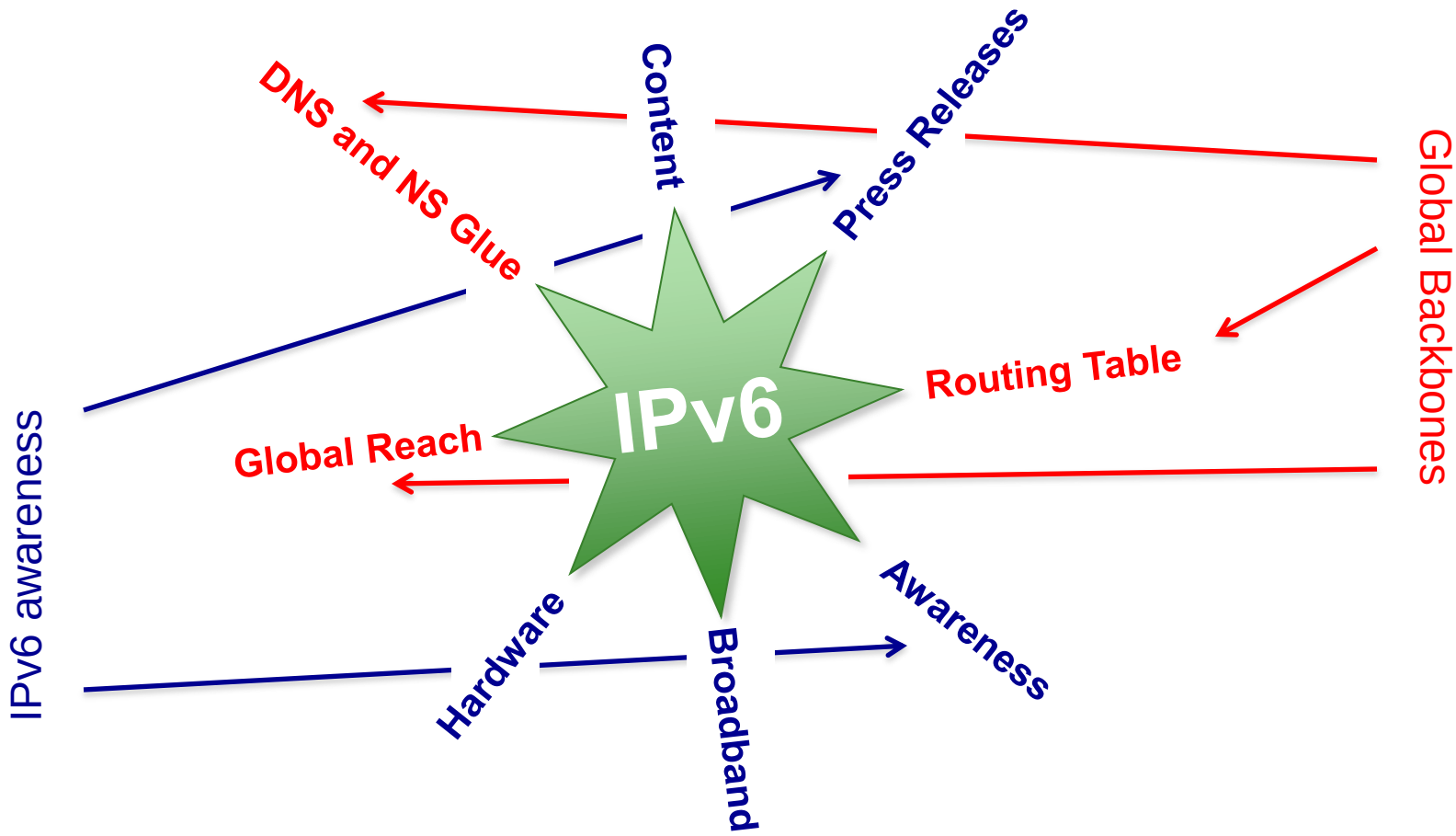
IPv6 and global deployment worldwide

NATIVE IPv6 EVERYWHERE

- IPv6 deployment is everywhere
  - IPv6 active at nearly all global Internet peering points
  - 90+ countries had a “live” IPv6 presence in Jan 2010
  - Now 125 countries

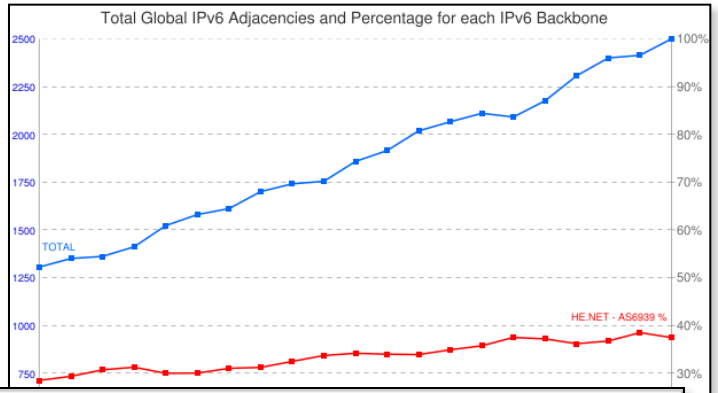


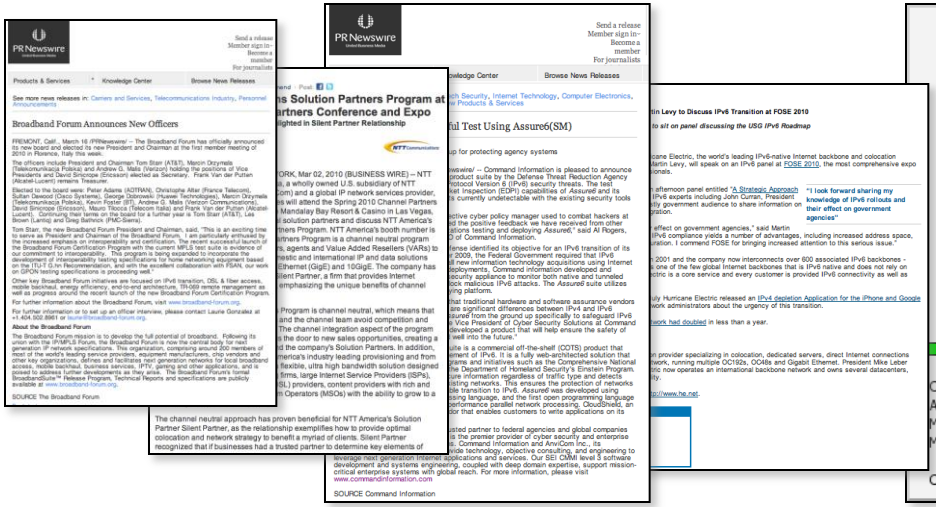
IPv6 and the global backbone story

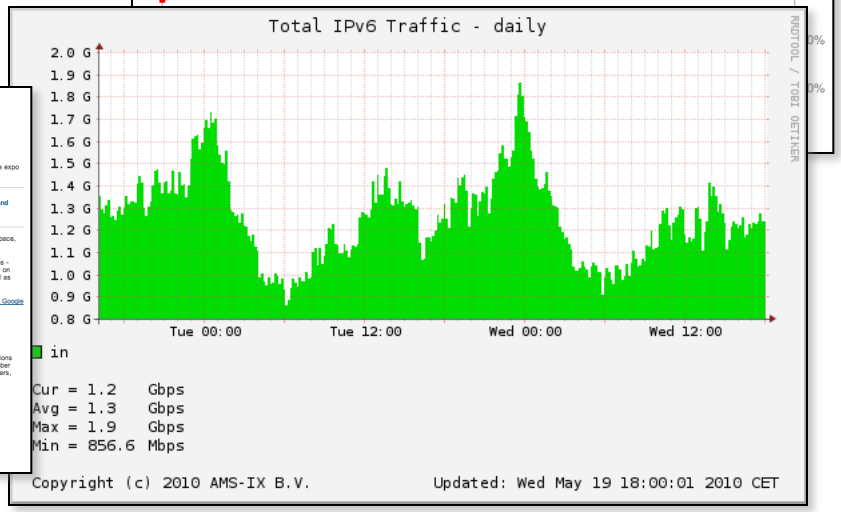


IPv6 deployment can be measured many ways

- 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?

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!

