No more IPv4
Impact on applications and measuring IPv6 deployment

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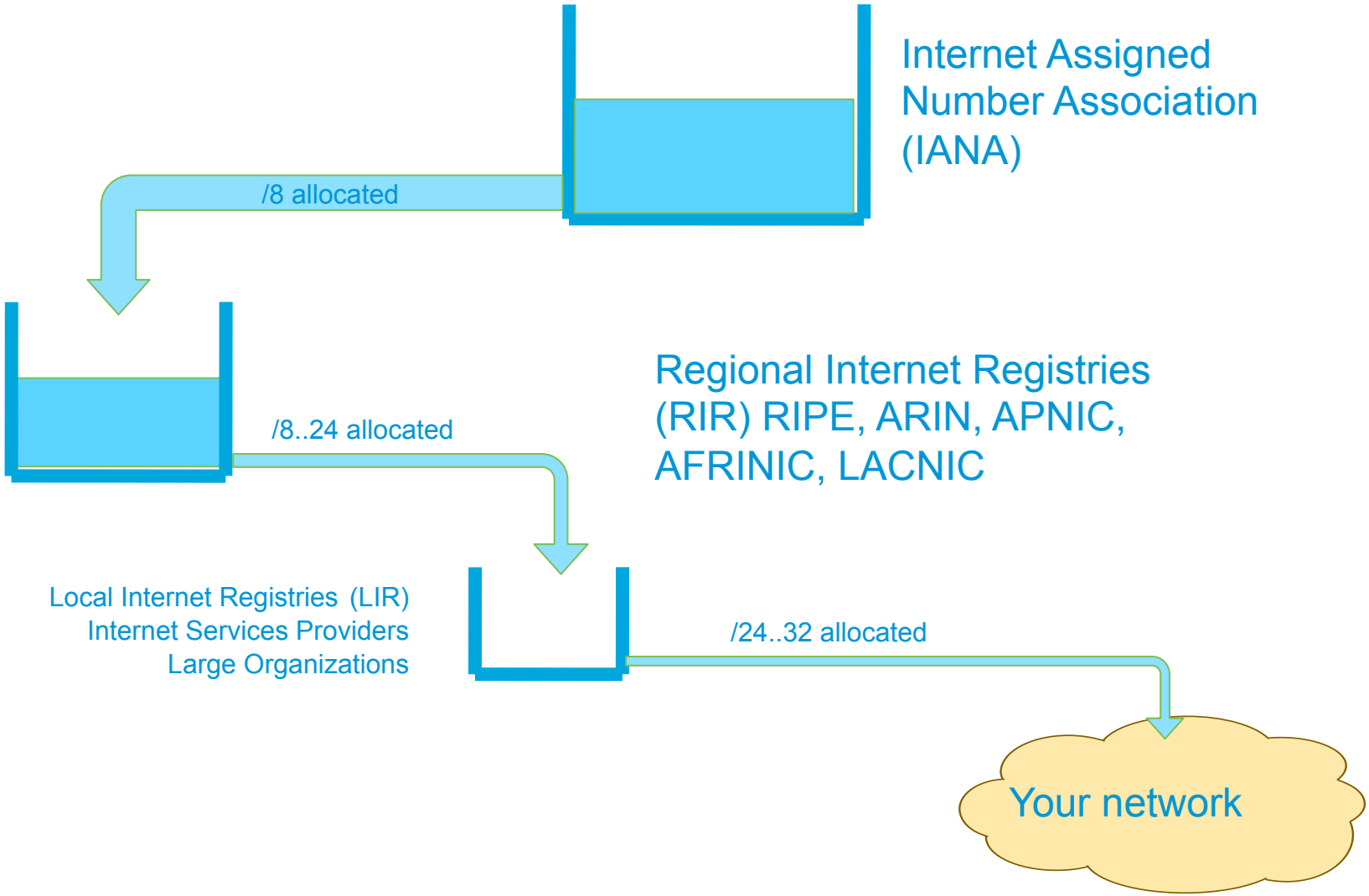
PGP fingerprint = F2CB F935 6F18 1A1E A274 6359 77FA 1A2D 30F9 E979

February 2014

A Word About IPv4 Address Allocation



No Doubt Anymore: I

APNIC IPv4 Address Pool Reaches Final /8

Published on: Friday, 15 April 2011

ish to inform you that as of Friday, 15 April 2011, the APNIC pool reached the Final /8 IPv4
ss block, bringing us to Stage Three of IPv4 exhaustion in the Asia Pacific.

/8 address policy

equests will now be assessed under section 9.10 in "Policies for IPv4 address space
gement in the Asia Pacific region".

's objective during Stage Three is to provide IPv4 address space for new entrants to the
t and for those deploying IPv6.

now, all new and existing APNIC account holders will be entitled to receive a maximum
tion of a /22 from the Final /8 address space.

NOW on IPv6

courage Asia Pacific Internet community members to deploy IPv6 within their organizations.
an refer to APNIC for information regarding IPv6 deployment, statistics, training, and related
al policies.

been anticipating for quite some time," states Raúl Echeberría,
presentative of the five RIRs. "The future of the Internet is in IPv6.
."

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14 September 2012 Last updated at 15:08 GMT

Share

Europe hits old internet address limits

By Mark Ward
Technology correspondent, BBC News

Europe has almost exhausted its stock of old-style internet addresses.

Strict rationing of these addresses - called IPv4 - has been started by the body that hands them out in Europe.

From now on, companies can only make one more application for IPv4 addresses and, if successful, will only get 1,024 of them.

In addition, any application for more old addresses must demonstrate how an organisation is using the new, replacement, addressing scheme.

Europe's stock of old-style net addresses has effectively run dry.

Impact on Internet Connectivity

- 3 approaches currently worked on by SP

  Dual-stack: SP allocates both IPv4 and IPv6 global addresses to his subscribers

  Shared IPv4 address: SP relies on NAT in his network to share a couple of global IPv4 addresses and allocates private IPv4 addresses to his subscriber

