

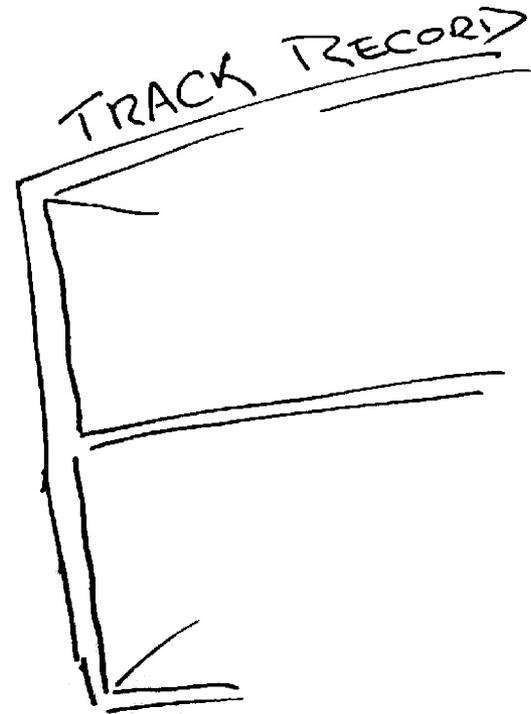
IPv4 Address Exhaustion: A Progress Report

Geoff Huston

Chief Scientist, APNIC

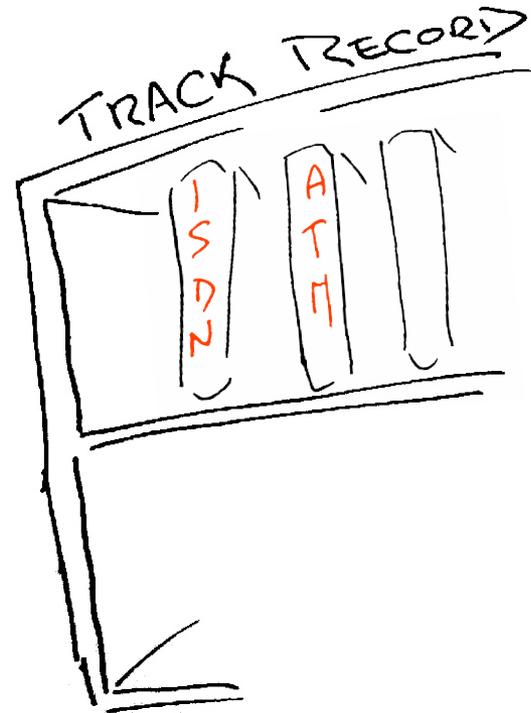


The mainstream
telecommunications
industry has a
rich history



The mainstream
telecommunications
industry has a
rich history

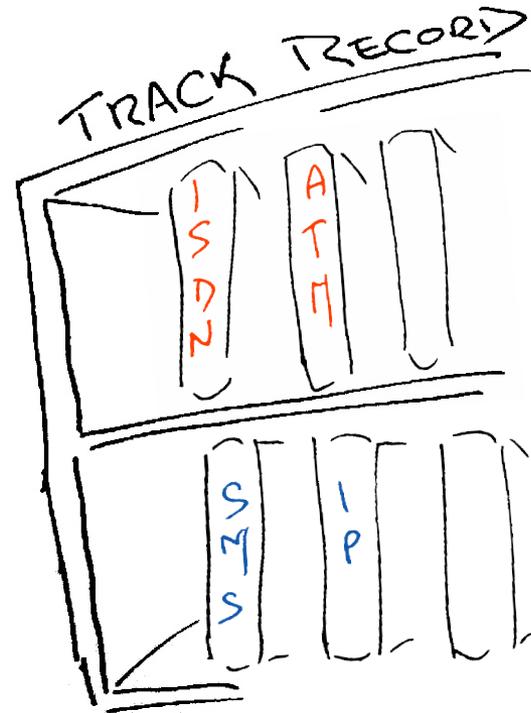
...of making very poor
technology choices



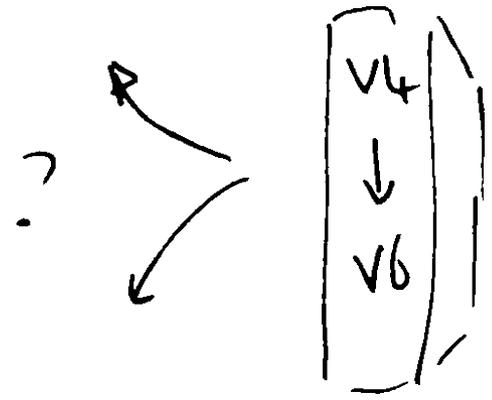
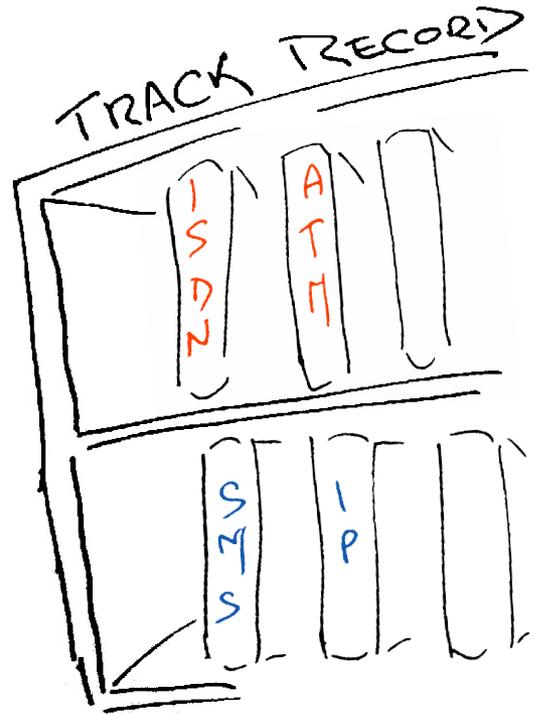
The mainstream
telecommunications
industry has a
rich history

...of making very poor
technology guesses

and regularly being
taken by
surprise!



So, how are we going with the IPv4 to IPv6 transition?



Do we really need to worry about
this?

Do we really need to worry about this?

Surely IPv6 will just happen — its just a matter of waiting for the pressure of IPv4 address exhaustion to get to sufficient levels of intensity.

Do we really need to worry about this?

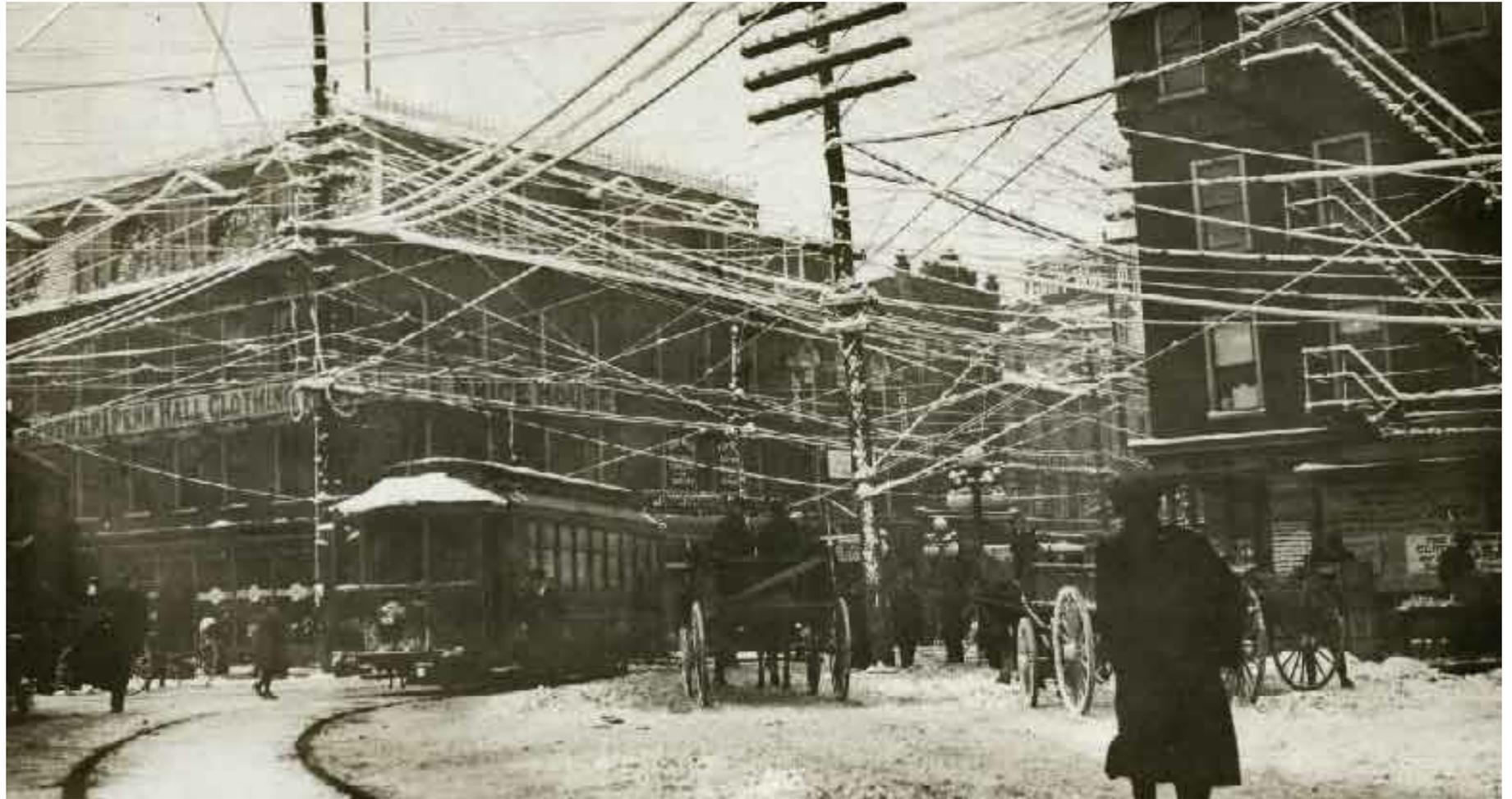
Surely IPv6 will just happen — its just a matter of waiting for the pressure of IPv4 address exhaustion to get to sufficient levels of intensity.

Or maybe not — let's look a bit closer at the situation ...

The
"inevitability"
of technological
evolution

wires





The
"inevitability"
of technological
evolution

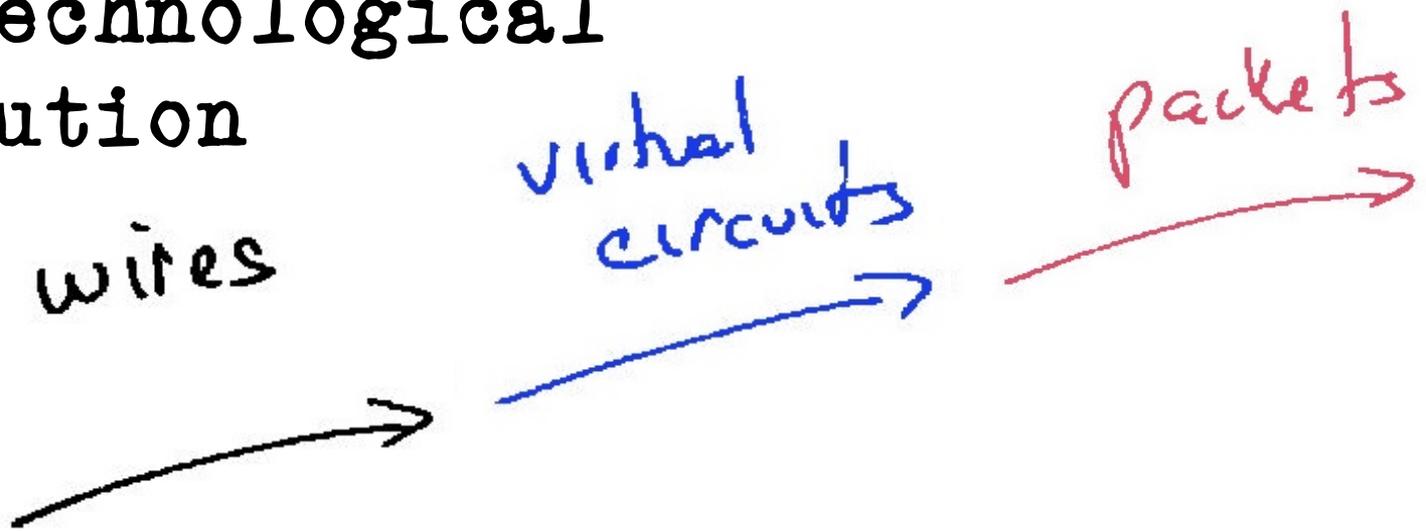
wires

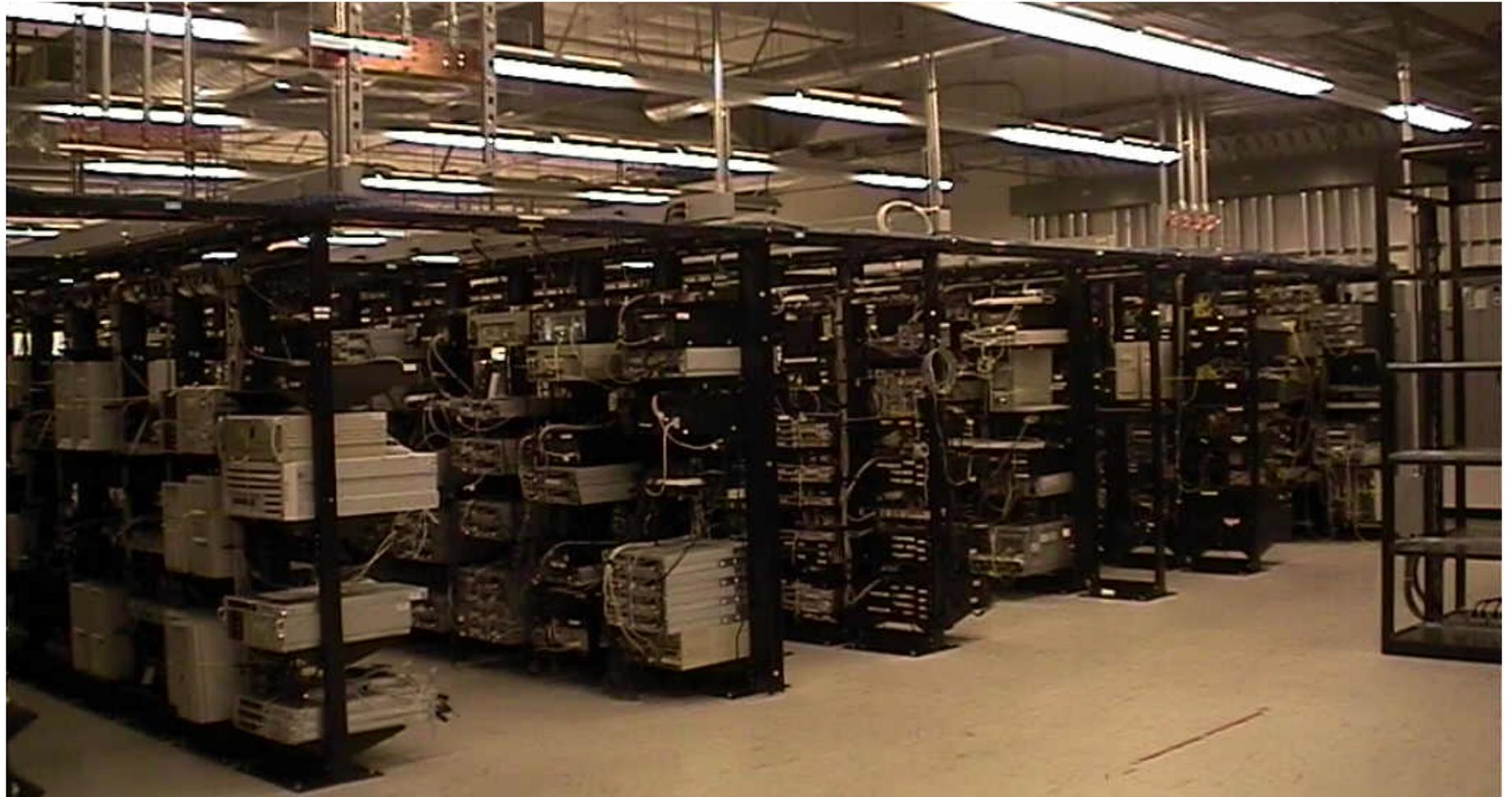
virtual
circuits



Well what did you expect? They are VIRTUAL circuits, so a picture was always going to be a challenge!