Showing IPv4/IPv6 route propagation in a graphical form

http://bgp.he.net/

Caveat:

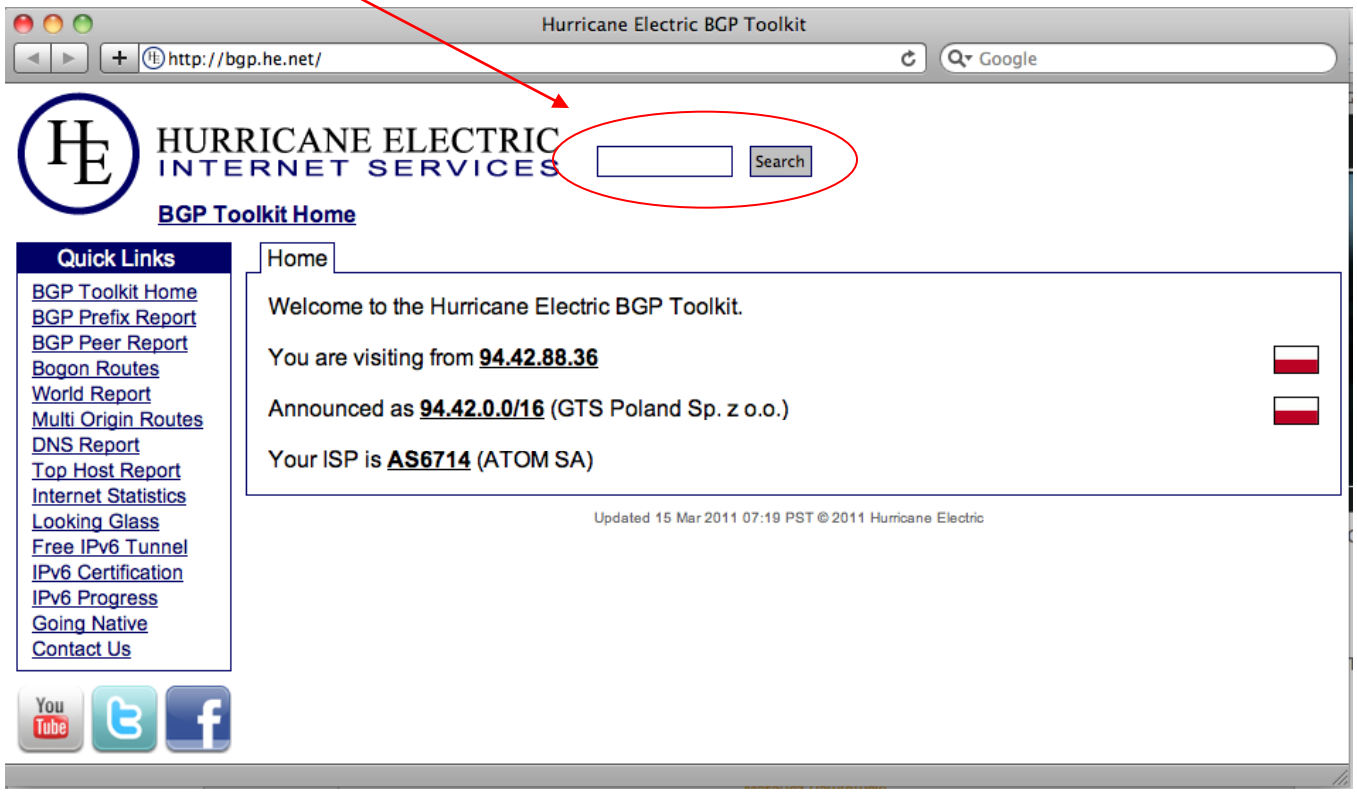
- This tool is only as good as its source data.
- IP information is uploaded from RIPE RIS & Oregon routeviews.
- Some views are missing; not all routes and paths are visible.

- NOT based on the Hurricane Electric routing tables.

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

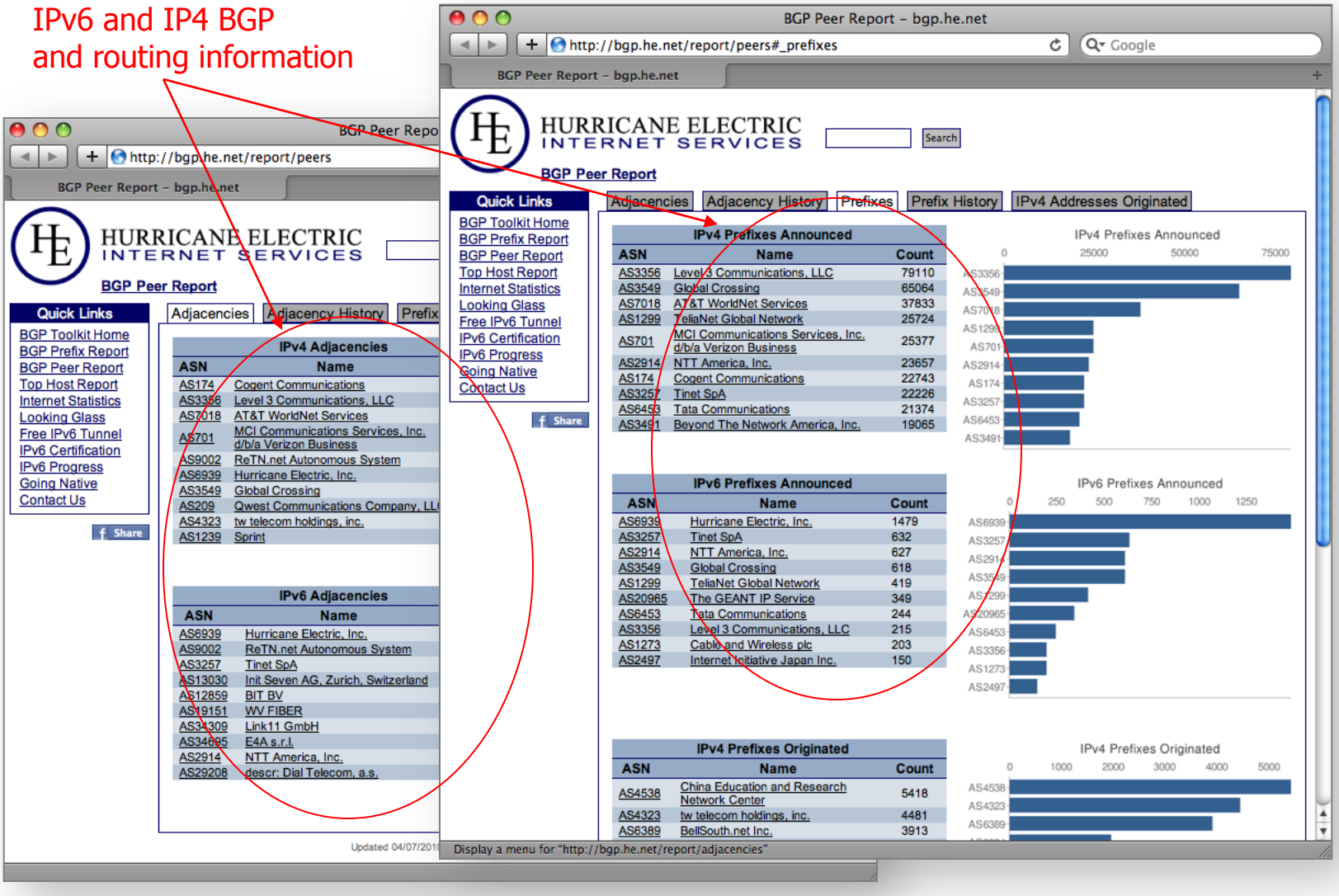
Search command

ASN AS6714
IPv4 address 94.42.88.36
IPv4 block 94.42.0.0/16
IPv6 address 2001:6d8:0:1::a:6
IPv6 block 2001:1a68::/32
DNS name plnog.pl
...etc ...