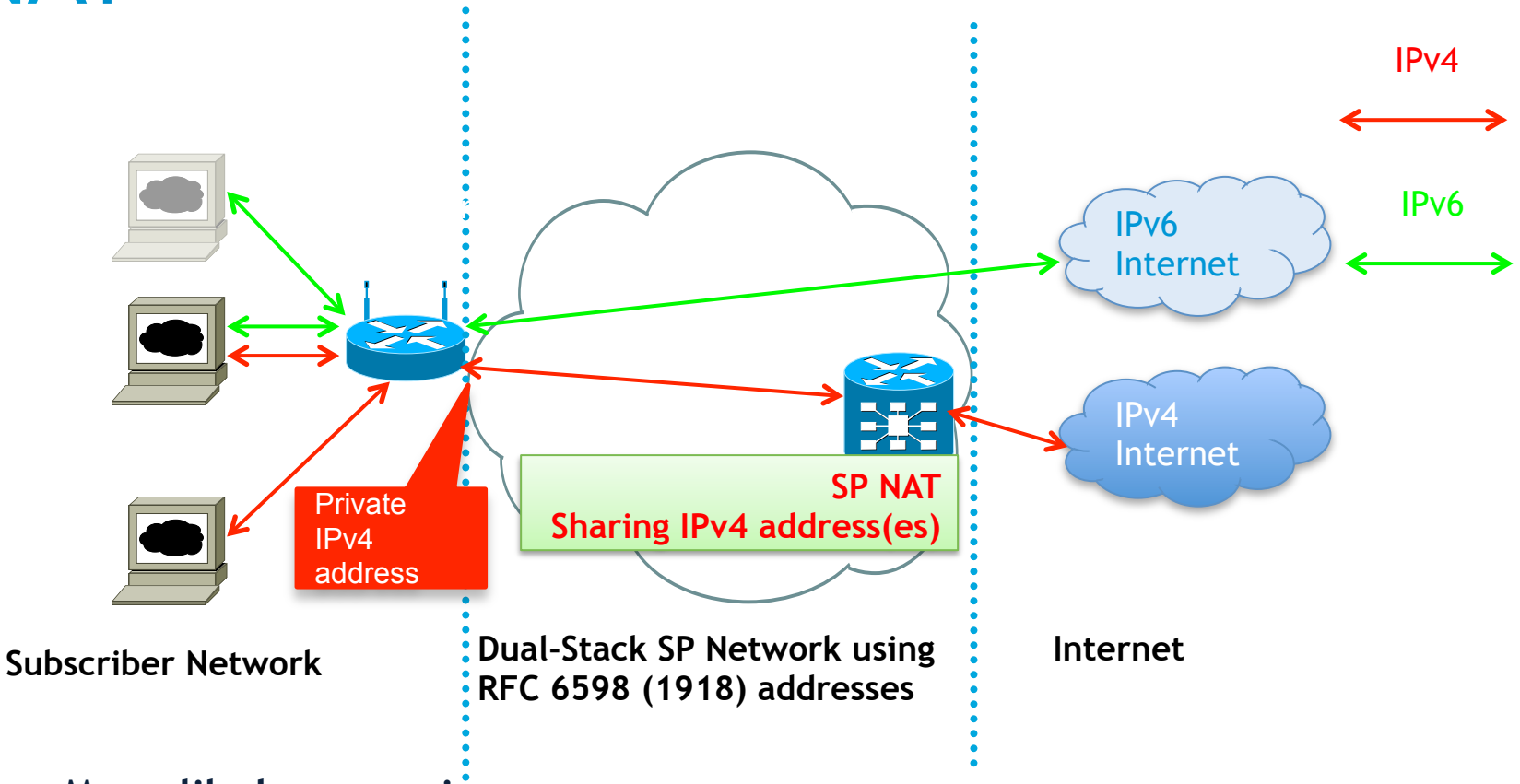
  IPv6 only

- It is expected that SP will deploy a combined and phased approach

  Sharing IPv4 global address is part of the solution

  IPv6-only as ultimate the goal, there is no alternative plan

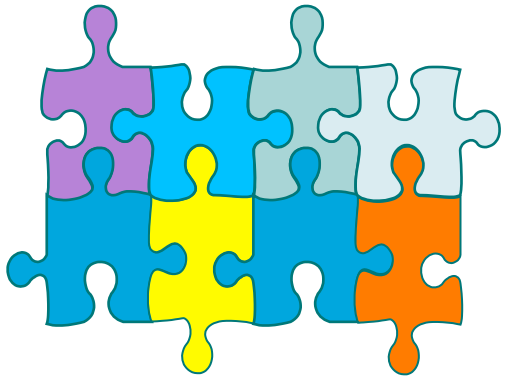
Service Providers Dual-Stack (IPv6 + IPv4) with SP IPv4 NAT



- More likely scenario:
  - IPv6 being available all the way to the consumer
  - SP core and customer has to use IPv4 NAT due to v4 depletion

Impact on Internet Applications

- Enterprises should expect their customers, partners, and remote employees to have a mix of connectivity
  - Public IPv4-only
  - Public IPv4 and IPv6
  - Shared IPv4-only
  - Shared IPv4 and IPv6
  - IPv6 only



Impact of Shared IPv4 Address on Applications

- Applications which could **work poorly or even not at all** when one side uses a shared IPv4 address

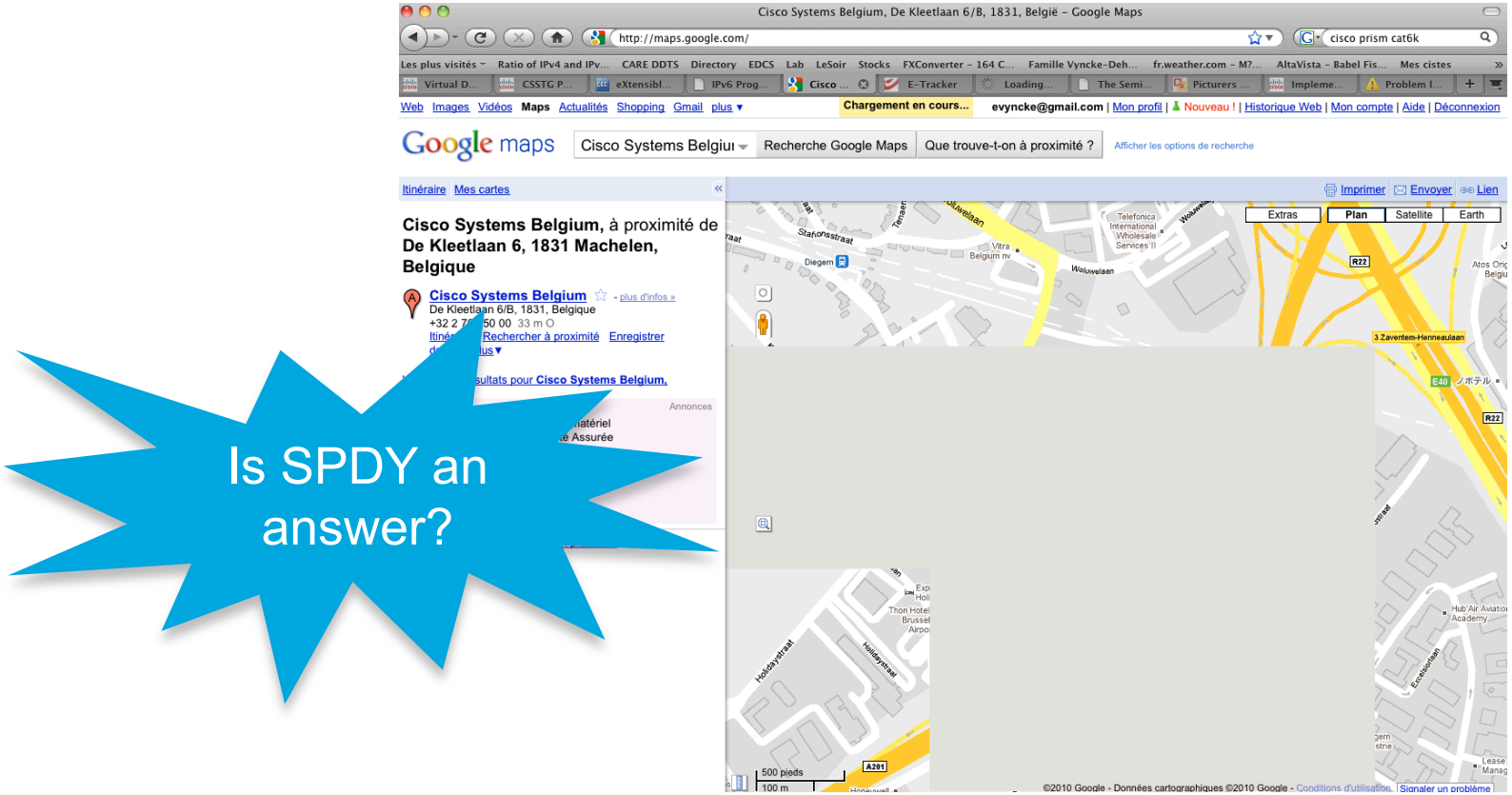
  Multiple TCP connections (like AJAX) in parallel

  Assuming that one IPv4 address = one user (for logging, for load balancing, for access control…)

  Expecting inbound connections (like active FTP)

  Using an application not yet supported by the NAT devices

Examples of Broken IPv4 Applications



Shared IPv4 Address and Reputation

- Every IPv4 address has a reputation

  Either blacklist or more sophisticated (senderbase.org)

  Used to detect spam, botnet members, …

- It is fine as long as:

  One IPv4 == One legal entity (subscriber)

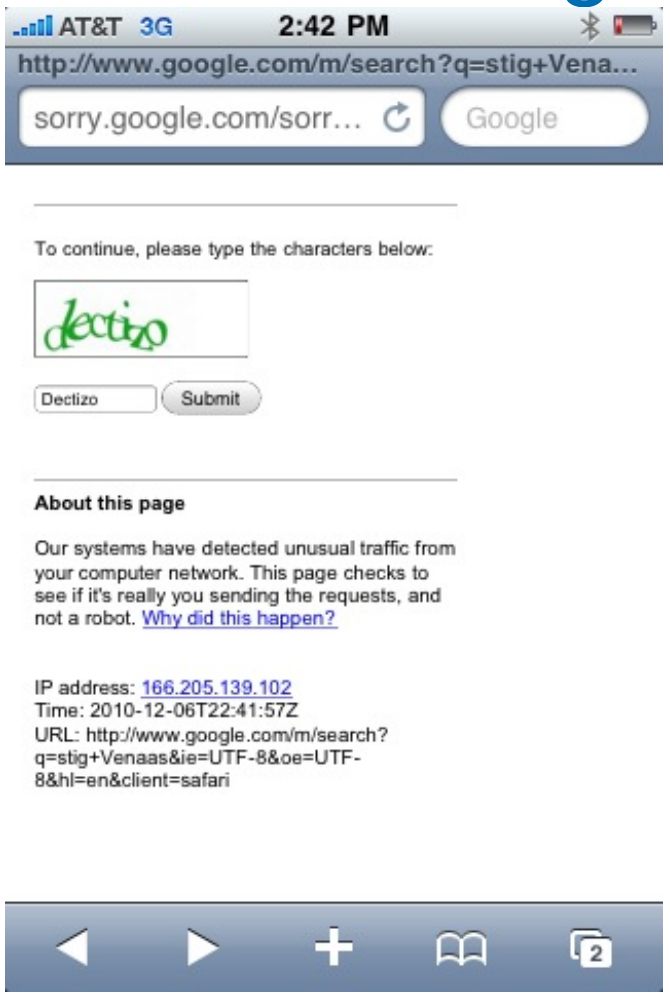
- What if

  One IPv4 == 10.000 entities/subscribers through SP NAT?

