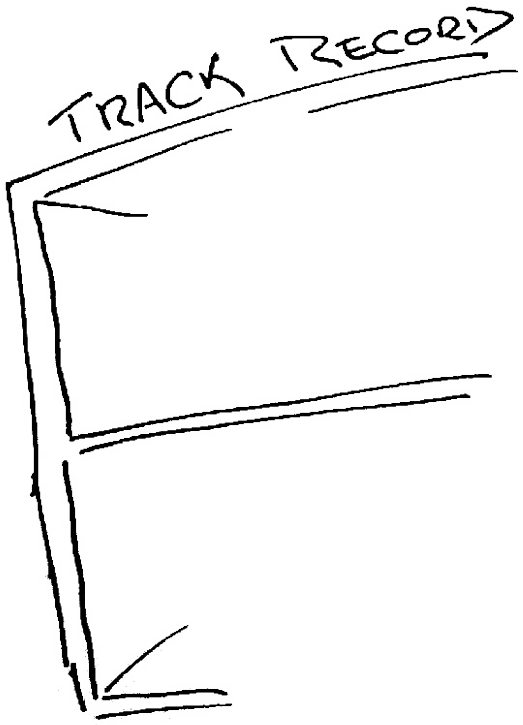
The Post-IPocalypse Internet

Geoff Huston

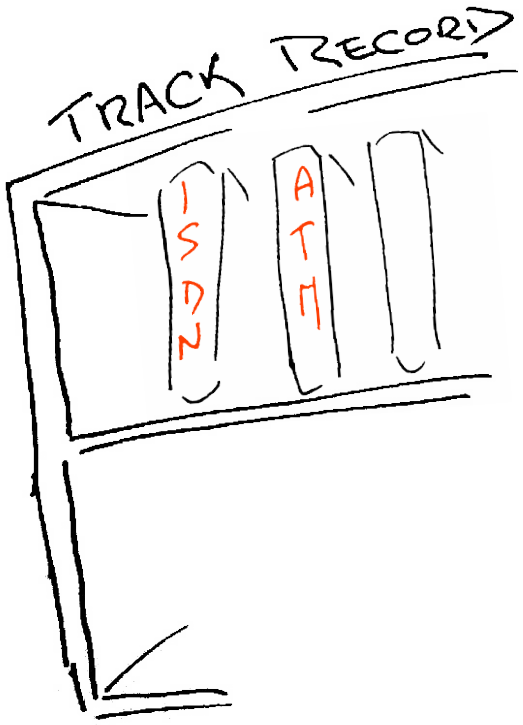
APNIC

The mainstream telecommunications industry has a rich history



The mainstream telecommunications industry has a rich history

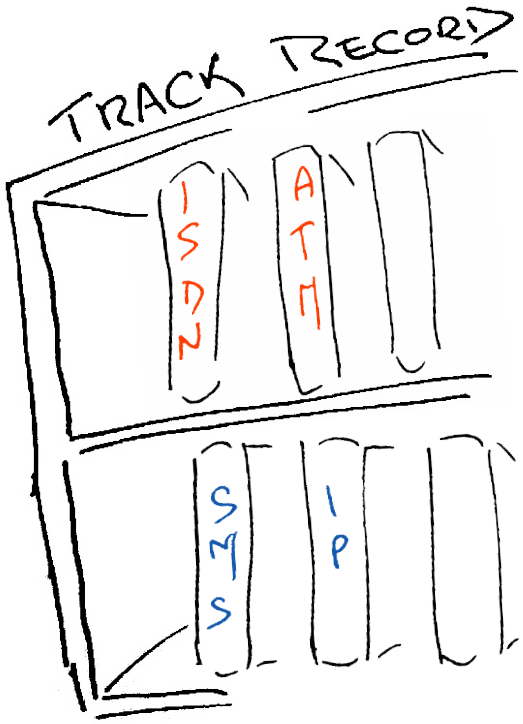
…of making very poor technology choices



The mainstream telecommunications industry has a rich history

…of making very poor technology guesses

and regularly being taken by surprise!



The Internet...

Has been a runaway success that has transformed not just the telecommunications sector, but entire social structures are being altered by the Internet!

And now we've used up most of the Internet's 32bit address pool

The Internet...

Has been a runaway succ[illegible]t
has transformed not [illegible]e
telecommunicati[illegible]or, but
entire socia[illegible]ctures are
being al[illegible] the Internet!

And [illegible]ve used up most of the
[illegible]'s 32bit address pool

This is should not be news - we've known about this looming iPocalypse for the past twenty years!

IETF Meeting - August 1990

Depletion Dates

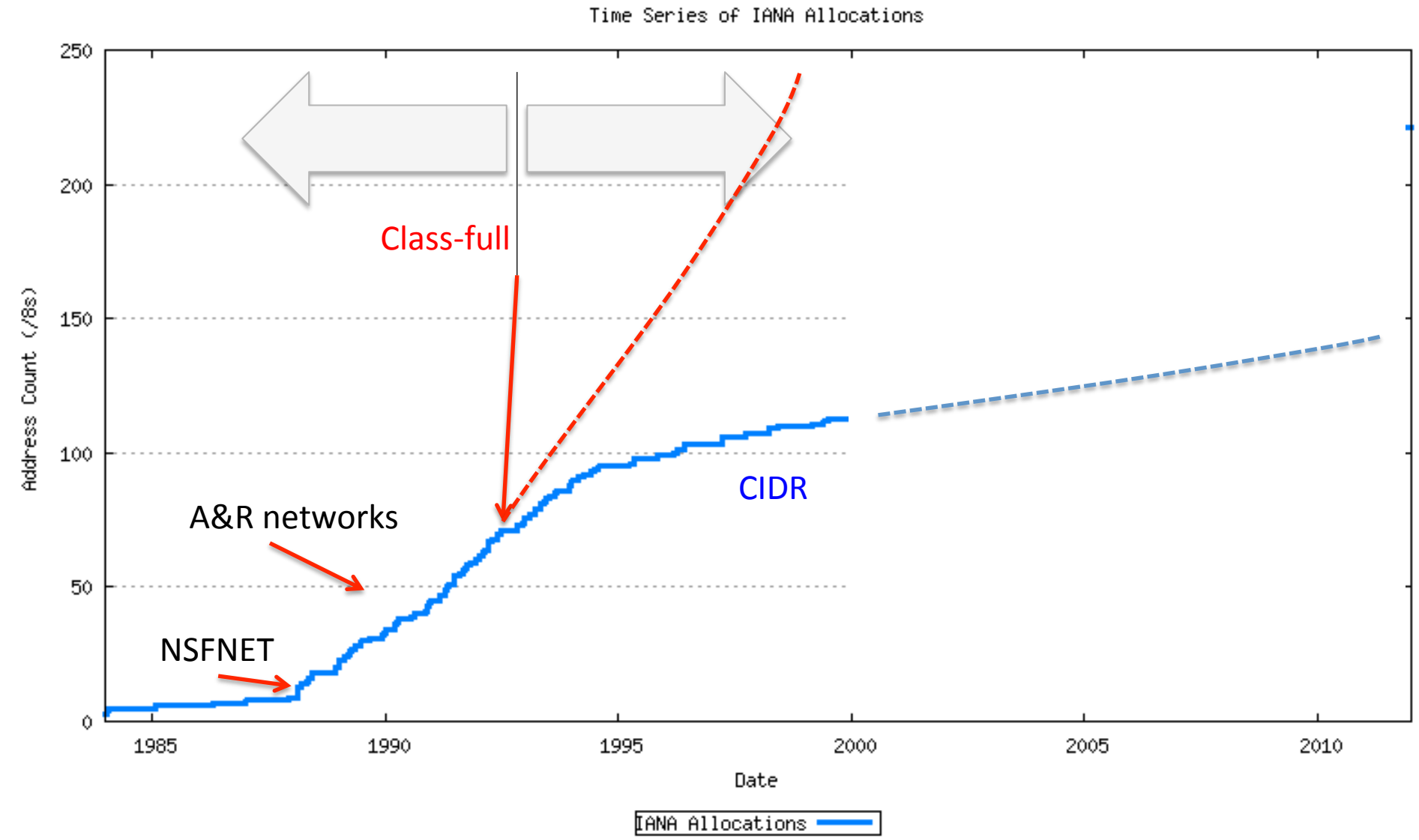
• Assigned Class "B" network numbers	Mar. 11, 1994
• NIC "connected" Class B network numbers	Apr. 26, 1996
• NSFnet address space*	Oct. 19, 1997
• Assigned Class "A-B" network numbers	Feb 17, 1998
• NIC "connected" Class A-B network numbers	Mar. 27, 2000
• BBN snapshots*	May 4, 2002