Example of BGP tools – IPv4/IPv6 statistics

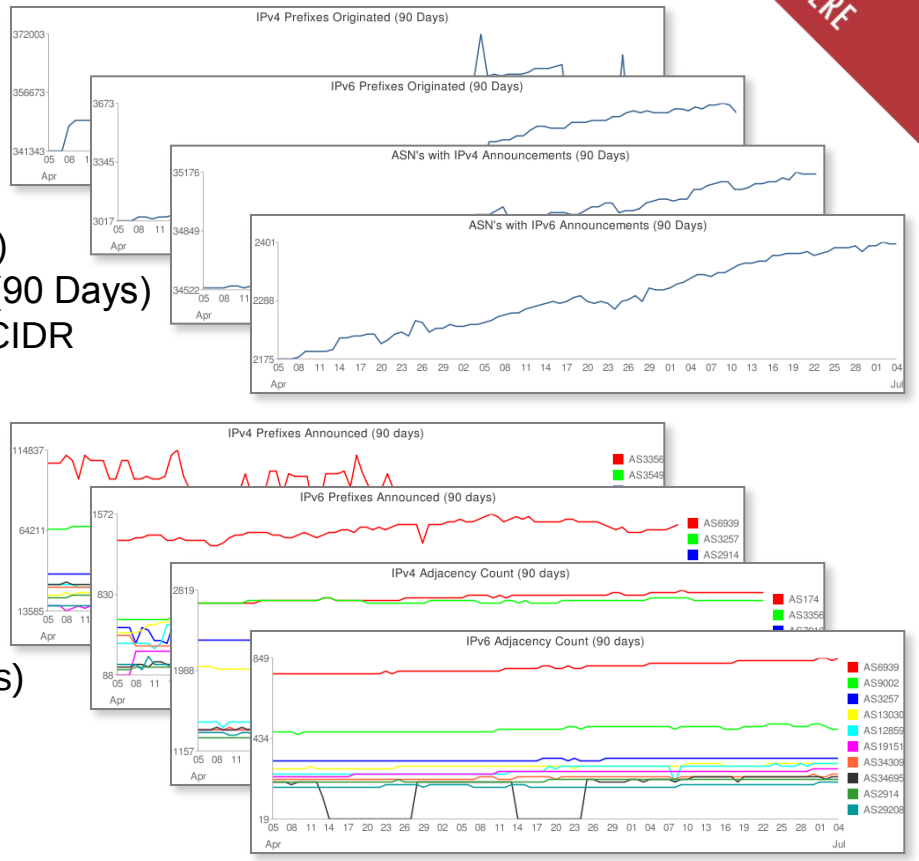
IPv6 and IP4 BGP
and routing information



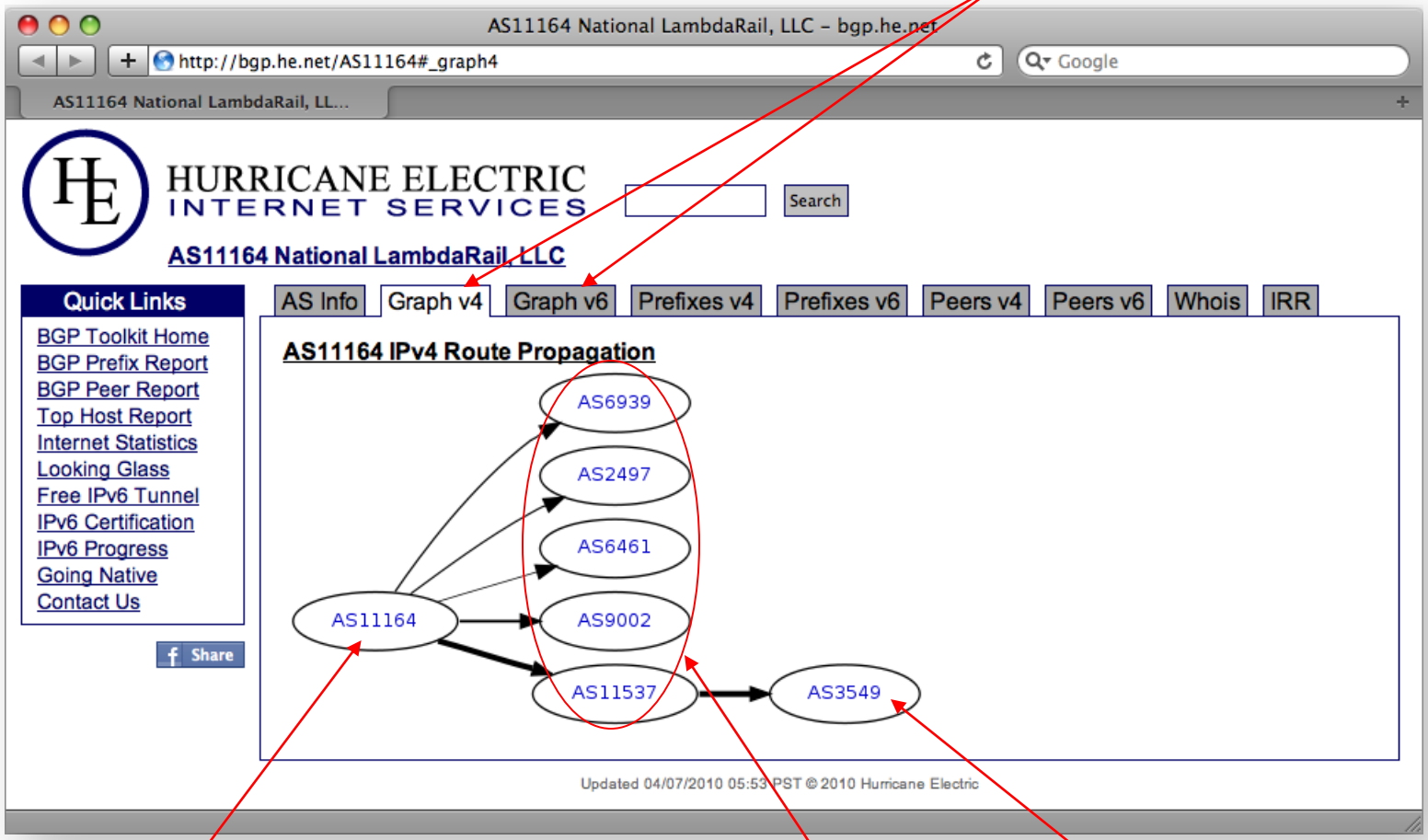
http://bgp.he.net/

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

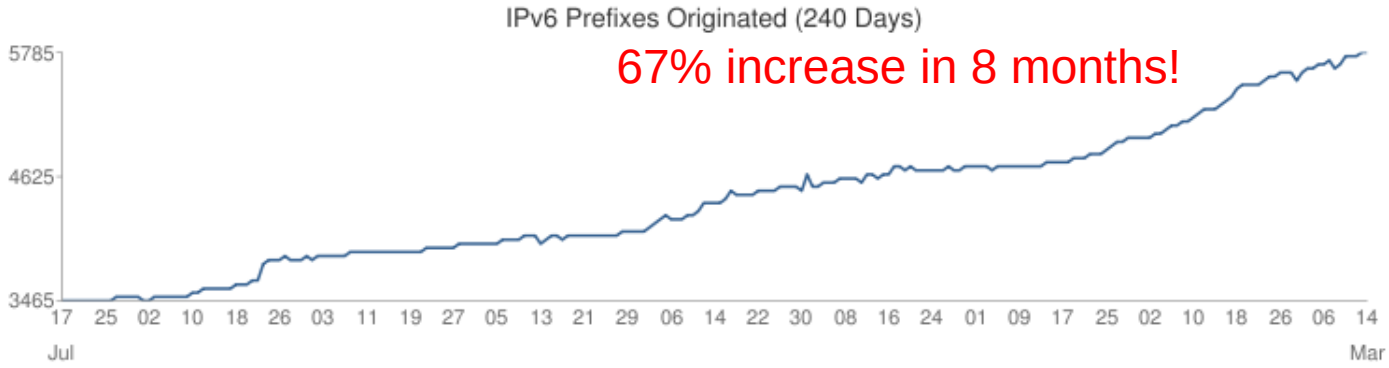
- BGP Prefix Report
  - Prefixes, Networks, Distribution
    - IPv4/IPv6 Prefixes Originated (90 Days)
    - ASN's with IPv4/IPv6 Announcements (90 Days)
    - IPv4/IPv6 Announced Prefix Count by CIDR
- BGP Peer Report
  - Adjacencies, Adjacency History
    - IPv4/IPv6 Adjacencies
    - IPv4/IPv6 Adjacency 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



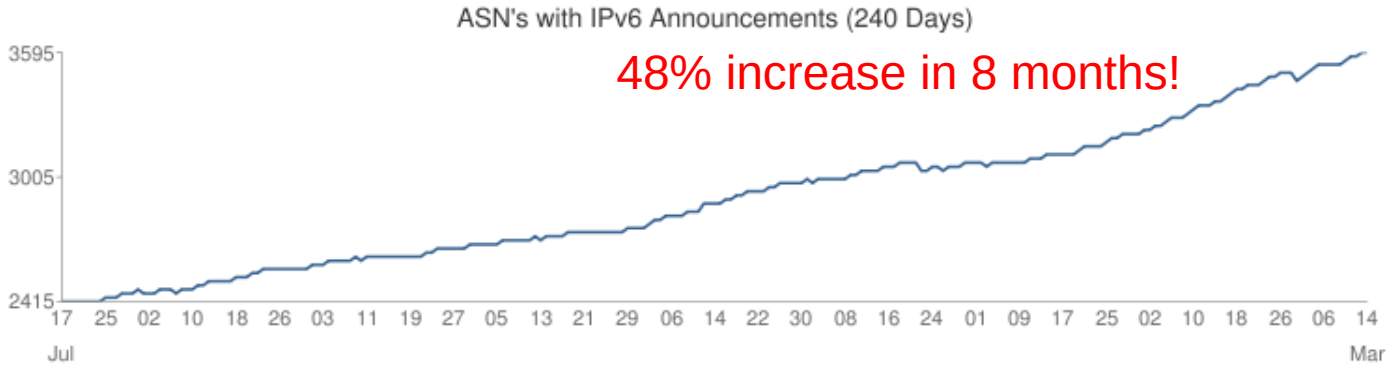
http://bgp.he.net/ – Route propagation graphs



Is IPv6 routing/interconnections/peering prevalent?



