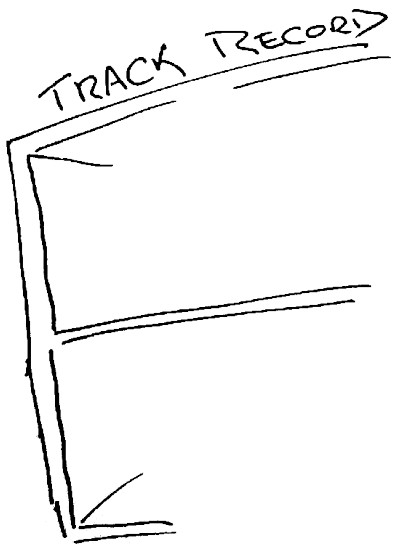
The Post-IPocalypse Internet

Geoff Huston AM

Chief Scientist, APNIC

The mainstream telecommunications industry has a rich history



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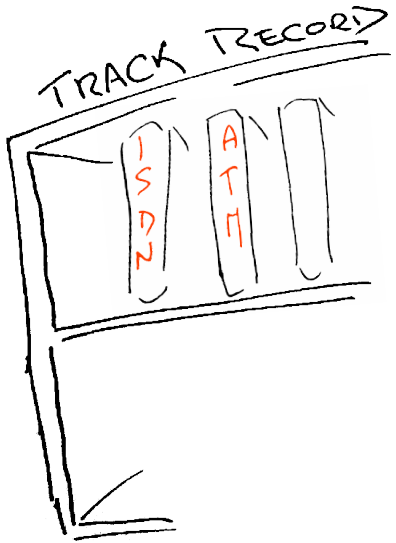
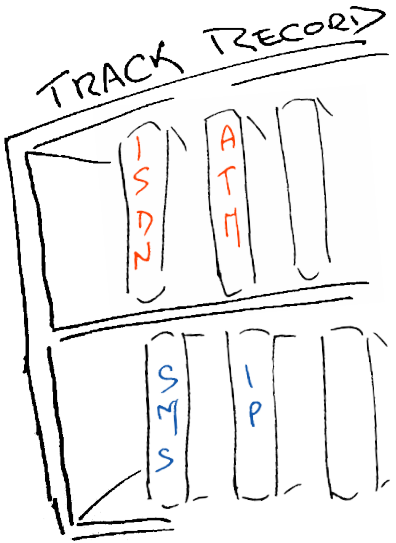


The mainstream telecommunications industry had a rich history

…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 then we used up the Internet's 32bit address pool

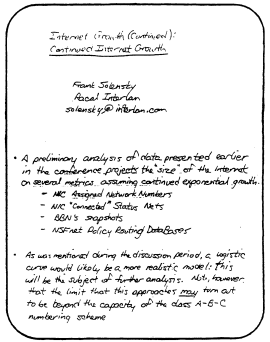
The Internet...

Has been a runaway success t… …s
transformed not just the … …mmunications
sector, but entire s… …ructures are
being altered by … …ternet!

And then we … … the Internet's 32bit
address …

This was not news — we knew that this iPocalypse was coming thirty years ago!

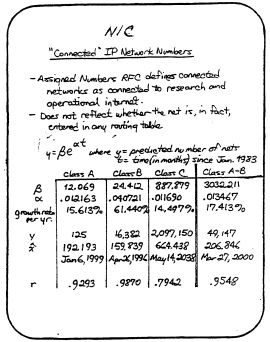
IETF Meeting - August 1990



Internet Growth (Continued):
Continued Internet Growth

Frank Solensky
Racal InterLan
solensky@FTP.InterLan.com

- A preliminary analysis of data presented earlier in the conference projects the "size" of the Internet on several metrics assuming continued exponential growth.
  - NIC "Assigned" Network Numbers
  - NIC "Connected" Static Nets
  - BBN's snapshots
  - NSFnet Policy Routing Databases
- As was mentioned during the discussion period, a logistic curve would likely be a more realistic model: This will be the subject of further analysis. Not, however, that the limit that this approach may turn out to be beyond the capacity of the class A-B-C numbering scheme



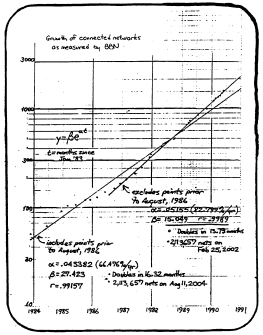
N/C

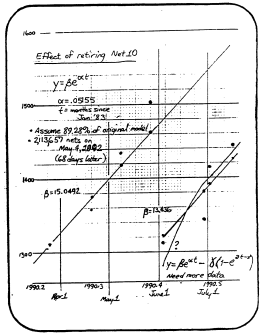
"Connected" IP Network Numbers

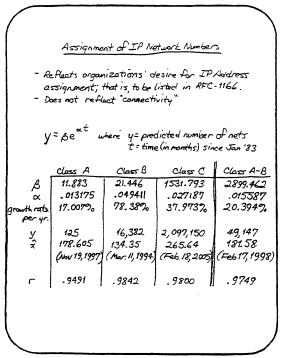
- Assigned Numbers RFC defines connected networks as connected to research and operational internet.
- Does not reflect whether the net is, in fact, entered in any routing table.

$y = \beta e^{\alpha t}$ where y = predicted number of nets, t = time (in months) since Jan. 1983

	Class A	Class B	Class C	Class A-B-C
β	12.069	24.412	887.879	3032.211
α	.012163	.040721	.011650	.03447
growth rate per yr:	15.615%	61.440%	14.497%	17.413%
y	125	16,382	2,097,150	49,147
x	192.193	159.839	624.438	206.846
	Jan 6, 1999	Apr 24, 1990	May 14, 2038	Mar 27, 2000
r	.9293	.9870	.7942	.9548





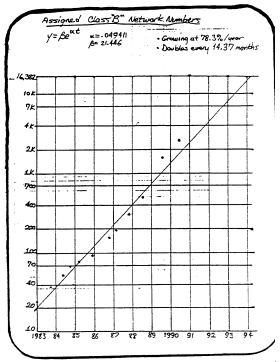


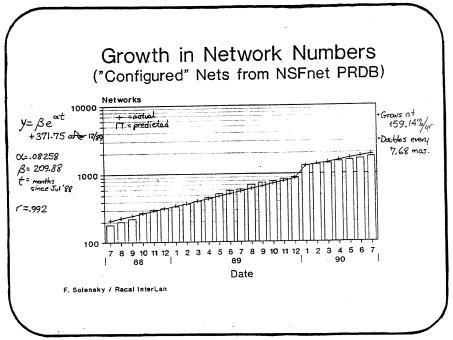
Assignment of IP Network Numbers

- Reflects organizations' desire for IP address assignment; that is, to be listed in RFC-1166.
- Does not reflect "connectivity"

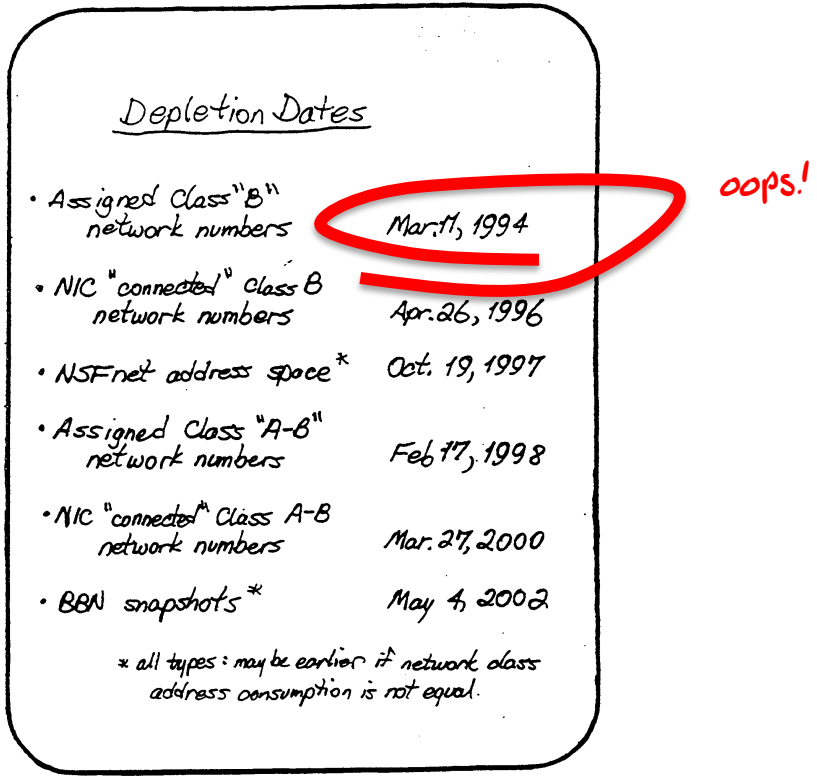
$y = \beta e^{\alpha t}$ where y = predicted number of nets, t = time (in months) since Jan '83