* all types: may be earlier if network class address consumption is not equal.

What did we do back in 1992?

We bought some time by removing the CLASS A, B, C address structure from IP addresses

CIDR worked!


Time Series of IANA Allocations
Address Count (/8s)
250
200
150
100
50
0
1985
1990
1995
2000
2005
2010
Date
Class-full
CIDR
A&R networks
NSFNET
IANA Allocations

What else did we do back in 1992?

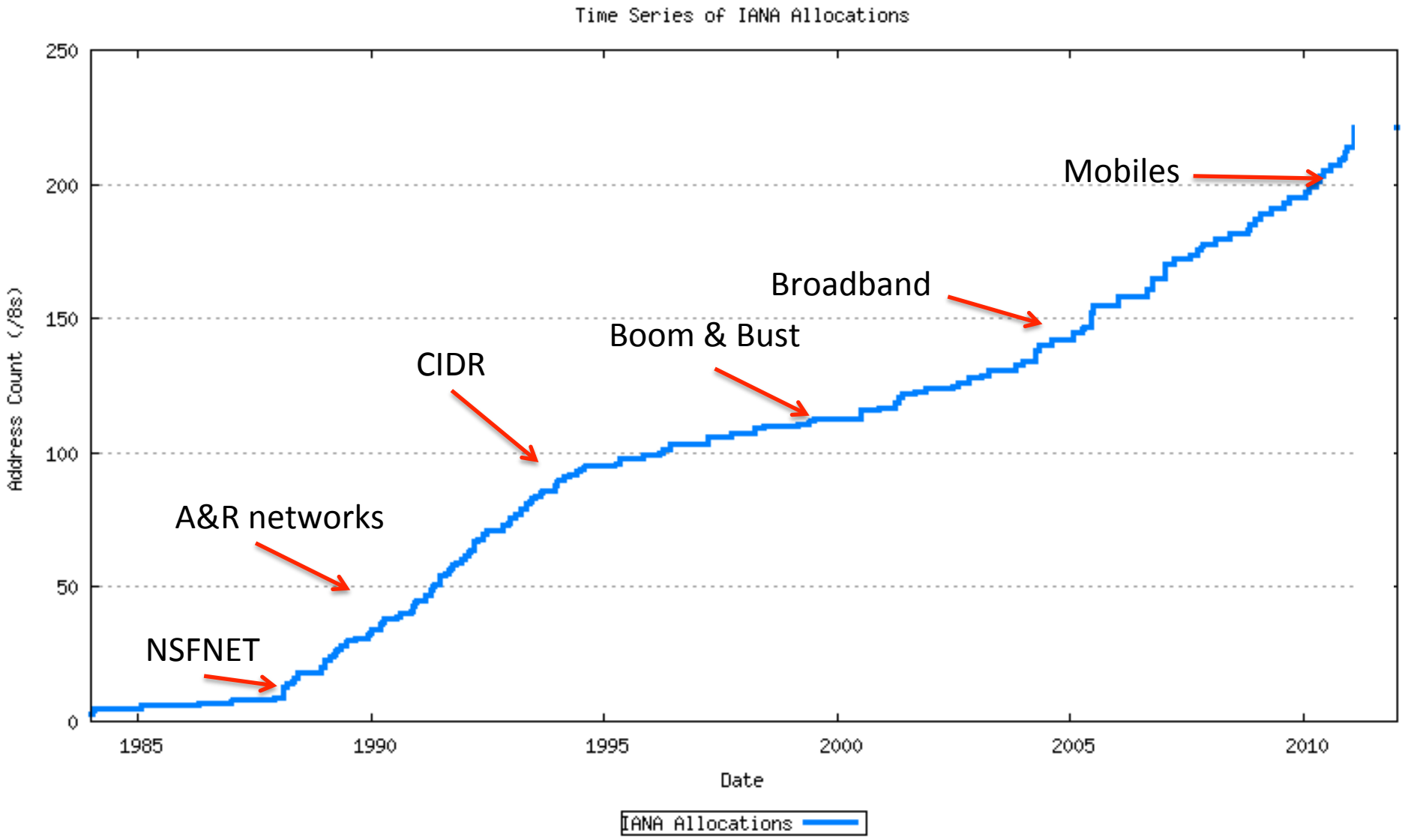
And we started working on a new Internet Protocol - to become IPv6 - to replace IPv4

We left the task of transition until after we had figured out what this new protocol would look like

ZZZZZZ

For a while this did not look to be an urgent problem...