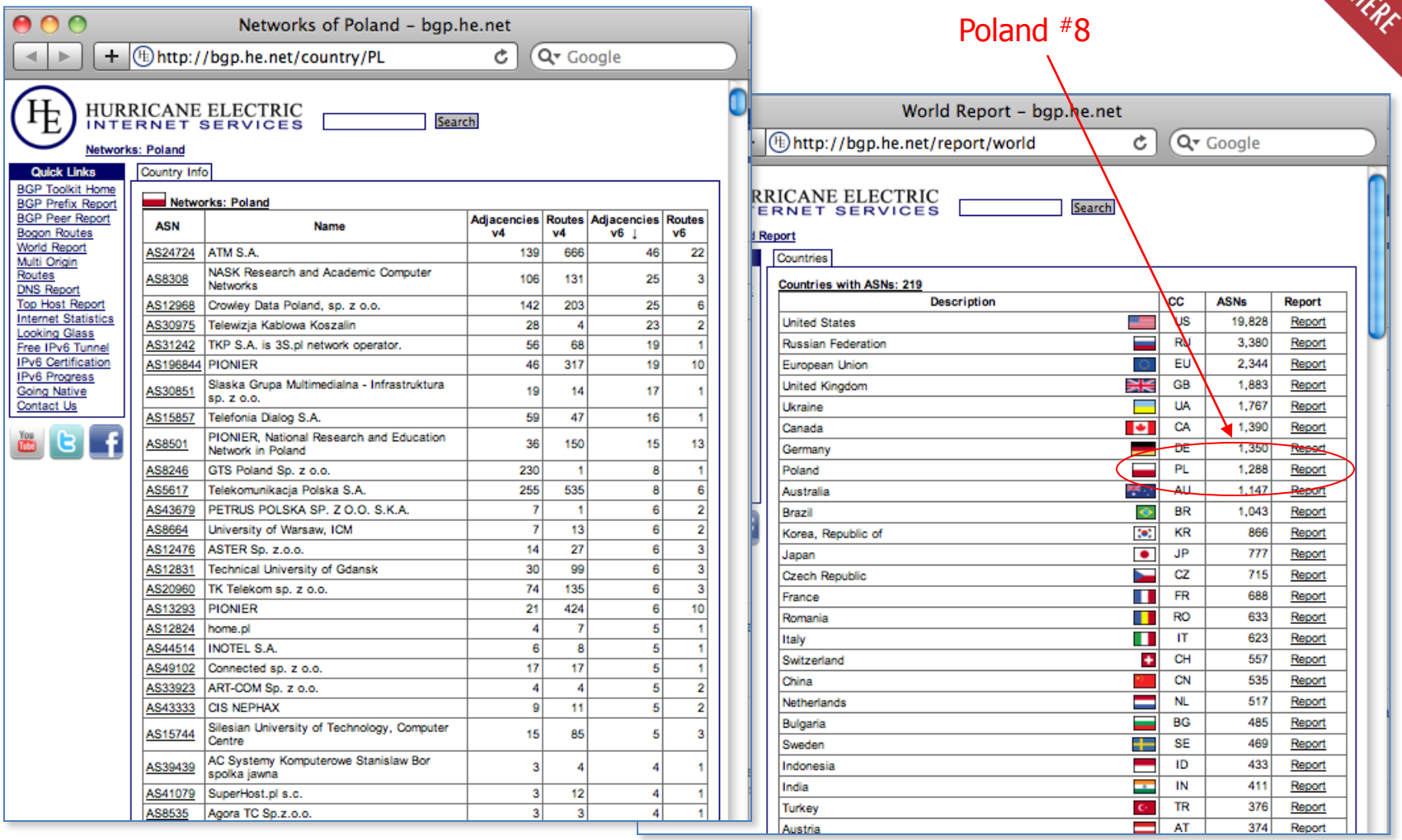
http://bgp.he.net/report/prefixes#_prefixes



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

Simple conclusion #1 – “up and to the right”

Is IPv6 alive and kicking in Poland?

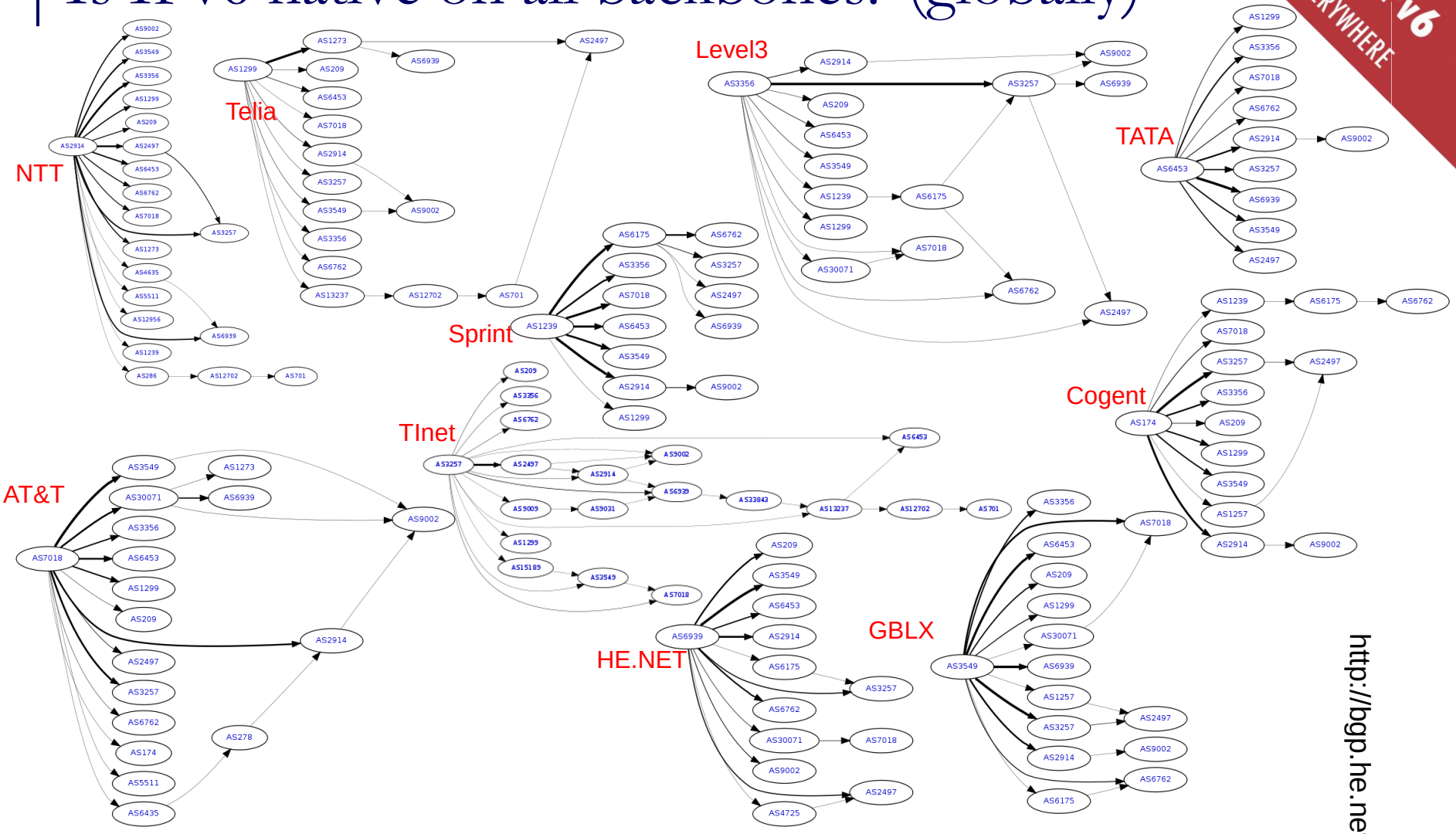


http://bgp.he.net/country/PL

http://bgp.he.net/report/prefixes#_countriesv6

However only 90 ASNs have IPv6 enabled (out of 1,288)

Is IPv6 native on all backbones? (globally)



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

IPv6 routing on backbones (the summary)

- Classic backbones have (finally) got IPv6
  - This is not news to a savvy IPv6 crowd!
  - The last "*tier1 backbone*" only-recently enabled IPv6
- 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!