The
"inevitability"
of technological
evolution





The
"inevitability"
of technological
evolution

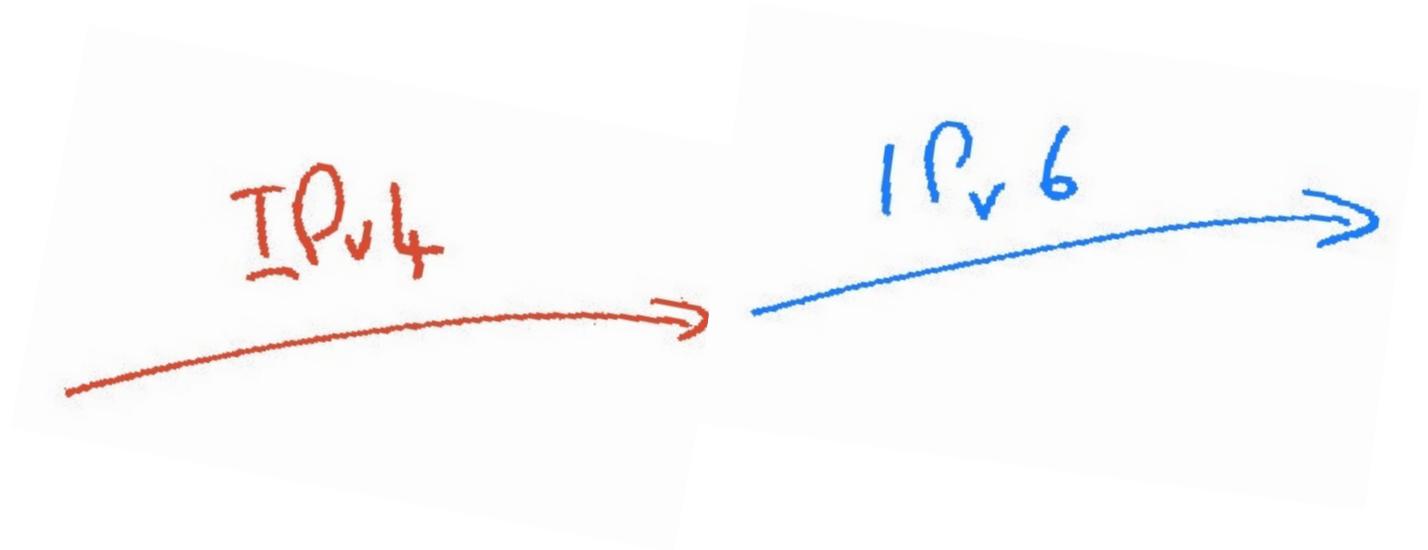
Now lets look at something a little
more topical to today!

The
"inevitability"
of technological
evolution?

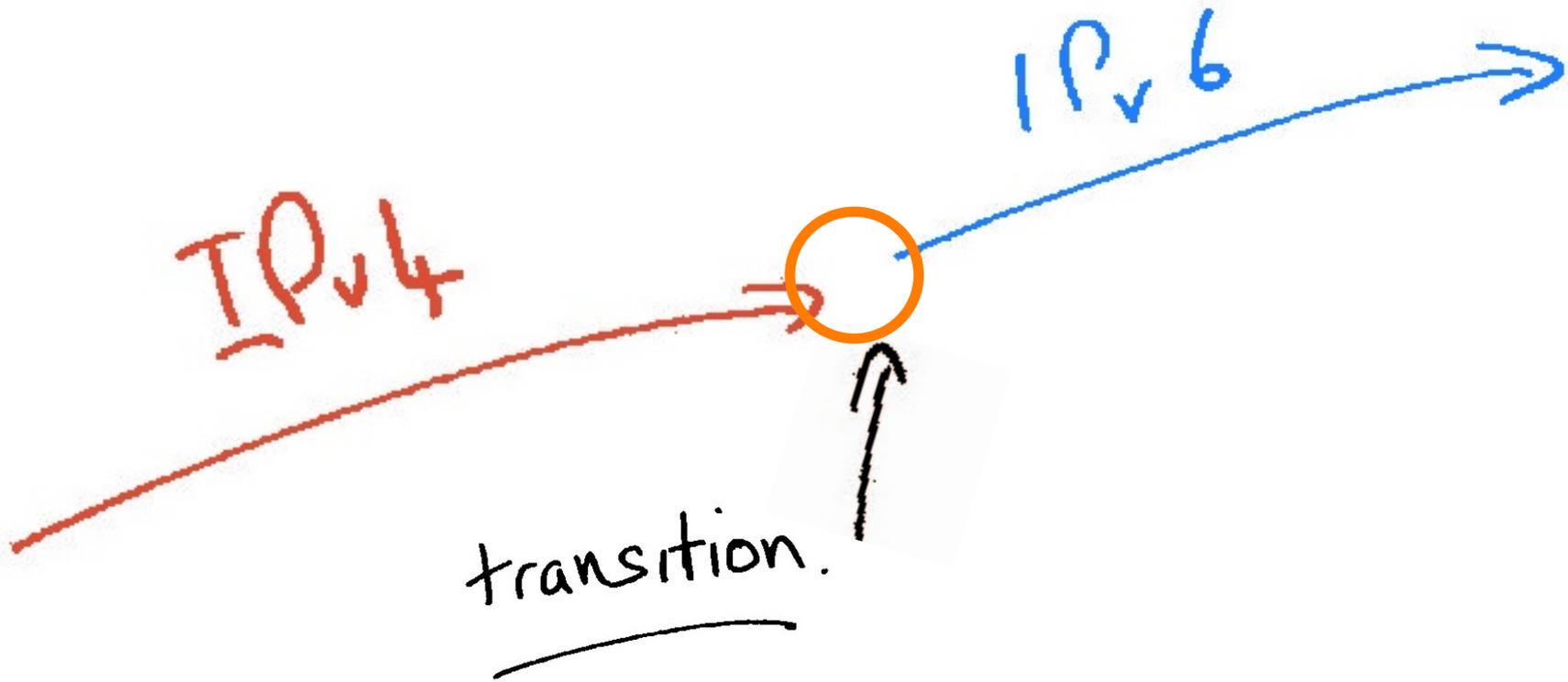
IPv4



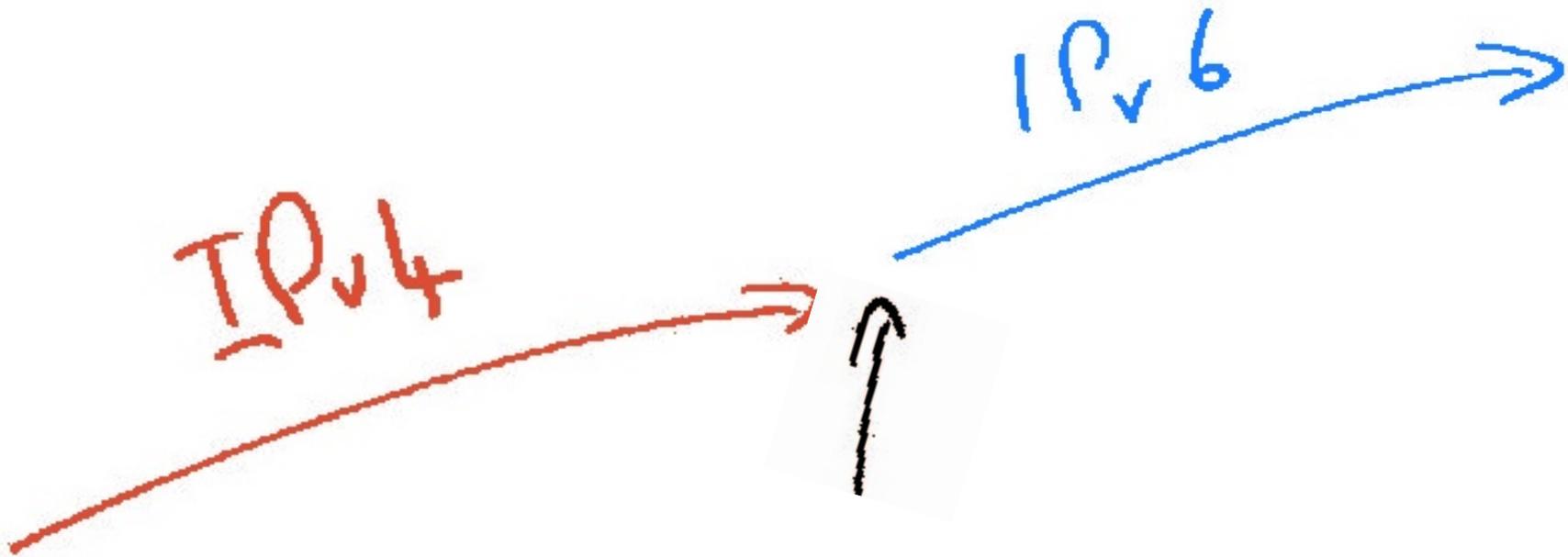
The
"inevitability"
of technological
evolution?



The challenge often
lies in managing the
transition from one
technology to another



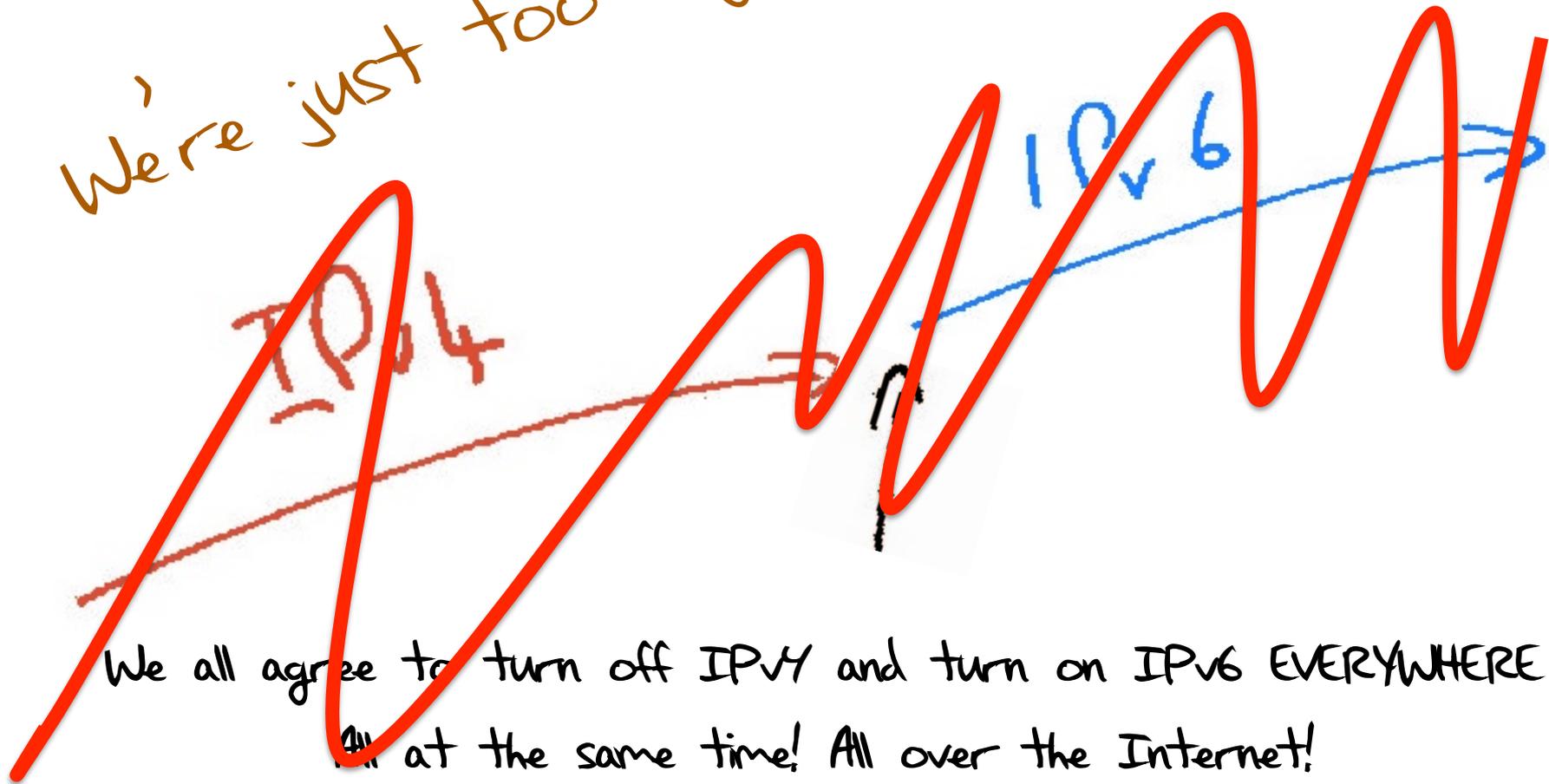
Option 1: Flag Day!



We all agree to turn off IPv4 and turn on IPv6 EVERYWHERE
All at the same time! All over the Internet!

