

APNIC **36**
CONFERENCE



XI'AN, CHINA
20 - 30 August 2013

Launch+365

Geoff Huston

research@apnic.net



I was going to talk about “IPv6 Launch”

and look at what has happened to the IPv6 Internet one year after the launch

But...

It's our 20th Birthday!

So I thought I would add a little nostalgia to the proceedings

It's our 20th Birthday!

Lets start by looking way back to my early presentations on IPv6, and see how they have changed over the years...

Launch-3650 10 years of IPv6 Presentations

Geoff Huston

research@apnic.net



A question to each of you...

A question to each of you...

How many IPv6 presentations have you sat through?

A question to each of you...

How many IPv6 presentations have you sat through?

- 20?
- 100?
- 1,000?
- I don't know - I was comatose by the end!

A reminder

In case you weren't paying attention at the time here's a few blasts from my archives...

11 years ago, in China



IP Version 6

Geoff Huston

Presentation to ICANN Meeting
Shanghai, October 2002

2002: On IPv6 Myths

[IPv6 vs IPv4]

- There is no compelling “feature” or aspect of V6 that does not have a functional counterpart in V4.
- Any industry adoption of V6 cannot be based on superior functionality of V6 over V4 as a protocol platform

The “anti-hype” message – IPv6 is not brighter, shiner, or more miraculous. It just has more addresses!

2003: On IPv6 Myths

[IPv6 vs IPv4]

- **A view from Noel Chiappa:**

“The IPv6 community got into the corner it's in now because it took the path of least technical resistance: IPv6 looks a lot like IPv4 because we "know "that IPv4 "works". Well, guess what, IPv4 *doesn't* work, and IPng needed to look really different, and those of us who tried to tell the rest of the IETF that didn't get very far - although I think we gave it a pretty good try.

So if the IPv6 community again takes the path of least technical resistance, having not learned the first time around that that's really not the answer, God help you all”.

Posting to IETF multi6 WG, 26 Feb 2003

The “anti-hype” message – IPv6 is not brighter, shiner, or more miraculous. It just has more addresses!

2003: On IPv6 Myths

[IPv6 Renumbering]

- A view from Tony Li:

“One of the big selling points of v6 was that renumbering was gonna be easy, right? So we didn't have to do funky addressing... Are you telling me that one of the selling points of v6 is bunk?”

Tony”

Posting to routing-discussion@ietf.org, 26th March 2003, within a discussion about the implications of deprecating of site-local addresses and whether there was a residual requirement for NAT-like functionality in IPv6

The “anti-hype” message – IPv6 is not brighter, shiner, or more miraculous. It just has more addresses!

2003: Wavering in the ranks!

[The Bottom Line]

- Its looking like its a NAT vs V6 choice
 - And its not obvious that the market is going to correctly balance the longer term interest against very short term expediency

I'm having moments of doubt and uncertainty!

2004: IPv6 Address Policies Revisited



It seems rather odd...

- To be considering address capacity issues in a technology that is really only ramping up.
- 128 bits allows an awesomely large pool of unique values

“If the earth were made entirely out of 1 cubic millimetre grains of sand, then you could give a unique address to each grain in 300 million planets the size of the earth” -- Wikipedia

- This is a highly speculative exercise....

Contemplating changing the HD Ratio and the 48 bit end site prefix.

“But you can’t do that! The installed base of IPv6 is too big to change!”

2005:

“One day man will travel
faster than a horse can run”

Rene Descarte

2005: defining terms of engagement

It looks like the IPv6 future may well be “revolution” where IPv6 is forced into direct competition with existing IPv4+NAT networks

And the primary leverage here is one of “cheaper” and “bigger”, and not necessarily “better”

The realization that IPv6 won't just happen – there are other factors at play here.

2006:

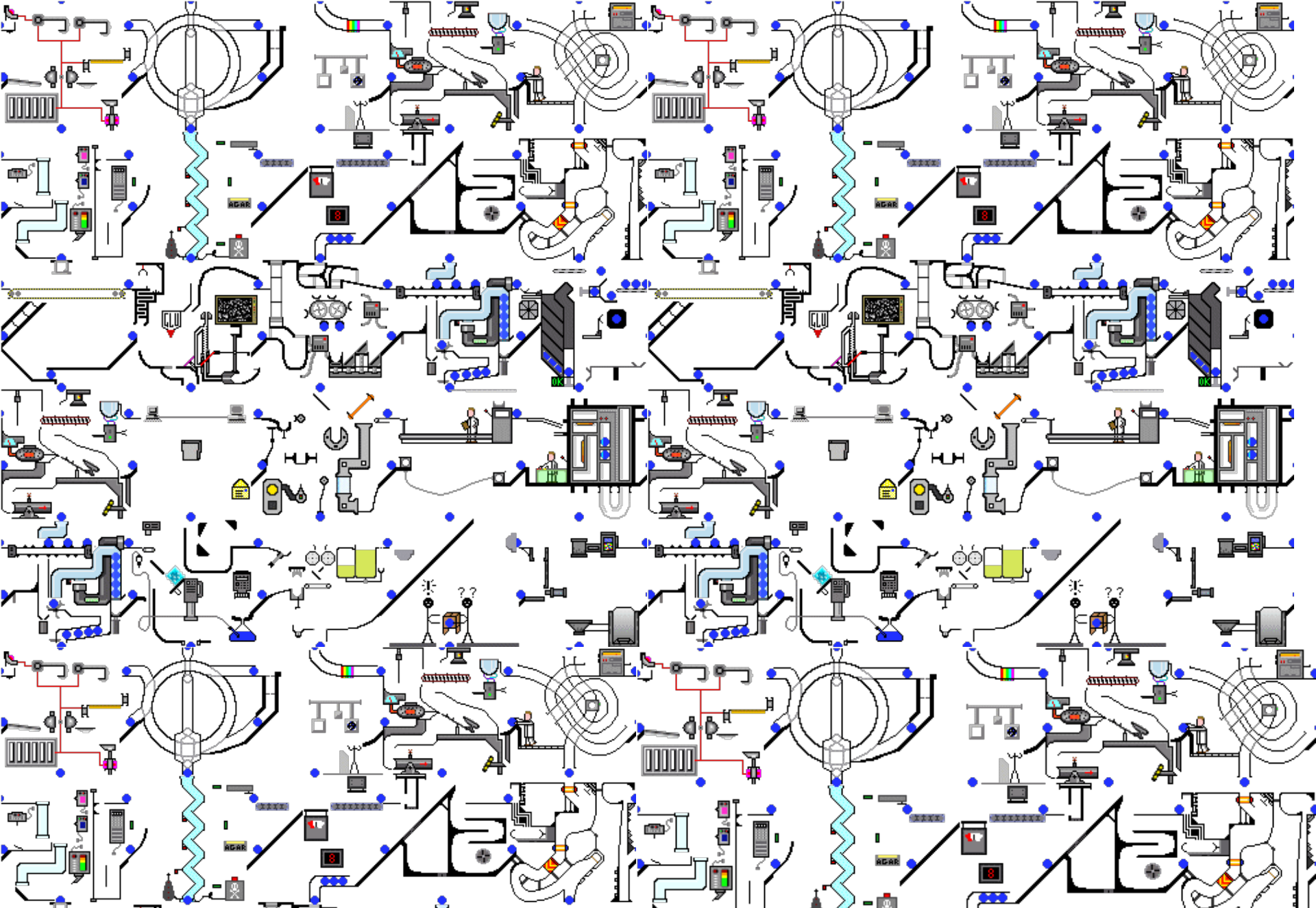
Technology - IPv6

- "IP with larger addresses"
- Address space requirements are no longer being easily met by IPv4
- This is an issue for high volume deployments including:
 - Pocket IP devices
 - Consumer devices
- IPv6 appears to offer reasonable technology solutions that preserve IP integrity, reduce middleware dependencies and allow full end-to-end IP functionality for a device-rich world

BUT

Noone wants to pay for widespread IPv6 deployment just yet!

Searching for drivers for IPv6 adoption



i could watch that for hours!

2007:

Maybe it's just deregulation

- Near term business pressures simply support the case for further deferral of IPv6 infrastructure investment
- There is insufficient linkage between the added cost, complexity and fragility of NAT-based applications at the edge and the costs of infrastructure deployment of IPv6 in the middle
 - Deregulated markets are not perfect information markets – pain becomes isolated from potential remedy

It's not just a technology issue – there are business drivers here as well

2008:

New Markets for IPv6?



The Universe of Tiny Things?

The world of billions of chattering devices unleashing new rivers of gold into the IP industry?

Or is this just the economy? There is no new money and these billions of chattering devices will generate much the same revenue as we have today

So we have to cram all these billions of new devices trillions of new packets into the same money that we have today.

technology leverage will make tomorrow's networks 1,000 times CHEAPER to deliver an IP packet than today's network?

Or have we reached some limit to the economic viability of communications that imply that ever smaller valued transactions can't be sustained over ever larger networks?

Do RFID and Bluetooth provide a different model of communication that is viable in the universe of things, where the identity is global but the communication is strictly limited in scope and

And if you ever are curious enough to enlarge this slide to see if there is text all the way down the page you will have got yourself to this point, where it becomes obvious that I've got nothing more to say and I want to fill up the bottom of the slide with tiny text.