	Class A	Class B	Class C	Class A-B
β	11.823	21.446	1531.793	2899.462
α	.013175	.049411	.027187	.015387
growth rate per yr:	17.007%	78.38%	37.973%	20.394%
y	125	16,382	2,097,150	49,147
x	178.605	134.35	265.64	181.58
	(Jan 15, 1997)	(Mar 11, 1994)	(Feb 18, 2003)	(Feb 17, 1998)
r	.9491	.9842	.9800	.9749





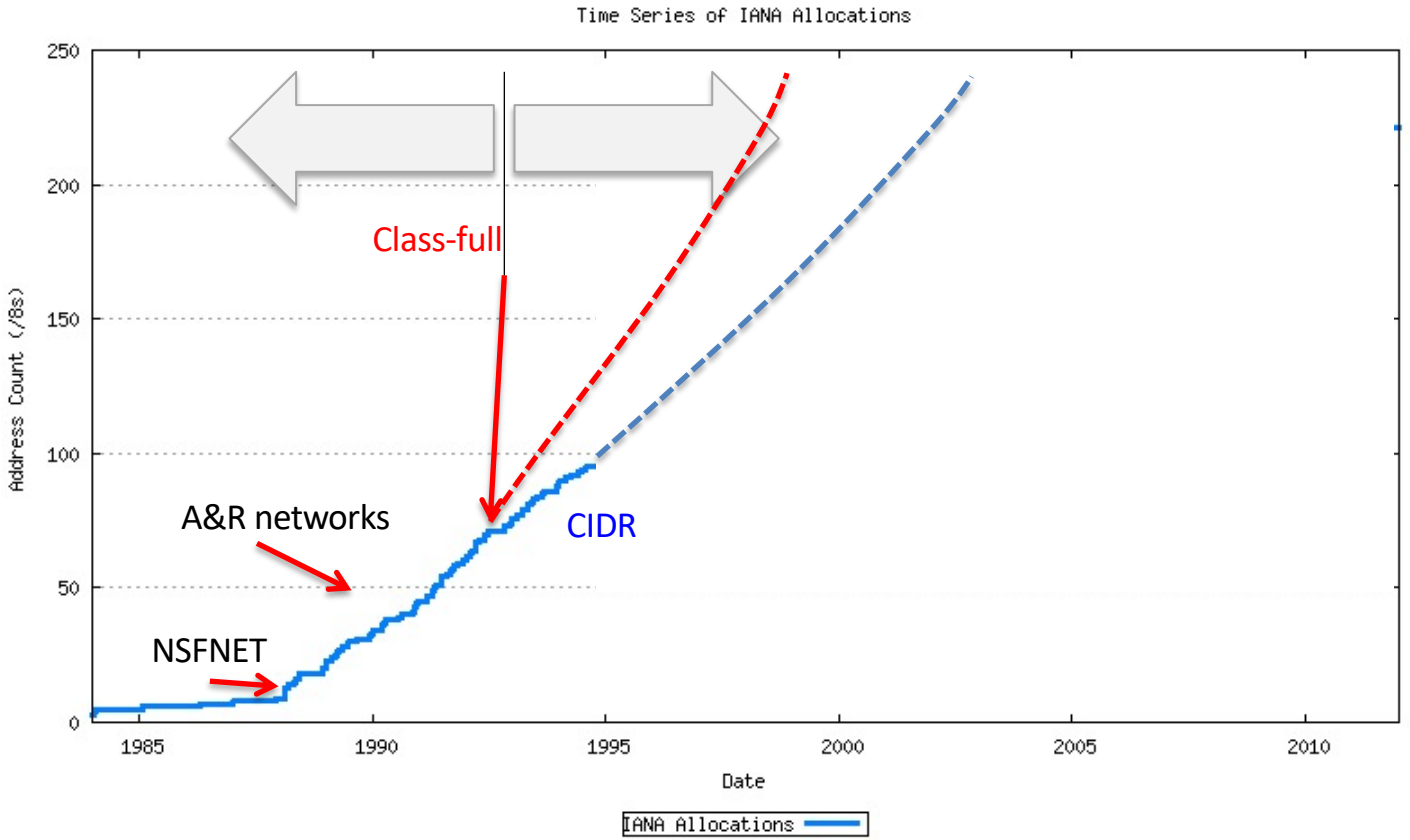
IETF Meeting - August 1990



What did we do back in 1992?

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

The CIDR Fix


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

What else did we do back in 1992?

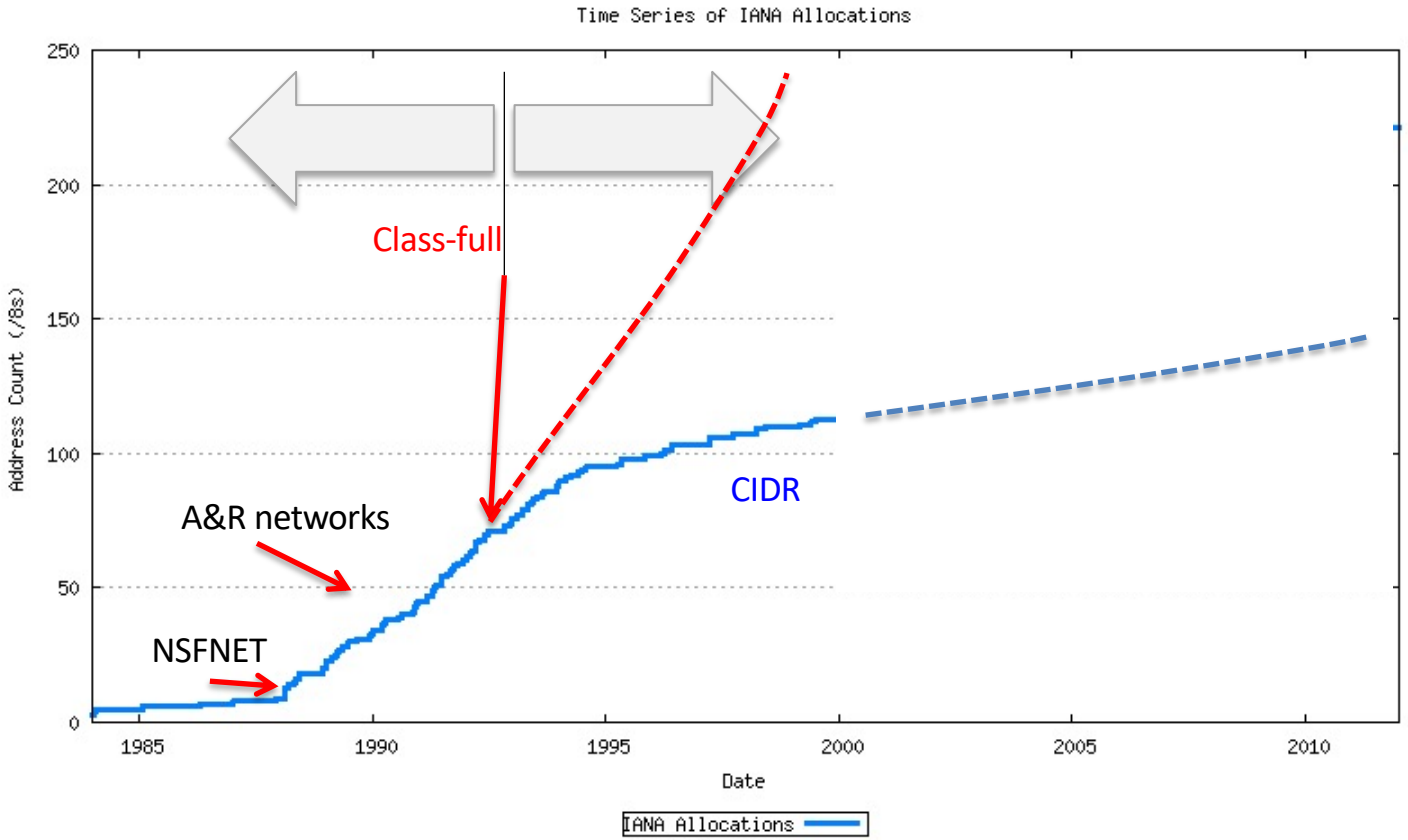
And we started working on a new Internet Protocol - to become IPv6 - to replace IPv4

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...