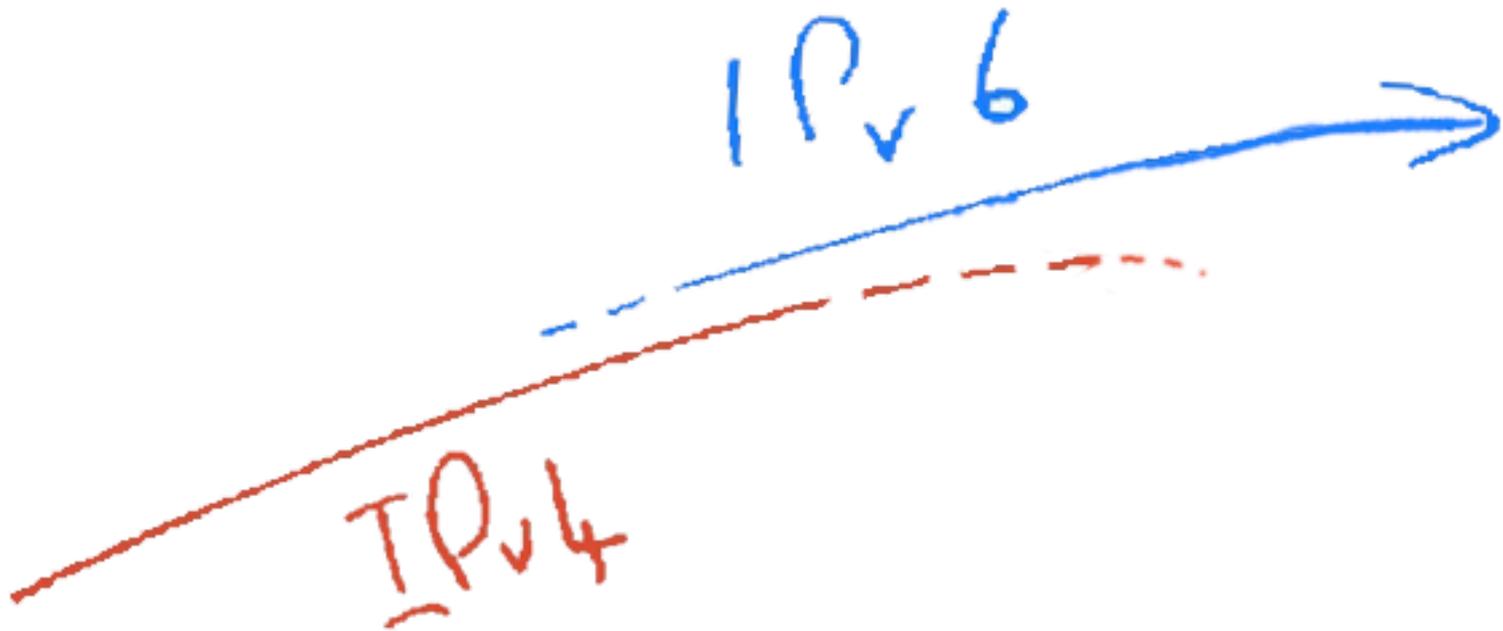
Option 1: Flag Day!

We're just too big!



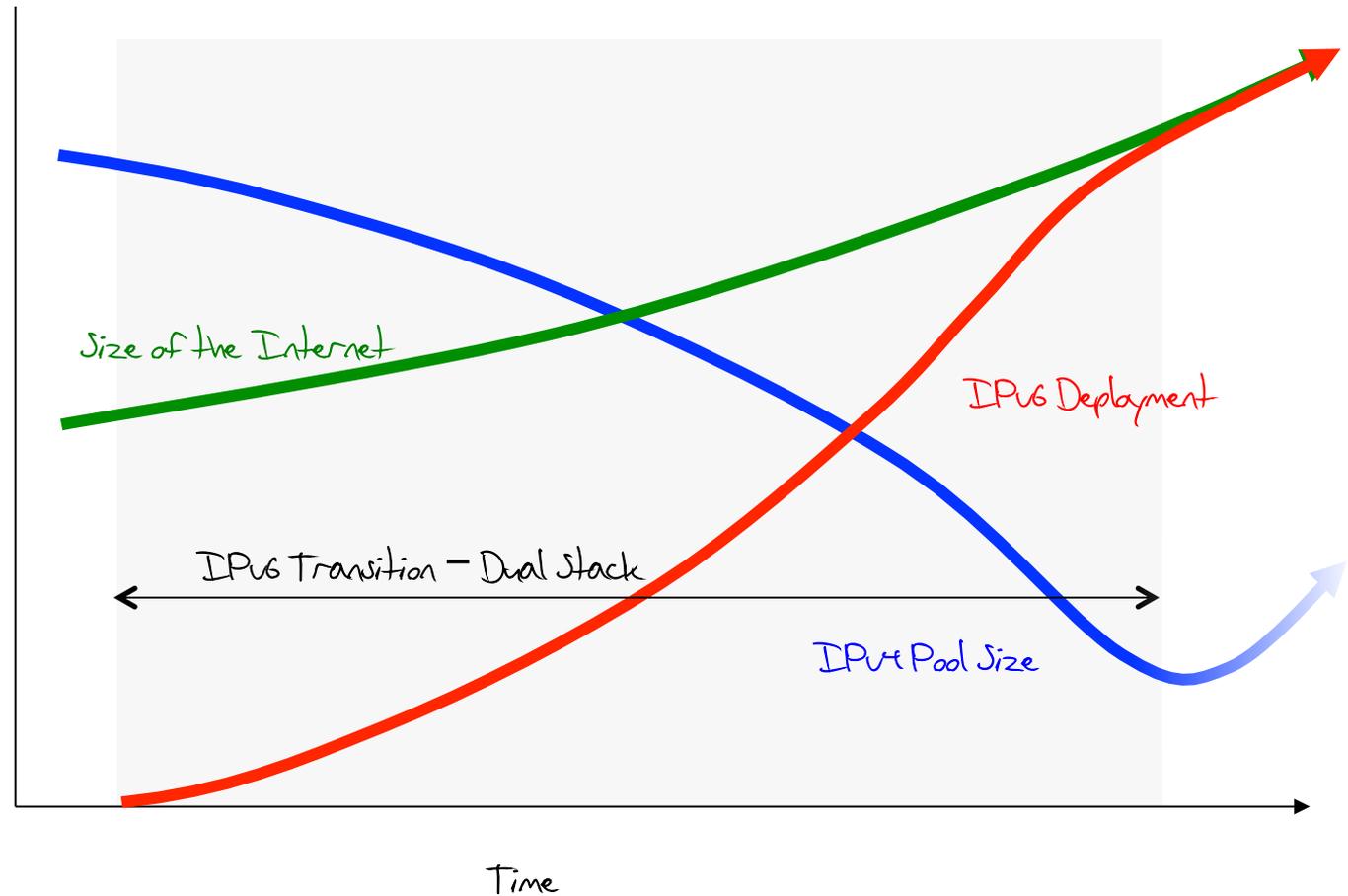
We all agree to turn off IPv4 and turn on IPv6 EVERYWHERE
All at the same time! All over the Internet!

Option 2: Parallel Transition!



We start to slide in IPv6 in parallel with IPv4
Then we gradually phase out IPv6

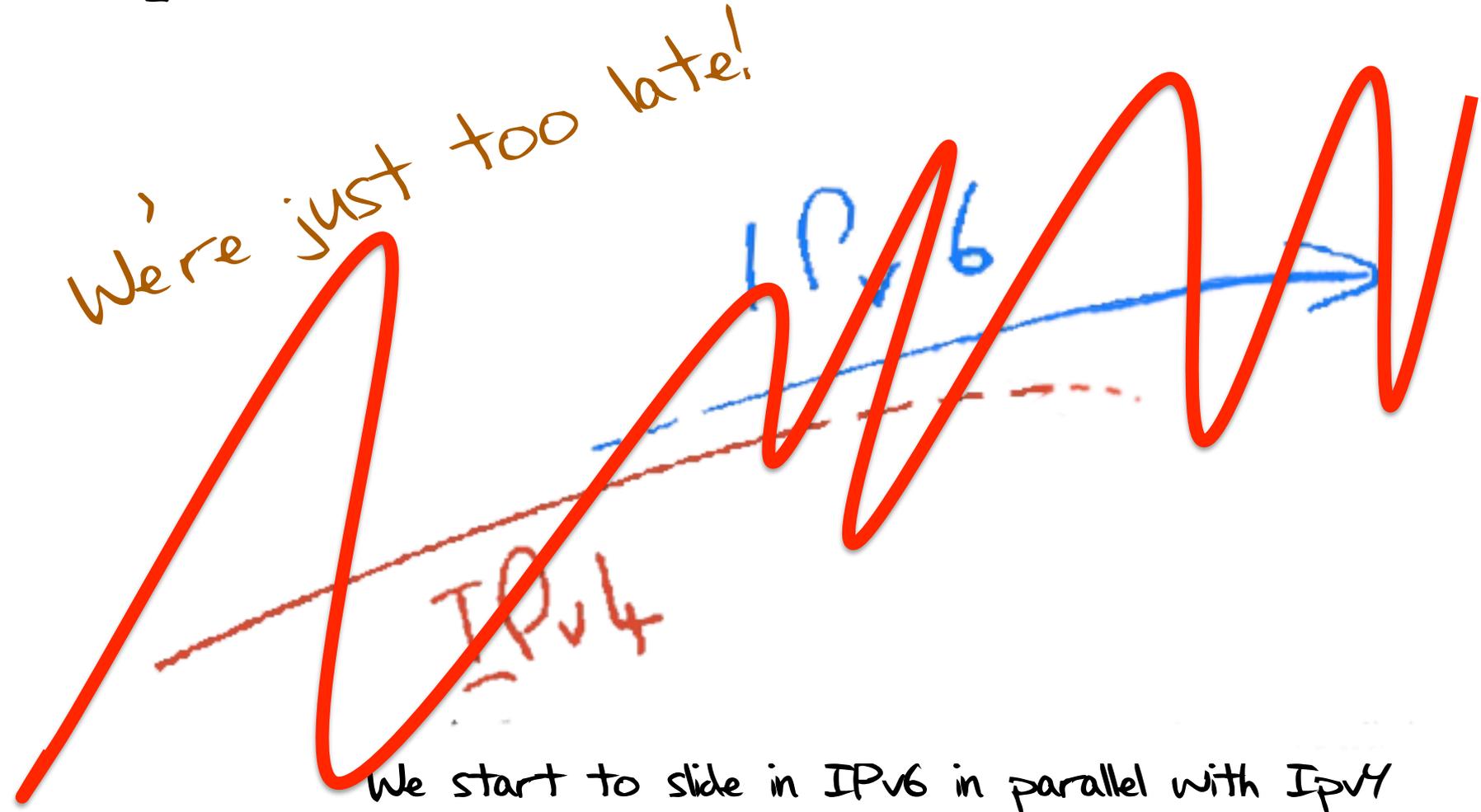
Option 2: Parallel Transition!



For this to work we have to start early and finish BEFORE IPv4 address pool exhaustion

Option 2: Parallel Transition!

We're just too late!



We start to slide in IPv6 in parallel with IPv4

Then we gradually phase out IPv6

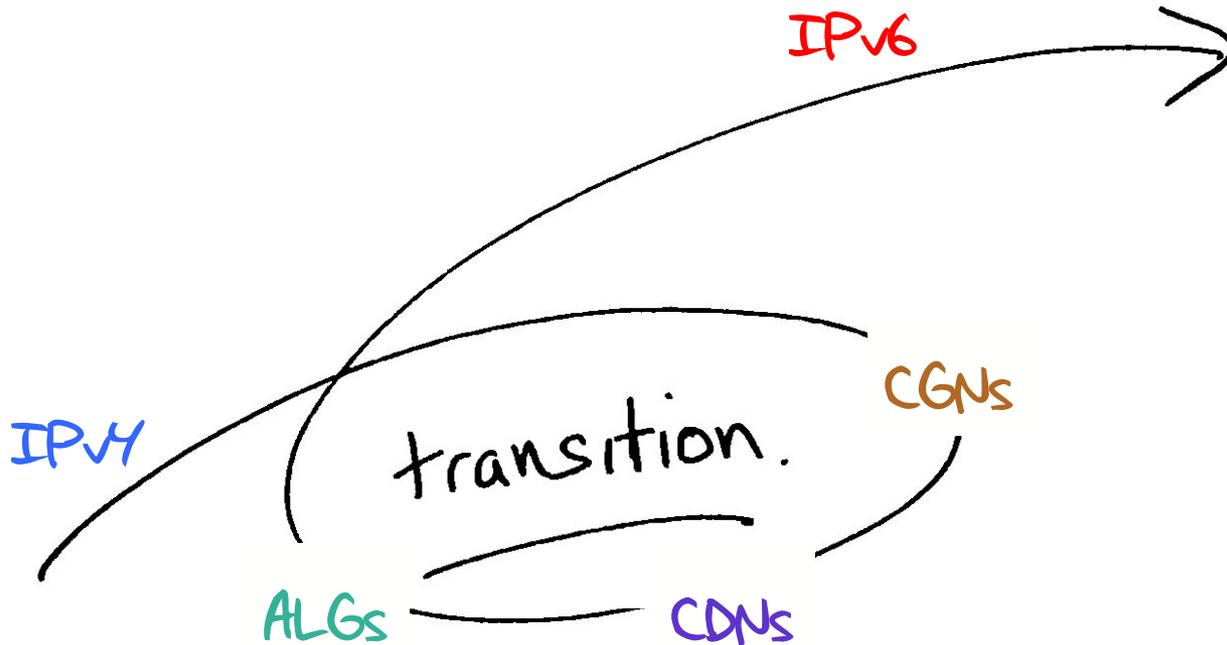
The small print: It's incredibly difficult for markets to plan without clear price signals, and we never managed to price future scarcity into the Internet model. Our chosen address distribution model was one that deliberately avoided any form of price-based market signaling. We sort of hoped that operators would price future risks. We were very wrong!

Hybrid IPv4

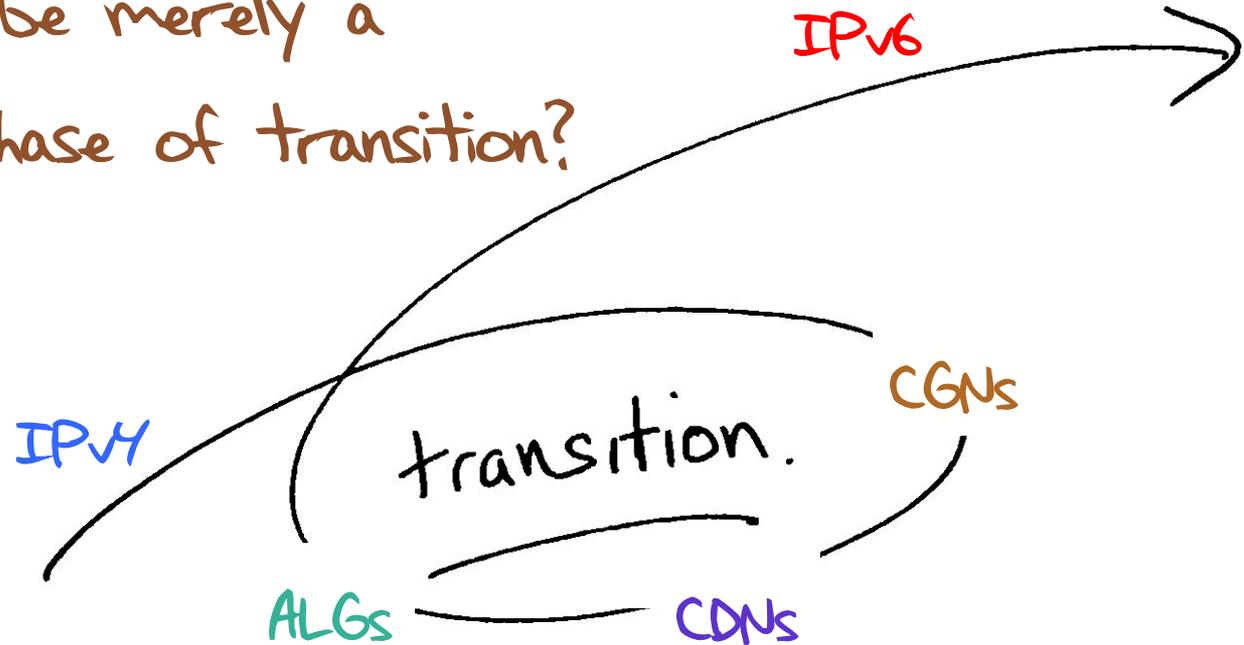


The increasing scarcity of IPv4 will force carriage providers to add address sharing mechanisms into the IPv4 network