2008

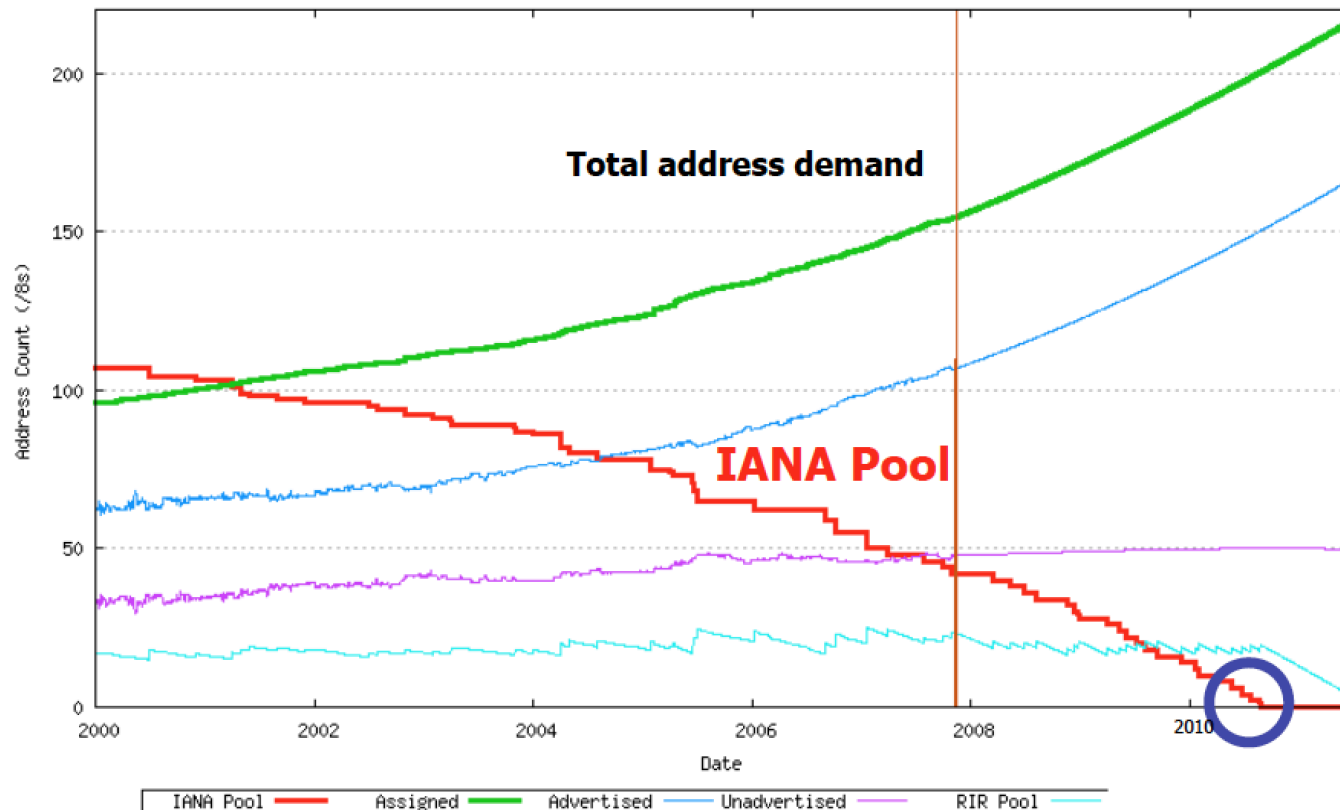
This is the time of the “**IPv4 exhaustion is coming. What are we going to do?**” presentations.

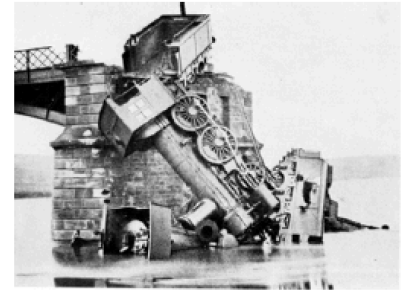
Lets dive into one of them for a few slides from 2008...

Ooops!



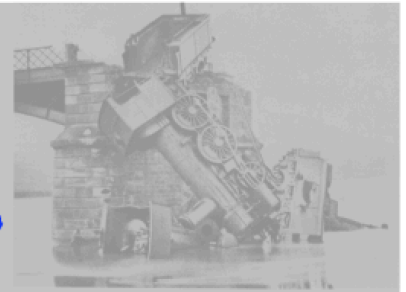
Data Prediction





That's 5th February 2011

<http://ipv4.potaroo.net>



That's 5th February 2011

YAWN - seen all this before
Its now **BORING!**

<http://ipv4.potaroo.net>

That's a highly uncertain prediction - it could be out by as much as 18 months



I can't model changes in demand due to:

Panic — last minute rush

New Policies - “reservations” of remaining address space

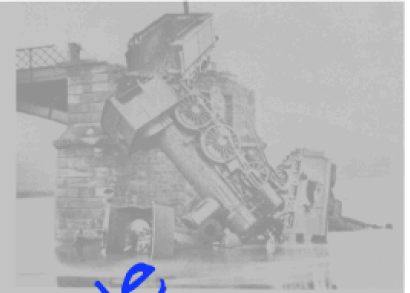
Change of relative IPv4 / IPv6 demands

And modeling uncertainty due to:

highly skewed data used to make projections

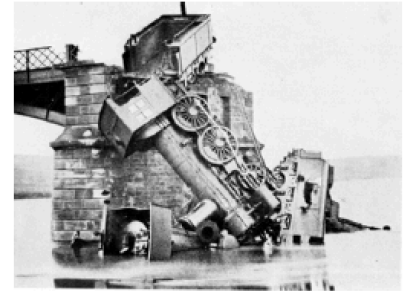


That's sometime between
late 2009 and early 2011

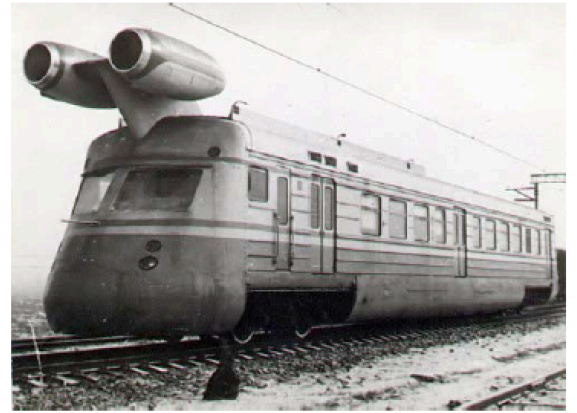


That's sometime between
late 2009 and early 2011

SO WHAT?
we've all heard this before
nothing new to see here - move
along!

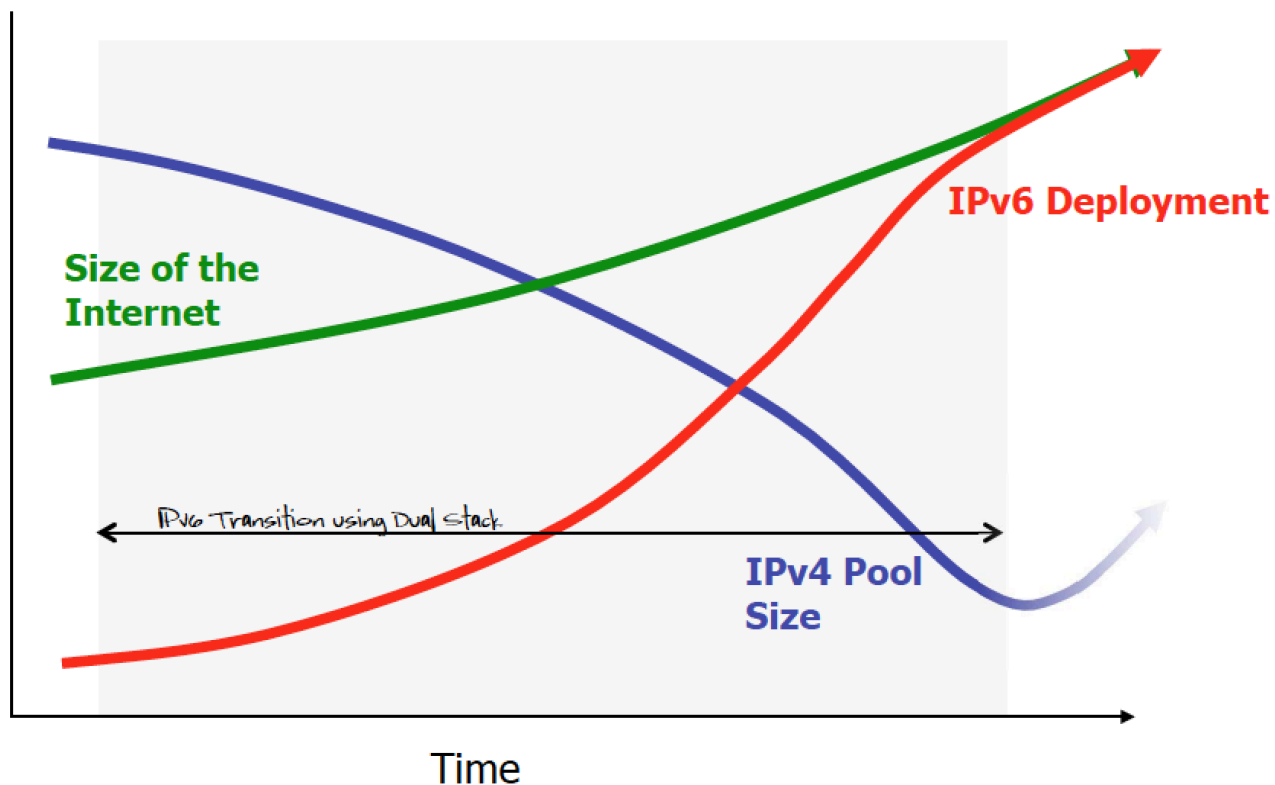


what then?