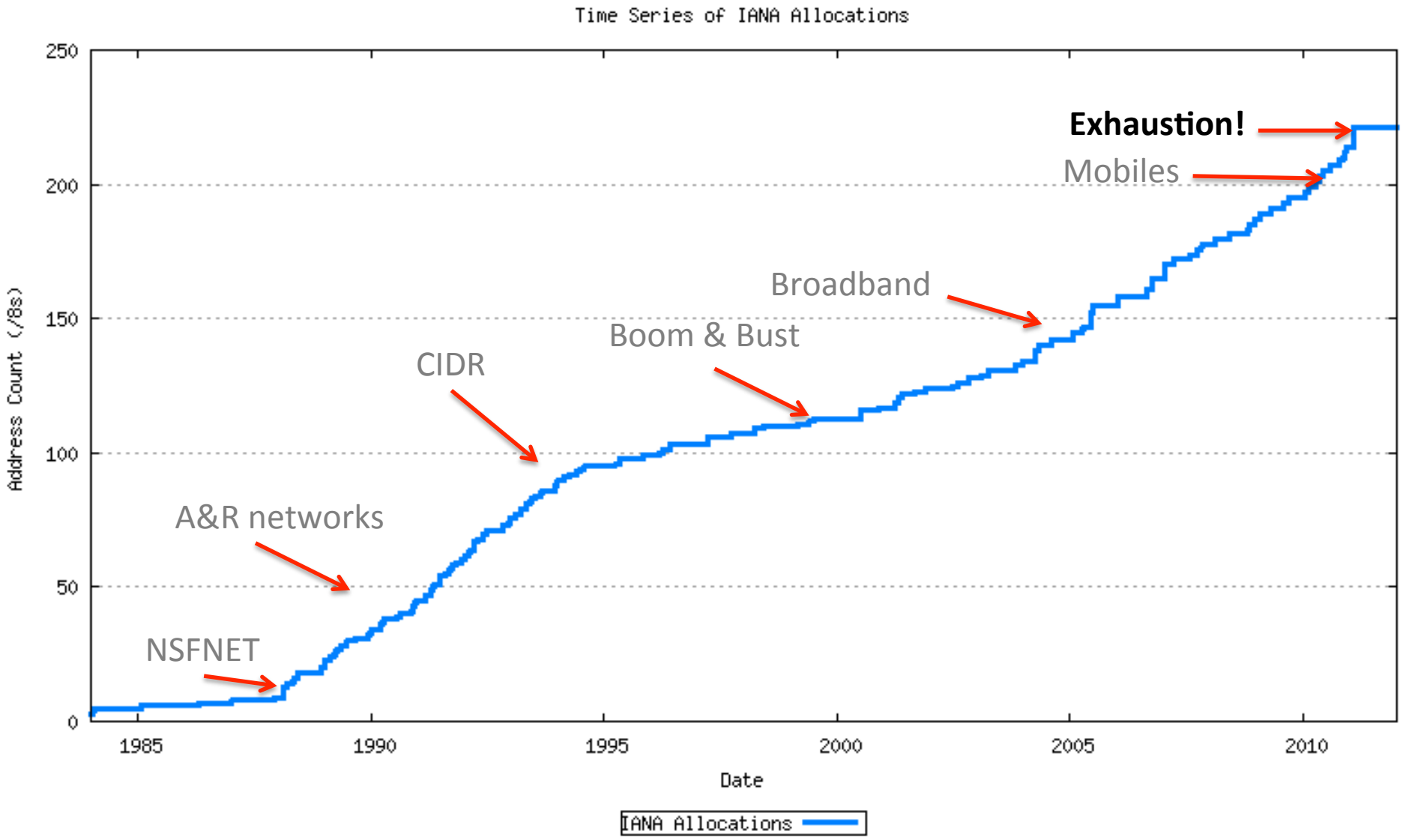
Meanwhile, we continued to build (IPv4) networks



The rude awakening

Until all of a sudden the IPv4 address piggy bank was looking extremely empty...

IPv4 Address Allocations



3 February 2011

Free Pool of IPv4 Address Space Depleted

IPv6 adoption at critical phase

Montevideo, 3 February 2011 – The Number Resource Organization (NRO) announced today that the free pool of available IPv4 addresses is now fully depleted. On Monday, January 31, the Internet Assigned Numbers Authority (IANA) allocated two blocks of IPv4 address space to APNIC, the Regional Internet Registry (RIR) for the Asia Pacific region, which triggered a global policy to allocate the remaining IANA pool equally between the five RIRs. Today IANA allocated those blocks. This means that there are no longer any IPv4 addresses available for allocation from the IANA to the five RIRs.

IANA assigns IPv4 addresses to the RIRs in blocks that equate to 1/256th of the entire IPv4 address space. Each block is referred to as a "/8" or "slash-8". A global policy agreed on by all five RIR communities and ratified in 2009 by ICANN, the international body responsible for the IANA function, dictated that when the IANA IPv4 free pool reached five remaining /8 blocks, these blocks were to be simultaneously and equally distributed to the five RIRs.

"This is an historic day in the history of the Internet, and one we have been anticipating for quite some time," states Raúl Echeberría, Chairman of the Number Resource Organization (NRO), the official representative of the five RIRs. "The future of the Internet is in IPv6. All Internet stakeholders must now take ... action to deploy IPv6."

Ooops!

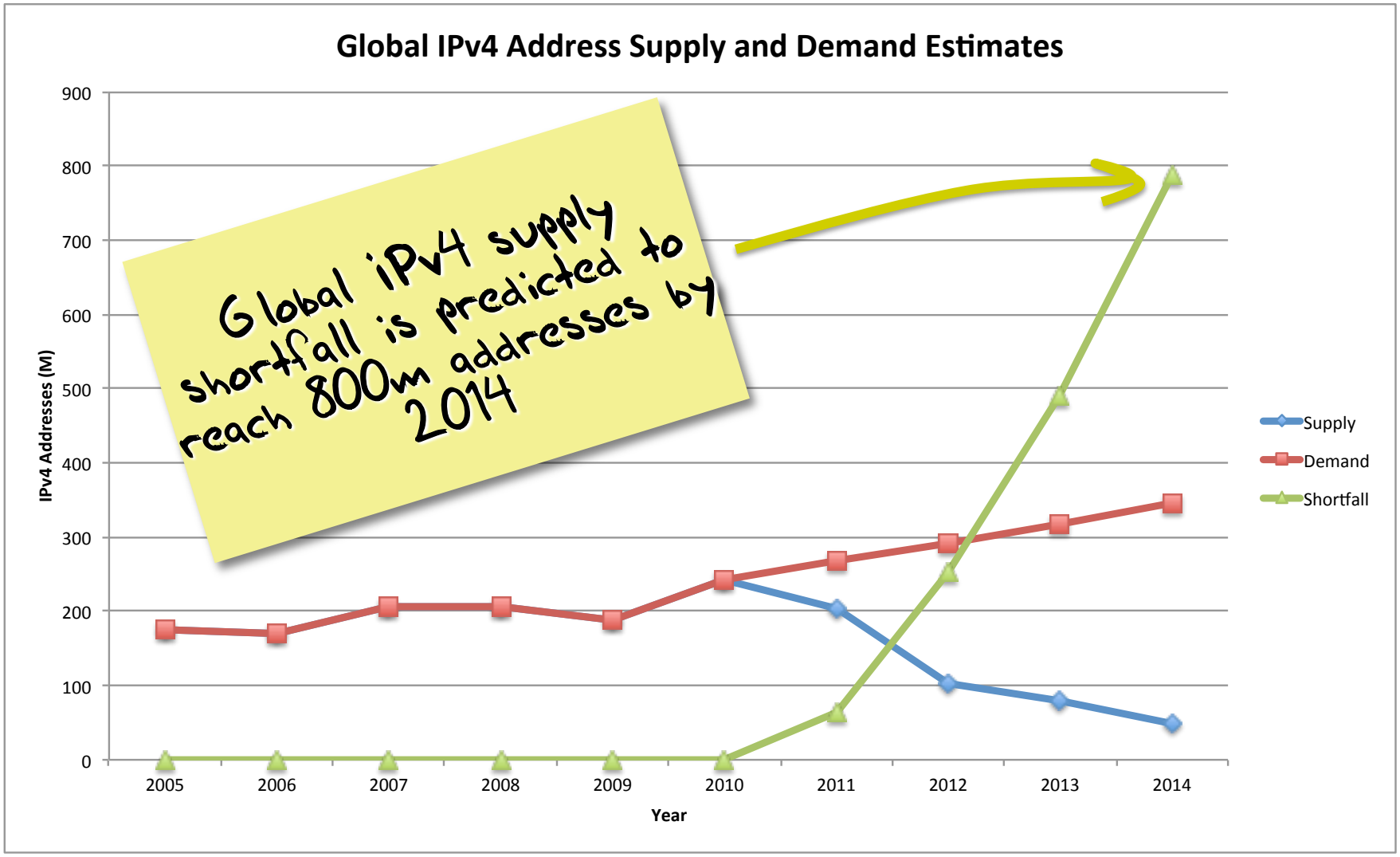
"This is truly a major turning point in the ... ," said Rod Beckstrom, ICANN's President and Chief Executive Officer. "Nobody was caught ... this ... Internet technical community has been planning for IPv4 depletion for quite some time. But it means the adoption of IPv6 is now of paramount importance, since it will allow the Internet to continue its amazing growth and foster the global innovation we've all come to expect."