To get from "here" to "there" requires an excursion through an environment of CGNs, CDNs, ALGs and similar middleware 'solutions' to IPv4 address exhaustion

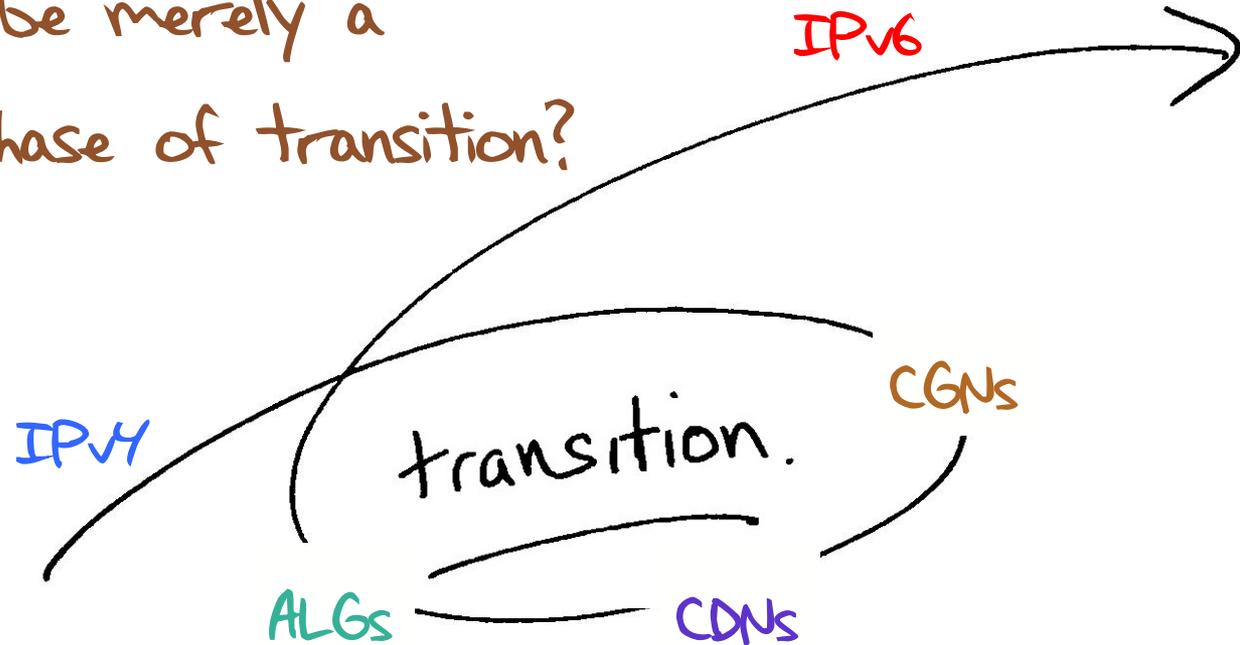


But will this be merely a temporary phase of transition?



Transition requires the network owner to undertake capital investment in network service infrastructure to support IPv4 address sharing/rationing.

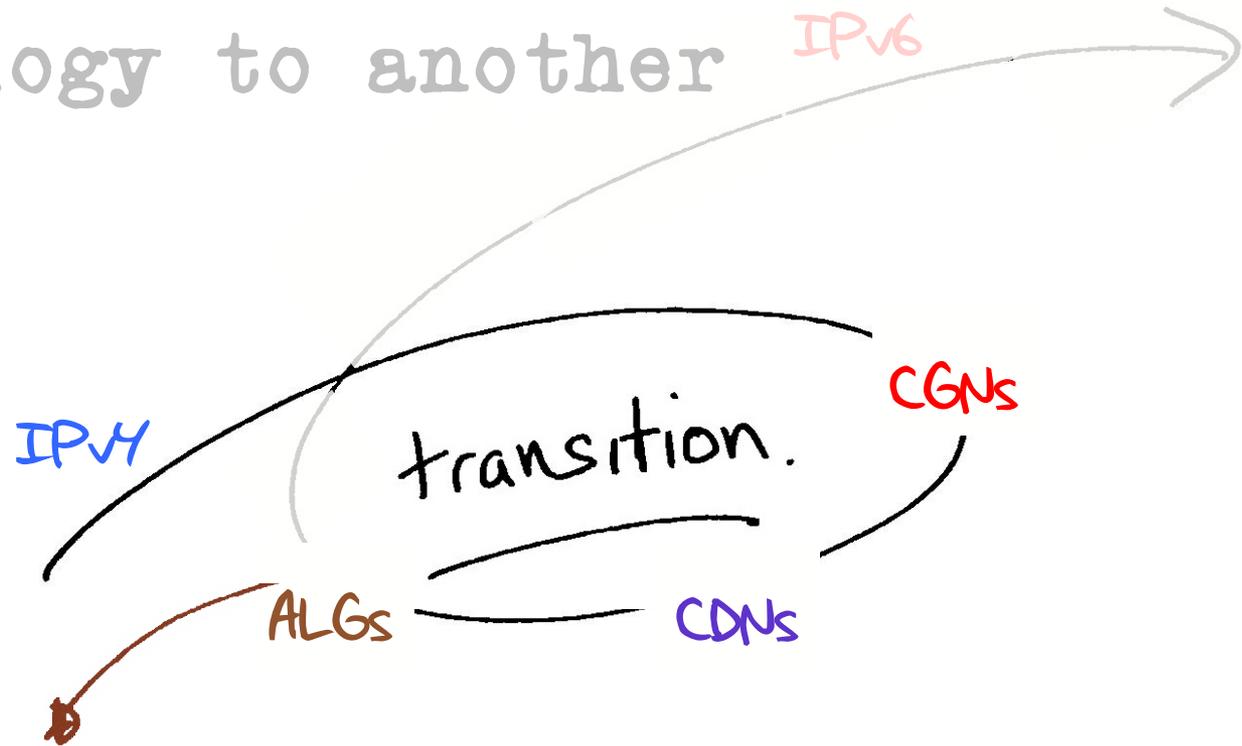
But will this be merely a temporary phase of transition?



Transition requires the network owner to undertake capital investment in network service infrastructure to support IPv4 address sharing/rationing.

What lengths will the network owner then go to to protect the value of this additional investment by locking itself into this "transitional" service model for an extended/indefinite period?

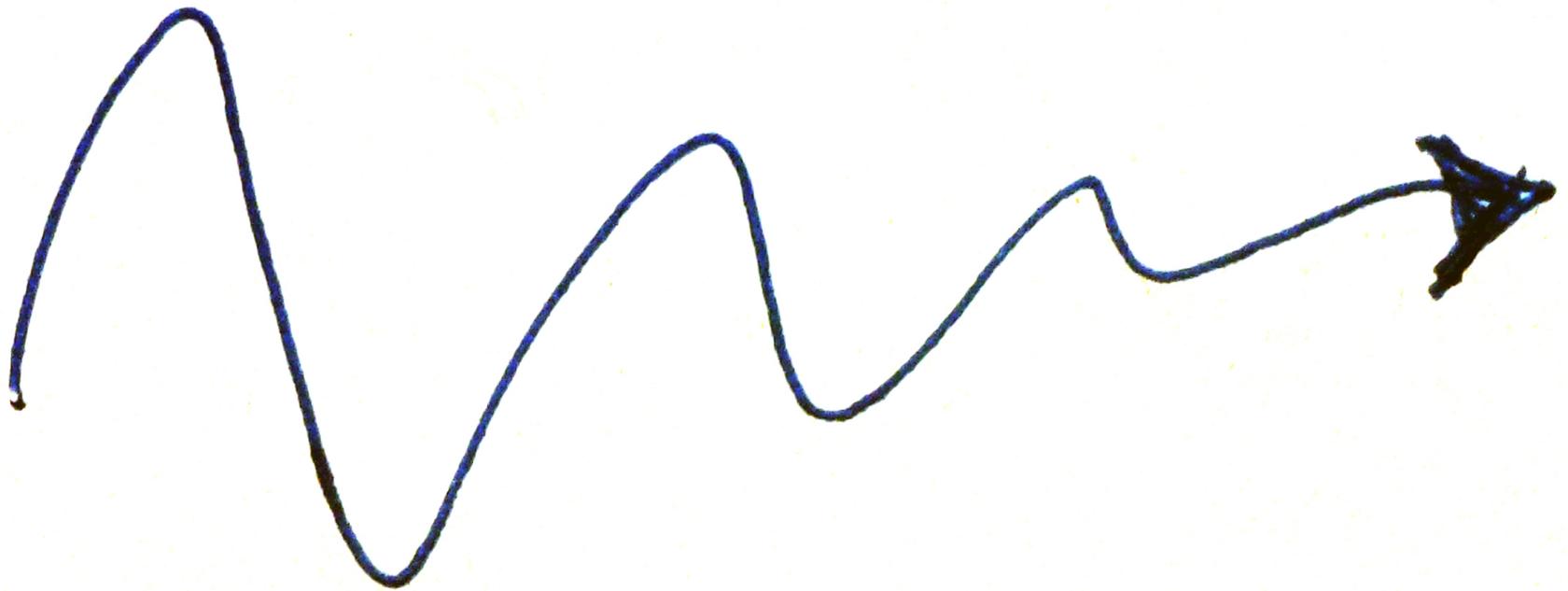
The challenge often lies in managing the transition from one technology to another



The risk in this transition phase is that the Internet heads off in a completely different direction!

A digression...

How "real" is this
risk?



A digression...

How "real" is this
risk?

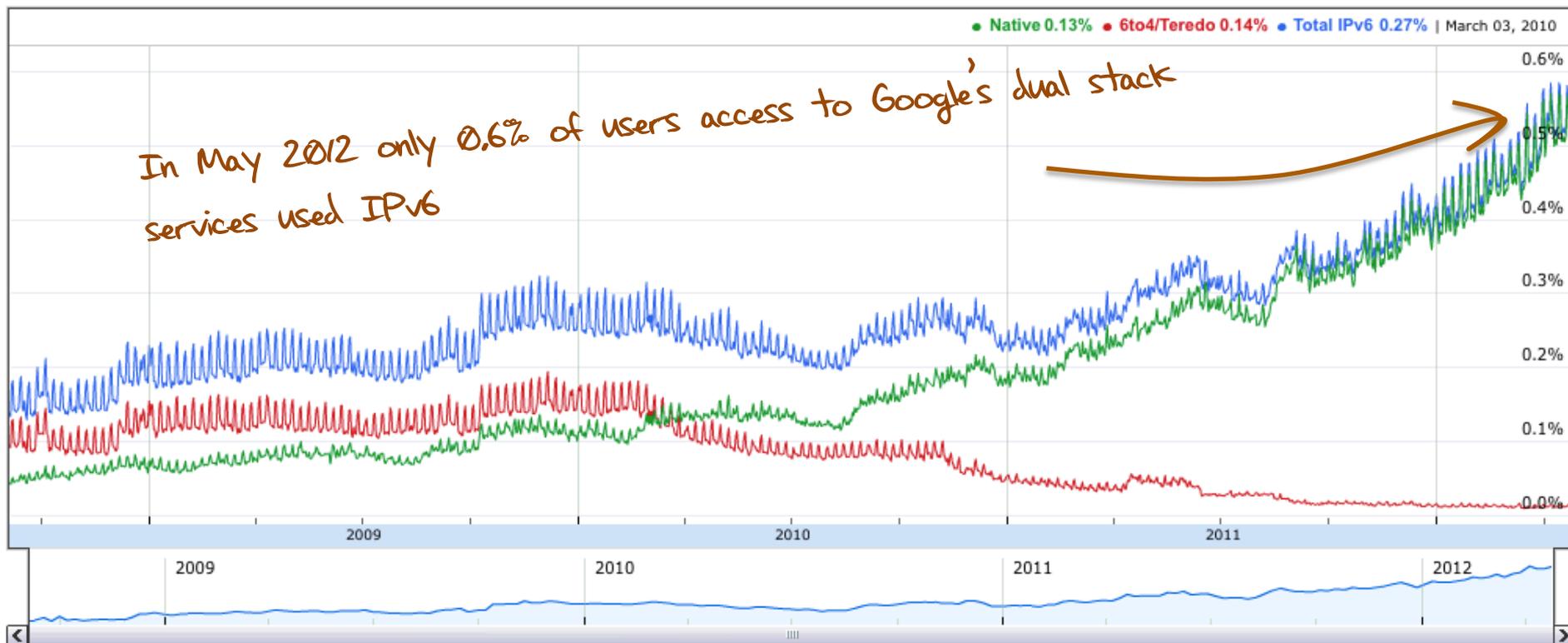
Is this industry seriously prepared to contemplate an
IPV4 forever strategy?

Some Measurements

49% of the IPv4 transit networks appear to be dual stack capable

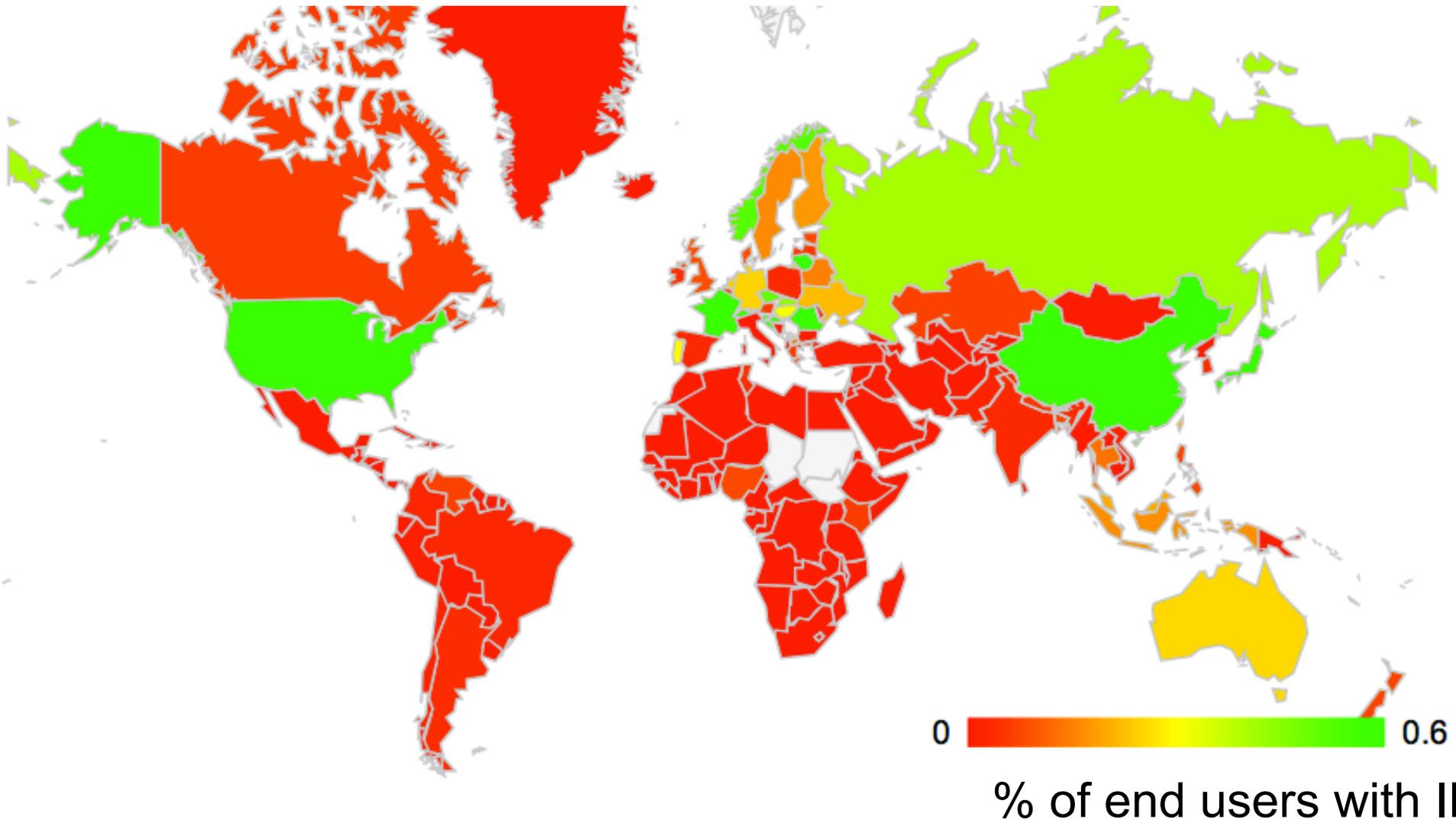
~50% of the Internet's end devices have an installed IPv6 stack

IPv6 capability, as seen by Google



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

Where is it?