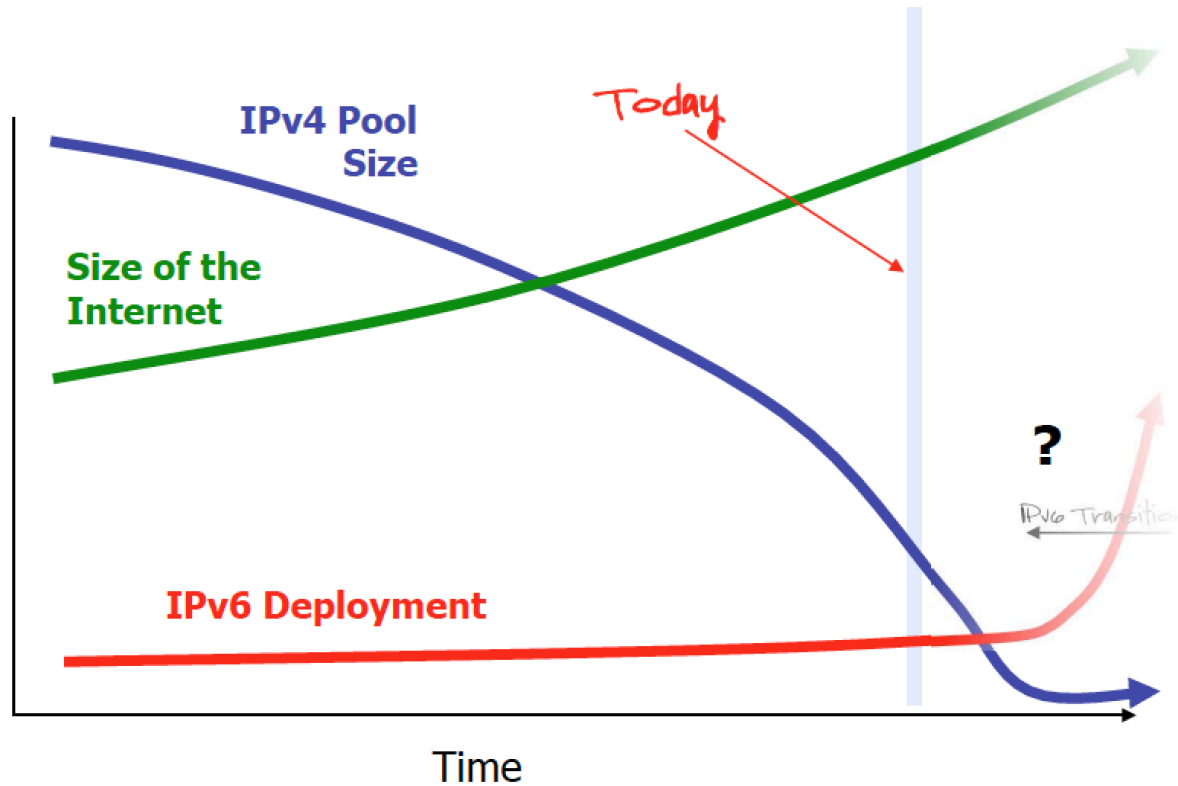


IPV6!

We had this plan ...



what's the revised plan?

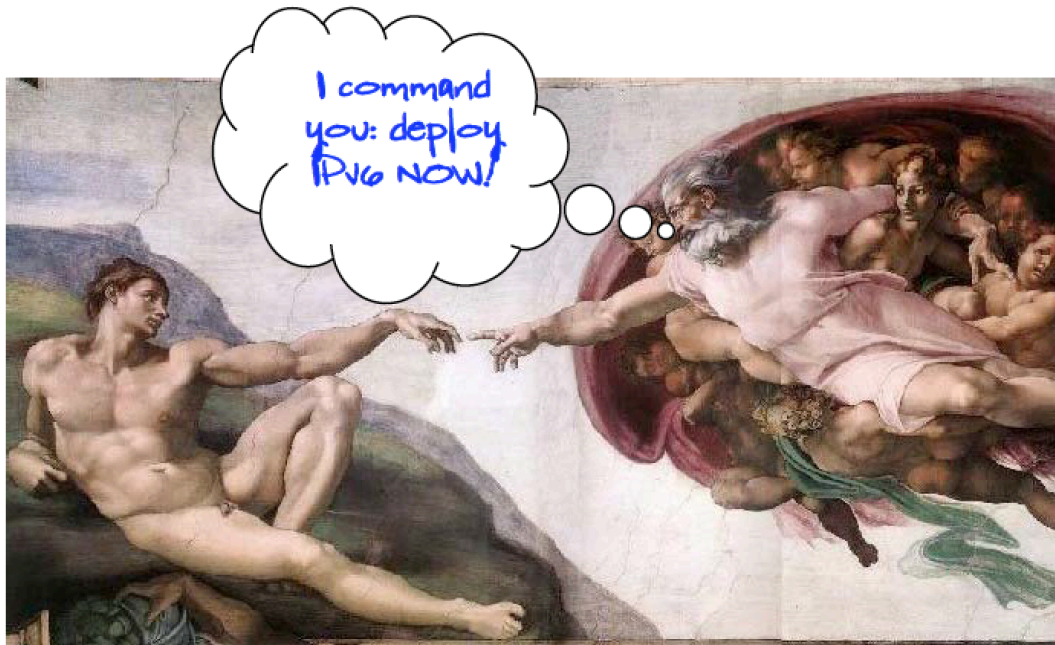


If IPv6 is the answer then...

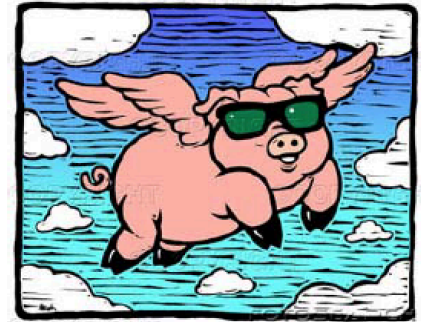


Plan A: its time to move!

The global internet adopts IPv6 universally
before **January 2009** and completely quits all
use of IPv4 well before address pool
exhaustion occurs



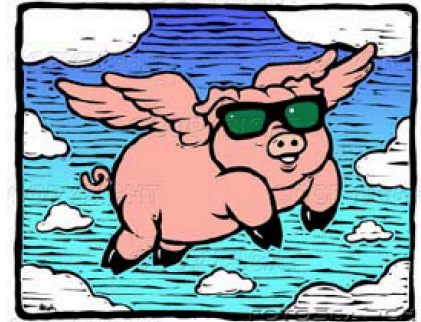
If IPv6 is the answer then..



Plan A: its time to move!

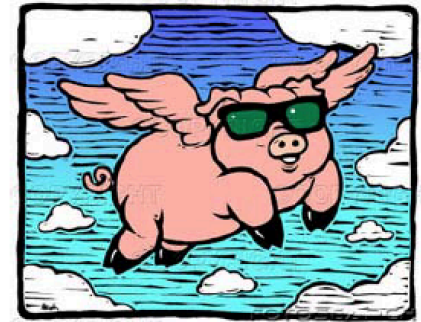
The global Internet, with more than 1.7 billion users, a similar population of end hosts, and hundreds of millions of routers, firewalls, and billions of lines of configuration codes, and hundreds of millions of ancillary support systems, where only a very small proportion are IPv6 aware, , are all upgraded and fielded to work with IPv6 **in the next 120 days**, and then completely quits all use of IPv4 in **10 days later**.

If IPv6 is the answer then..

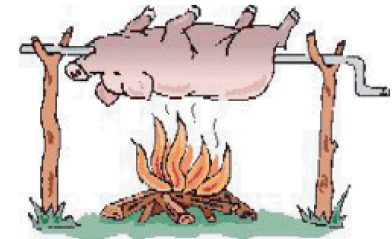


Plan A: its time to move!

The global Internet, with more than 1.7 billion users, a similar population of end hosts, and hundreds of millions of routers, firewalls, and billions of lines of configuration codes, and hundreds of millions of ancillary support systems, where only a very small proportion are IPv6 aware, , are all upgraded and fielded to work with IPv6 **in the next 120 days**, and then completely quits all use of IPv4 in **10 days later**.



Really.



BIG and FAST don't go together!

If IPv6 is the answer then...



Plan B: Dual Stack

Leisurely IPv6 deployment

and

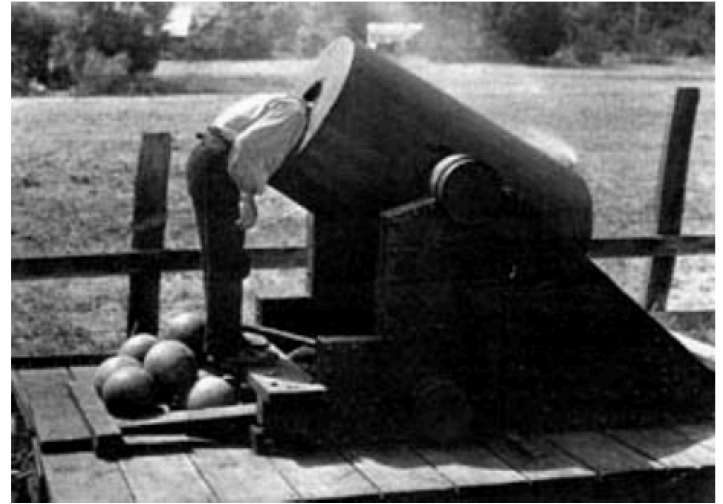
Persist with IPv4 networks using more NATs

If IPv6 is the answer then...