IPv6 is the "next generation" of the Internet Protocol, providing a hugely expanded address space and allowing the Internet to grow into the future. "Billions of people world wide use the Internet for everything from sending tweets to paying bills. The transition to IPv6 from IPv4 represents an opportunity for even more innovative applications without the fear of running out of essential Internet IP addresses," said Vice President of IANA Elise Gerich.

Adoption of IPv6 is now vital for all Internet stakeholders. The RIRs have been working with network operators at the local, regional, and global level for more than a decade to offer training and advice on IPv6 adoption and ensure that everyone is prepared for the exhaustion of IPv4.

"Each RIR will have its final full /8 from IANA, plus any existing IP address holdings to distribute. Depending on address space requests received, this could last each RIR anywhere from a few weeks to many months. It's only a matter of time before the RIRs and Internet Service Providers (ISPs) must start denying requests for IPv4 address space. Deploying IPv6 is now a requirement, not an option," added Echeberría. IPv6 address space has been available since 1999. Visit http://www.nro.net/ipv6/ for more information on IPv6, or

Coping with Demand



The rude awakening

Until all of a sudden the IPv4 address piggy bank was looking extremely empty...

And transition to IPv6 is suddenly a very important topic!

The problem is...

We now need to fuel an ever-expanding Internet:

- without any feed of more IPv4 addresses

and

- without sufficient IPv6 deployment to cut over

What now?

An after-market for IPv4 addresses is now emerging

Market Mania!

The emergence of a market in IPv4 addresses is now a certainty.

But the outcomes of this market are by no means assured...

If the price goes too high then this will generate acute instability and potentially fragment the network

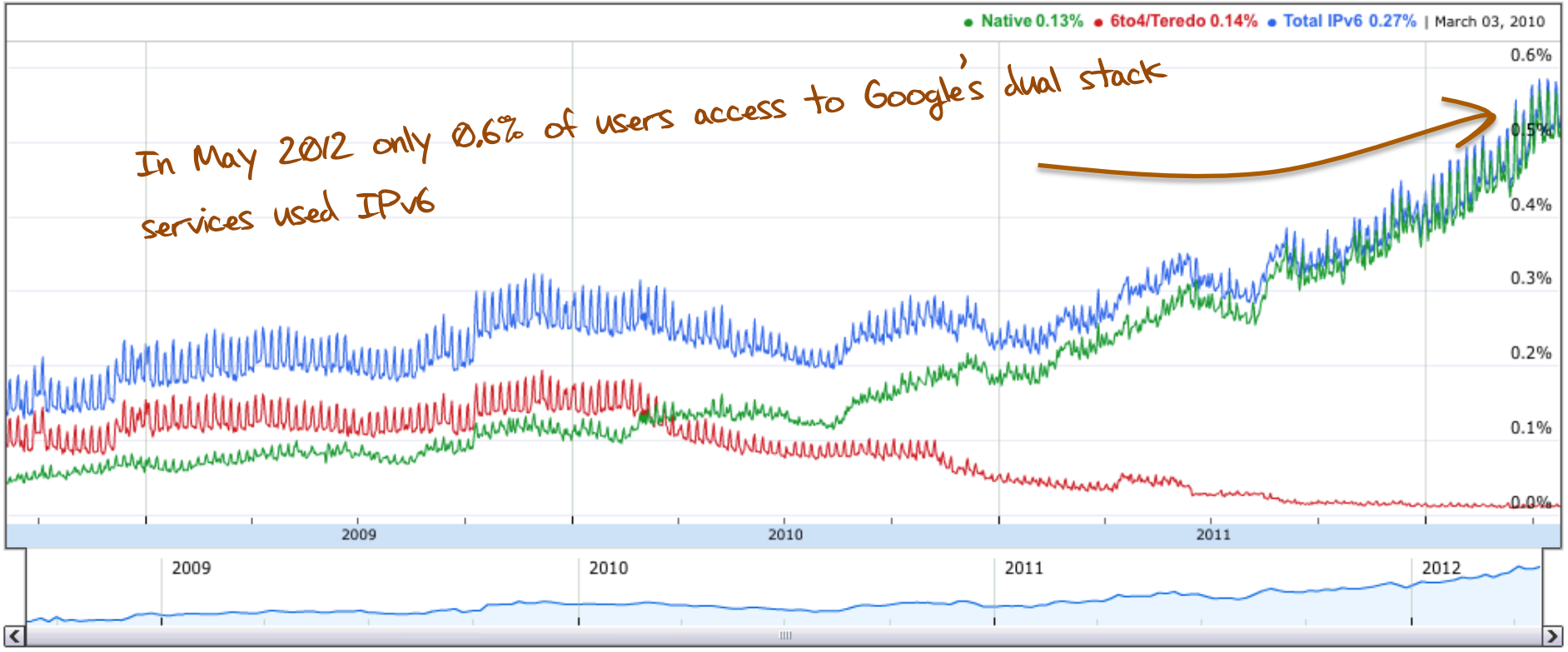
If the price is highly volatile this will deter new investors in networked services and entrench the incumbent services and incumbent providers

If the price is too low then there is little incentive for incumbents to move away from IPv4 and commence investments in IPv6, leading to stasis and entrenched incumbents

What now?