CIDR worked!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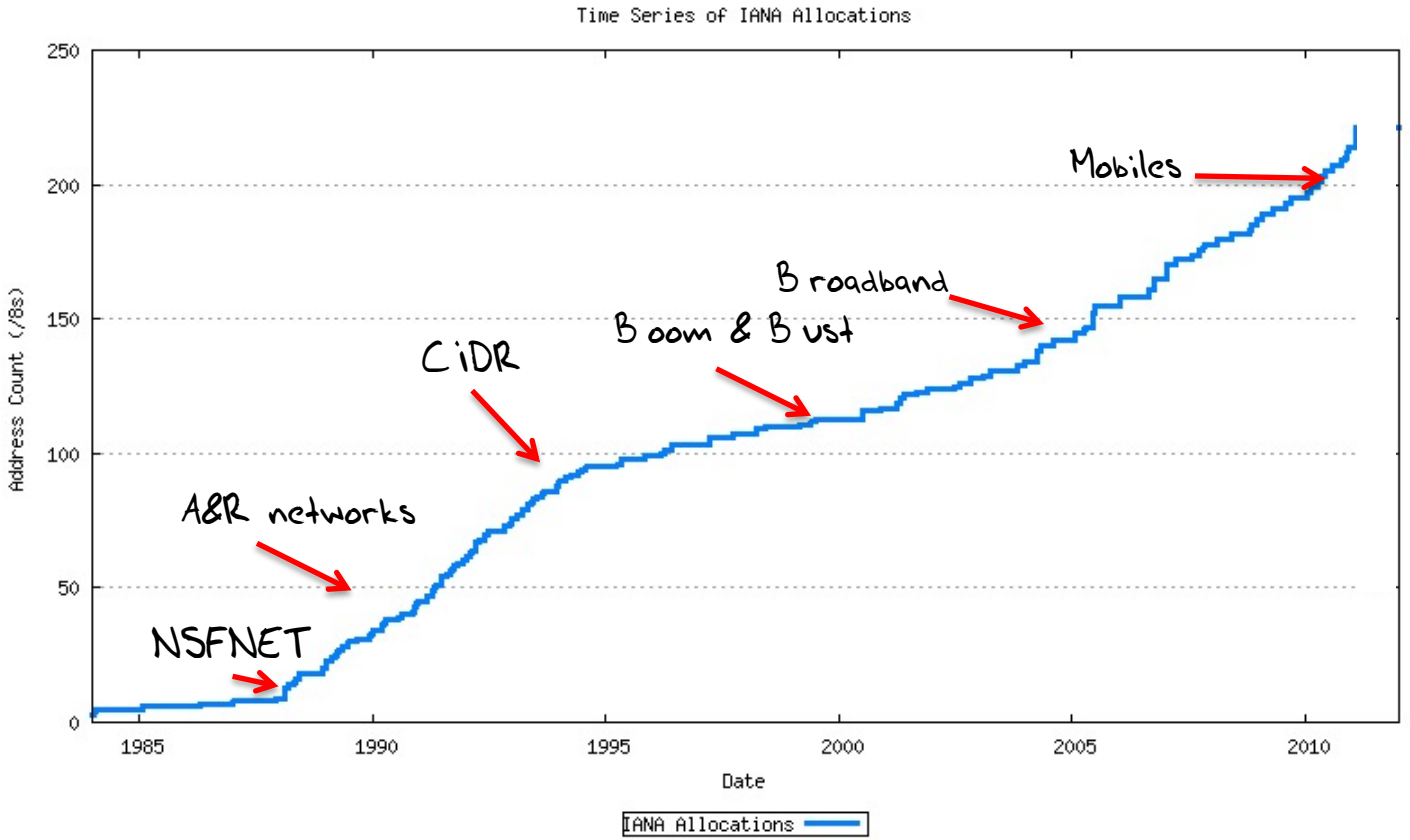
CIDR
IANA Allocations

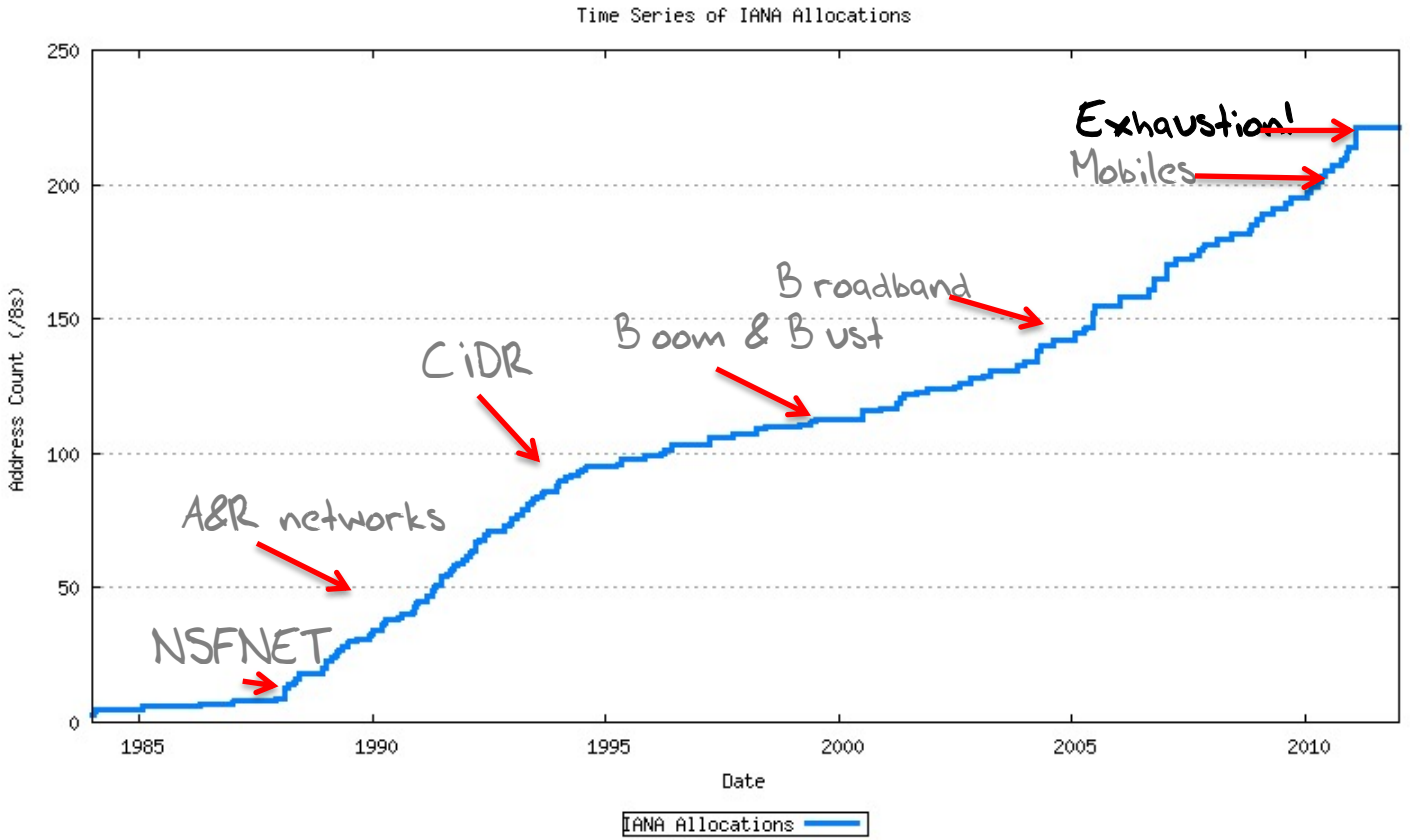
Meanwhile, we continued to build (IPv4) networks



The rude awakening

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

IPv4 Address Allocations



NRO

AfriNIC APNIC ARIN LAC RIPE NCC

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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 definitive action to deploy IPv6."

Ooops!

"This is truly a major turning point in the [illegible] development of the Internet," said Rod Beckstrom, ICANN's President and Chief Executive Officer. "Nobody was caught off guard by this, the 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.

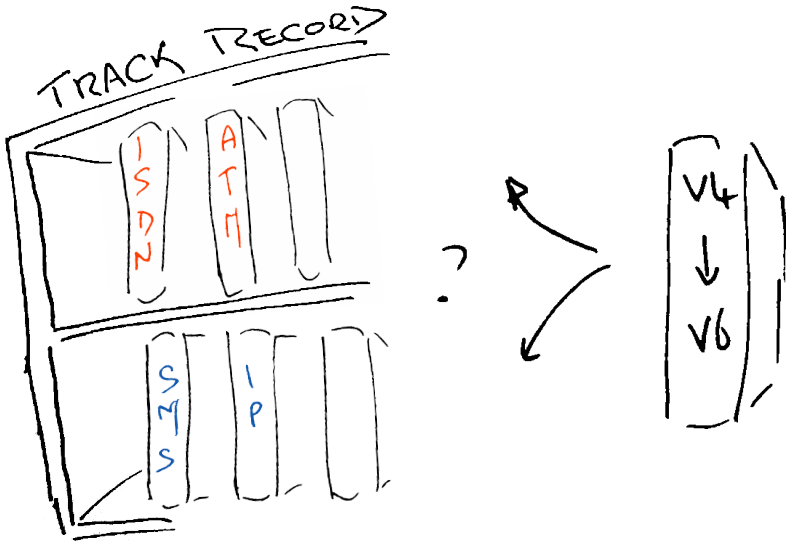
"Each RIR will have its final full /8 from IANA, plus any existing IP address holdings to distribute. Depending on address space requests received, this could last each RIR anywhere from a few weeks to many months. It's only a matter of time before the RIRs and Internet Service Providers (ISPs) must 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

The rude awakening

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

And transition to IPv6 suddenly became a very important topic!

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



Do we really need to worry about this?