Plan B: Dual Stack

Make IPv4 work using more intense levels of NAT deployment in new products and services for as long as the existing deployed networks continue to use IPv4
This may take a decade or two

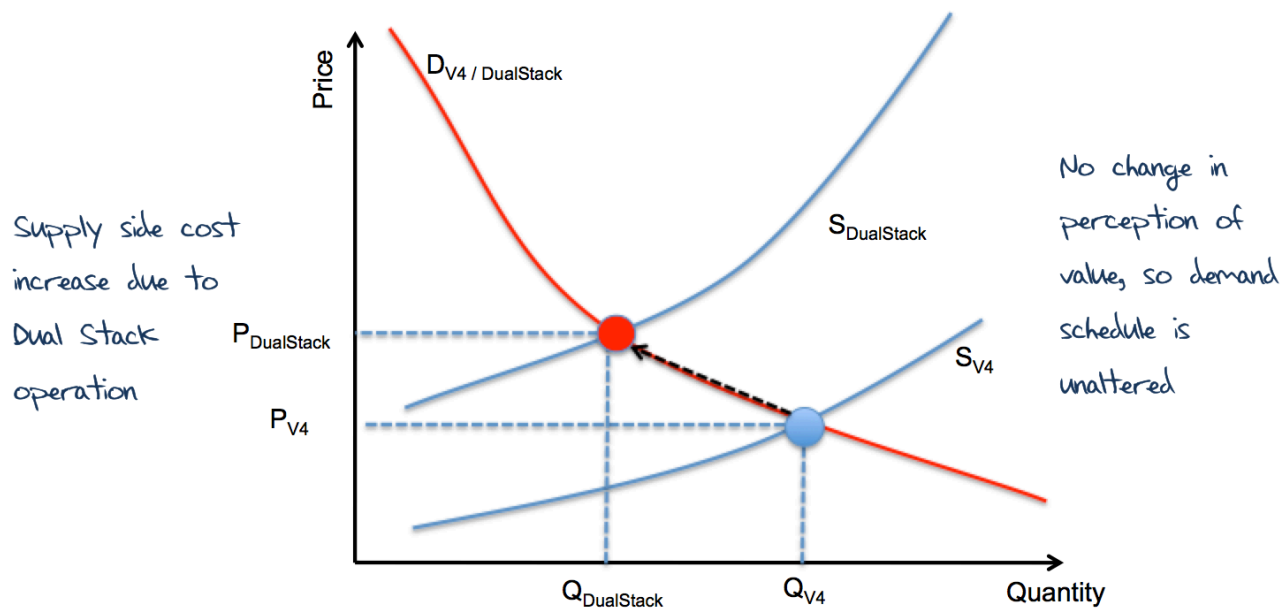


Its just not looking very good is it?

why are we here?

2010 – invoking economics!

IPv4 to Dual Stack: The Demand Schedule Shift



Supply side cost increase due to Dual Stack operation

No change in perception of value, so demand schedule is unaltered

Equilibrium point is at a lower quantity if Dual Stack supply costs are passed on to customers

2010 – invoking economics!

Is this a bit like the economics of climate change?

Right now individual short term interests are leading the Internet towards collective long term sub-optimal outcomes

At some point very soon the Internet will need some external impetus to restate short term interests to align with common longer term objectives

If we want IPv6 to happen we might need a large kick in the rear to get us there!

2012: measurement

Counting IPv6...

Some 50% of the Internet's transit ISPs support IPv6 transit

Some 50% of the Internet's host devices have an active IPv6 stack

and the rest run Windows XP!

But only 0.5% of the Internet actually uses IPv6!

and the problem appears to lie in the last mile access infrastructure!

Which brings us to...

6 June 2012



Was it only a year ago?

World IPv6 Launch

“This time it’s forever”

Urging service providers to turn on IPv6, and leave it on.

Reach out to network, access and content providers to start moving in public on IPv6 services

Some Questions one year later...

- Did it work?
- What has changed in the past 12 months?
- Who is deploying IPv6?
- Where are they?

APNIC's IPv6 Measurements

- The Internet is all about end-to-end services
- We want to also perform end-to-end measurements
- But how can we measure the IPv6 capability of millions of end users?
- And do so day by day?

Measuring Millions?

Option A - Be Google!



Measuring Millions

Option B - Use Google!

Use their online ad network as a vehicle for embedded measurement tests

Embedded on the ad are 3 tests

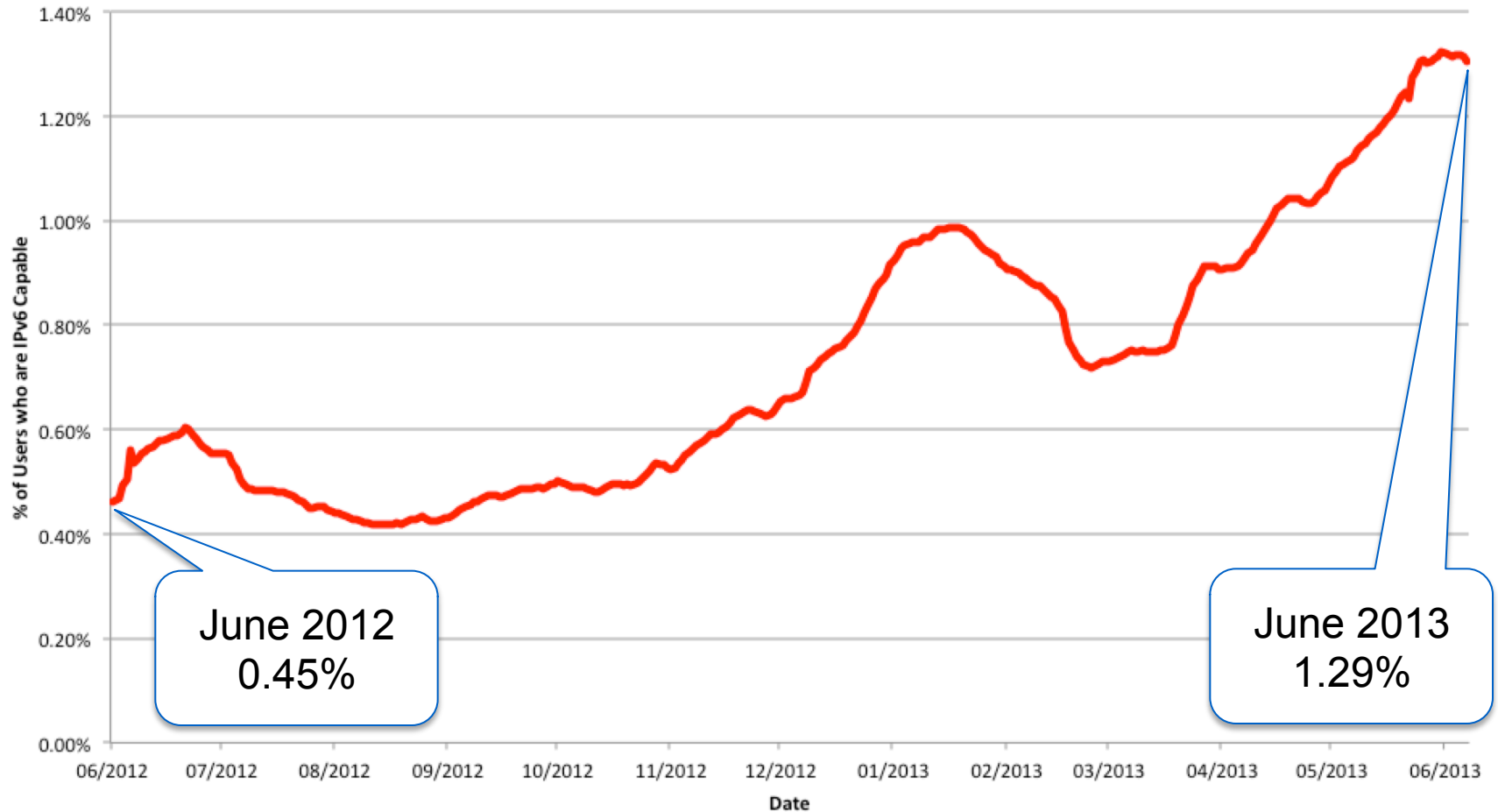
- V4 only URL
 - Control comparison (Reliability, RTT)
- Dual Stack URL
 - Which protocol will the client PREFER to use?
- V6 only URL
 - Is the client CAPABLE of using IPv6?

And this is what we saw

When we asked 300,000 new end users every day about their IPv6 capability we saw this...