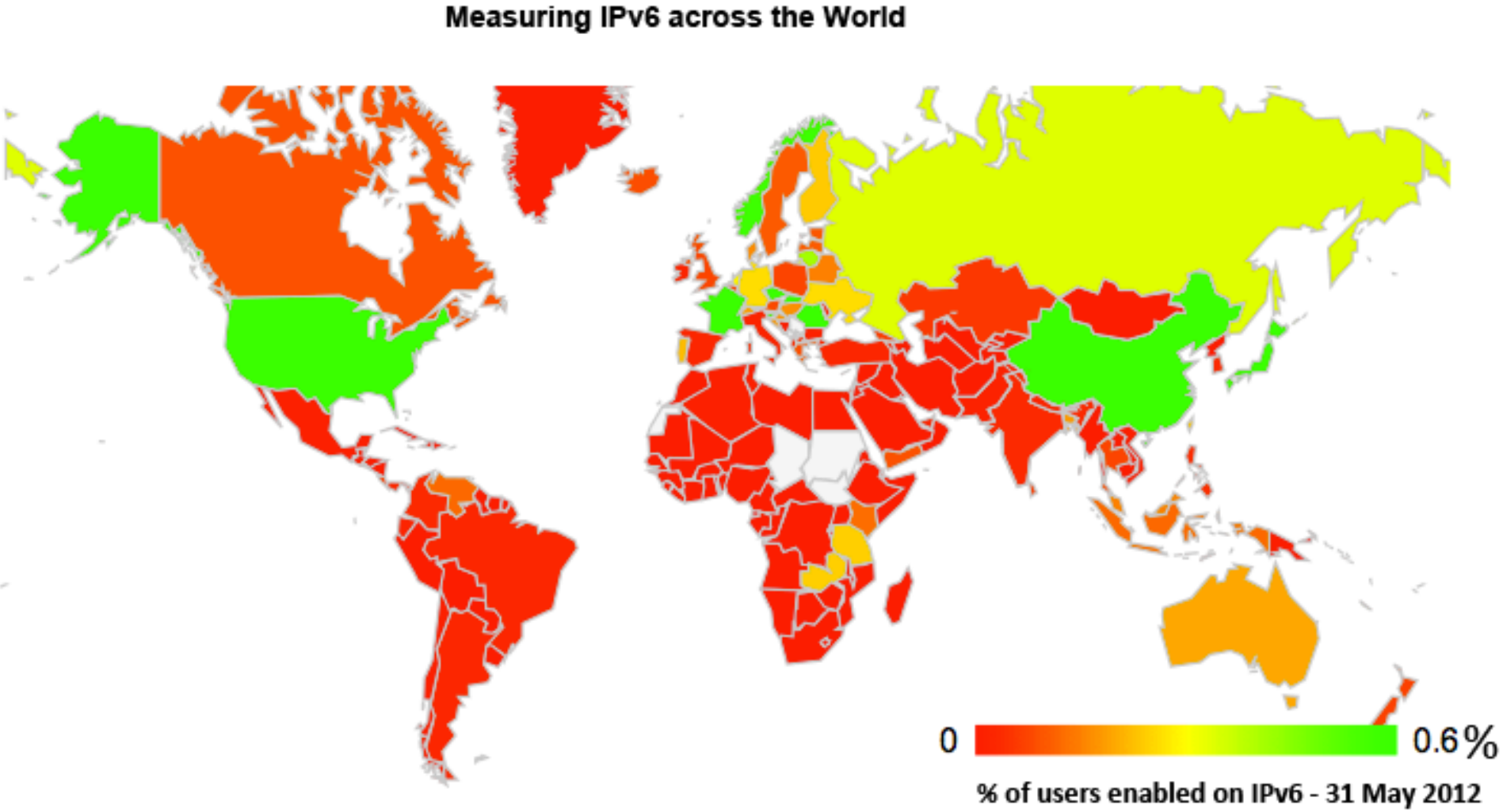
And the metrics of IPv6 deployment could be a lot higher than they are today..

IPv6 capability, as seen by Google



http://www.google.com/intl/en/ipv6/statistics/

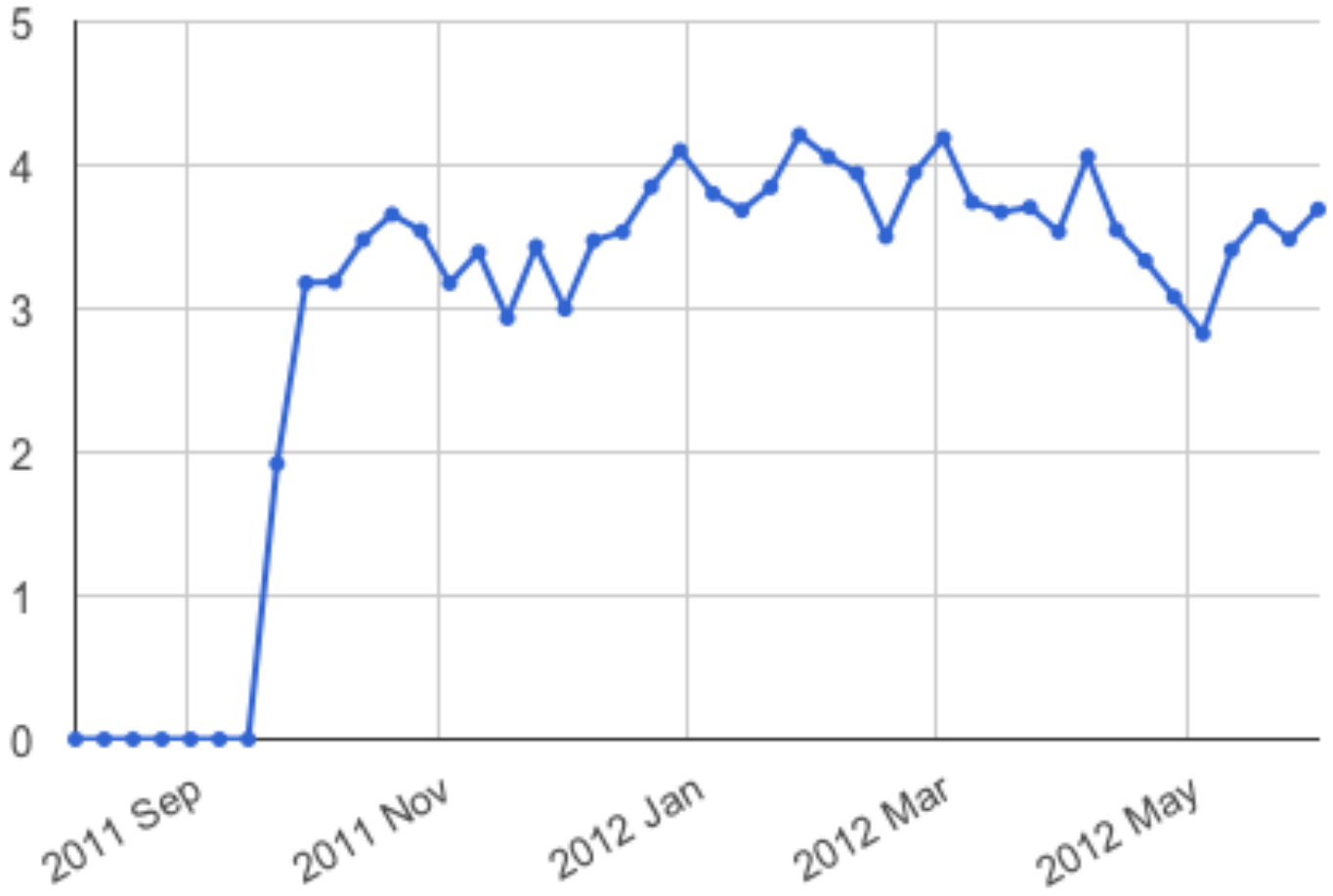
Where is it?