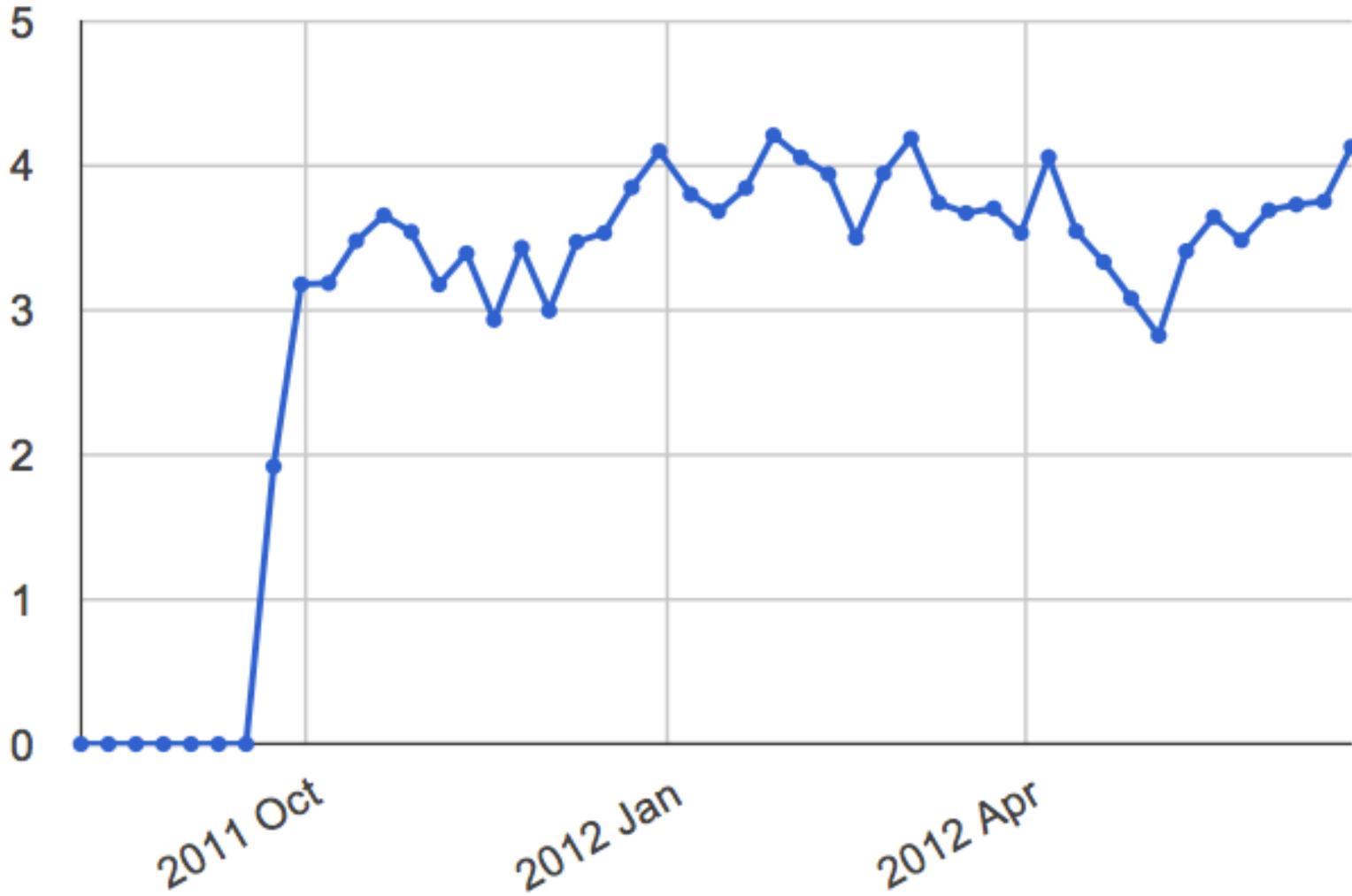


<http://labs.apnic.net/index.shtml>

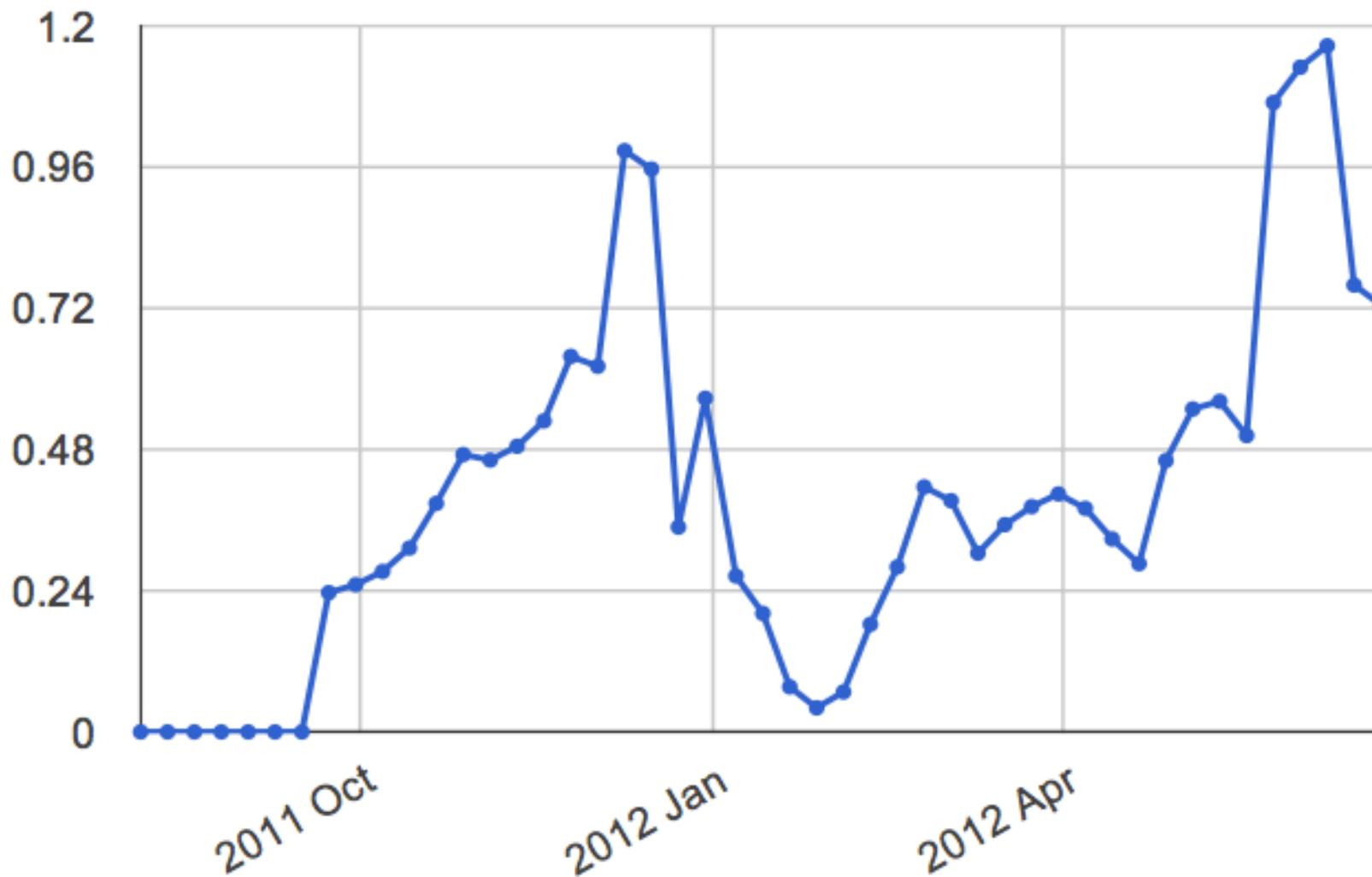
United States



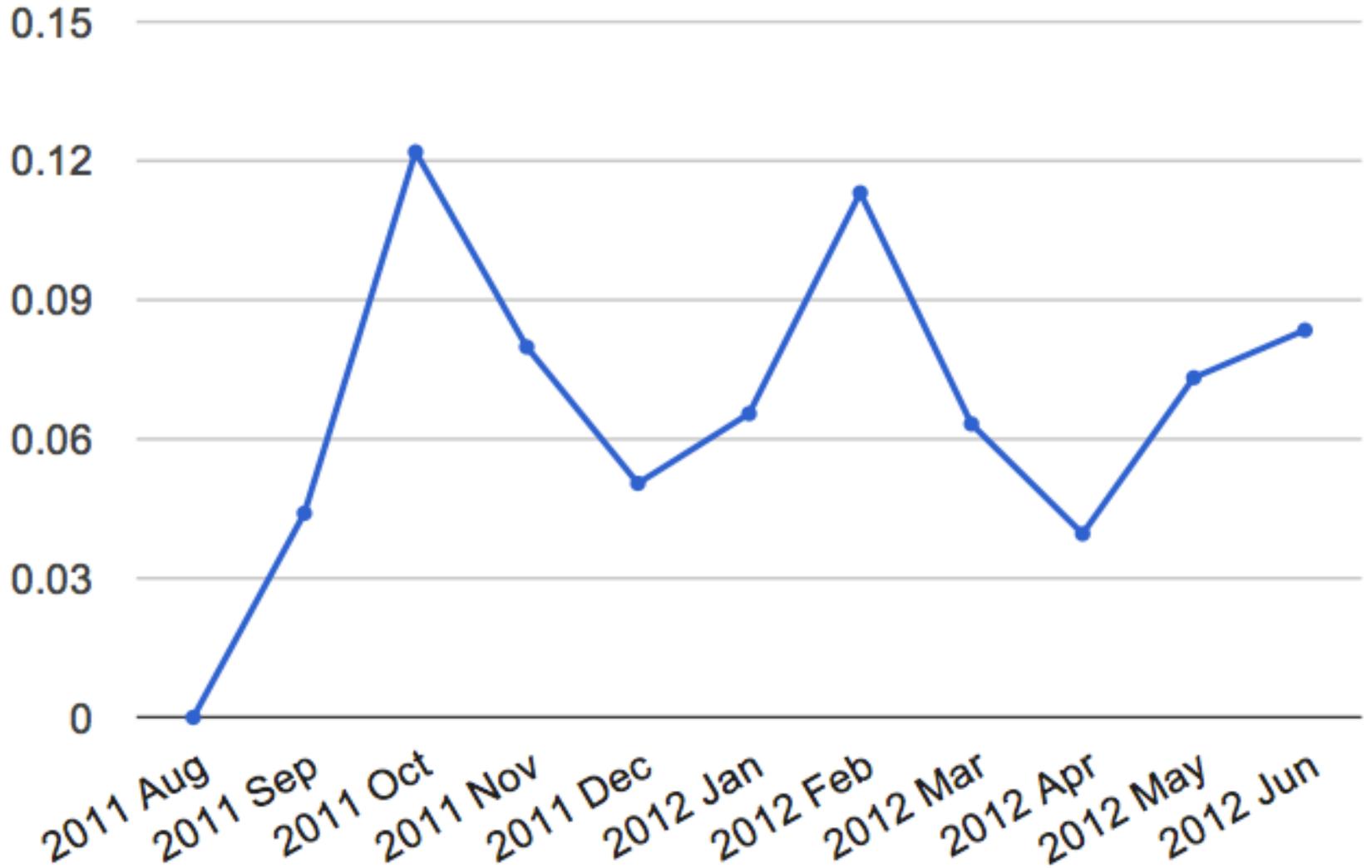
France



China



UK



Some Measurements

49% of the IPv4 transit networks appear to be dual stack capable

48% of the Internet's end devices have an installed IPv6 stack that can be tickled into life

0.6% of the Internet's end devices have native IPv6 delivered to them

Some Measurements

49% of the IPv4 transit networks appear to be dual stack capable

48% of the Internet's end devices have an installed IPv6 stack

0.6% of the Internet's end devices have native IPv6 delivered to them

Where's the problem here?

The last mile access service business is not doing IPv6 because:

- A) they are stupid
- B) they are lazy
- C) they are uninformed
- D) they are broke
- E) they operate in an economic and business regime that makes provisioning IPv6 an unattractive investment option for them

The last mile access service business is not doing IPv6 because:

A) they are stupid

B) they are lazy

C) they are uninformed

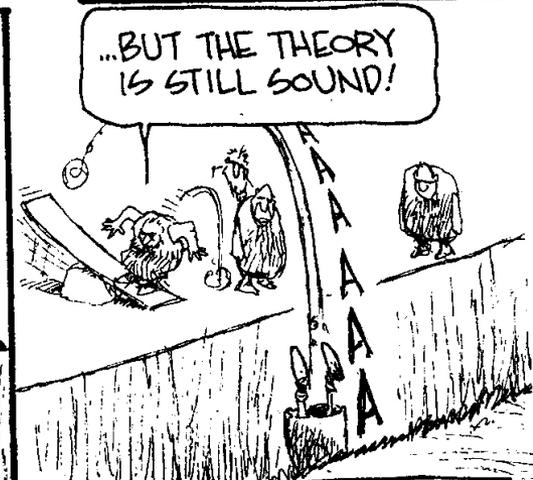
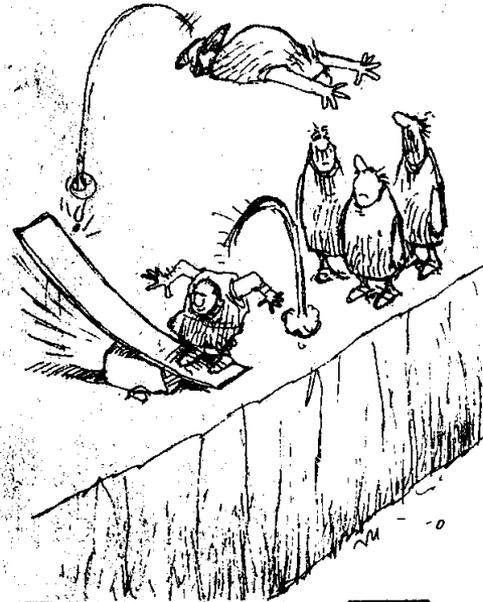
D) they are broke

 **E)** they operate in an economic and business regime that makes provisioning IPv6 an unattractive investment option for them

Hint!