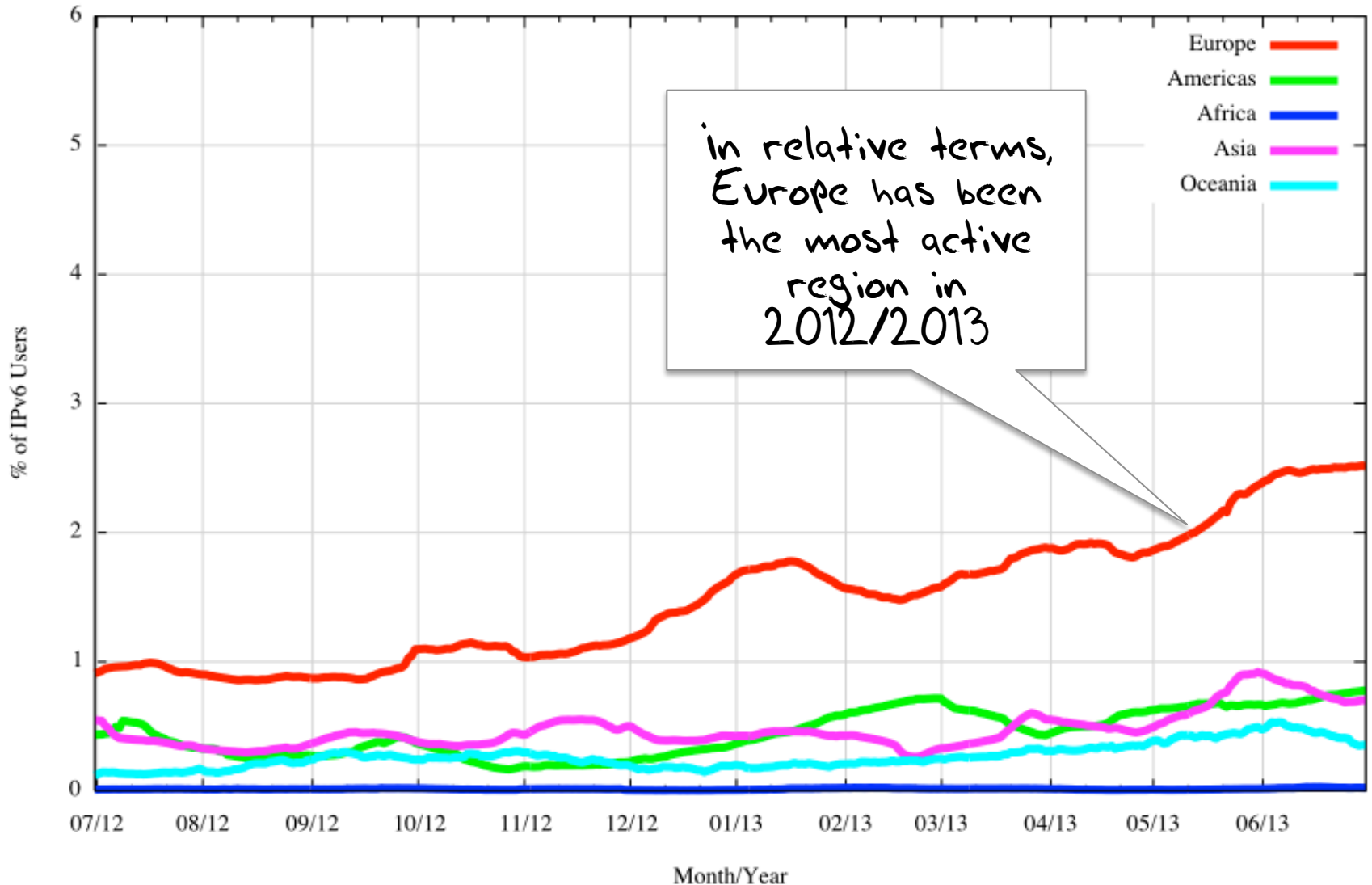
IPv6, Globally

IPv6 Deployment Measurement



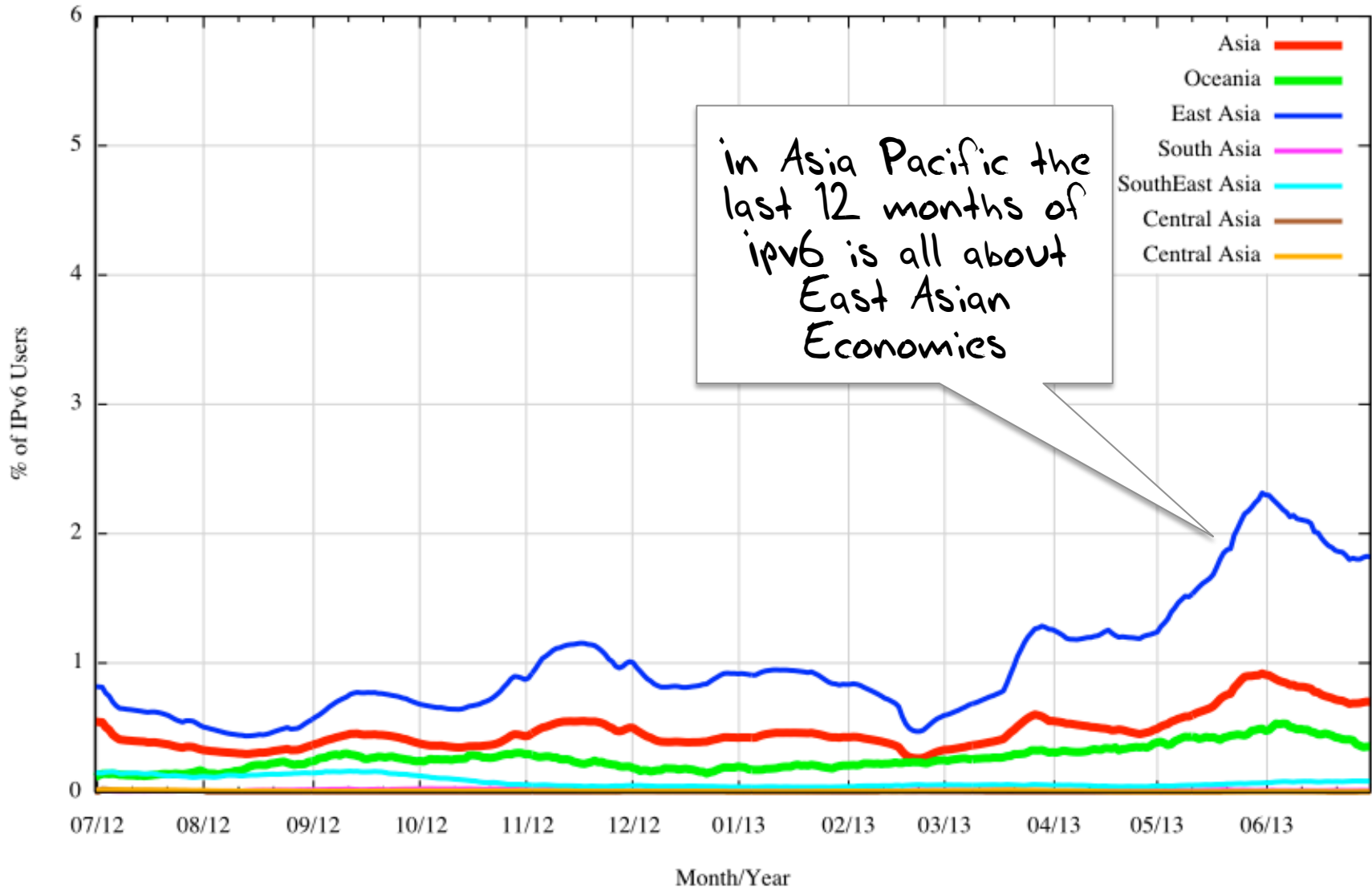
IPv6, Regionally

IPv6 Preferred - by Region



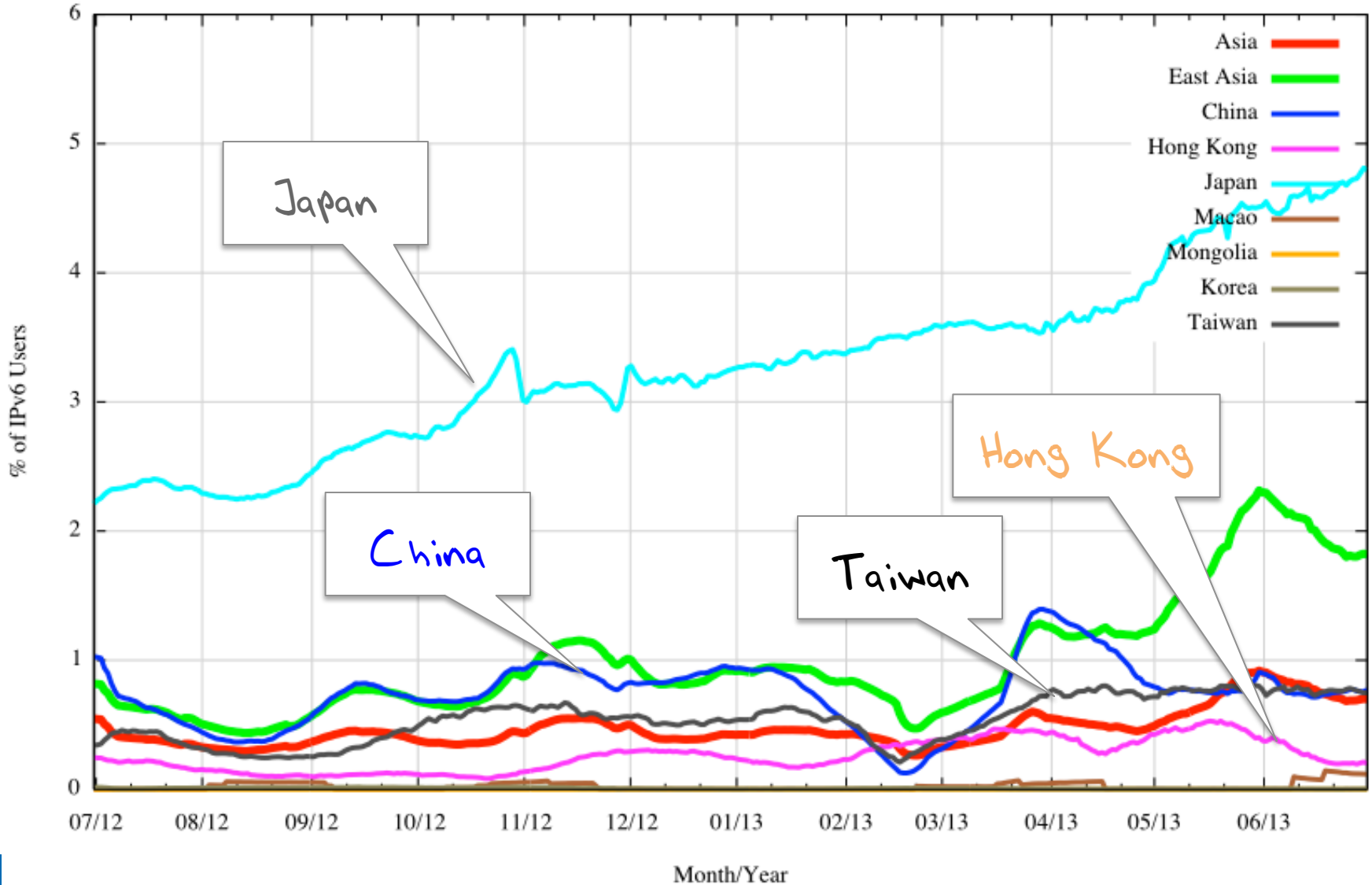
IPv6 in the AP Region

IPv6 Preferred in Asia - by SubRegion



IPv6 in East Asia

IPv6 Preferred in Asia - by SubRegion



Globally Speaking

- IPv6 did not happen everywhere and all at once in 2012 / 2013
- Some economies have been very active in terms of IPv6 deployment
- So lets look at this on a country-by-country basis...

Where is IPv6?

The National Top 20 – Then and Now

2012

| Rank | Economy | % of Internet Users | # of IPv6 Users (est) |
|------|----------------|---------------------|-----------------------|
| 1 | Romania | 7.40% | 641,389 |
| 2 | France | 4.03% | 2,013,920 |
| 3 | Luxembourg | 2.59% | 12,049 |
| 4 | Japan | 1.75% | 1,766,799 |
| 5 | Slovenia | 1.07% | 15,175 |
| 6 | United States | 1.01% | 2,500,684 |
| 7 | China | 1.01% | 5,209,030 |
| 8 | Croatia | 0.85% | 22,551 |
| 9 | Switzerland | 0.80% | 51,575 |
| 10 | Lithuania | 0.66% | 13,845 |
| 11 | Czech Republic | 0.55% | 39,694 |
| 12 | Norway | 0.51% | 23,333 |
| 13 | Slovakia | 0.44% | 19,112 |
| 14 | Russian Fed. | 0.39% | 238,576 |
| 15 | Germany | 0.32% | 217,494 |
| 16 | Hungary | 0.31% | 19,896 |
| 17 | Portugal | 0.30% | 16,406 |
| 18 | Netherlands | 0.27% | 40,870 |
| 19 | Australia | 0.25% | 49,425 |
| 20 | Taiwan | 0.24% | 38,843 |

2013

| Rank | Economy | % of Internet Users | # of IPv6 Users (est) |
|------|----------------|---------------------|-----------------------|
| 1 | Romania | 10.84% | 1,053,237 |