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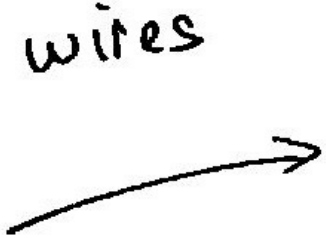
Surely IPv6 will just happen — its just a matter of waiting for the pressure of IpV4 address exhaustion to get to sufficient levels of intensity.

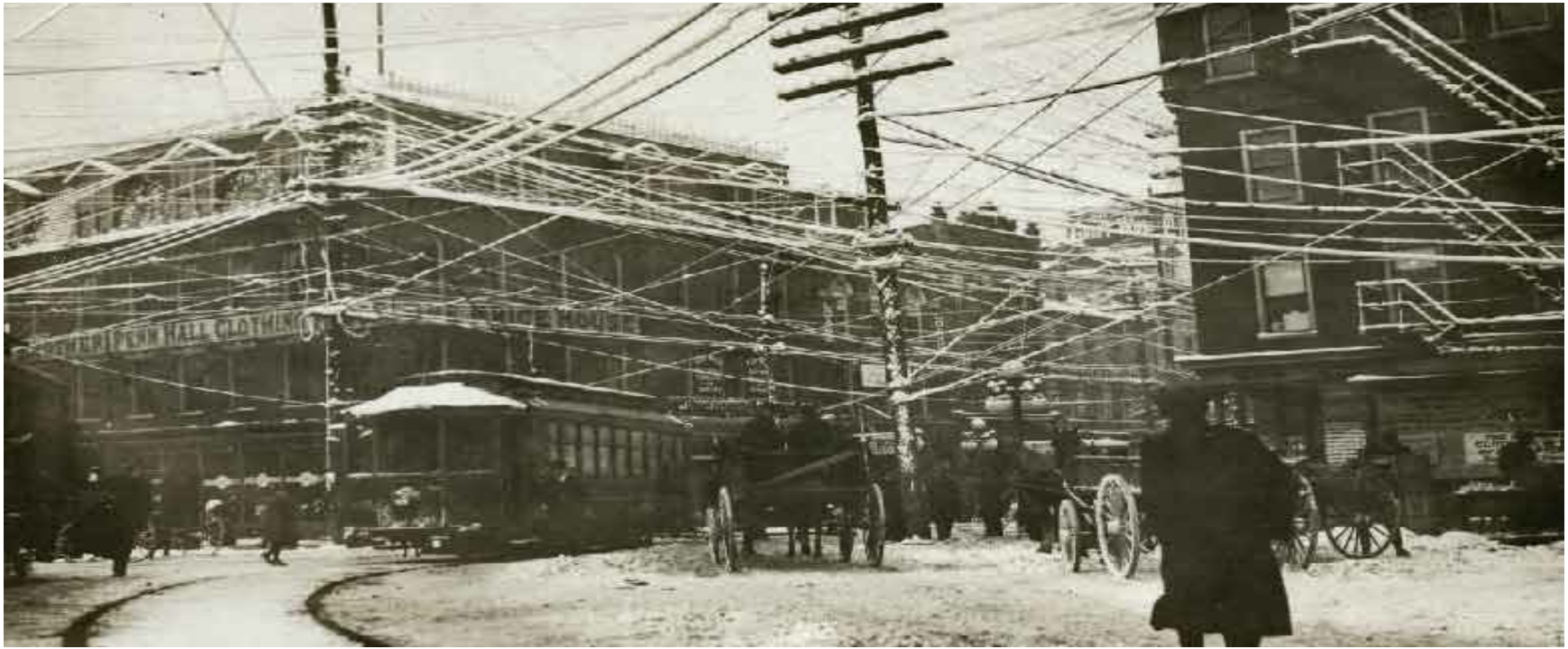
Do we really need to worry about this?

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





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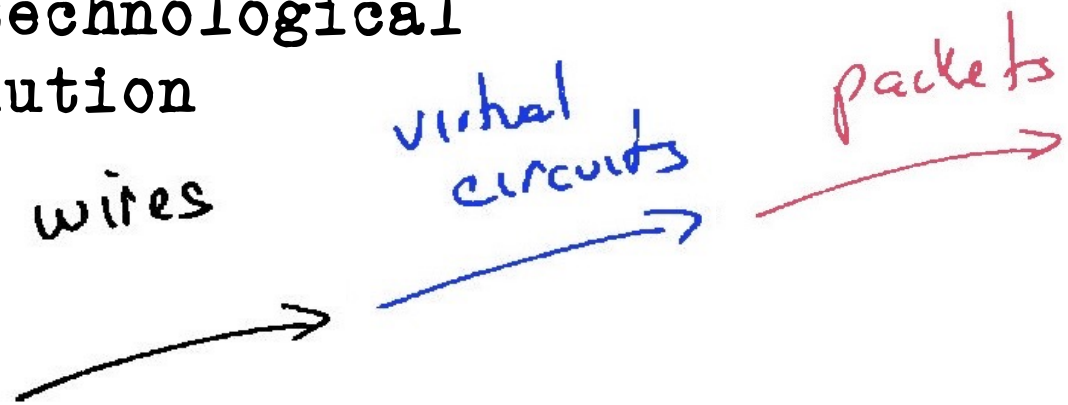


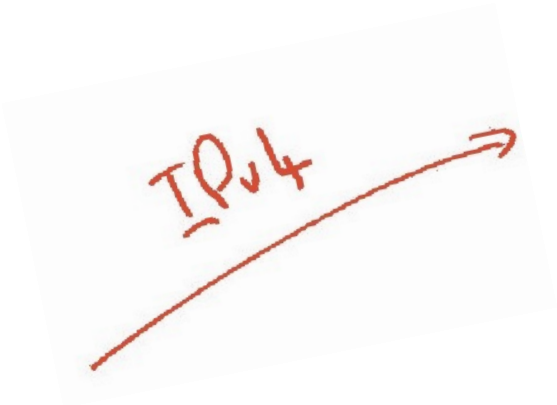
The "inevitability" of technological evolution

Each time we shifted the technology base of the networks, the cost efficiencies of the "new" technology in effect motivated the shift from the older technology to the new

The "inevitability" of technological evolution

Now let's look at something a little more topical to today!

The
"inevitability"
of technological
evolution?