Shared IPv4 Address and Rate Limiting

Applications throttle use per IPv4 address

- When address is sharing by 1000's of people the usage threshold is crossed
- And rate limiters are triggered even for legit traffic
- Example with AT&T using NAT for mobile phones



Shared IPv4 Address Forensic

- Servers currently keep the remote IPv4 address in their log
- Law Enforcement Agencies (LEA) can request any ISP to get the subscriber ID of this IPv4 address on a specific time

- With SP NAT, there will be 10,000 subscribers using this IPv4 address

Shared IPv4 Address and Forensic (Cont.)

- SP will have to keep all the translation log (data retention)

  <time, subscriber internal IP, subscriber internal TCP/UDP port, **subscriber external TCP/UDP port**, Internet IP, Internet TCP/UDP port>

  <10:23:02 UTC, 10.1.2.3, 6543, **23944**, 91.121.200.122, 80>

- **AND, the server will have to extend the log to include the TCP/UDP port**

  See also RFC 6302 "Internet-Facing Server Logging"

- *"At 10:23:02 who was using the shared port 23944?"*

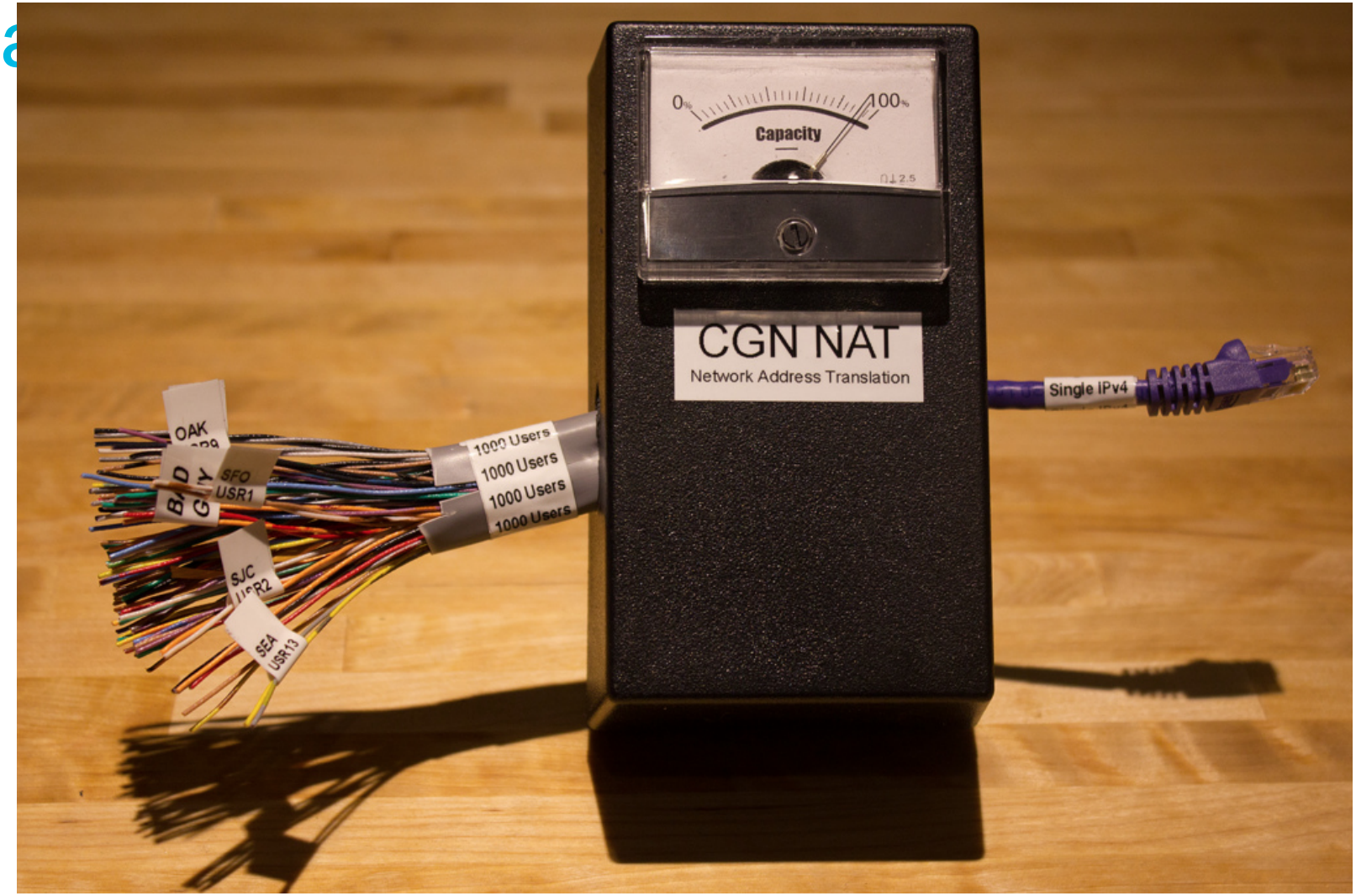
For Your Reference

Logging Remote TCP Port in Apache

```
LogFormat "[%h]:%{remote}p %l %u %t \"%r\" %>s %b" common
```

```
[10.55.185.71]:53958 - - [09/Sep/2011:10:10:26 +0200] "GET /nav/ HTTP/
1.1" 200 7112

[10.55.185.71]:53958 - - [09/Sep/2011:10:10:27 +0200] "GET /nav/nav.js
HTTP/1.1" 200 33519

[2001:6f8:1468:1000::4]:3268 - - [09/Sep/2011:10:10:49 +0200] "GET /
ping_ws.php HTTP/1.0" 200 53
```

Ca



Courtesy of Jason Fesler, Yahoo (V6 World Congress 2012)

Courtesy of Jason Fesler, Yahoo (V6 World Congress 2012)

Short Introduction to IPv6

IPv6 in One Slide

- IPv6 is IPv4 with larger addresses
  - 128 bits vs. 32 bits
  - NAT no more needed => easier for applications
    - Simpler hence more security
- Data-link layer unchanged: Ethernet, WiFi, xDSL, …
- Transport layer unchanged: UDP, TCP, …
- Applications “unchanged”: HTTP, SSL, SMTP, …
- IPv6 is not really BETTER than IPv4 because it is ‘new’
  - IPv6 has been specified in 1995…
  - IPsec is identical in IPv4 & IPv6
  - Only benefit is a much larger address space

Address Representation

- Format:

  x:x:x:x:x:x:x:x where x is 16 bits hexadecimal field

  2001:0000:130F:0000:0000:09C0:876A:130B

  Case insensitive

  Leading zeros in a field are optional:

  2001:0:130F:0:0:9C0:876A:130B

  Successive fields of 0 are represented as ::, but only once in an address:

  2001:0:130F::9C0:876A:130B

  2001::130F::9C0:876A:130B 

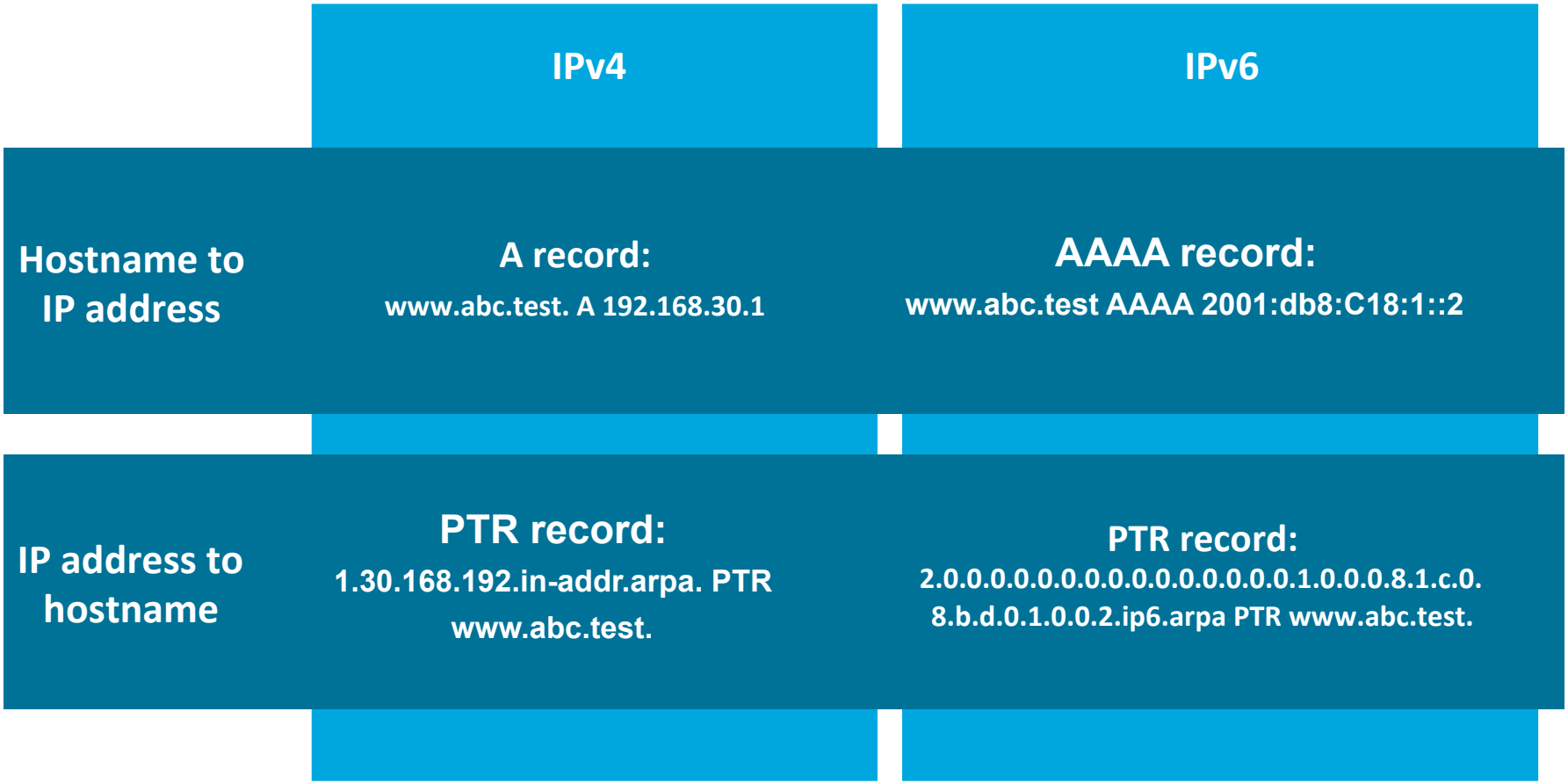
  FF01:0:0:0:0:0:0:1 => FF01::1

  0:0:0:0:0:0:0:1 => ::1

  0:0:0:0:0:0:0:0 => ::

IPv6 and DNS

Actual DNS requests are transported over IPv4 or IPv6 and is not related to the request content.



IPv6 Readiness: Devices

- Hosts are ready
  - Since Windows Vista: enabled by default, disabling it = no more support from Microsoft
  - Mac OS X, iOS, Android, Linux, */BSD: enabled by default
- Network devices (routers, switches, phones, …) are also ready
  - Some minor performance drop
  - IPv6 routing protocols are identical to IPv4: OSPF, BGP, …
  - Usually IPv6 is for free
  - Just beware of FIB/RIB size which can double with IPv6
  - Low cost residential CPE has appeared in 2011
- ➔ add IPv6-support as a requirement for all your RFP
  - Use IPv6 Forum 'IPv6-ready logo'
  - If public sector, copy the text from RIPE 554

IPv6 Readiness: Applications

- Microsoft: Active Directory, Exchange, Filesharing, SQL server, SharePoint…
- Public domain: apache, PHP, bind named, …
- Commercial applications: Infoblox, …

- Your own application????
  - Not too complex to port application to dual-stack, some changes in socket library
  - But it will require extensive/expensive testing…

Innocent W2K3 -to- W2K8 Upgrade

Windows 2003

```
C:\>ping svr-01

Pinging svr-01.example.com [10.121.12.25] with 32 bytes of
data:
Reply from 10.121.12.25: bytes=32 time<1ms TTL=128
Reply from 10.121.12.25: bytes=32 time<1ms TTL=128
Reply from 10.121.12.25: bytes=32 time<1ms TTL=128
Reply from 10.121.12.25: bytes=32 time<1ms TTL=128
```

Upgraded Host to Windows 2008

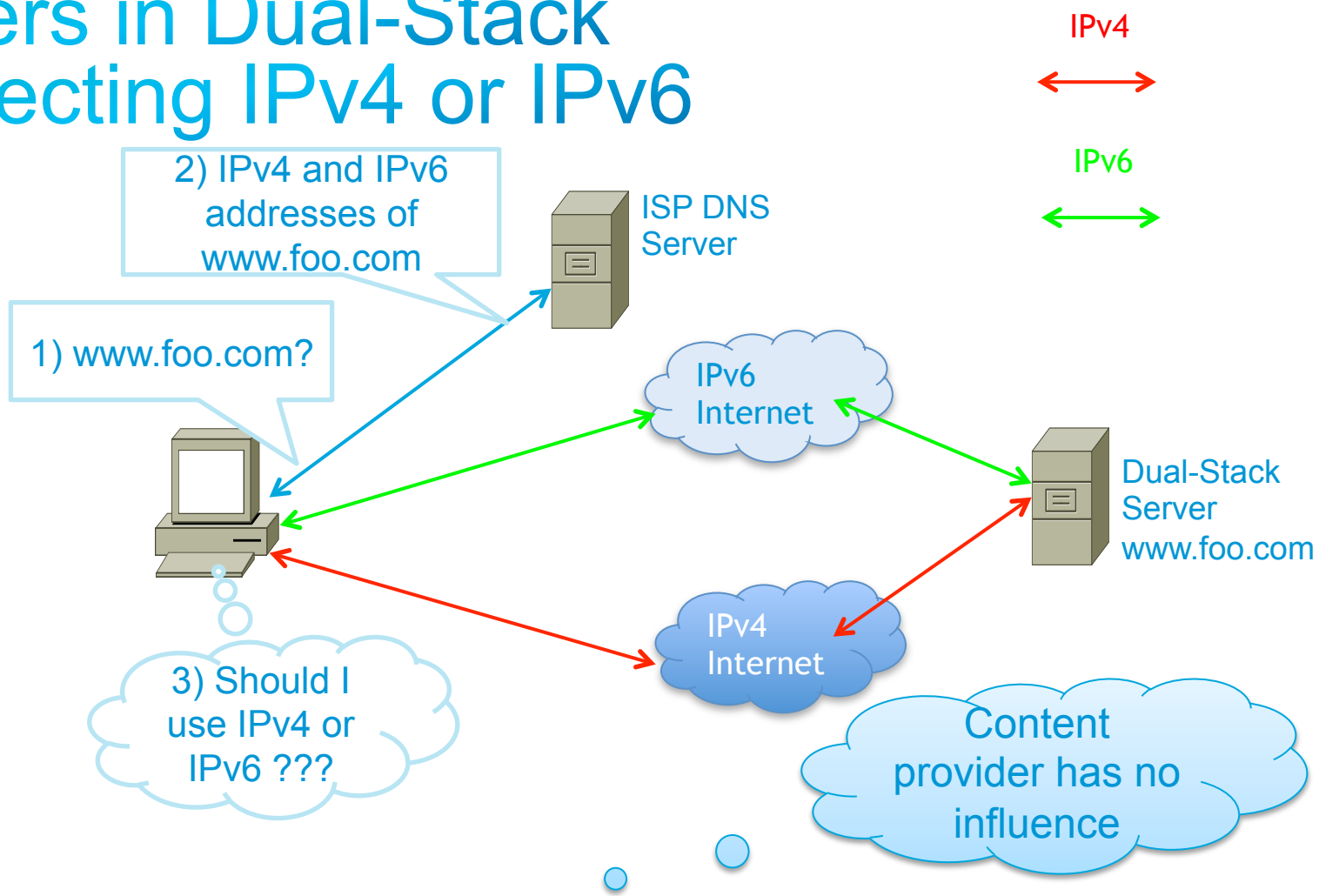
```
C:\>ping svr-01

Pinging svr-01 [fe80::c4e2:f21d:d2b3:8463%15] with 32 bytes
of data:
Reply from fe80::c4e2:f21d:d2b3:8463%15: time<1ms
Reply from fe80::c4e2:f21d:d2b3:8463%15: time<1ms
Reply from fe80::c4e2:f21d:d2b3:8463%15: time<1ms
Reply from fe80::c4e2:f21d:d2b3:8463%15: time<1ms
```

ALL recent OS have IPv6 enabled by default and prefer it...