Hurricane Electric's IPv6 Tunnelbroker

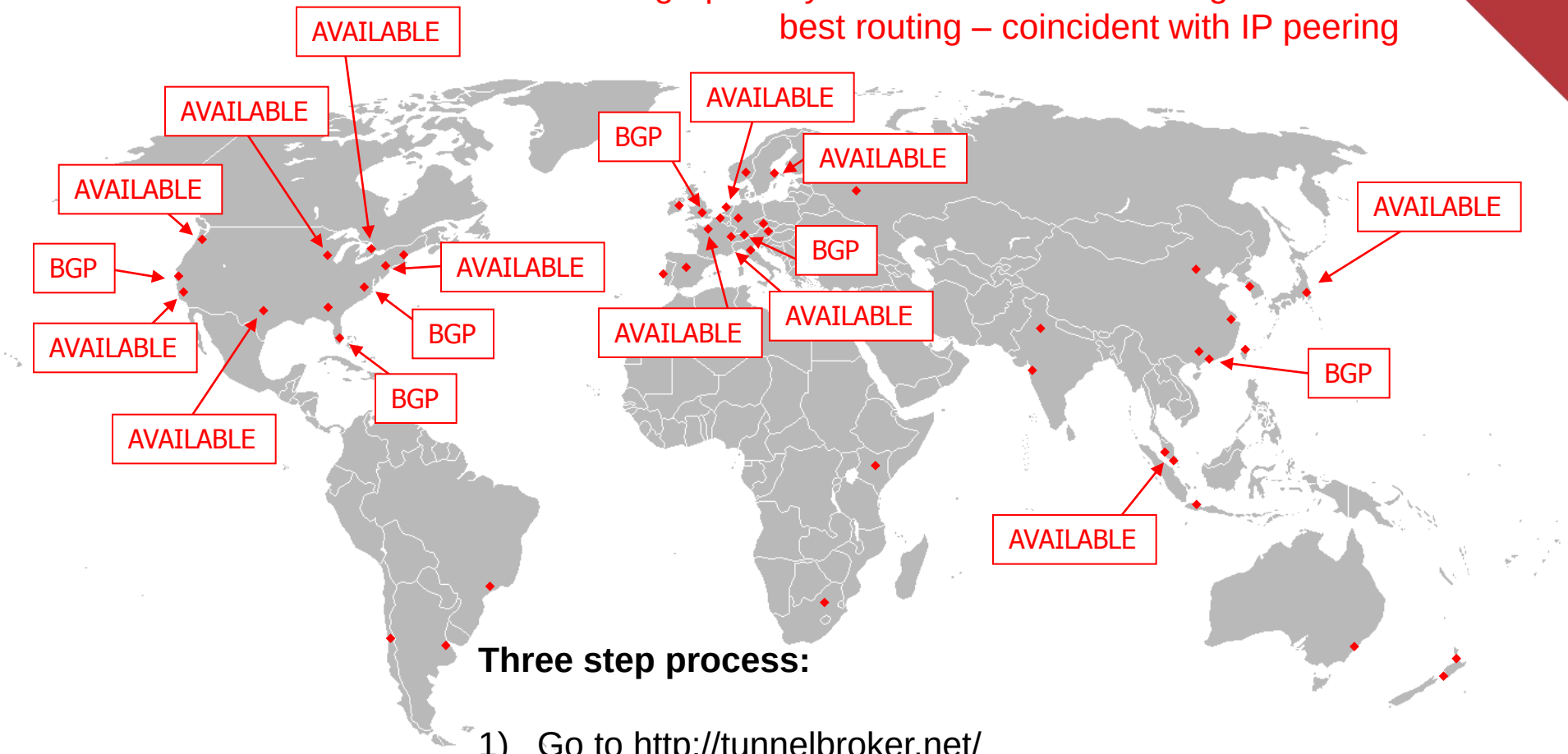
http://tunnelbroker.net/

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

Hurricane Electric – IPv6 tunnelbroker.net

Native IPv6 Everywhere

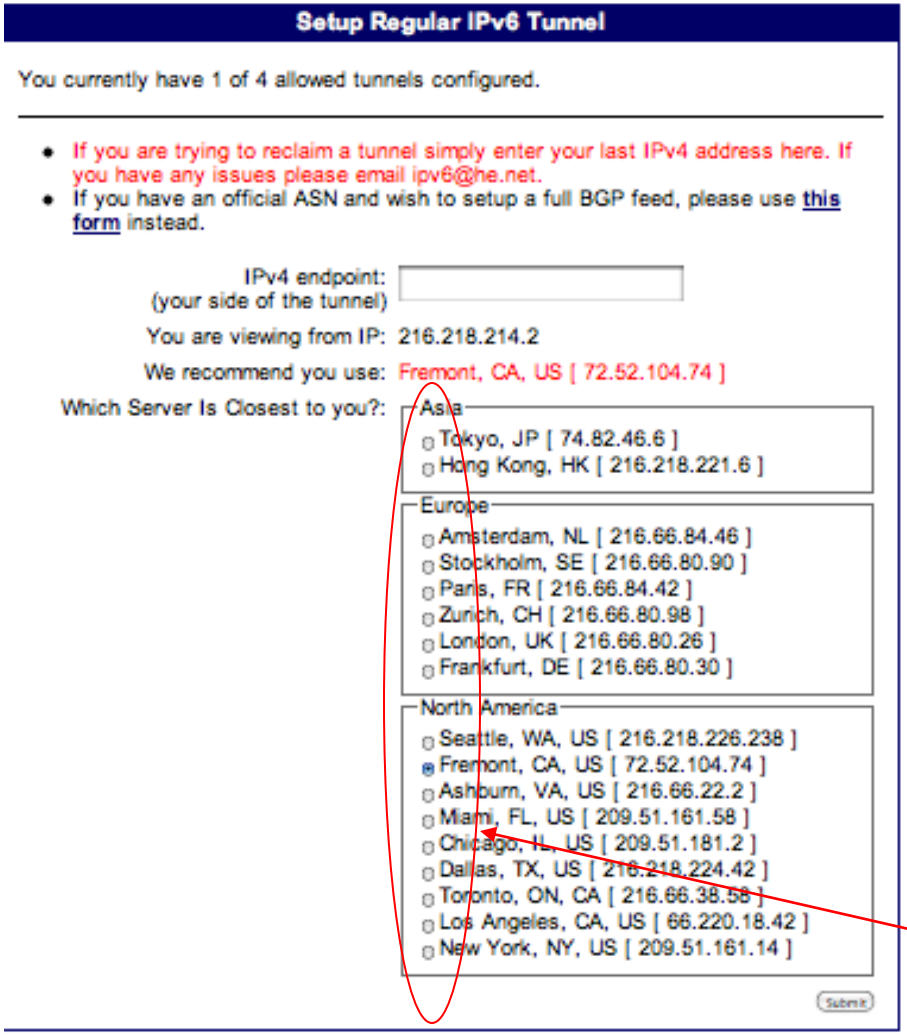
Geographically diverse locations allowing customers best routing – coincident with IP peering



Three step process:

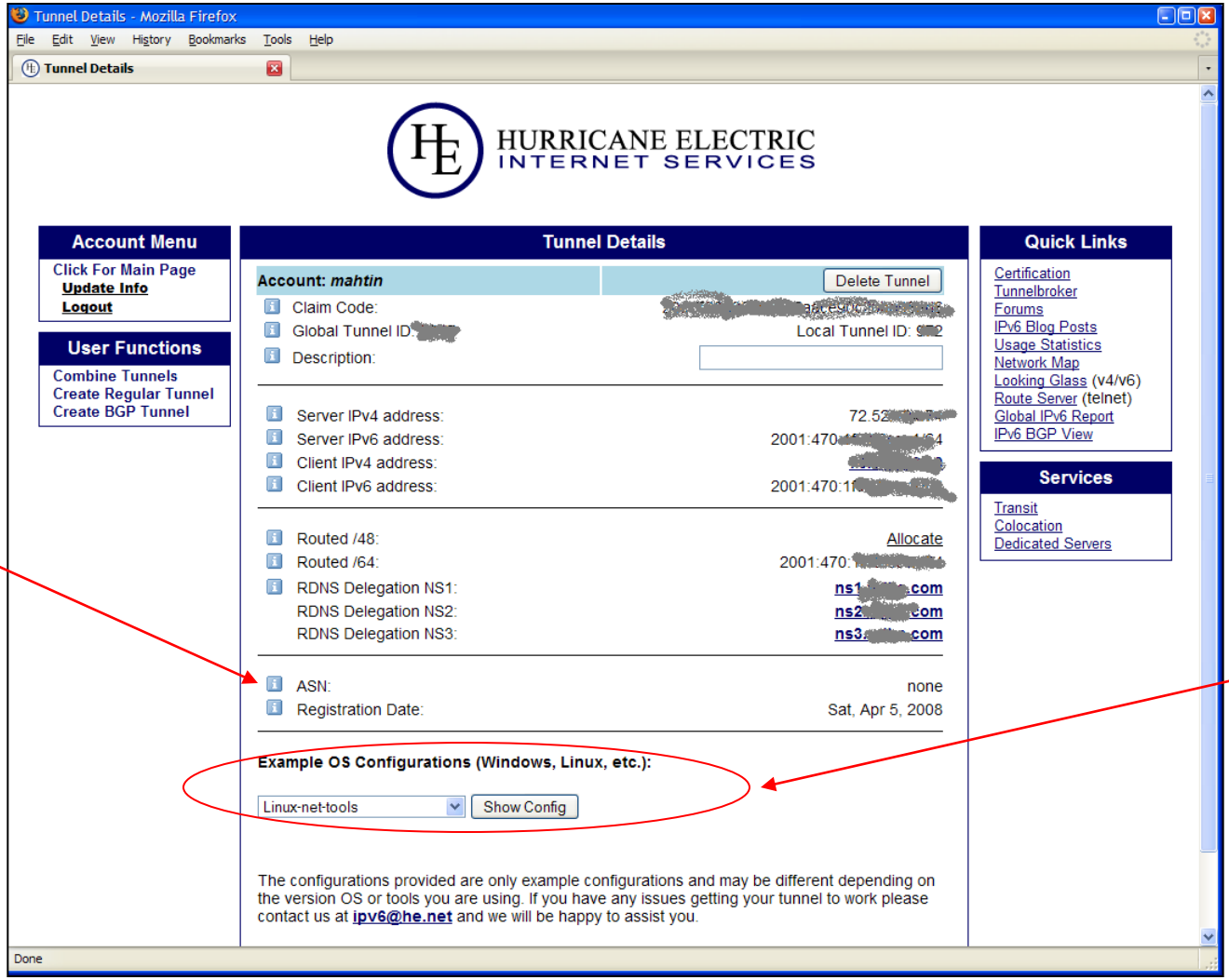
1) Go to http://tunnelbroker.net/
2) Setup an account – choose a location
3) Setup your own host or router to allow tunnels

Hurricane Electric – IPv6 tunnelbroker.net setup



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 & Windows 7

```
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

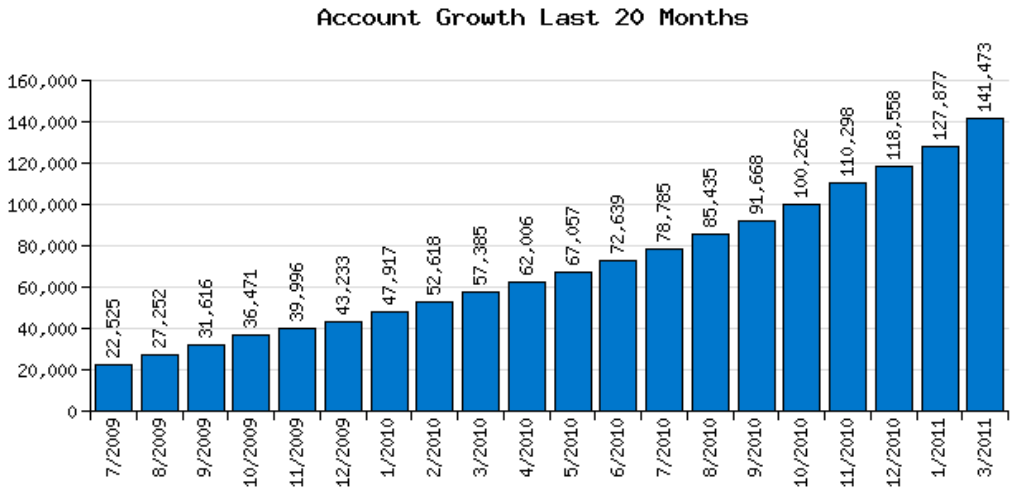
```
interfaces {
    ip-0/1/0 {
        unit 0 {
            tunnel {
                source ##.##.##.##;
                destination 72.52.##.##;
            }
            family inet6 {
                address 2001:470:##:##::2/64;
            }
        }
    }
}
routin
    rib
        s
        }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