The
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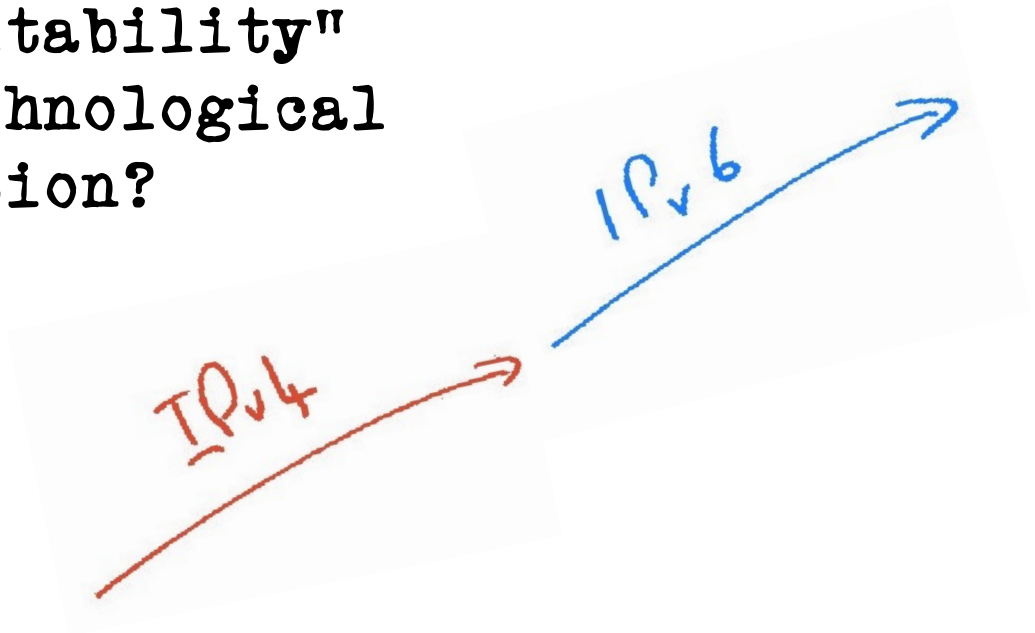
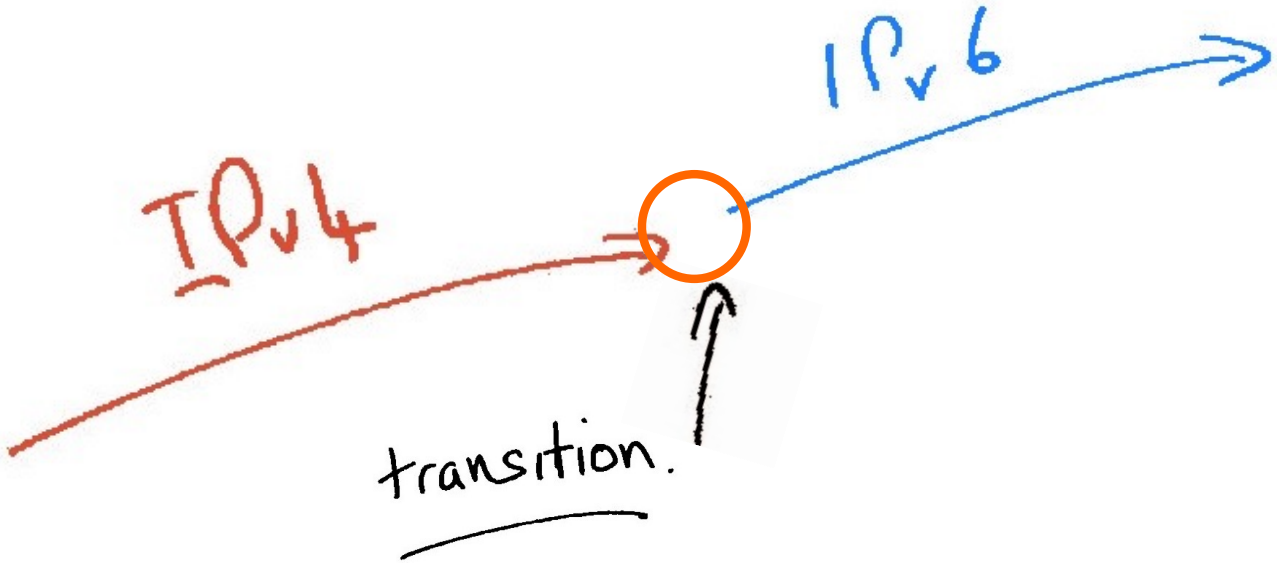
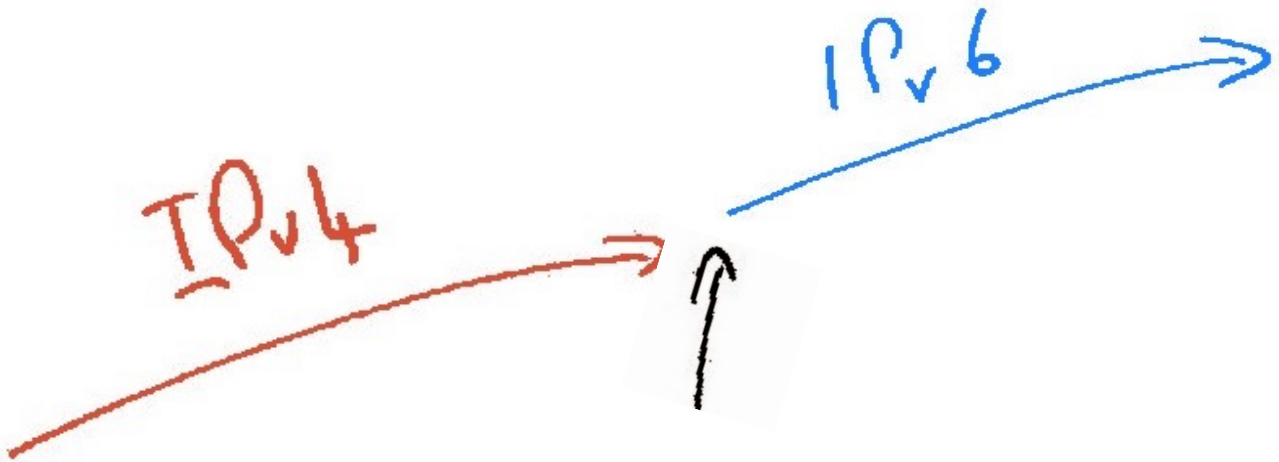


The challenge often lies in managing the transition from one technology to another



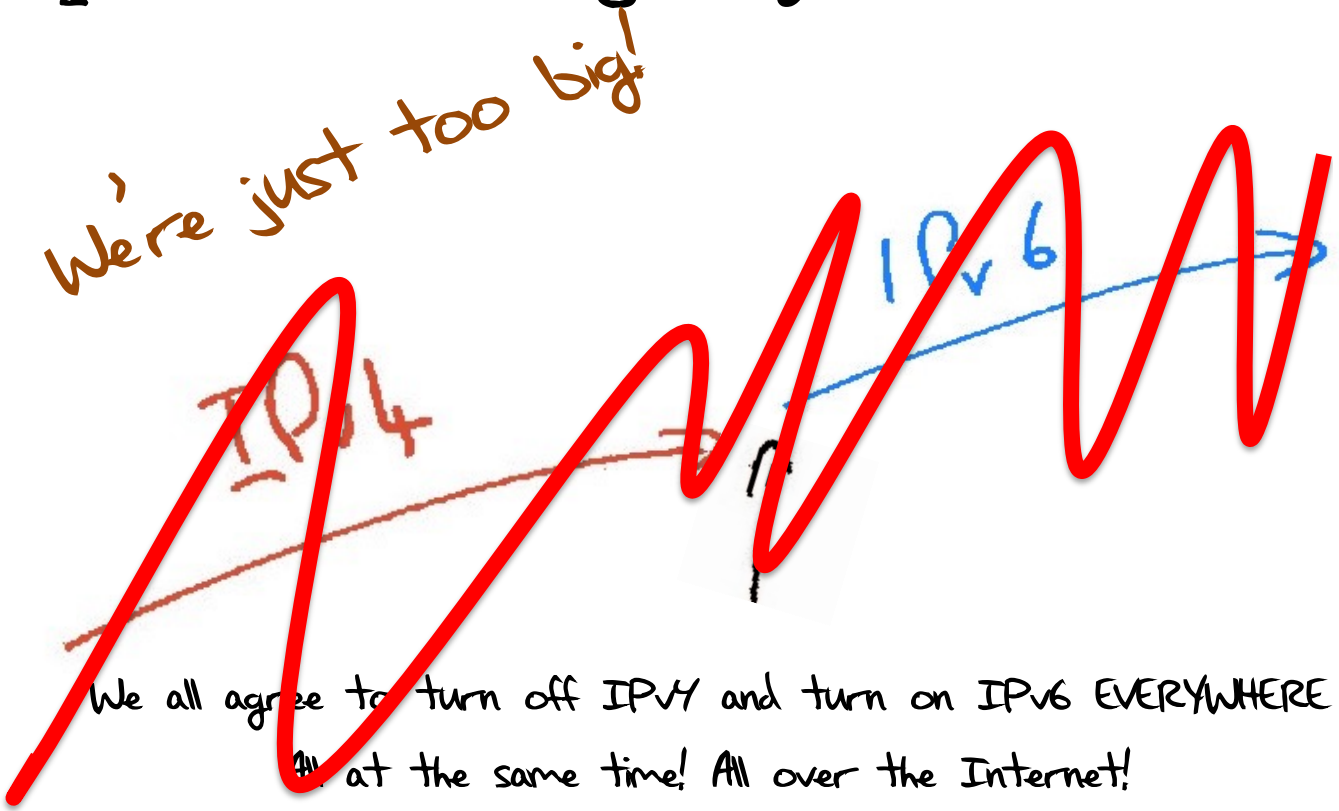
Option 1: Flag Day!



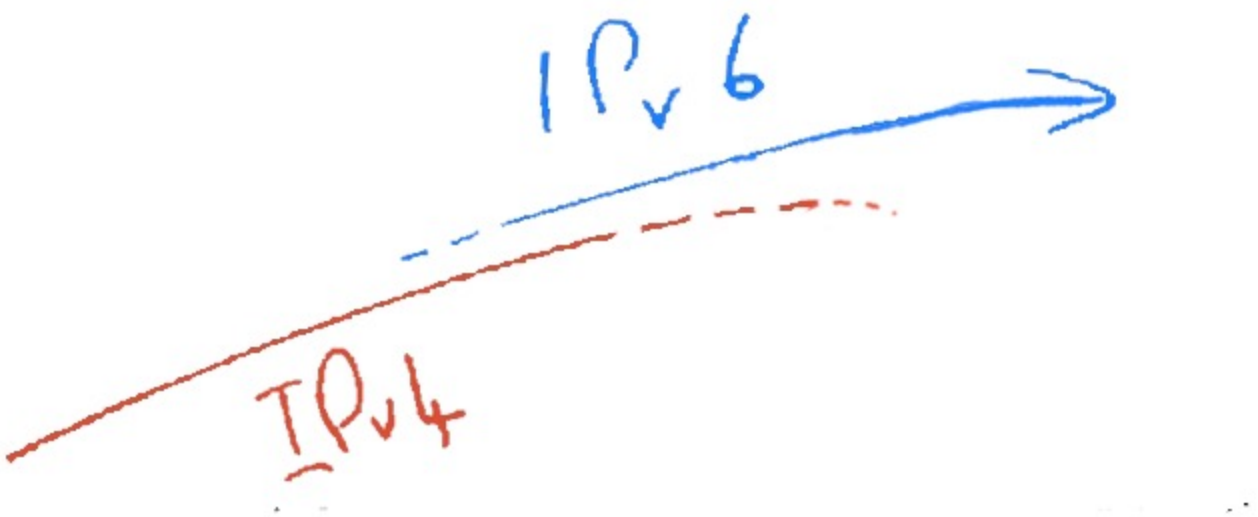
We all agree to turn off IPv4 and turn on IPv6 EVERYWHERE

All at the same time! All over the Internet!