=> Enable IPv6 host security and IPv6 IPS

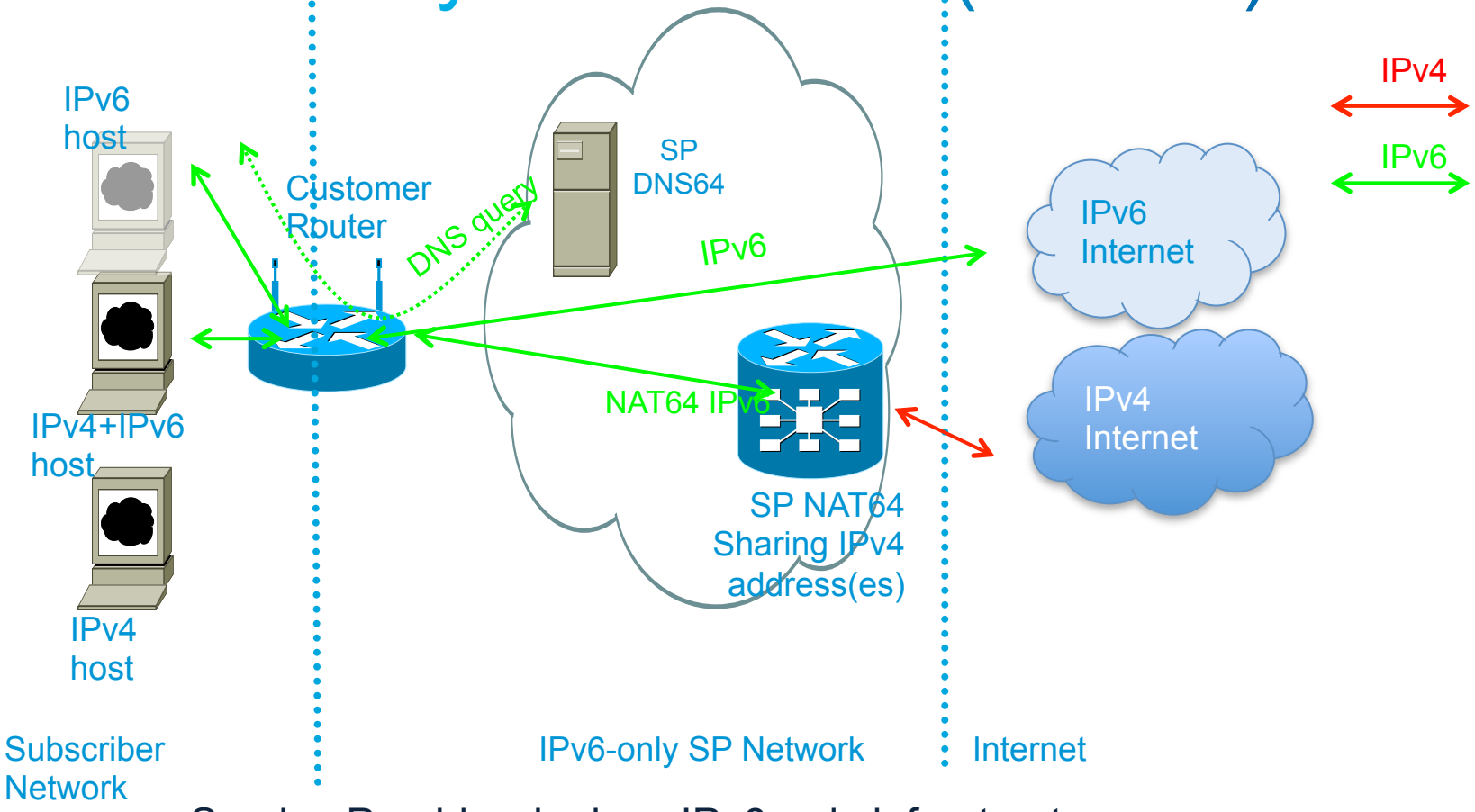
IPv4-IPv6 Coexistence

Users in Dual-Stack Selecting IPv4 or IPv6



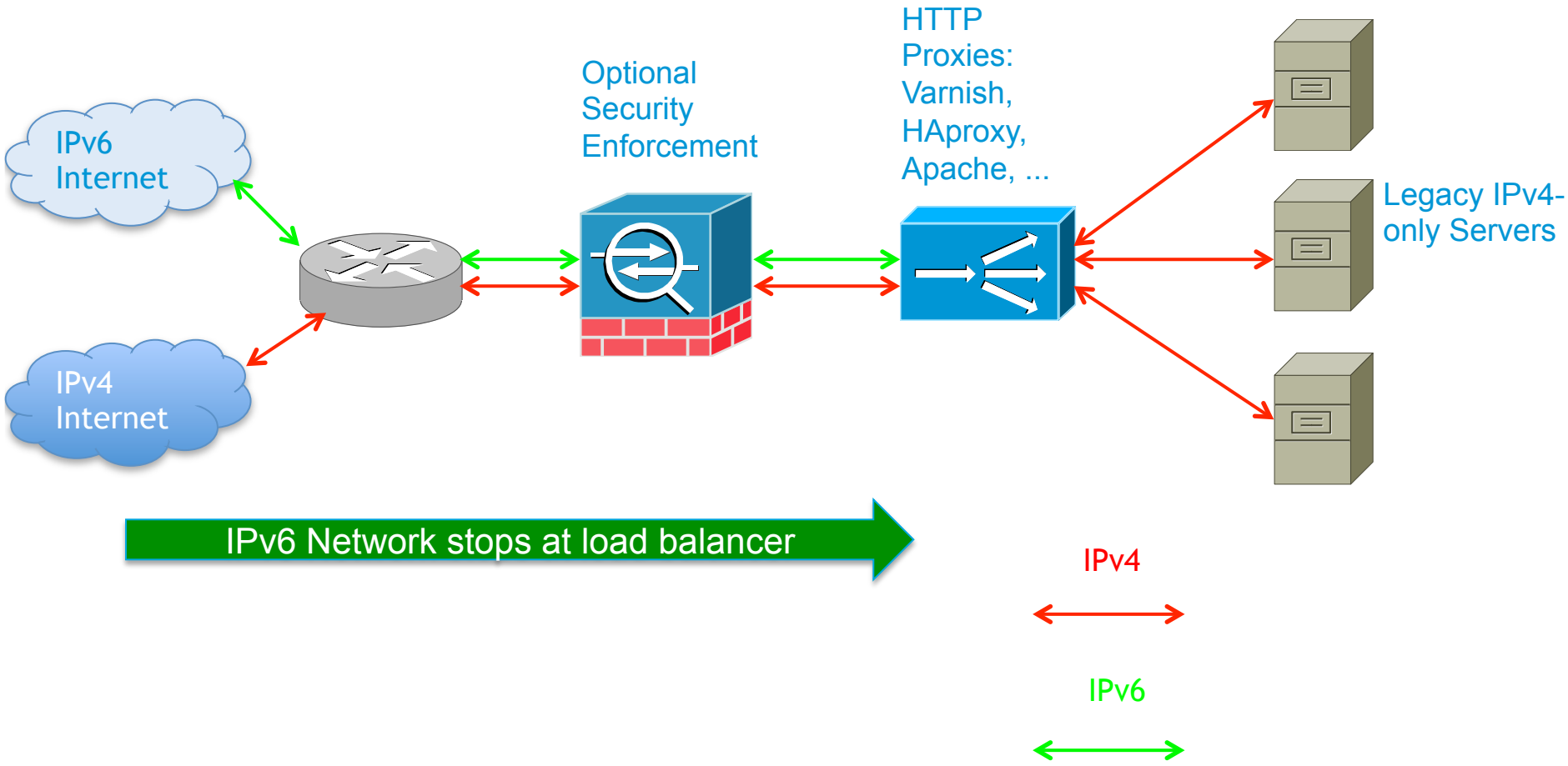
Decision by the USER/INITIATOR:
-RFC 6555: Happy Eyeball, try both and keep the fastest
-RFC 6724: local policy, usually IPv6 is preferred

Address Family Translation (NAT64)



- Service Provider deploys IPv6-only infrastructure:
  - Only IPv6 is available to the consumer
  - IPv4 Internet available via Address Family Translation on SP NAT device

Dual-Stack Internet Edge with HTTP Proxy



Impact on Applications

Impact of IPv6 on Applications...