Economics!

NON SEQUITUR



THE FIRST ECONOMIST



©11 WILEY INK, INC. 9-1
DIST. BY UNIVERSAL UCLICK

WILEYINK@PITALINK.NET

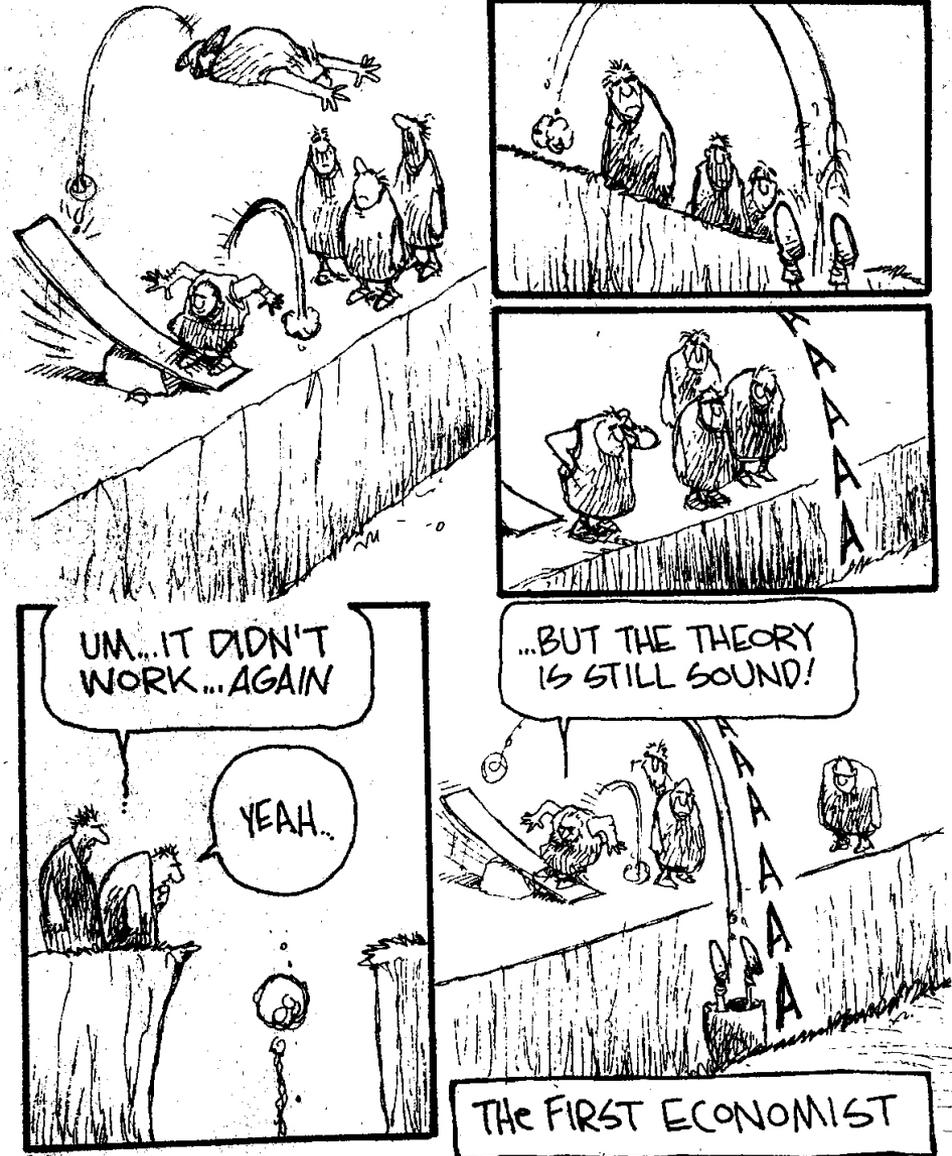
GOCOMICS.COM

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-

NON SEQUITUR



The last mile access service business is not doing IPv6 because:

A) they are stupid

B) they are lazy

C) they are uninformed

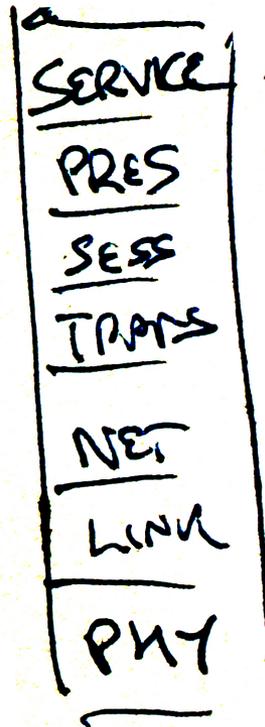
D) they are broke

Why is IPv6 such an unattractive business proposition for Carriage Providers?

They operate in an economic and business regime that makes

provisioning IPv6 an unattractive investment option for them

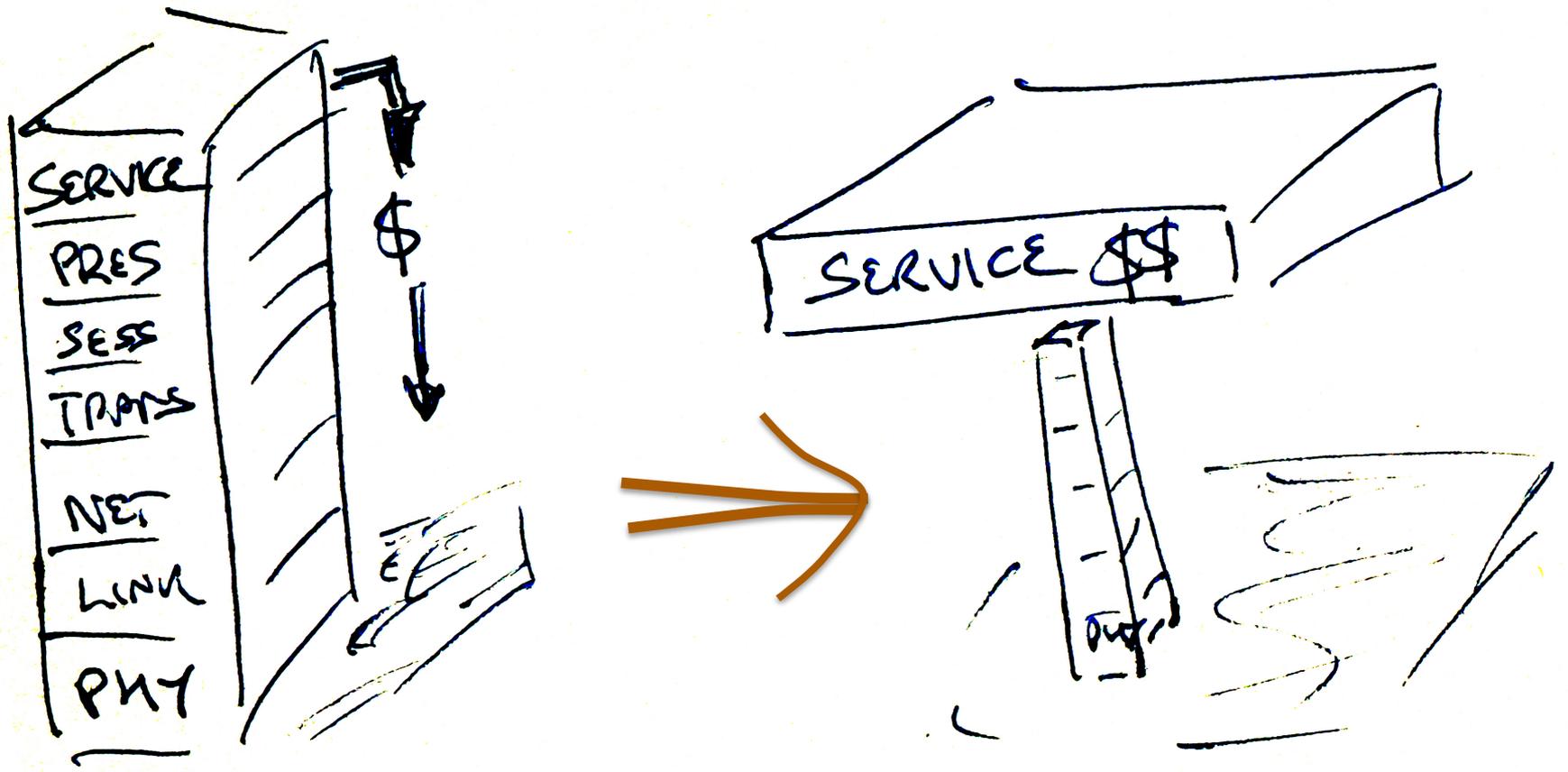
Back to networking basics....



Telco nostalgia...

The historical
vertically integrated
service architecture

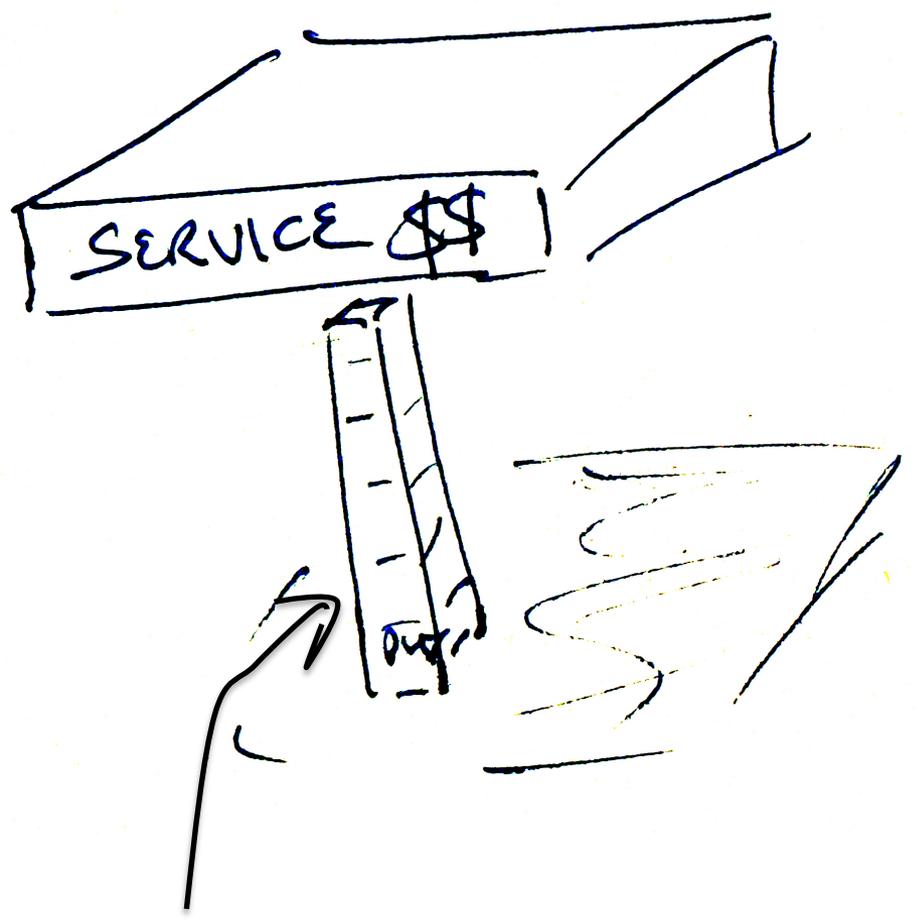




Devolution of the integrated service architecture through an open IP service architecture and deregulation



Devolution of the integrated service architecture

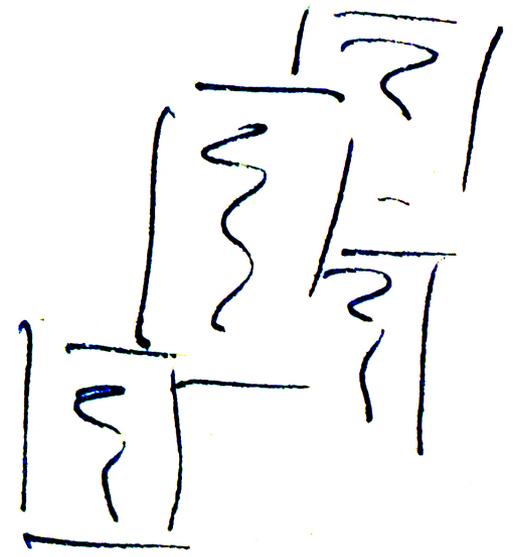


Where's the money to invest in new network services?

Users



Services



Access Provider



Users

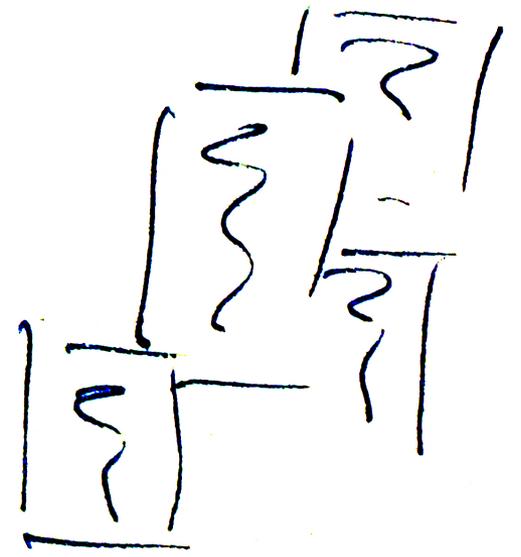


Gatekeeper



Access Provider

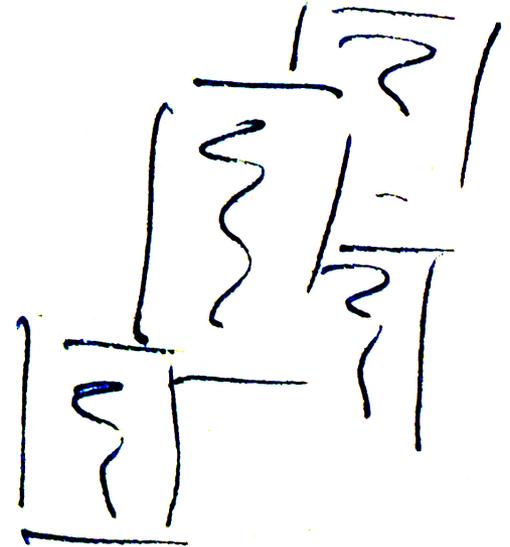
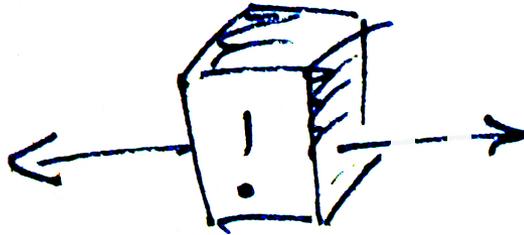
Services



CGNs and ALGs and similar IPv4
rationing middleware devices
provide control points in the IPv4
network that allow monetary
extraction from both consumers and
content providers