Option 1: Flag Day!



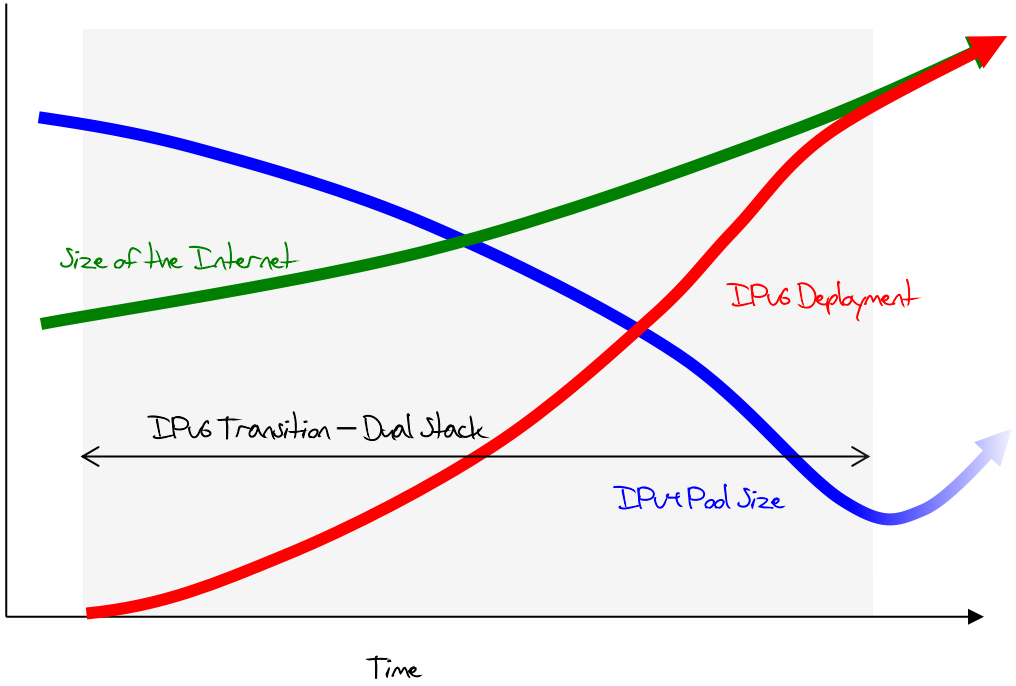
Option 2: Parallel Transition!



We start to slide in IPv6 in parallel with IpV4

Then we gradually phase out IPv6

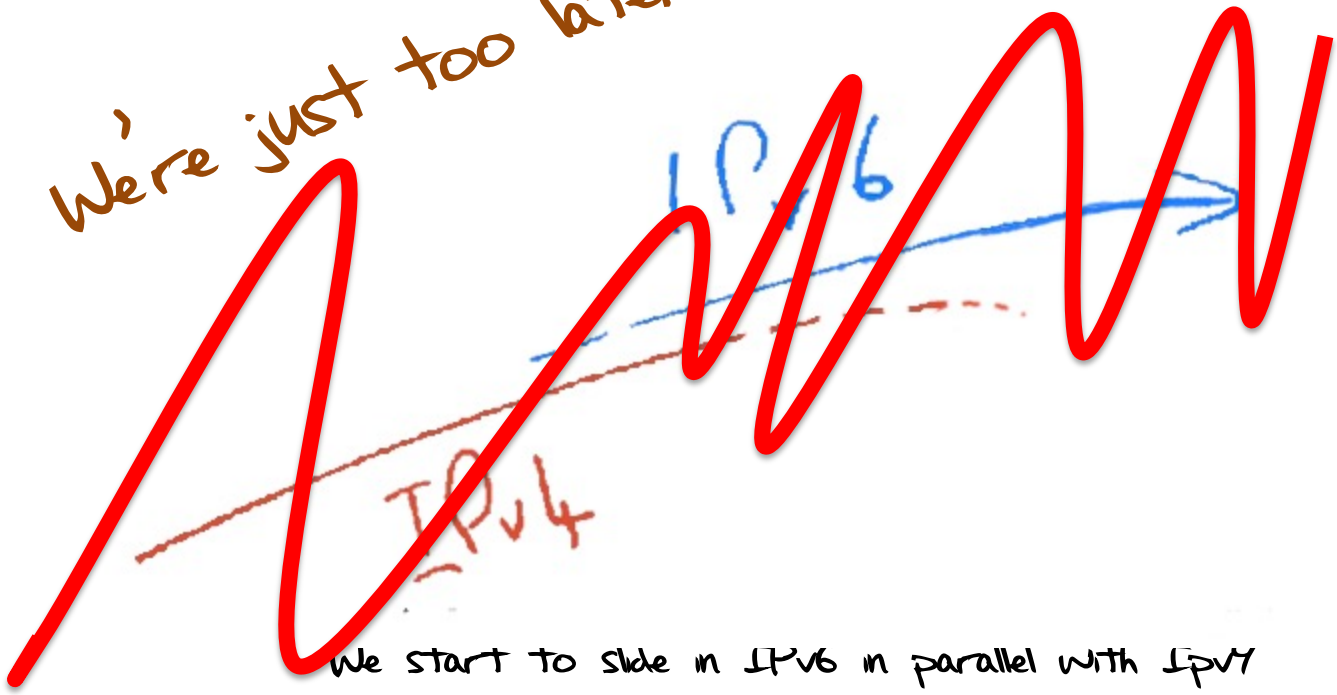
Option 2: Parallel Transition!



For this to work we have to start early and finish

BEFORE IPv4 address pool exhaustion

Option 2: Parallel Transition!



We start to slide in IPv6 in parallel with IPv4

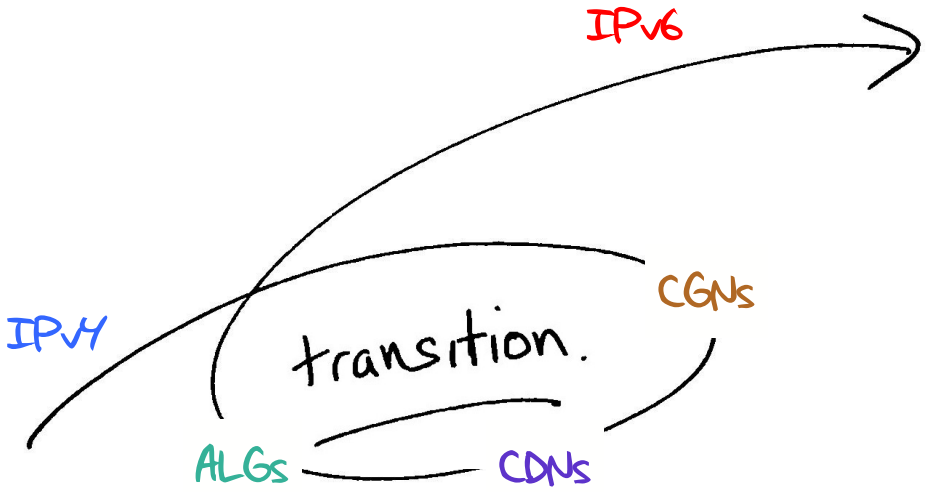
Then we gradually phase out IPv6

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

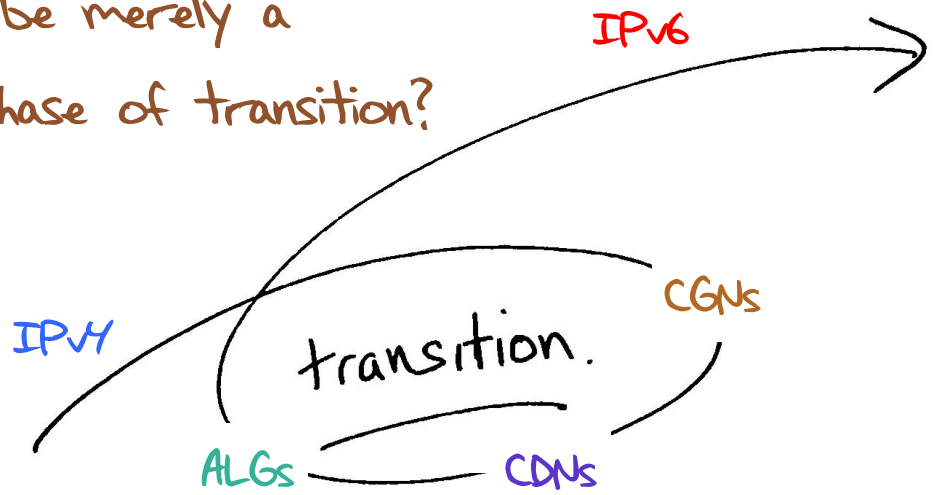
The increasing scarcity of IpV4 will force carriage providers to add address sharing mechanisms into the IPV4 network