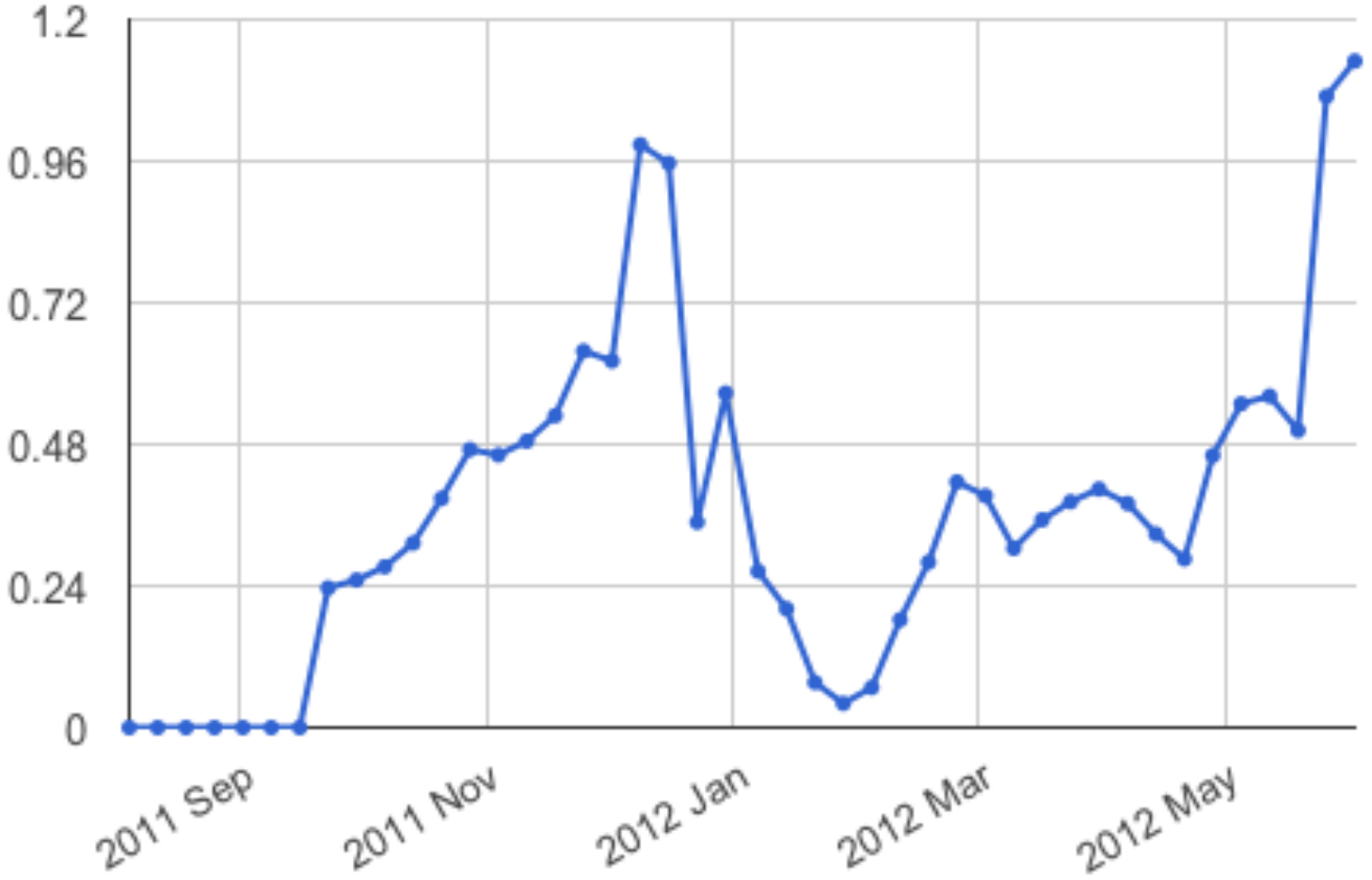
http://labs.apnic.net/index.shtml

United States

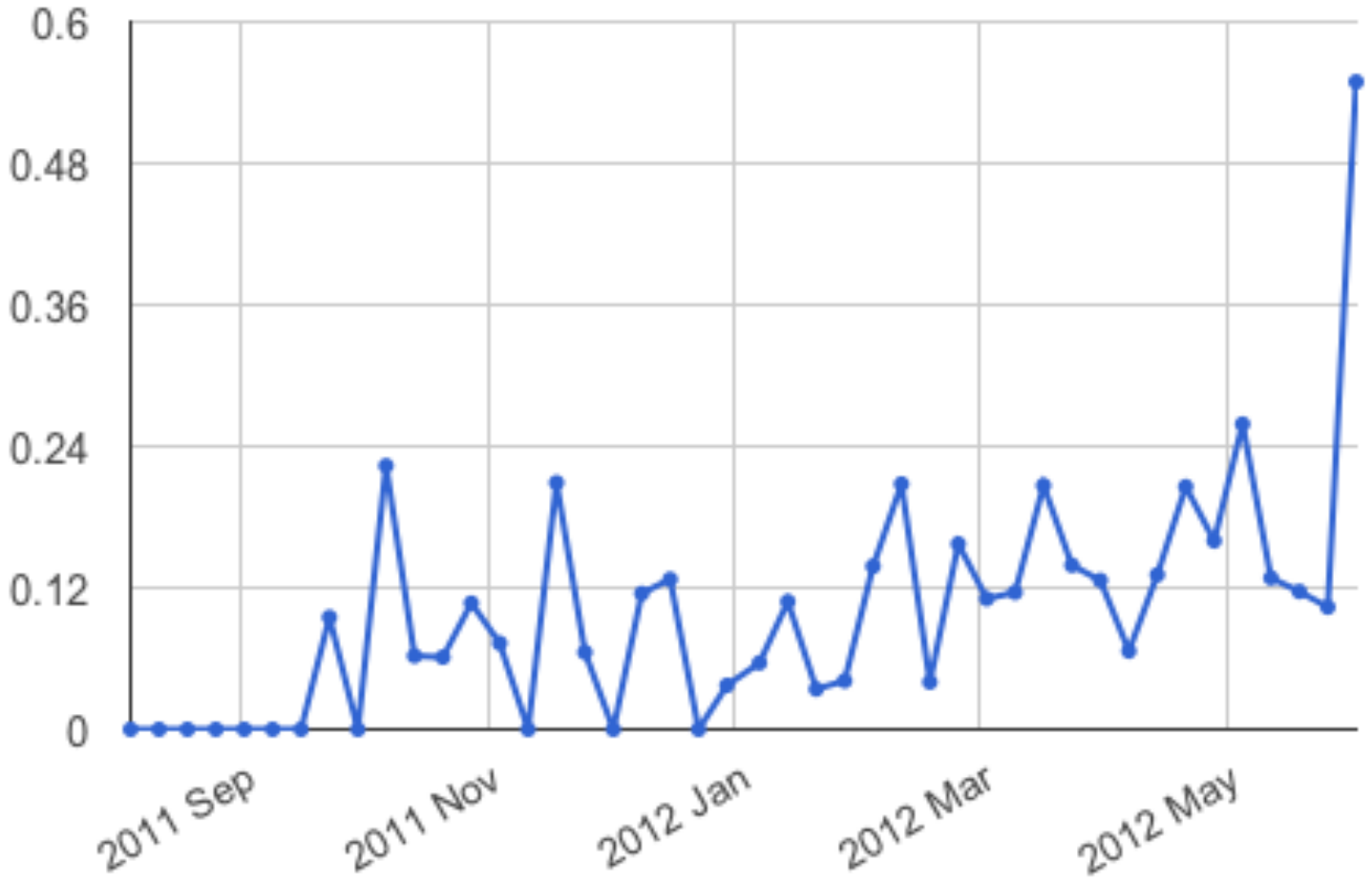
France



China


1.2
0.96
0.72
0.48
0.24
0
2011 Sep
2011 Nov
2012 Jan
2012 Mar
2012 May

Hong Kong


0.6
0.48
0.36
0.24
0.12
0
2011 Sep
2011 Nov
2012 Jan
2012 Mar
2012 May

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!

What's gone wrong?

It seems that we've managed to achieve only 2 out of 3 necessary prerequisites for IPv6 deployment

And the third area, the last mile access infrastructure, is once more proving to be very challenging

What's gone wrong?