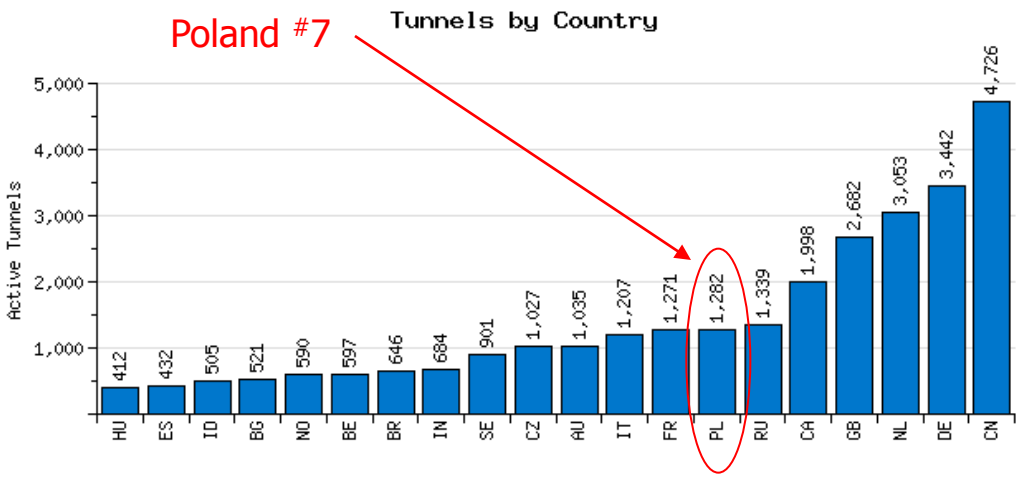
Cisco IOS

```
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.net stats

Country	Users	%
United States	21,887	38.00 %
China	4,726	8.20 %
Germany	3,442	6.00 %
Netherlands	3,053	5.30 %
United Kingdom	2,682	4.60 %
Canada	1,998	3.50 %
Russian Federation	1,339	2.30 %
Poland	1,282	2.20 %
France	1,271	2.20 %
Italy	1,207	2.10 %
Australia	1,035	1.80 %
Czech Republic	1,027	1.80 %
Sweden	901	1.60 %
India	684	1.20 %
Brazil	646	1.10 %
Belgium	597	1.00 %
Norway	590	1.00 %
Bulgaria	521	0.90 %
Indonesia	505	0.87 %
Spain	432	0.75 %
Hungary	412	0.71 %
Ukraine	403	0.70 %
Slovenia	388	0.67 %
Switzerland	360	0.62 %
Romania	337	0.58 %
Austria	298	0.52 %
Japan	283	0.49 %
Hong Kong	282	0.49 %





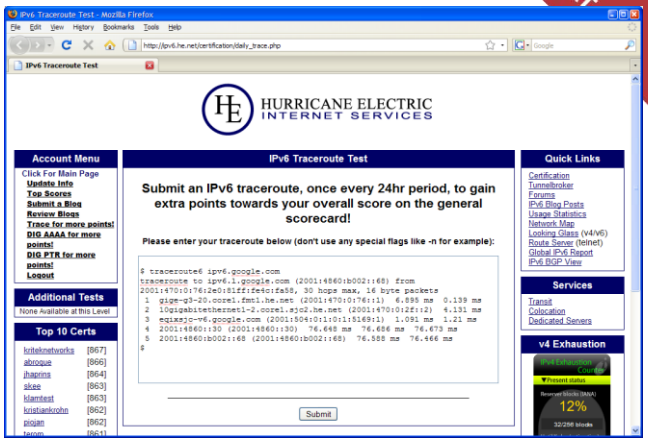
Stats available at: http://tunnelbroker.net/

Hurricane Electric's Free IPv6 Certification Program

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

Hurricane Electric – IPv6 Certification (and 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!

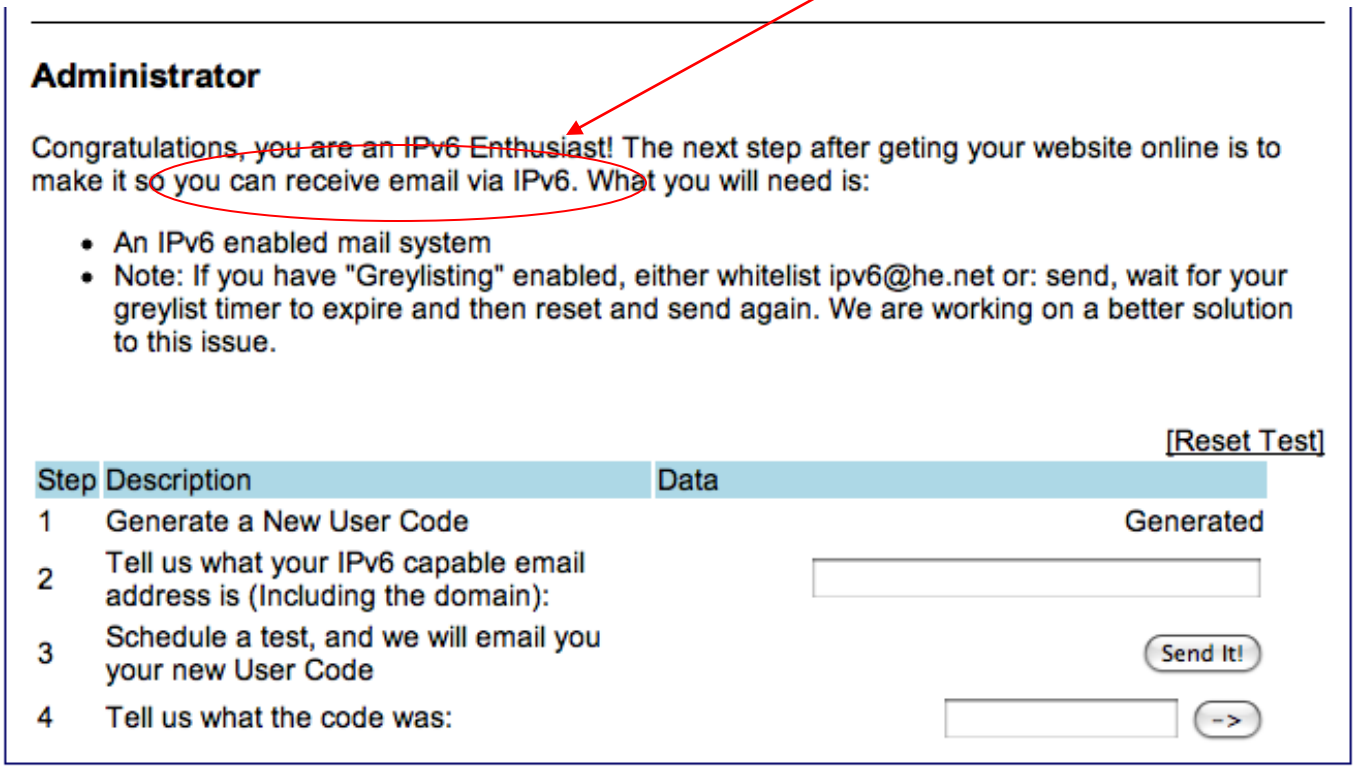
http://ipv6.he.net/certification/

28,500++ Certifications!

Hurricane Electric – IPv6 Certification (sample test)

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.

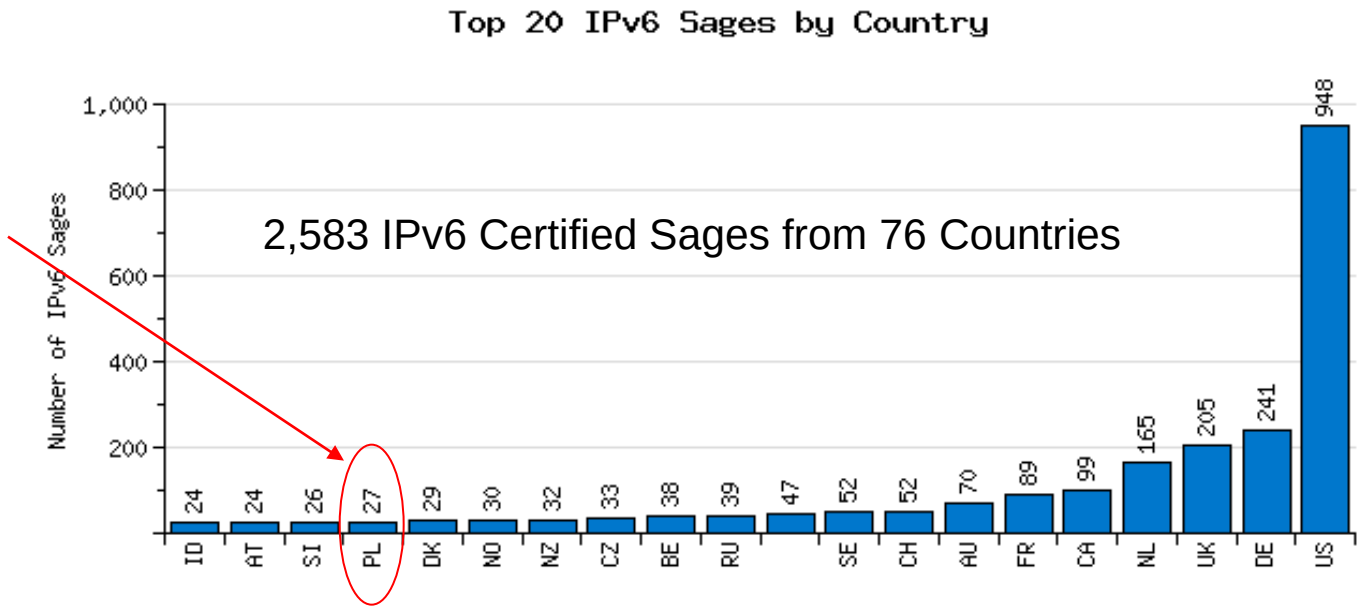
Sage Test
This test validates that you have IPv6 Glue at your registrar

Hurricane Electric – IPv6 Certification – Sages

EU (European Union)	1,051