Option 3: Hybrid Transition

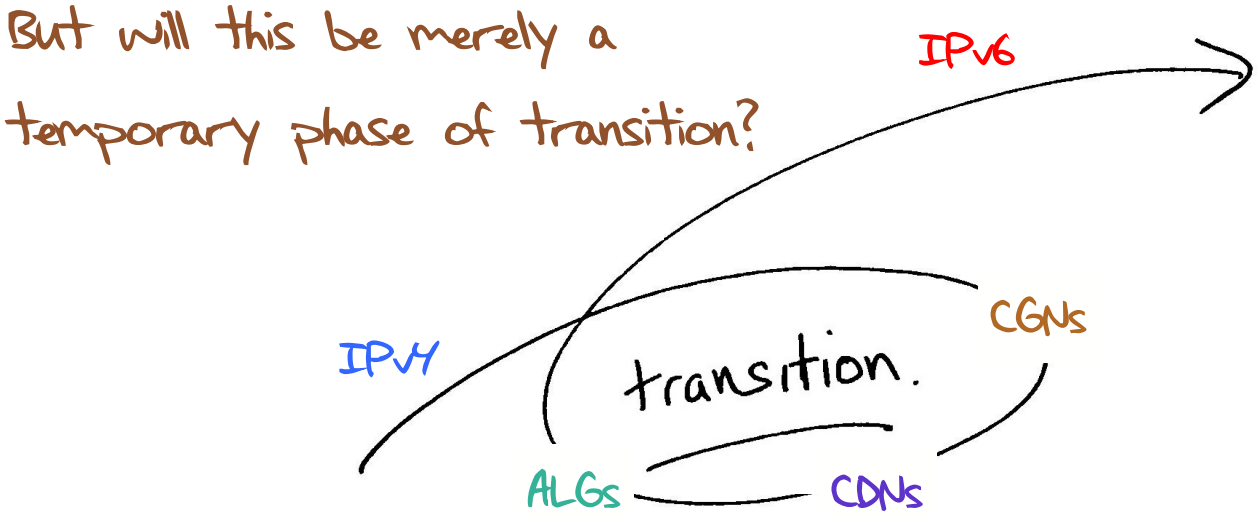


To get from "here" to "there" requires an excursion through an environment of CGNs, CDNs, ALGs and similar middleware 'solutions' to IPV4 address exhaustion

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.



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 problem is...

We are now supporting an ever-expanding Internet:

- without any feed of more IPv4 addresses

  and

- without sufficient IPv6 deployment to cut over

The problem is...

We are now supporting an ever expanding Internet:

- without any more IPv4 addresses and
- without sufficient IPv6 deployment to cut over

And, surprisingly, its working!!!

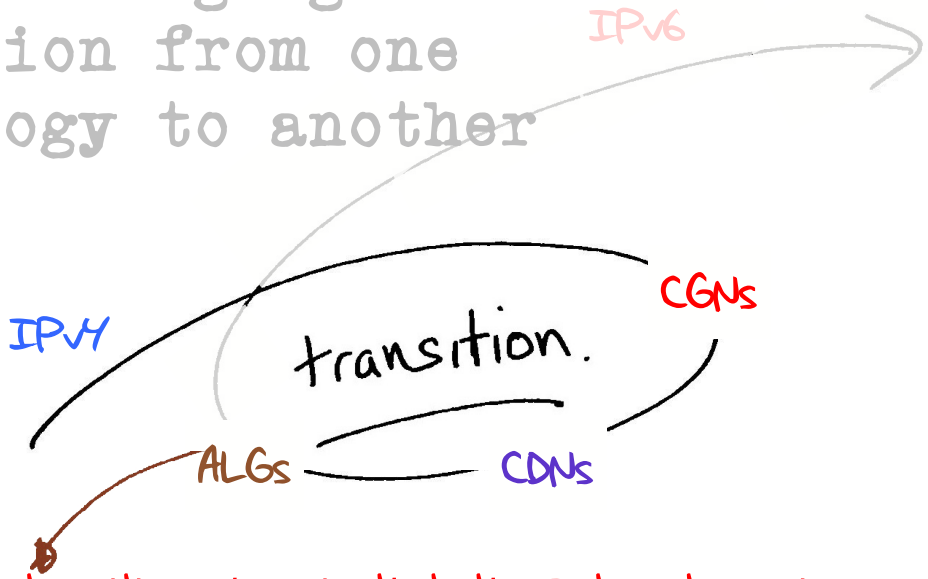
The problem is...

We are now supporting an ever expanding Internet:

- without any more IPv4 addresses and
- without sufficient IPv6 deployment to cut over

And, surprisingly, so far it's working!!!

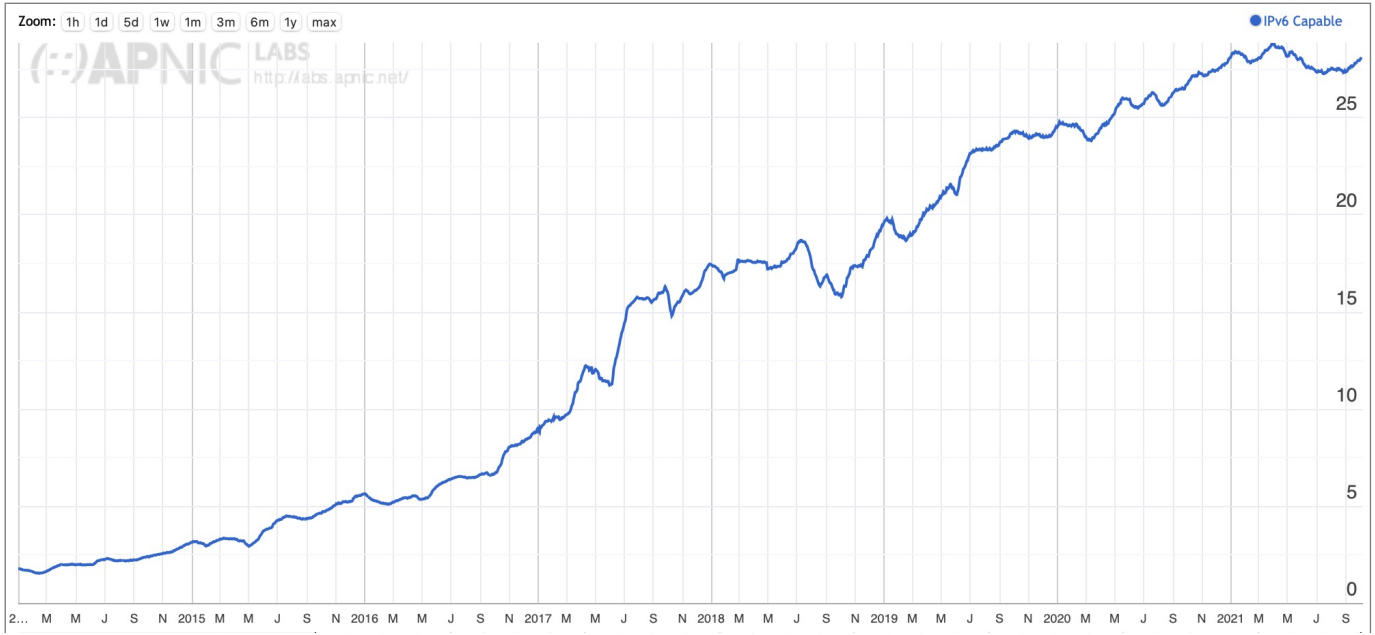
The challenge often lies in managing the transition from one technology to another



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

Just how are we going?