| 2 | Switzerland | 10.72% | 700,777 |
| 3 | Luxembourg | 6.96% | 32,535 |
| 4 | France | 5.46% | 2,824,465 |
| 5 | Belgium | 4.17% | 339,651 |
| 6 | Japan | 4.13% | 4,137,476 |
| 7 | Germany | 3.24% | 2,212,062 |
| 8 | United States | 2.72% | 6,768,264 |
| 9 | Peru | 2.42% | 273,370 |
| 10 | Czech Republic | 2.12% | 157,203 |
| 11 | Singapore | 1.58% | 54,060 |
| 12 | Norway | 1.21% | 53,677 |
| 13 | Slovenia | 0.92% | 13,230 |
| 14 | China | 0.90% | 4,651,953 |
| 15 | Greece | 0.78% | 44,572 |
| 16 | Portugal | 0.76% | 45,408 |
| 17 | Taiwan | 0.72% | 120,180 |
| 18 | Netherlands | 0.70% | 109,425 |
| 19 | Australia | 0.69% | 121,256 |
| 20 | Slovakia | 0.52% | 21,169 |

Where is IPv6?

The National Top 20 – Then and Now

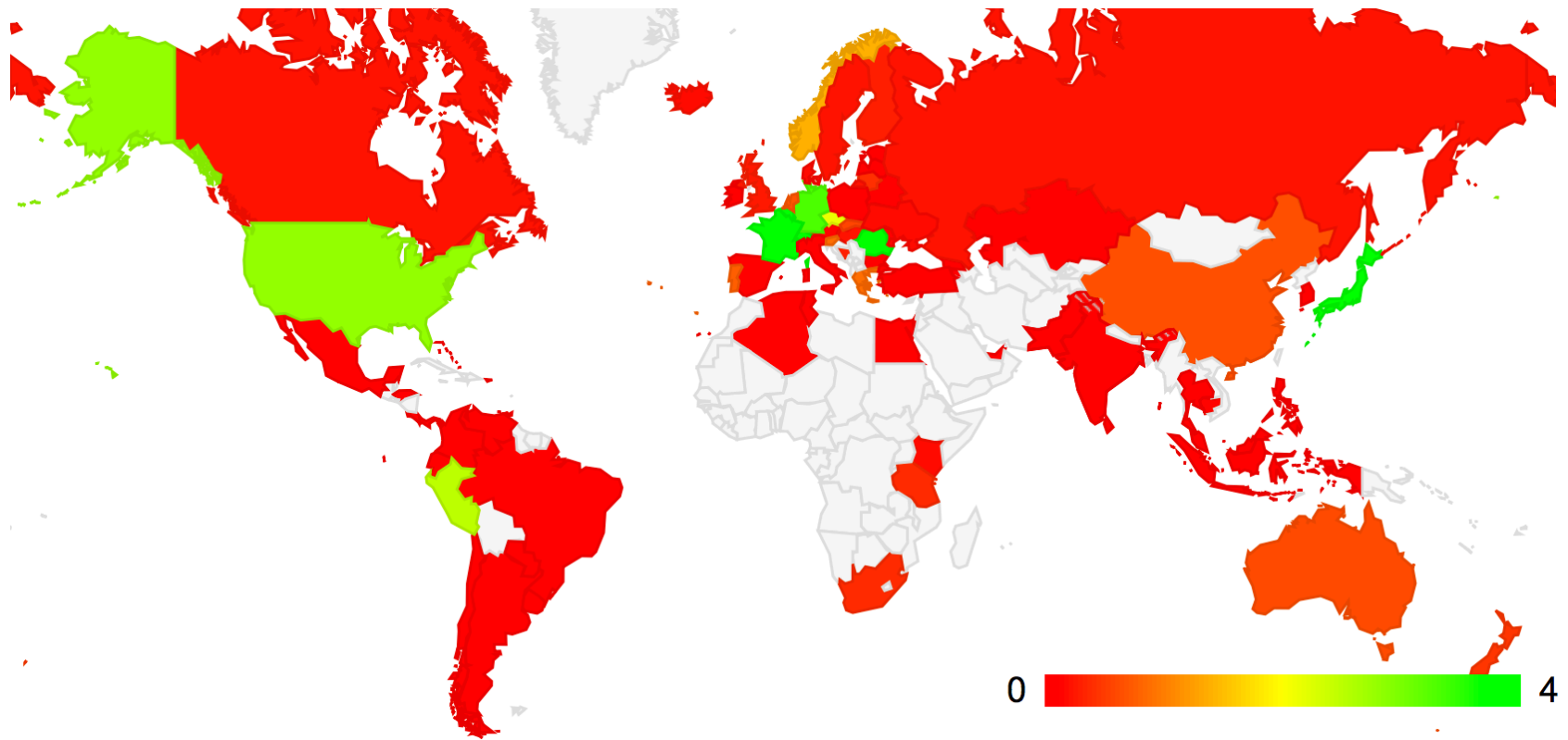
2012

| Rank | Economy | % of Internet Users | # of IPv6 Users (est) |
|------|----------------|---------------------|-----------------------|
| 1 | Romania | 7.40% | 641,389 |
| 2 | France | 4.03% | 2,013,920 |
| 3 | Luxembourg | 2.59% | 12,049 |
| 4 | Japan | 1.75% | 1,766,799 |
| 5 | Slovenia | 1.07% | 15,175 |
| 6 | United States | 1.01% | 2,500,684 |
| 7 | China | 1.01% | 5,209,030 |
| 8 | Croatia | 0.85% | 22,551 |
| 9 | Switzerland | 0.80% | 51,575 |
| 10 | Lithuania | 0.66% | 13,845 |
| 11 | Czech Republic | 0.55% | 39,694 |
| 12 | Norway | 0.51% | 23,333 |
| 13 | Slovakia | 0.44% | 19,112 |
| 14 | Russian Fed. | 0.39% | 238,576 |
| 15 | Germany | 0.32% | 217,494 |
| 16 | Hungary | 0.31% | 19,896 |
| 17 | Portugal | 0.30% | 16,406 |
| 18 | Netherlands | 0.27% | 40,870 |
| 19 | Australia | 0.25% | 49,425 |
| 20 | Taiwan | 0.24% | 38,843 |