Users

Services



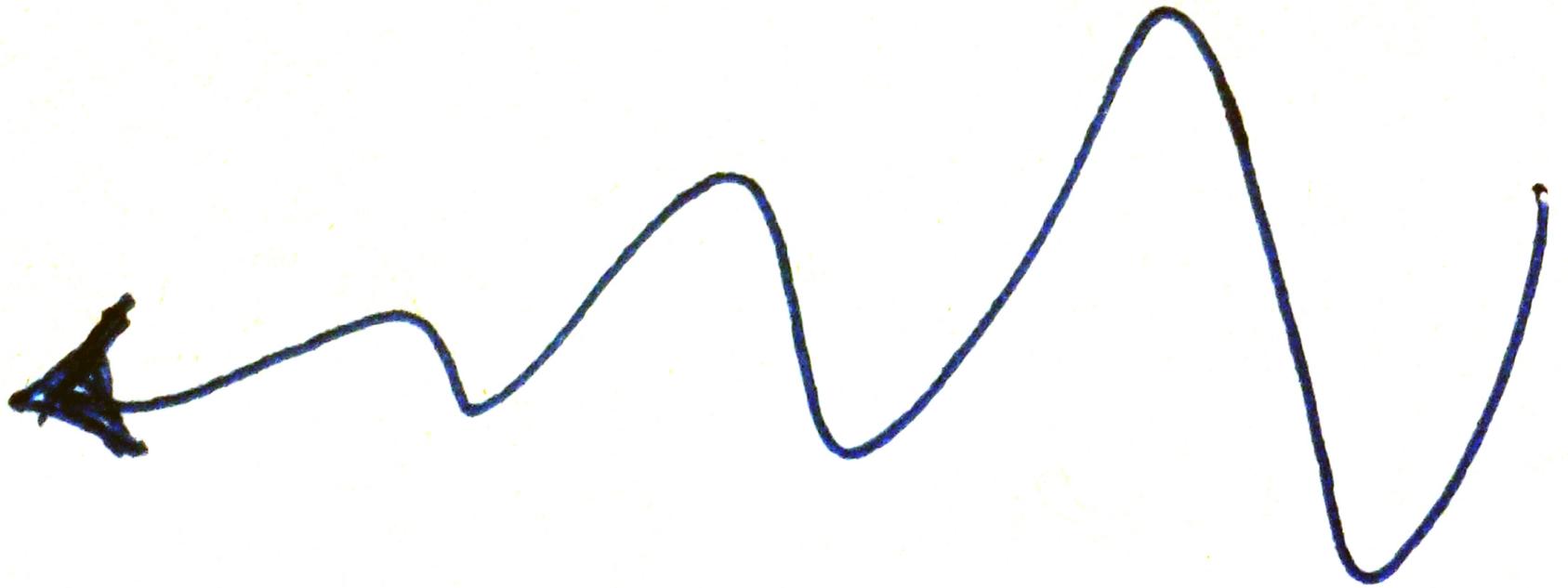
Access Provider



A digression...

How "real" is this
risk?

Is this industry seriously prepared to contemplate an
IPV4 forever strategy? **Yes — it's a possibility!**



How can we "manage" this transition?

How can we "manage" this transition?

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?

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

And the data on IPv6 uptake so far suggests that we are still not managing this at all well. Progress at the customer edge of the network with IPv6 access is glacial.

How can we "manage" this transition?

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

And at the moment we seem to be making the task even harder, not easier, by adding even more challenges into the path we need to follow!

Challenges:

1. This is a deregulated and highly competitive environment

Challenges:

1. This is a deregulated and highly competitive environment

It is NOT a case of a single
"either/or" decision



Challenges:

1. This is a deregulated and highly competitive environment

There are many different players
Each with their own perspective



Challenges:

1. This is a deregulated and highly competitive environment

There are many different players
Each with their own perspective



And all potential approaches will be explored!

Challenges:

1. This is a deregulated and highly competitive environment

There is no plan!

Challenges:

1. This is a deregulated and highly competitive environment

There is no plan, just the interplay of various market pressures

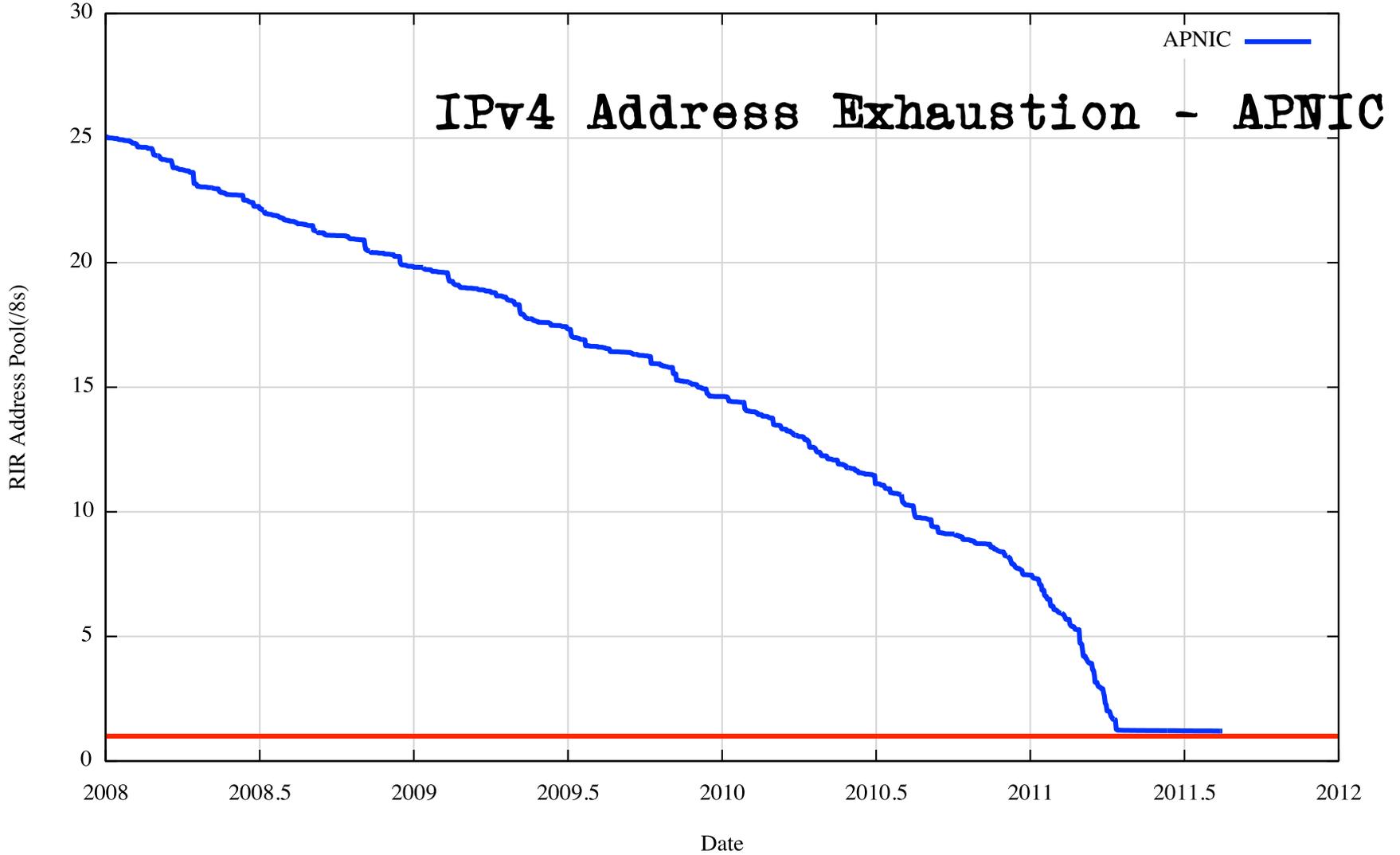
Challenges:

1. This is a deregulated and highly competitive environment

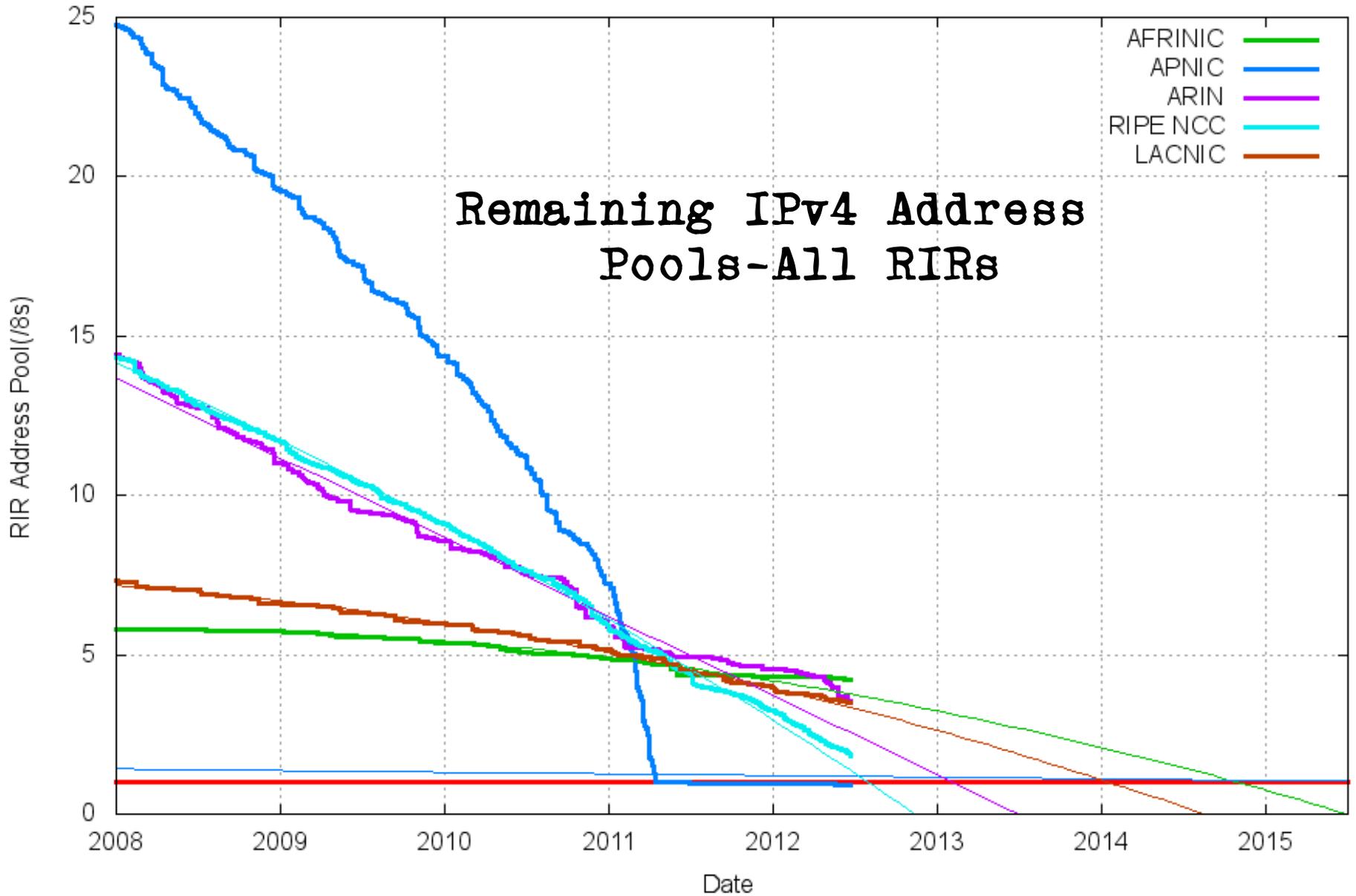
There is no plan, just the interplay of various market pressures

2. Varying IPv4 Address Exhaustion Timelines

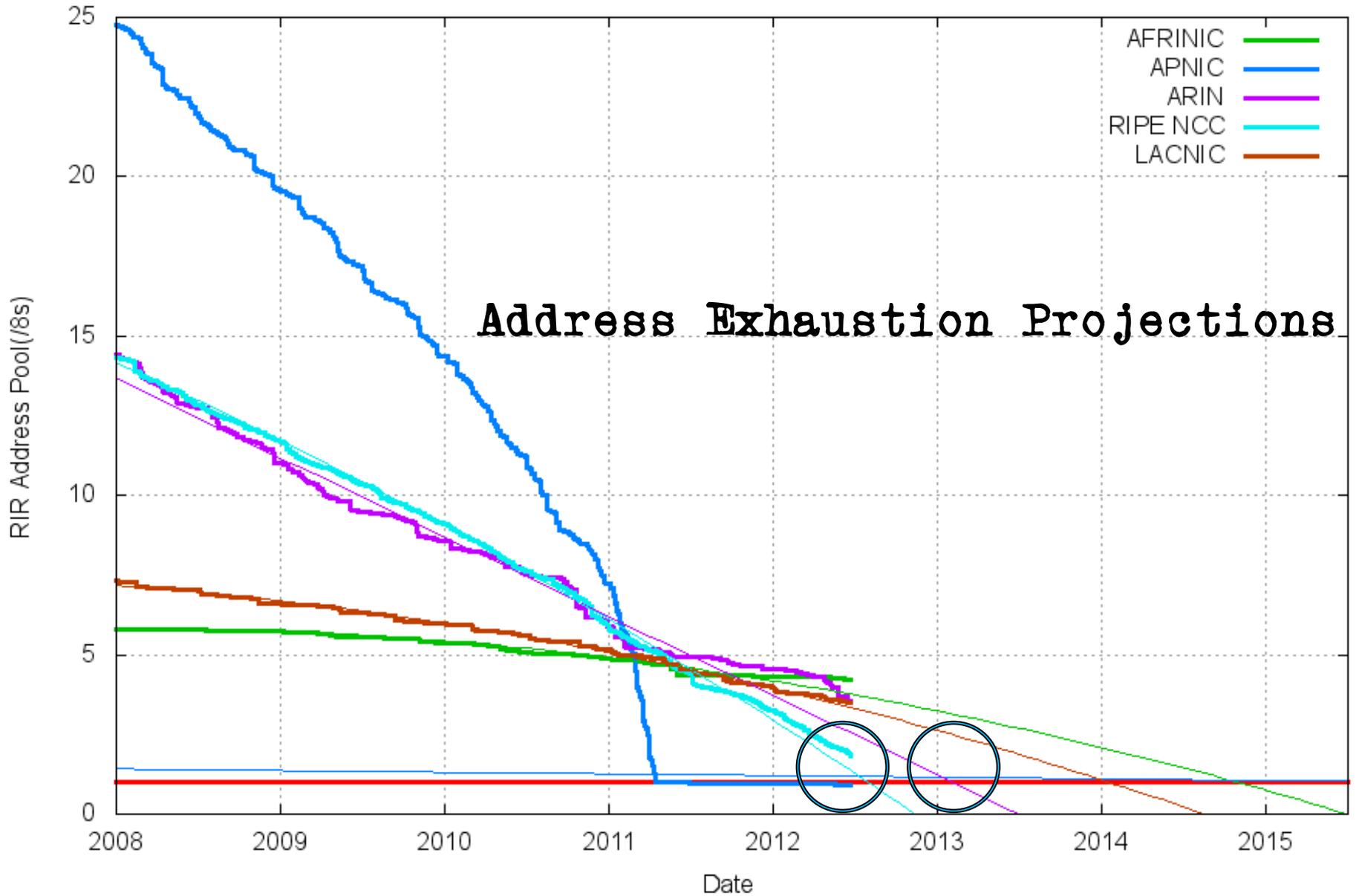
RIR IPv4 Address Run-Down Model



RIR IPv4 Address Run-Down Model



RIR IPv4 Address Run-Down Model



Exhaustion Predictions

RIR	Predicted Exhaustion Date *	Remaining Address Pool (2 Oct 2011)
APNIC	19 April 2011 (actual)	0.93 /8s
RIPE NCC	28 July 2012	1.84 /8s
ARIN	4 February 2013	3.54 /8s
LACNIC	17 January 2014	3.49 /8s
AFRINIC	28 Oct 2014	4.20 /8s

** Here "exhaustion" is defined as the point when the RIR's remaining pool falls to 1 /8*

So what?