United States	948

Europe	1,202
North America	1,057
South America	39
Asia	125
Africa	8
Oceania	105
Unknown	47
TOTAL	2,583

Poland #17



Sage level is the highest level obtainable.

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

Summary

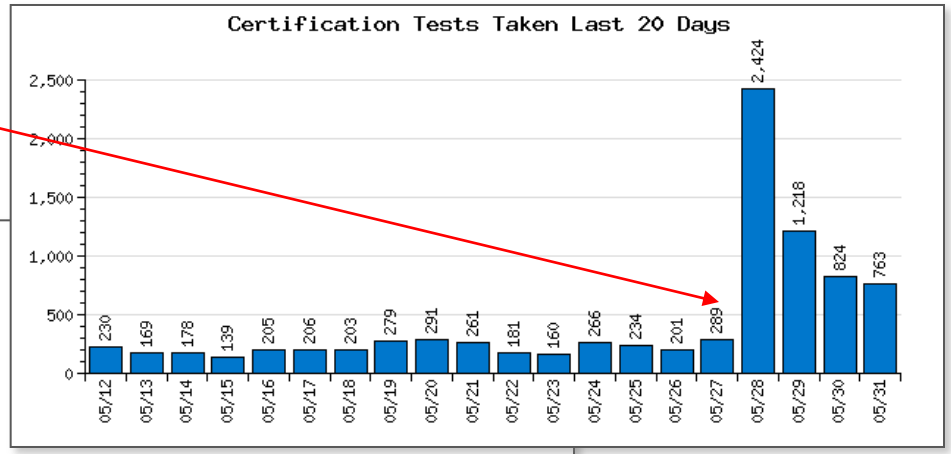
IPv6 certification (on a lighter note) …

Motivating people to think about IPv6

… maybe t-shirts will help?

Summary – IPv6 certifications and t-shirts

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



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.

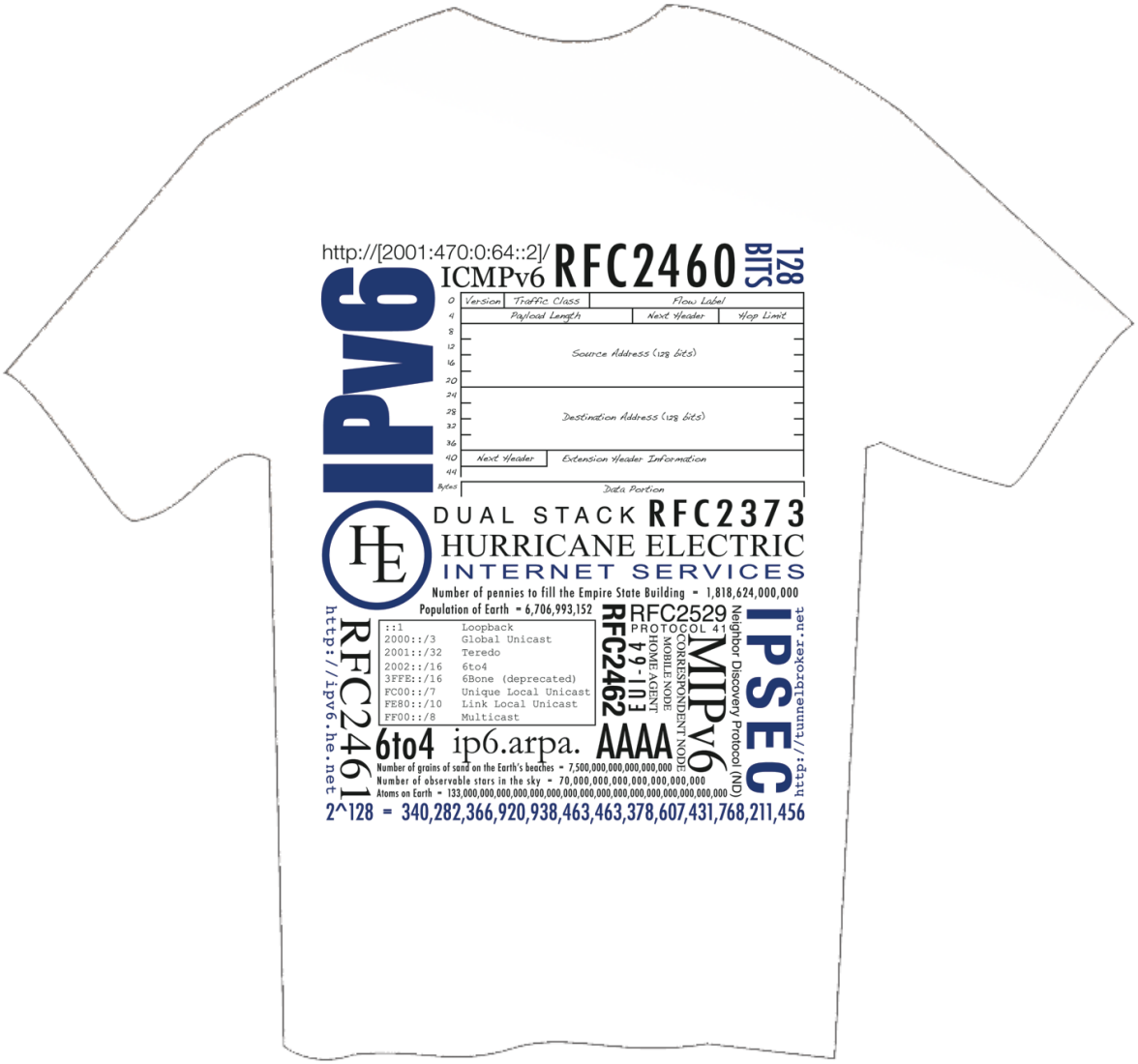
After making certain it is correct (remember to click "Update Info" if you made changes, before validating), you will see T-shirt size selections for S/M/L/XL/XXL, and a button that will submit your preferred shirt size and log that you have validated your address.

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. …

Summary – IPv6 certifications and t-shirts



Hurricane Electric - Exhaustion Counters

Finally. Maybe this will help convince someone important…

Exhaustion Counters

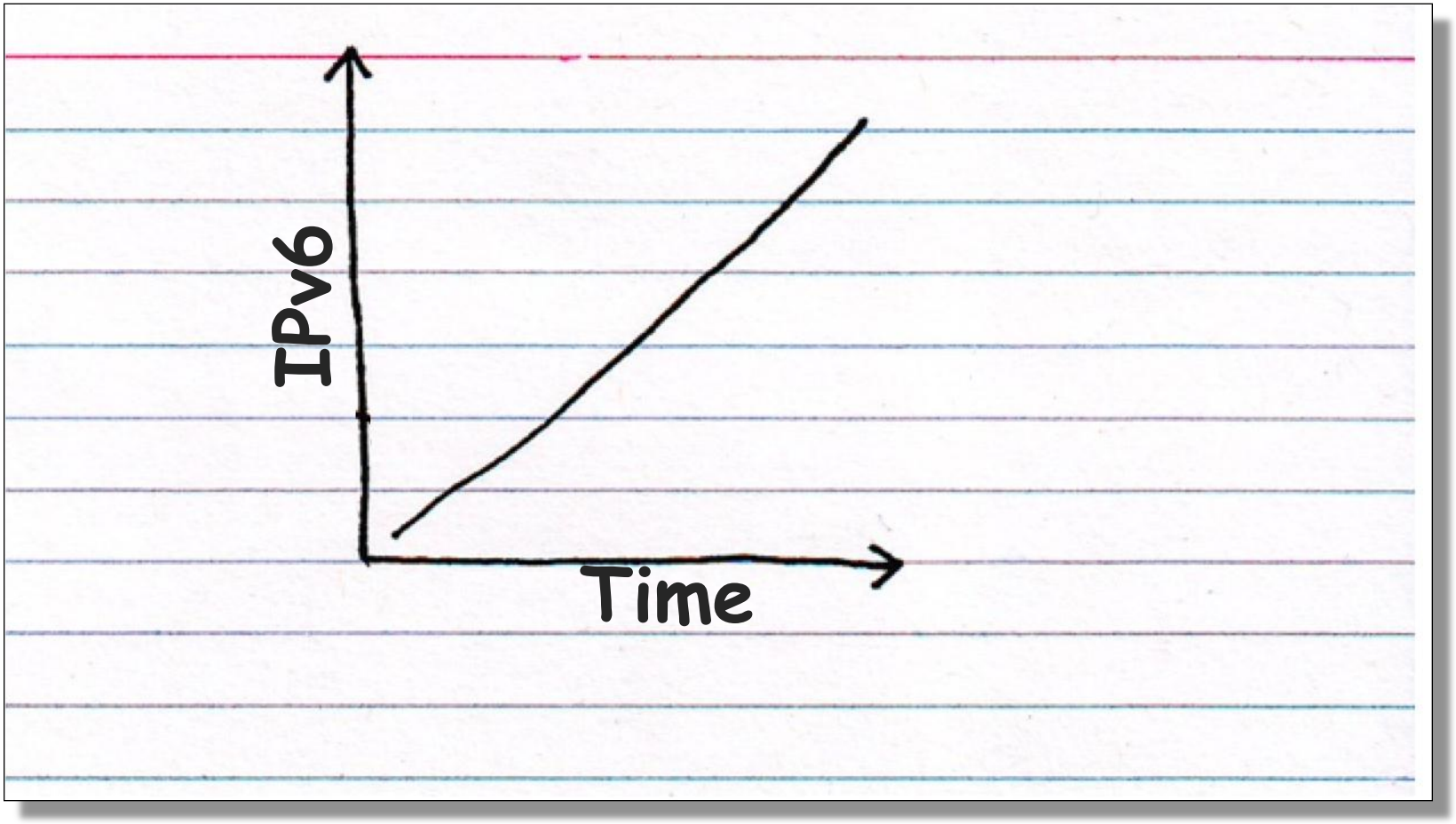
http://ipv6.he.net/statistics/

Hurricane Electric IPv4 Exhaustion Counters

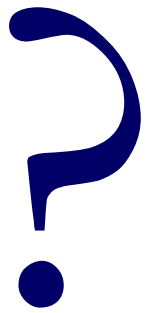
http://ipv6.he.net/statistics/

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

Summary – Have a positive IPv6 mindset



Q&A



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