- Is the software package available?
- What about the network part?
- No more NAT!
- What about the logs and DB?
- What about the API?

  Socket library

  RFC 6724

IPv6-Enabled Applications

- Most open-source packages have been IPv6 enabled for several years
  - BIND `listen-on-v6 { any; };`
  - SSH (including WinSCP, Putty)
    - On by default, else `ListenAddress ::`
  - Apache
  - Sendmail, Qmail,
  - Postfix `inet_protocols=all`
  - VLC, Mozilla
- Specific IPv6 open-source
  - Dibbler: DHCP server
  - Wide-DHCP
  - Linux-DHCP
  - Ip6tables
  - radvd

IPv6-only Networks?

- Mostly experimental, such as FOSDEM or CERNET or ...
- T-Mobile (US) 4G mobile network is IPv6 only
- IETF has a SUNSET4 working group for 2 years now
- 6th June 2014, a day without IPv4

  https://www.facebook.com/groups/ipv6.only.day/ 6th June 2014

  https://secure.avaaz.org/en/petition/IT_professionals_worldwide_Turn_off_the_Legacy_IP_Protocol_IPv4_for_the_day_of_06th_June_2014

- And BSD 10.0 without IPv4 ☺

  https://www.zabbadoz.net/users/bz/blog/20140131-e9e7b6ead61ee2fd3e7337576663b128.html

The Network Part of IPv6 Applications
Path MTU Discovery

- No fragmentation by routers
  - Path MTU Discovery MUST work
  - Free flow of ICMPv6 must be guaranteed
  - All routers must be able to send ICMP
    - Even if using link-local address on infrastructure
- Let's get real: it does not in 2011
  - **Set the MSS to 1220 (minimum MTU of 1280 – 40 – 20)**
  - Or *setsockopt()* and IPV6_MTU

No more NAT

- With IPv6, NAT is no more required
- Real peer-to-peer applications are now trivial

  No need for a relay ‘in the cloud’

- Additional benefits, no need for periodic keep-alive packets (used to keep the translation state in stateful NAT devices)

  Saving mobile battery ☺

IPv6 and Back End Databases
IPv6 Addresses are Larger…

- User Interface

  Needs to accept wider data

  Needs to accept : in addresses

  Multiple ways to represent the same address

  1. Use lower case (uppercase is reserved for MAC addresses)
  2. Canonicalization with `inet_pton()` & `inet_ntop()`

  Needs to redesign GUI to fit field in the screen ☹

- Logging the remote address

  Needs to support 2 address families

  Needs to store 39 characters instead of 15

- Audit

  Need to adapt to IPv6

  Multiple IPv6 addresses per end host

  Multiple ways to write an IPv6 address

  Privacy extension ... Changing IPv6 address

The socket() API in C or C++

- Mostly unchanged, but should use some new functions
  - `inet_ntop, inet_pton`
  - `getaddrinfo, getnameinfo`
  - `struct sockaddr_storage`
- Either one socket

  AF_INET6 in all calls

  IPv4 address in compatibility mode (::ffff:192.0.0.2)

  S = socket(AF_INET6, ...)
- Or two sockets (one IPv4 & one IPv6) for specific options

  Happy eye-ball: clients open two connections and use the ‘better’ one

The IPv6 Support in Other Language

- Most of the scripting languages Python, Perl, PHP, ...
  - IPv6 support built-in
  - **Scripts with FQDN simply work ☺**
  - Beware of logging remote IP* addresses
  - Some OS (Windows, Mac OS/X) also have Happy Eyeballs

RFC 6724: Source Address Selection (SAS)

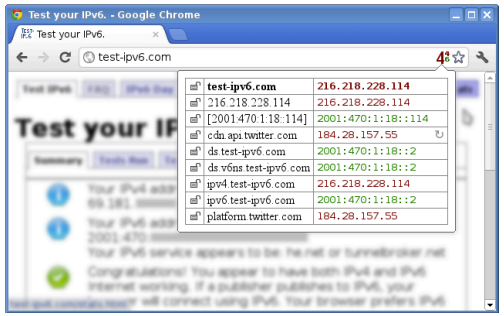
- Policy
  - Several local host addresses
  - Several remote server addresses
  - Which one to use?
- Scope is important in RFC 6724
  - Link-local vs. global

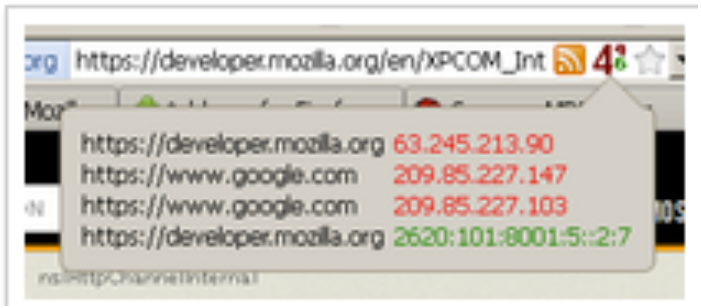
Prefix	Precedence	Label
::1/128	50	0
::/0	40	1
::ffff:0:0/96	35	4
2002::/16	30	2
2001::/32	5	5
fc00::/7	3	13
::/96	1	3
fec0::/10	1	11
3ffe::/16	1	12

Is IPv6 Used? How to Measure ?

How do you know you are using IPv6 ?

- test-ipv6.com
- Browser (Chrome & Firefox)
  IPvFoo & IPvFox





- iPhone/iPad
  Ipv6config
  IPv6toolkit

or IPView

- Android
  IPv6 & more

or IPv6 config

1000 EUR Question
How to monitor deployment?

- Looking at future?
  - Interviews
  - Monitoring ‘precursors’ (IPv6 prefixes, devices, ...)
- Looking at current state of the Internet
  - Open metrics => open results
  - Worldwide view

IPv6-enabled ISP Subscribers

- Measure the web traffic
  - Using a small web bug (1x1 pixel transparent GIF)
    - Used by Google, and others
    - Can precisely measure IPv4, IPv6 and dual-stack
    - E.g. http://www.vyncke.org/countv6/
  - Web servers log files
    - Easier but cannot check IPv4, IPv6
  - Google Ads
    - Used by APnic
    - All ads are in flash and flash can try to download IPv4, IPv6, dual-stack and report
- Participate in dual-stack peer-to-peer networks such as BitTorrent

More on Web bug

- By inserting a 1x1 pixel transparent image (or IFRAME)

  Or even better 3 images:

  IPv4-only

  IPv6-only

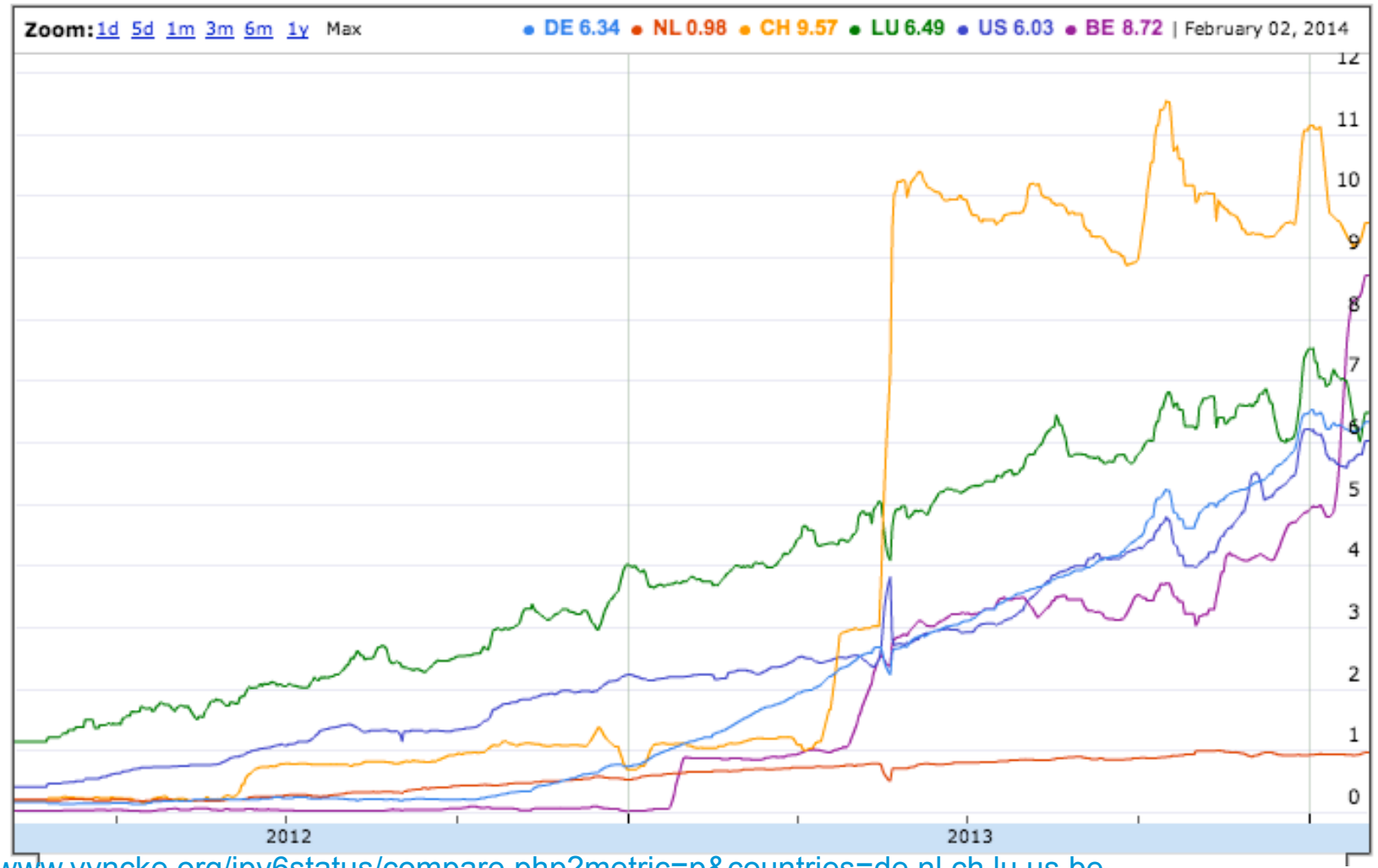
  Dual-stack then check whether IPv4 or IPv6 was preferred

- IPv6 brokenness (old 6to4 CPE mainly): can reach IPv4-only but not dual-stack (because IPv6 was preferred but broken), cfr Tore Anderson's experiment
- IPv6 non-managed tunnels (Sixxs, Gogonet, Hurricane Electric) because the AS is different between IPv4 and IPv6
- Can generate a lot of data and CPU load => sampling on large sites

Worldwide IPv6 Users
The “mother” of deployment measures

http://www.google.com/ipv6/statistics.html

IPv6 Google Users Evolution



http://www.vyncke.org/ipv6status/compare.php?metric=p&countries=de,nl,ch,lu,us,be

Monitoring IPv6 Web Content

- Simple and easy
- Try to connect to www.example.org over IPv6

  Make a AAAA DNS request

  Then try to connect to it by TCP on port 80
- But, also try www6.example.org IPv6.example.org, ...

  This is an indicator of 'IPv6 under test' or 'IPv6 pilot'
- Can be extended to measure email and DNS servers of a domain

www.alexa.com is your friend

- List of most visited web sites
- Freely available top-1-million

  == Which are popular sites visited by the whole Internet

  Then class by country top level domain: .be, .ch, .lu

  Issues:

  www.ice-watch.com is actually in Belgium

  www.youtu.be is actually outside of Belgium

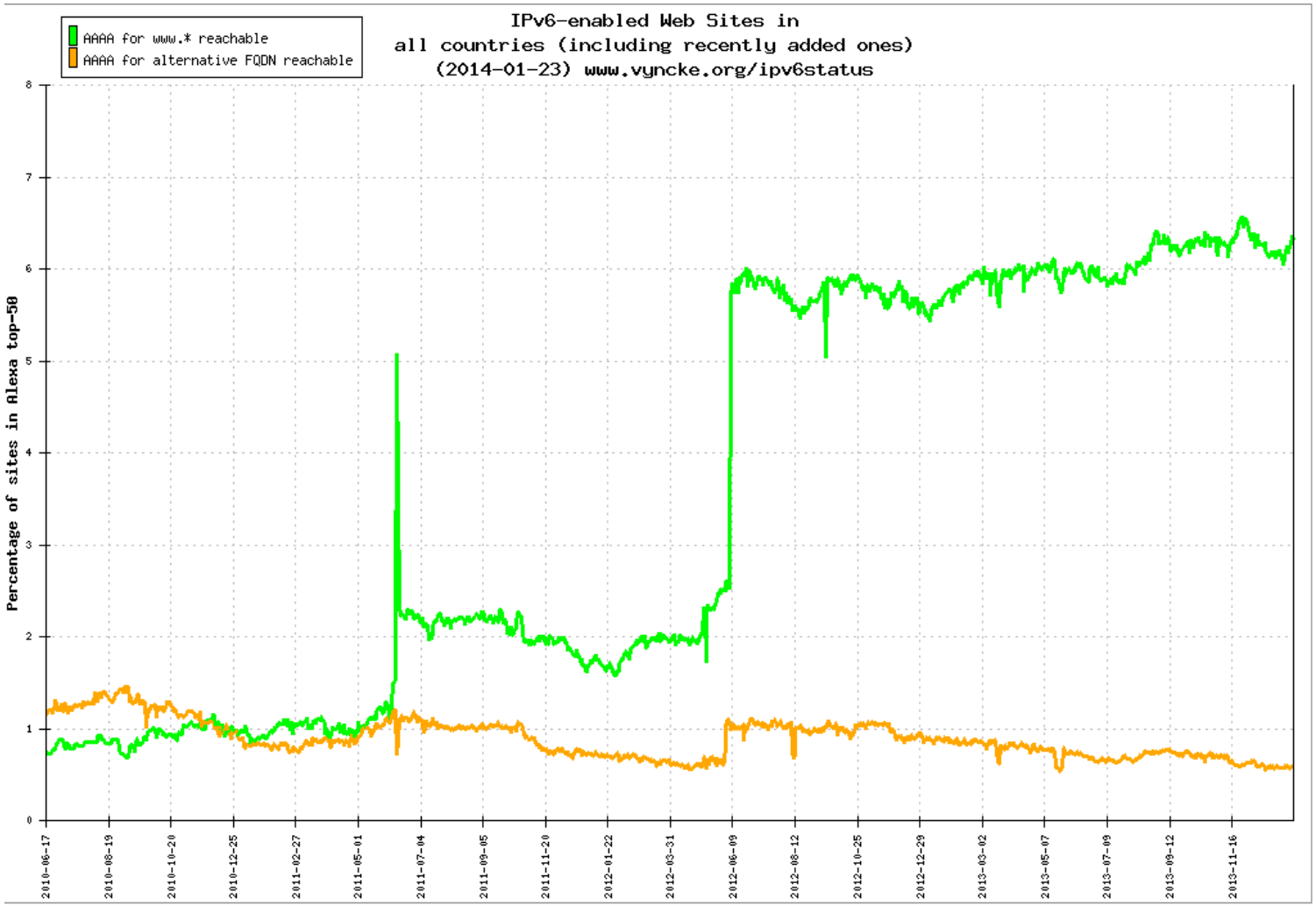
  Estimation of IPv6-readiness of a country
- Paying list of visited web sites by country

  == Which are popular sites actually visited by users of this country

  E.g. google.ch, facebook.com, google.com, live.com, ...