Reality Acceptance

Reality Acceptance

Or not

Reality Acceptance

Or not

Is IPv4 address exhaustion a "here and now" problem or a "some time in the future" problem?

Reality Acceptance

Or not

Is IPv4 address exhaustion a "here and now" problem or a "some time in the future" problem?

Well, that depends on where you happen to be!
If it hasn't happened to you yet, then denial is still an option!

Reality Acceptance

Or not

Is IPv4 address exhaustion a "here and now" problem or a "some time in the future" problem?

It's not happening until its happening to me!

Challenges:

1. This is a deregulated and highly competitive environment

There is no plan, just the interplay of various market pressures

2. Varying IPv4 Address Exhaustion Timelines

There is a credibility problem!

Challenges:

1. This is a deregulated and highly competitive environment

There is no plan, just the interplay of various market pressures

2. Varying IPv4 Address Exhaustion Timelines

There is a credibility problem: This industry has a hard time believing reality over its own mythology

Challenges:

1. This is a deregulated and highly competitive environment

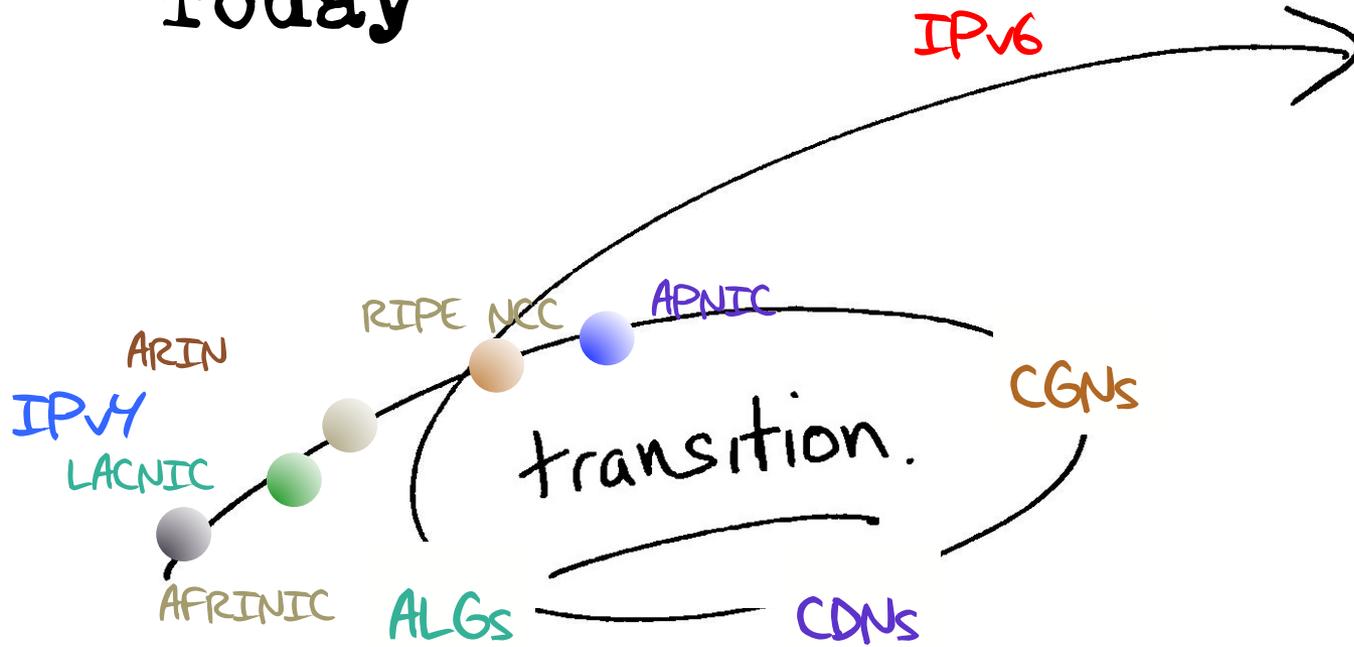
There is no plan, just the interplay of various market pressures

2. Varying IPv4 Address Exhaustion Timelines

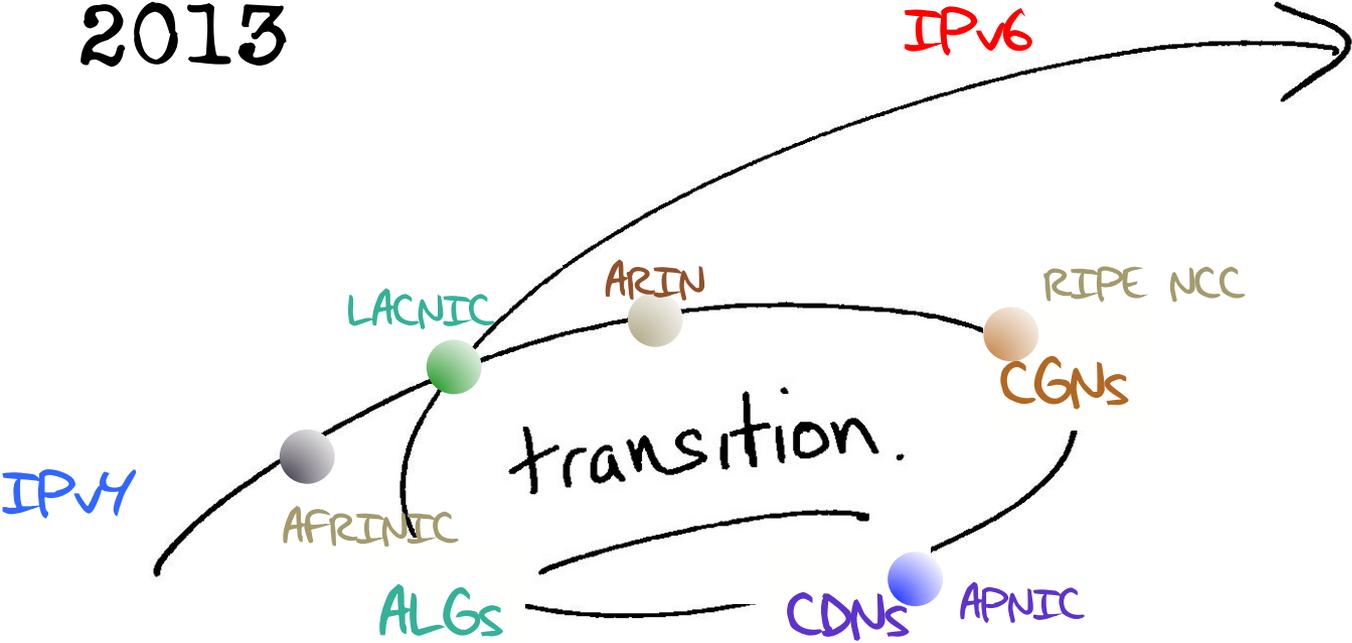
There is a credibility problem: This industry has a hard time believing reality over its own mythology

3. Regional Diversity

Today



2013



By 2013 it is possible that different regions of the world will be experiencing very different market pressures for the provision of Internet services, due to differing transitional pressures from IPv4 exhaustion

By 2013 it is possible that different regions of the world will be experiencing very different market pressures for the provision of Internet services, due to differing transitional pressures from IPv4 exhaustion

What's the level of risk that the differing environments of transition lead to significantly different outcomes in each region?

By 2013 it is possible that different regions of the world will be experiencing very different market pressures for the provision of Internet services, due to differing transitional pressures from IPv4 exhaustion

Will we continue to maintain coherency of a single Internet through this transition?

What's the level of risk that the differing environments of transition lead to significantly different outcomes in each region?

The Myth of the Long Term Plan

The Myth of the Long Term Plan

"Transition will take many years...

5 years, maybe 10 years, maybe longer"

The Myth of the Long Term Plan

"Transition will take many years...

5 years, maybe 10 years, maybe longer"

Are we still firmly committed to the plans we had 5 years ago?

The Myth of the Long Term Plan

"Transition will take many years...

5 years, maybe 10 years, maybe longer"

Are we still firmly committed to the plans we had 5 years ago?

How about our 10 year old plans?

The Myth of the Long Term Plan

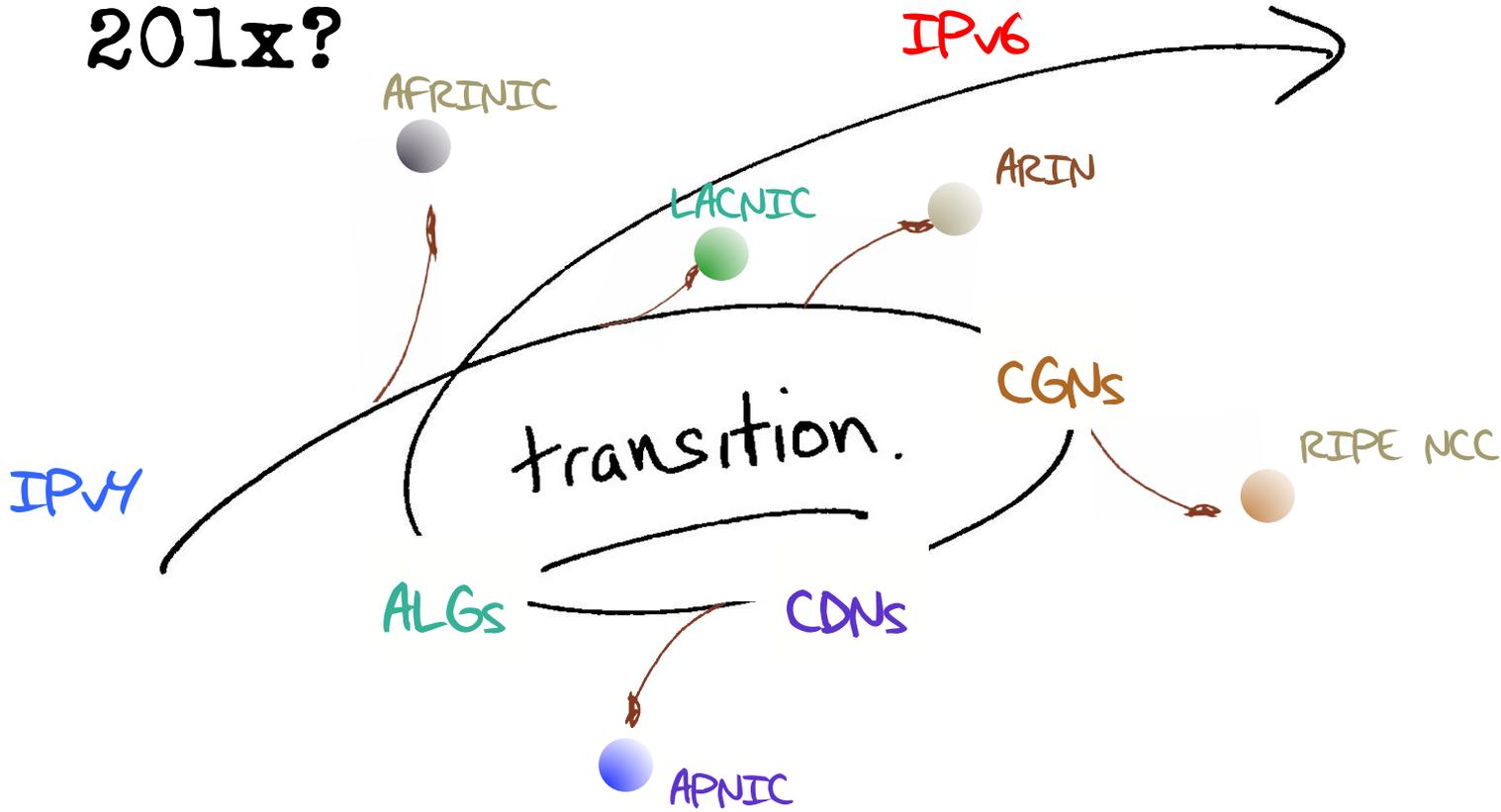
“Transition will take many years...

5 years, maybe 10 years, maybe longer”

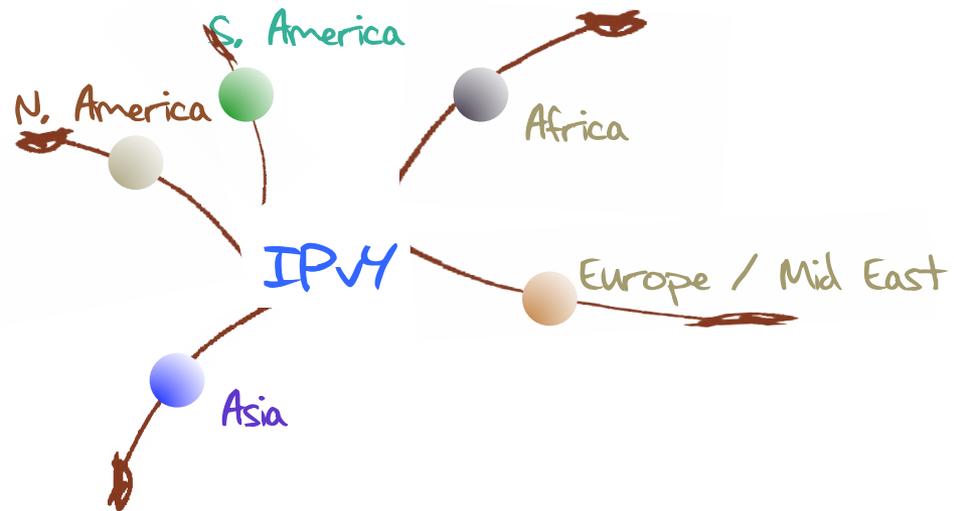
Are we still committed to the plans we had 5 years ago? How about our 10 year old plans?

The longer the period of transition, the higher the risk of completely losing the plot and heading into other directions!

201x?



20xx?



Challenges:

1. This is a deregulated and highly competitive environment

There is no plan, just the interplay of various market pressures

2. Varying IPv4 Address Exhaustion Timelines

There is a credibility problem: This industry has a hard time believing reality over its own mythology

3. Regional Diversity

One network is not an assured outcome!

Challenges:

1. This is a deregulated and highly competitive environment

There is no plan, just the interplay of various market pressures

2. Varying IPv4 Address Exhaustion Timelines

There is a credibility problem: This industry has a hard time believing reality over its own mythology

3. Regional Diversity

One network is not an assured outcome: Market pressures during an extended transition may push the Internet along different paths in each region

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 long transit

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?

This ... CGNs ... ts a ... le ... industry

if 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 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 through 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 or "safeguarded"

Scarcity generates pain and uncertainty

Extended scarcity prolongs the pain and increases the unpredictability of the entire transition process

No matter how hard we may want it to be otherwise, "scarcity" and "fairness" are not synonyms!

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!



Thank You!