It seems that we've managed to achieve only 2 out of 3 necessary prerequisites for IPv6 deployment

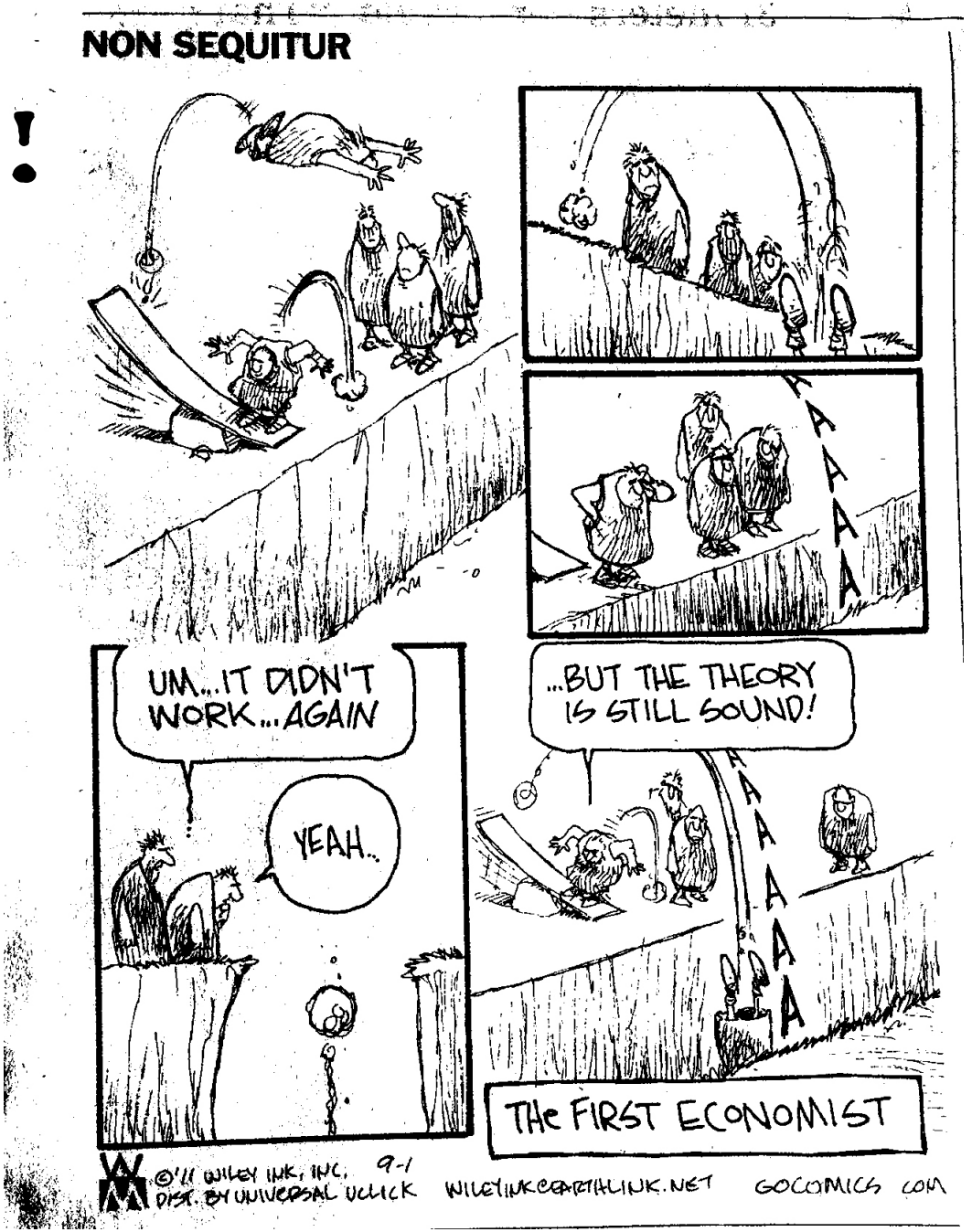
To support further growth the access industry has to secure more IPv4 addresses, deploy (and fund) IPv4 address extension mechanisms, in addition to funding an IPv6 deployment program

What's gone wrong?

It seems that we've managed to achieve only 2 out of 3 necessary prerequisites for IPv6 deployment

Why didn't we do this a few years ago when it would've been far easier to undertake this transition?

Economics!