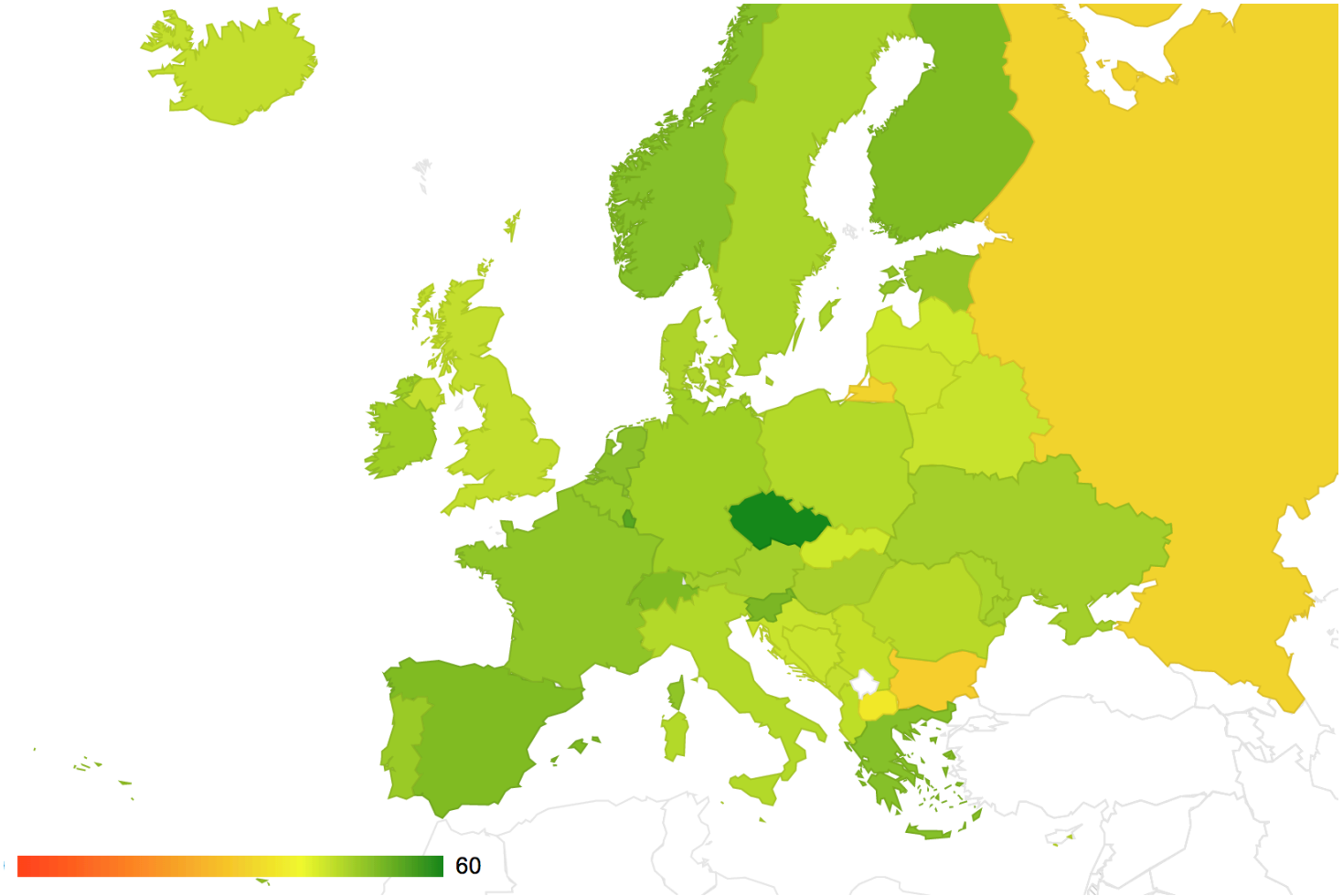
  Assuming a long-tail distribution, can estimate the amount of IPv6 traffic IF all subscribers were dual-stack

Worldwide IPv6 Web Servers



http://www.vyncke.org/ipv6status/plotsite.php?metric=w&global=y&pct=y

Web Servers Location

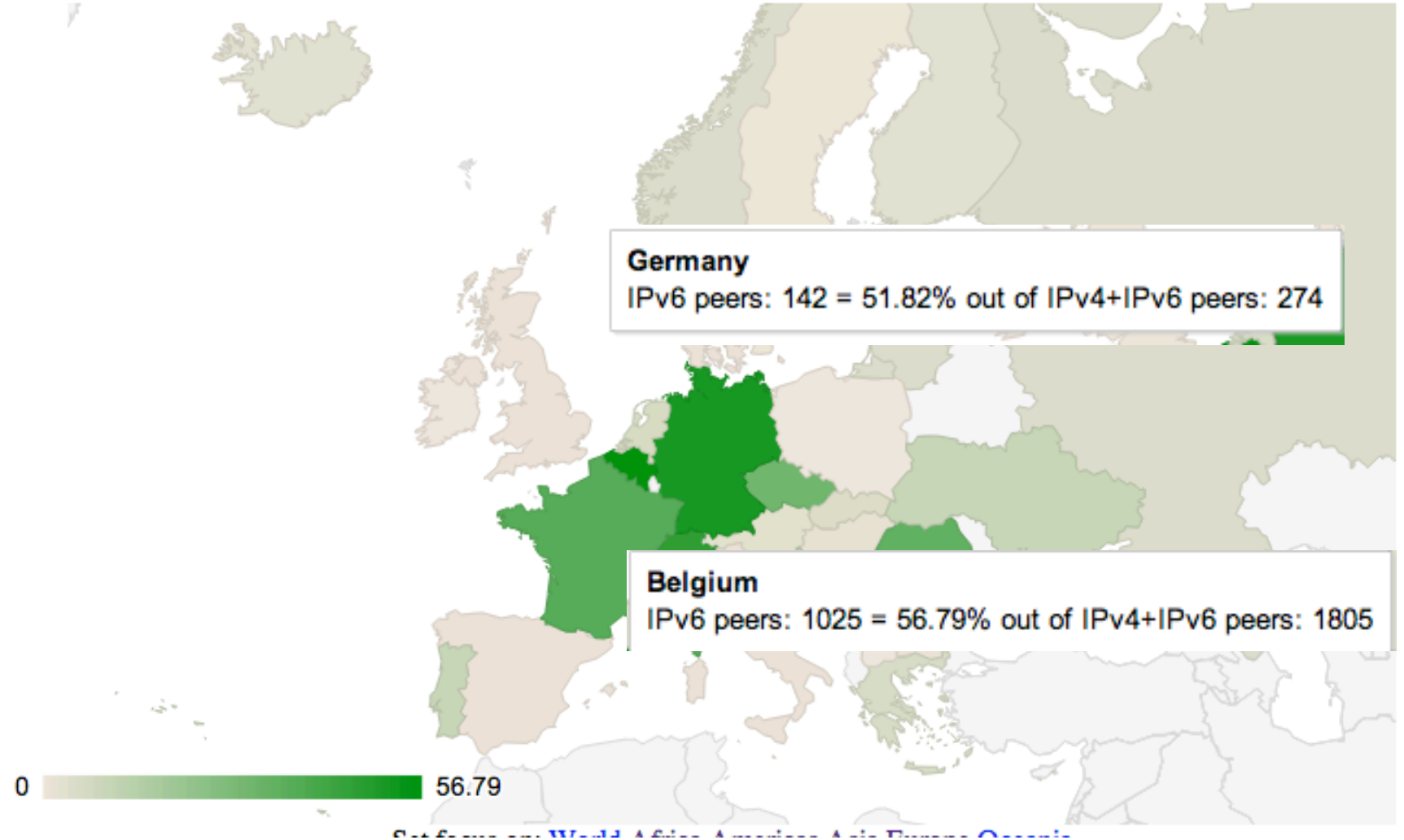


http://6lab.cisco.com/stats/

More on BitTorrent

- BitTorrent is a dual-stack peer-to-peer file exchange
  - Some trackers have dual-stack peer lists
  - Private Exchange is also dual-stack
  - Distributed Hash Table does not appear to be dual-stack
- draft-vyncke-ipv6-traffic-in-p2p-networks
- Of course, only pretend to have the file, do not upload/download it

European BitTorrent Jan-2013



http://www.vyncke.org/ipv6status/p2p.php?date=2014-01-22&region=150&ipv6=native

Questions?

Thank you.