2013

| Rank | Economy | % of Internet Users | # of IPv6 Users (est) |
|------|----------------|---------------------|-----------------------|
| 1 | Romania | 10.84% | 1,053,237 |
| 2 | Switzerland | 10.72% | 700,777 |
| 3 | Luxembourg | 6.96% | 32,535 |
| 4 | France | 5.46% | 2,824,465 |
| 5 | Belgium | 4.17% | 339,651 |
| 6 | Japan | 4.13% | 4,137,476 |
| 7 | Germany | 3.24% | 2,212,062 |
| 8 | United States | 2.72% | 6,768,264 |
| 9 | Peru | 2.42% | 273,370 |
| 10 | Czech Republic | 2.12% | 157,203 |
| 11 | Singapore | 1.58% | 54,060 |
| 12 | Norway | 1.21% | 53,677 |
| 13 | Slovenia | 0.92% | 13,230 |
| 14 | China | 0.90% | 4,651,953 |
| 15 | Greece | 0.78% | 44,572 |
| 16 | Portugal | 0.76% | 45,408 |
| 17 | Taiwan | 0.72% | 120,180 |
| 18 | Netherlands | 0.70% | 109,425 |
| 19 | Australia | 0.69% | 121,256 |
| 20 | Slovakia | 0.52% | 21,169 |

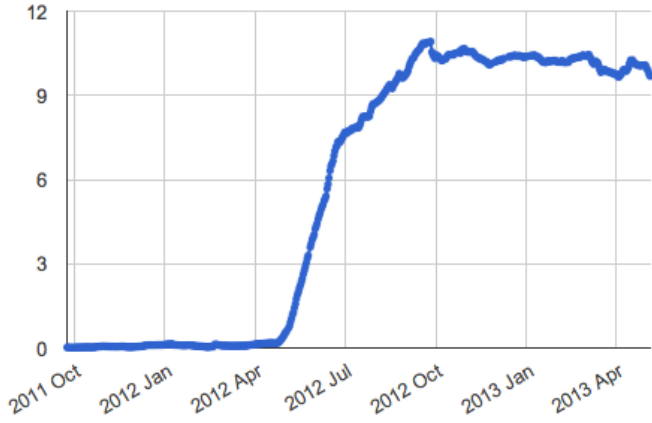
The IPv6 world, Geographically Speaking...



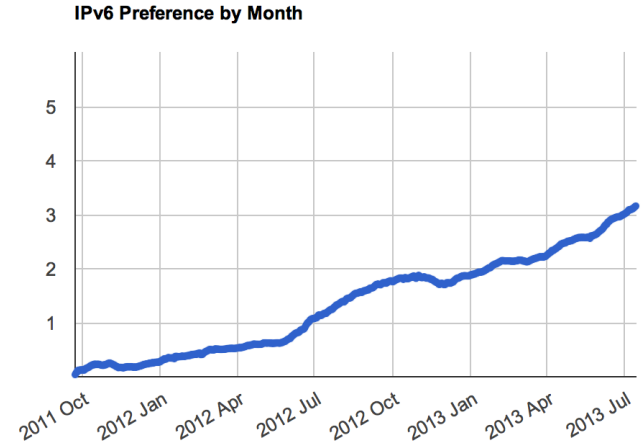
Nationally, who's deploying IPv6 over the past year?

| 2013 Rank | Economy | Diff (%) | Diff IPv6 User Count |
|-----------|------------------|----------|----------------------|
| 1 | Switzerland | +9.92% | + 649,202 |
| 2 | Luxembourg | +4.37% | + 20,486 |
| 3 | Belgium | +4.07% | + 331,153 |
| 4 | Romania | +3.44% | + 411,848 |
| 5 | Germany | +2.92% | +1,994,568 |
| 6 | Peru | +2.41% | + 272,327 |
| 7 | Japan | +2.38% | +2,370,677 |
| 8 | United States | +1.71% | +4,267,580 |
| 9 | Czech Republic | +1.57% | + 117,509 |
| 10 | Singapore | +1.43% | + 48,524 |
| 11 | France | +1.43% | + 810,545 |
| 12 | Greece | +0.70% | + 40,530 |
| 13 | Norway | +0.70% | + 30,344 |
| 14 | Taiwan | +0.48% | + 81,337 |
| 15 | Portugal | +0.46% | + 29,002 |
| 16 | Australia | +0.44% | + 71,831 |
| 17 | Netherlands | +0.43% | + 68,555 |
| 18 | New Zealand | +0.35% | + 13,174 |
| 19 | South Africa | +0.33% | + 34,022 |
| 20 | Bosnia and Herz. | +0.32% | + 8,914 |

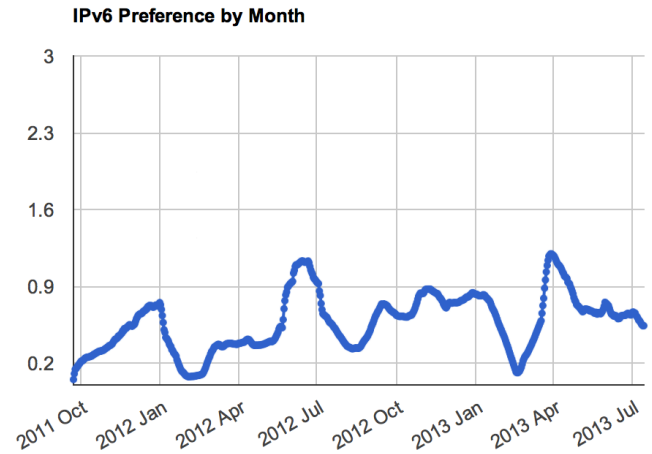
And Some Countries...



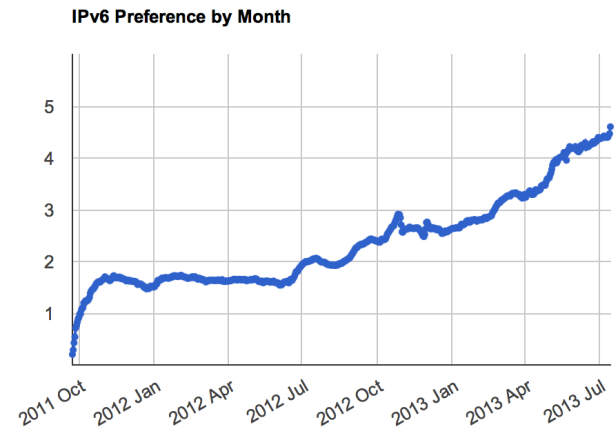
Romania



United States



China



Japan

Drilling down to the AS level...

Economy AS Number AS Name 2012 IPv6 (%) 2013 IPv6 (%)

United States of America

| | | | |
|---------|---|-----|-----|
| AS6939 | Hurricane Electric | 29% | 37% |
| AS22394 | Cellco Partnership DBA Verizon Wireless | 6% | 20% |
| AS7018 | AT&T Services | 6% | 15% |
| AS3561 | Savvis | 1% | 5% |
| AS7922 | Comcast | 1% | 3% |

Japan

| | | | |
|---------|----------------|-----|-----|
| AS2516 | KDDI | 16% | 27% |
| AS18126 | Chubu Telecomm | 0% | 23% |
| AS17676 | Softbank | 1% | 4% |

Germany

| | | | |
|---------|---------------------|----|-----|
| AS3320 | Deutsche Telekom AG | 0% | 5% |
| AS31334 | Kabel Deutschland | 1% | 7% |
| AS29562 | Kabel BW GmbH | 0% | 10% |

France

| | | | |
|---------|----------|-----|-----|
| AS12322 | Free SAS | 19% | 22% |
|---------|----------|-----|-----|

Switzerland

| | | | |
|---------|-----------|-----|-----|
| AS67722 | Swisscomm | 0% | 23% |
| AS559 | Switch | 11% | 18% |

Romania

| | | | |
|--------|--------------|-----|-----|
| AS8708 | RCS & RDS SA | 11% | 24% |
|--------|--------------|-----|-----|

Belgium

| | | | |
|---------|------------|----|-----|
| AS12392 | Brutele SC | 0% | 33% |
| AS2611 | BELNET | 2% | 22% |

Peru

| | | | |
|--------|------------------------|----|----|
| AS6147 | Telefonica del Peru SA | 0% | 3% |
|--------|------------------------|----|----|

Czech Republic

| | | | |
|---------|----------------------|-----|-----|
| AS2852 | CESNET z.s.p.o. | 20% | 27% |
| AS5610 | Telefonica Czech | 0% | 3% |
| AS51154 | Internethome; s.r.o. | 0% | 2% |

Economy AS Number AS Name 2012 IPv6 (%) 2013 IPv6 (%)

United Kingdom

| | | | |
|---------|---------|-----|-----|
| AS786 | JANET | 51% | 68% |
| AS13213 | UK2 Ltd | 0% | 23% |

Taiwan

| | | | |
|--------|-----------------|----|-----|
| AS9264 | Academic Sinica | 0% | 21% |
| AS1659 | Taiwan Academic | 2% | 8% |

Australia

| | | | |
|--------|-----------|-----|-----|
| AS7575 | AARNet | 13% | 21% |
| AS4739 | Internode | 5% | 11% |