NON SEQUITUR
AAAAA
UM...IT DIDN'T WORK...AGAIN
YEAH..
...BUT THE THEORY IS STILL SOUND!
AAAAA
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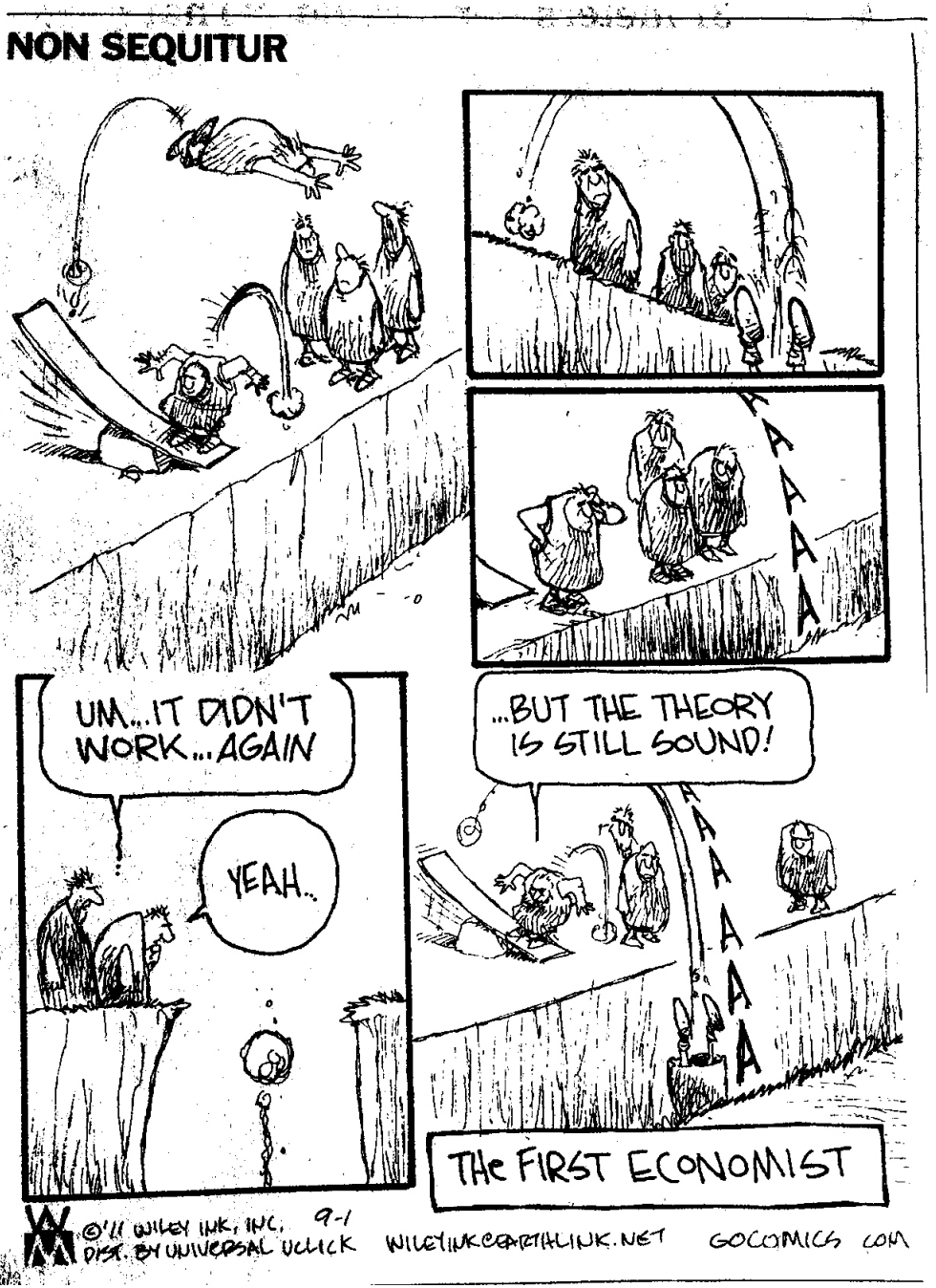
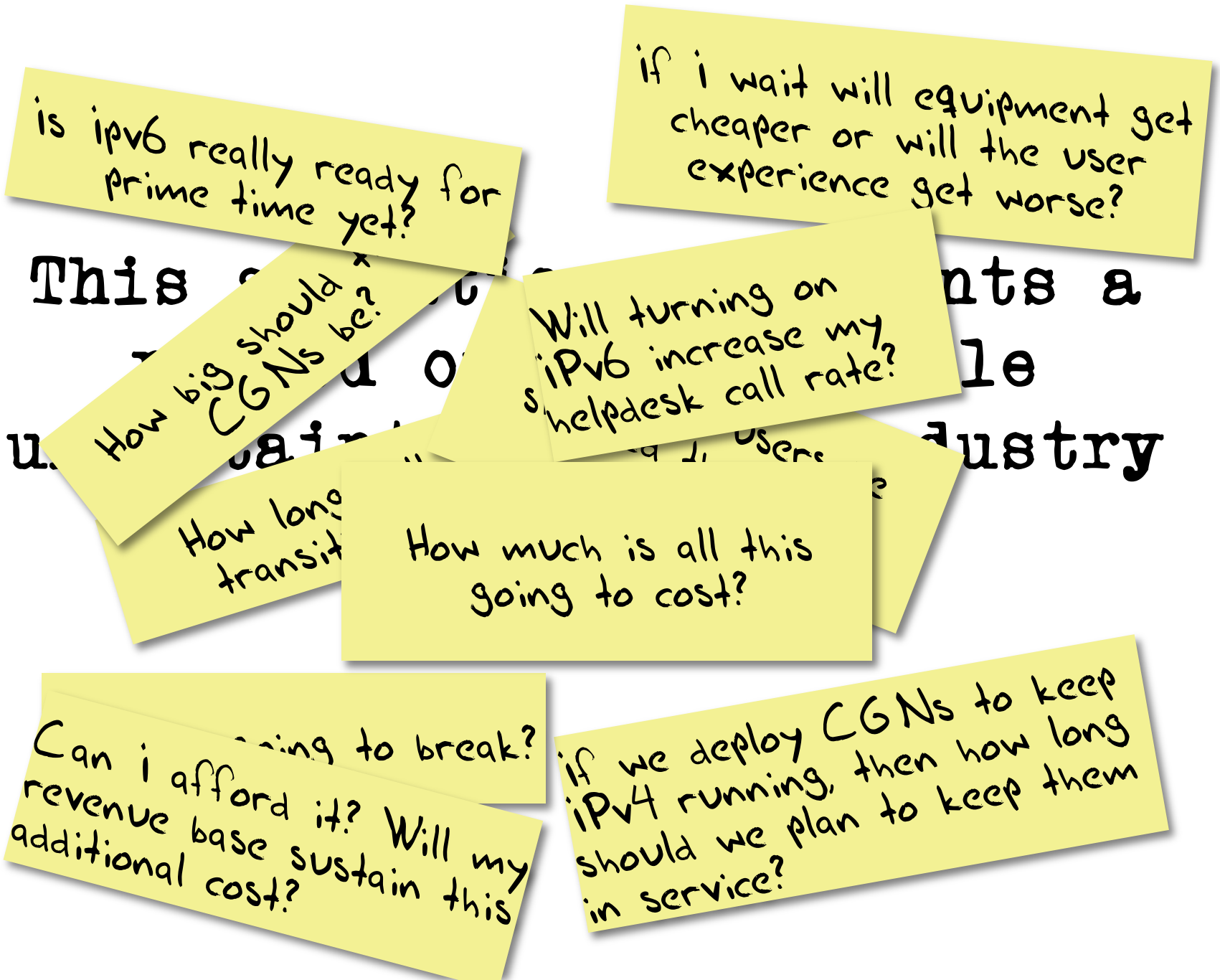
GOCOMICS.COM

Economics!

The Internet's last mile access is mired in commodity utility economics. Relentless competition has resulted in a sector where margins are thin. A move to IPv6 represents expenditure without immediate revenue gain. This is classic case of economic dislocation in an unbundled industry, where expenditure in one sector: -carriage- yields benefits in another sector: -content-



This situation represents a period of considerable uncertainty for our industry


is ipv6 really ready for prime time yet?
if i wait will equipment get cheaper or will the user experience get worse?
How big should CGNs be?
Will turning on IPv6 increase my helpdesk call rate?
How much is all this going to cost?
Can i afford it? Will my revenue base sustain this additional cost?
if we deploy CGNs to keep IPv4 running, then how long should we plan to keep them in service?

Where is this heading?

In the next five years...

In the next five years...

So we need to chose carefully!

We need to think about how to build a post-PC world where content, computation, storage and communications are sustainable abundant and openly available commodities.

And its not yet clear which path the internet will take!

And its not yet clear which path ~~the internet~~ will take!

market forces

If IPv6 is what we are after as an open and accessible platform for further network growth and innovation then the public interest in a continuing open and accessible network needs to be expressed within the dynamics of market pressures.

Today's question is:

How can we do this?

How can we "manage" this transition?

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To ensure that the industry maintains a collective focus on IPv6 as the objective of this exercise!

How can we "manage" this transition?

To ensure that the industry maintains a collective focus on IPv6 as the objective of this exercise!

And to ensure that we do not get distracted by attempting to optimize what were intended to be temporary measures

How can we "manage" this transition?

This was always going to be a very hard question to try and answer!

How can we "manage" this transition?

The data on IPv6 uptake so far suggests that we are still not managing this at all well.

How can we help the Internet through this transition?

How can we help the Internet through this transition?

Or at least, how can we avoid making it any worse than it is now?

Yes, that was intentionally left blank!

I really don't know what will work.

And as far as I can see, nor does anyone else!

But even though I don't have an answer here, I have some thoughts to offer about this issue of pulling the Internet though this transition

Three thoughts...

Firstly

If we want one working Internet at the end of all this, then keep an eye on the larger picture

Think about what is our common interest here

and try to find ways for local interests to converge

with our common interest in a single cohesive network

that remains open, neutral, and accessible

Secondly

Addresses should be used in working networks, not hoarded

- Scarcity generates pain and uncertainty
- Hoarding exacerbates scarcity in both its intensity and duration
- Extended scarcity prolongs the pain and increases the unpredictability of the entire transition process
- Closed or opaque address markets create asymmetric information that encourages speculation and hoarding, further exacerbating the problem

Finally...

Bring it on! A rapid onset of exhaustion and a rapid transition represents the best chance of achieving an IPv6 network as an outcome

The more time we spend investing time, money and effort in deploying IPv4 address extension mechanisms, the greater the pain to our customers, and the higher the risk that we will lose track of the intended temporary nature of transition and the greater the chances that we will forget about IPv6 as the objective!

The risk here is no less than the future of open networking and open content – if we get this wrong we will recreate the old stifling vertically bundled carriage monopolies of the telephone era!

And at that point we've lost everything!

Thank You!