Netherlands

| | | | |
|--------|-----------------|----|-----|
| AS3265 | XS4ALL Internet | 6% | 27% |
|--------|-----------------|----|-----|

Singapore

| | | | |
|--------|------------------|----|-----|
| AS7472 | Starhub Internet | 0% | 13% |
| AS4773 | MobileOne Ltd. | 0% | 10% |

Greece

| | | | |
|--------|-----------|-----|-----|
| AS5408 | Greek R&D | 17% | 19% |
|--------|-----------|-----|-----|

South Africa

| | | | |
|--------|-------|----|----|
| AS2018 | TENET | 0% | 3% |
|--------|-------|----|----|

Canada

| | | | |
|---------|----------------|-----|-----|
| AS6453 | TATA Comms. | 10% | 13% |
| AS22995 | Xplornet Comms | 0% | 9% |

Norway

| | | | |
|---------|-----------------|-----|------|
| AS224 | Uninett | 16% | 24% |
| AS39832 | Opera Software | 1% | 100% |
| AS57963 | Lynet Internett | 0% | 56% |

Portugal

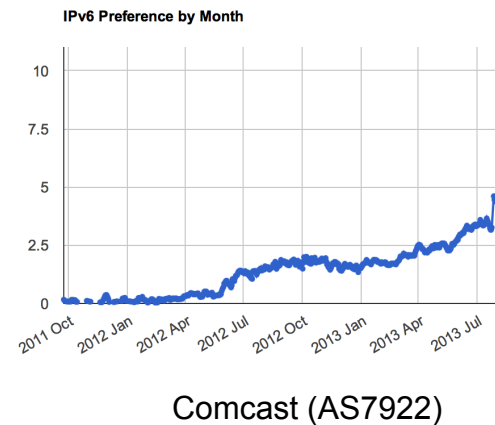
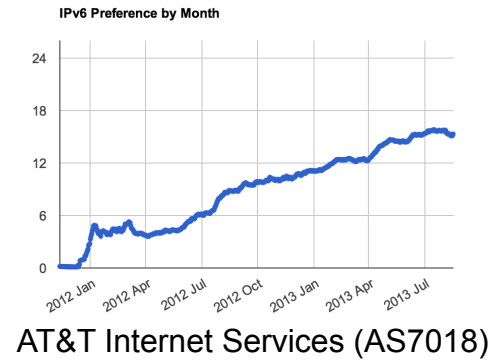
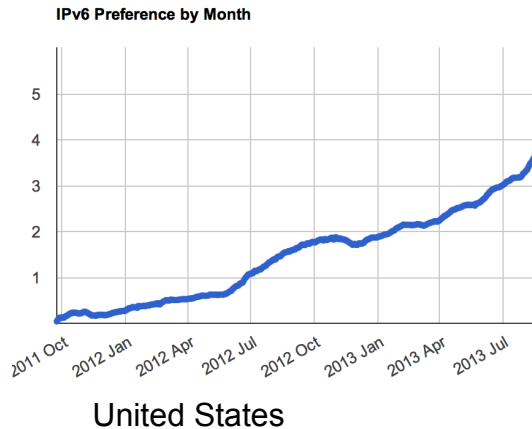
| | | | |
|--------|-----------------|----|----|
| AS3243 | PT Comunicacoes | 0% | 1% |
|--------|-----------------|----|----|

Luxembourg

| | | | |
|--------|-------------------|----|-----|
| AS6661 | Postes et Telecom | 4% | 14% |
|--------|-------------------|----|-----|

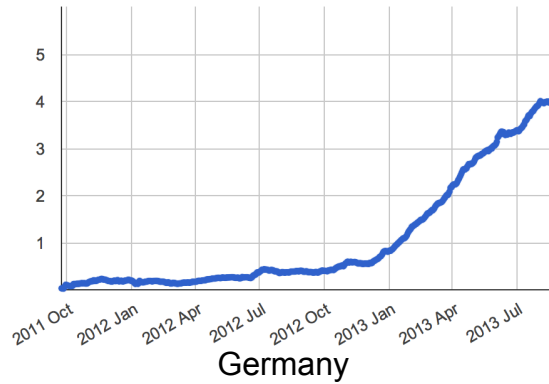
Moving on...

The pace of deployment continues in some countries

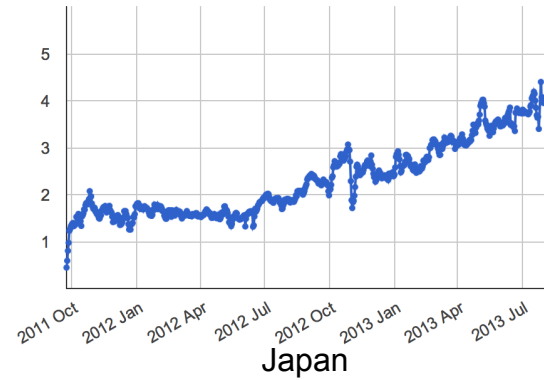


Moving on...

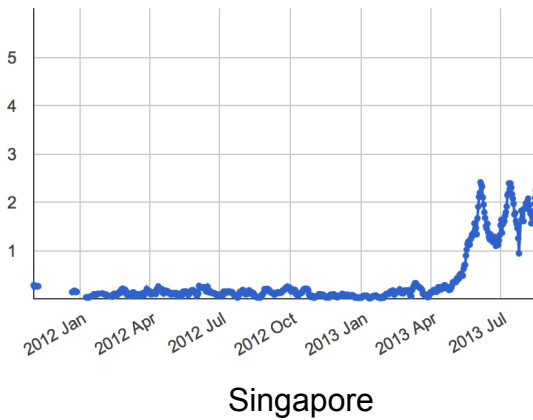
IPv6 Preference by Month



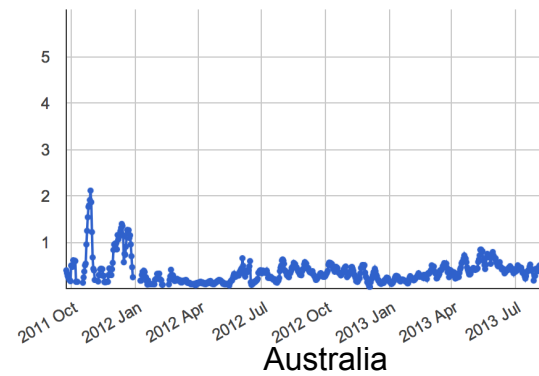
IPv6 Preference by Month



IPv6 Preference by Month

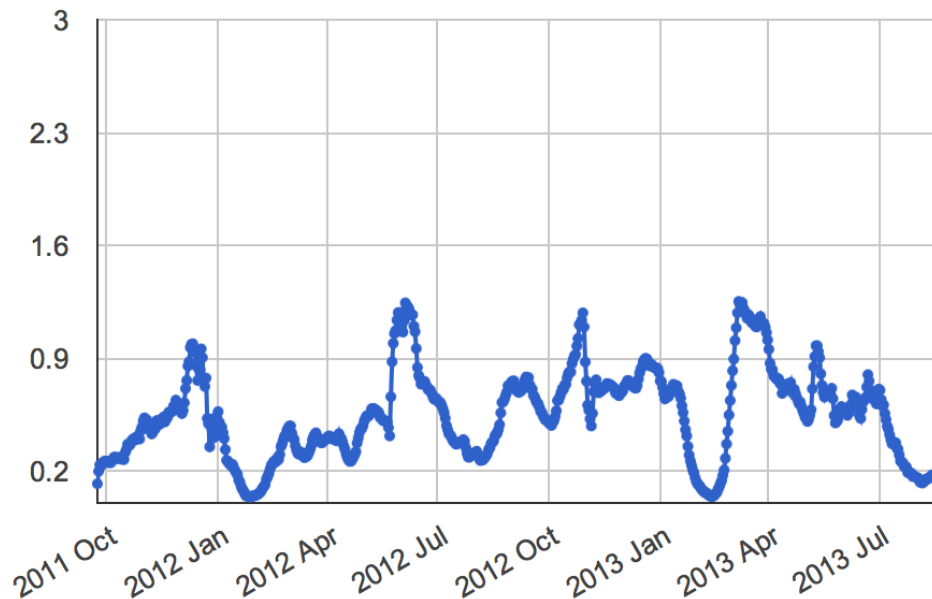


IPv6 Preference by Month



And then there's China...

IPv6 Preference by Month



This high variance is difficult to explain. This is a view of clients' IPv6 capabilities when the client is located within China and the server is external to China. The picture may be different if the experiment's server was located within China as well.

What are we seeing?

IPv6 deployment is not happening everywhere.

IPv6 is not happening all at once.

But it IS happening.

What are we seeing?

What we appear to be seeing are concentrated areas of quite intense IPv6 activity.

Is IPv6 still “A Waiting Game”?

So far what we have heard from many industry actors about IPv6 is:

“I’m waiting for others. I’ll jump when they jump.”

Is IPv6 still “A Waiting Game”?

In the past year we have seen a number of major commercial network service operators, primarily in the United States, Japan, Germany, France, Switzerland, China and Romania, launch programs that integrate IPv6 services into their mass market retail offerings.

Is IPv6 still “A Waiting Game”?

Is this effort “enough” to break out of the waiting game?

I'd like to think so!

A question to each of you...

How many IPv6 presentations have you sat through?

- 21?
- 101?
- 1,001?
- I don't know - I was comatose by the end!

APNIC **36**
CONFERENCE

Thank You!