Use of IPv6 for World (XA)



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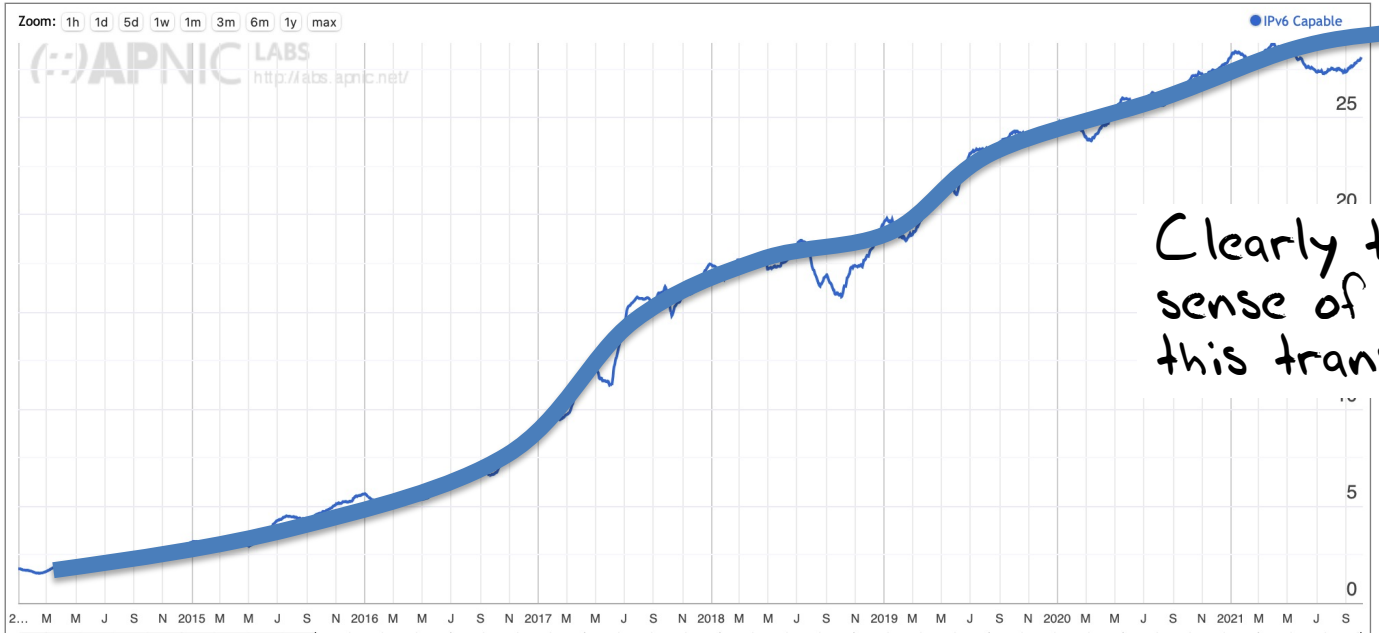
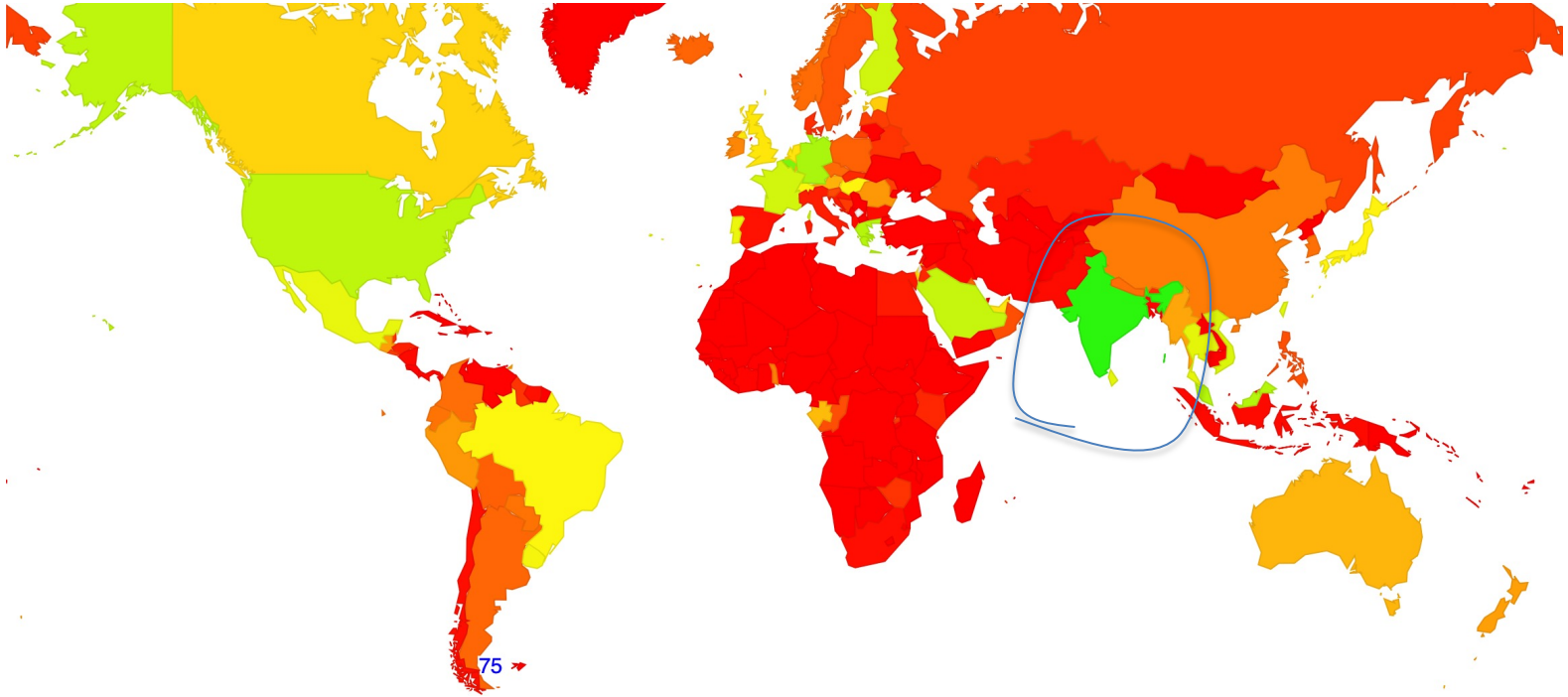


28%

Clearly there is no sense of urgency in this transition!

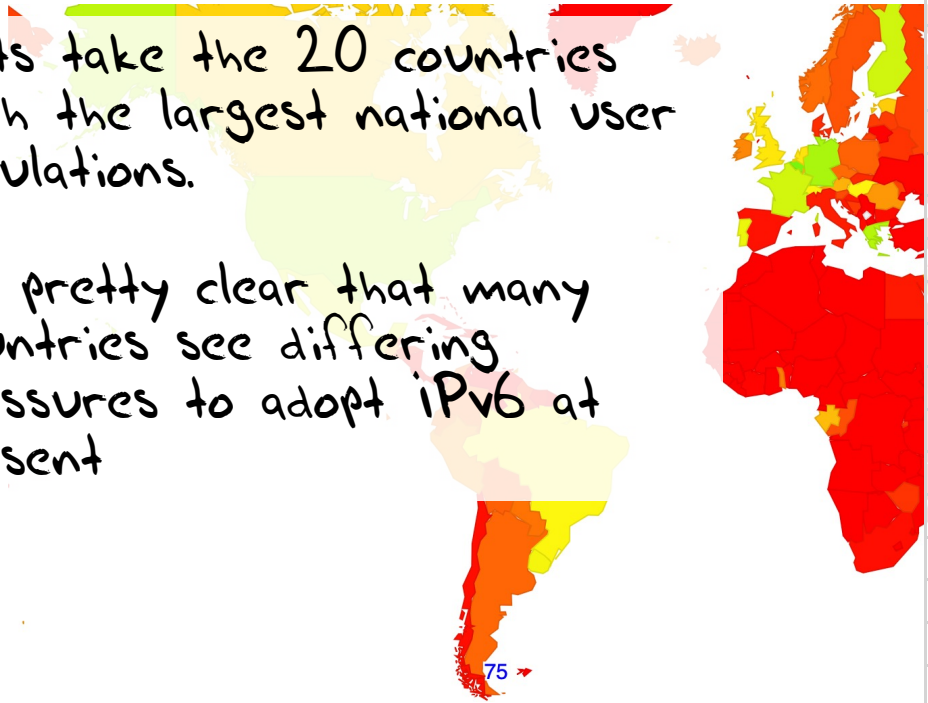
Where is it?



Where is IPv6?

Lets take the 20 countries with the largest national user populations.

its pretty clear that many countries see differing pressures to adopt IPv6 at present



Rank	Country	Users (Est)	IPv6
1	China	836,707,225	19%
2	India	616,081,465	75%
3	United State	250,406,218	49%
4	Brazil	168,711,777	38%
5	Indonesia	123,491,428	1%
6	Russia	120,559,409	10%
7	Japan	112,591,349	38%
8	Mexico	92,947,480	30%
9	Philippines	74,915,133	12%
10	Germany	70,713,647	51%
11	Turkey	65,593,672	0%
12	United Kingd	65,546,354	35%
13	Nigeria	65,154,753	0%
14	Iran	64,805,149	0%
15	Vietnam	55,008,530	45%
16	Egypt	54,508,448	4%
17	France	54,359,815	45%
18	South Korea	51,646,139	17%
19	Thailand	46,888,802	43%
20	Spain	43,032,407	3%

What's the Problem?

Is there IPv6 in Android, iOS, Mac OS, Windows and Linux? Do platforms support IPv6?

Clearly, YES!

Does every access ISP support IPv6?

Well, NO!!

Does every service support IPv6?

Well, NO!!

Why?

- Dual Stack networks are more complex to operate and support
- Some server platforms perceive Dual Stack as slower and less reliable than IPv4 only
- We seem to be comfortable with extensive use of NATs

Most importantly, we don't seem to care any more!

Economics!


NON SEQUITUR
AAAAA
UM...IT DIDN'T WORK...AGAIN
YEAH..
...BUT THE THEORY IS STILL SOUND!
AAAAA
THE FIRST ECONOMIST
©'11 WILEY INK, INC. 9-1
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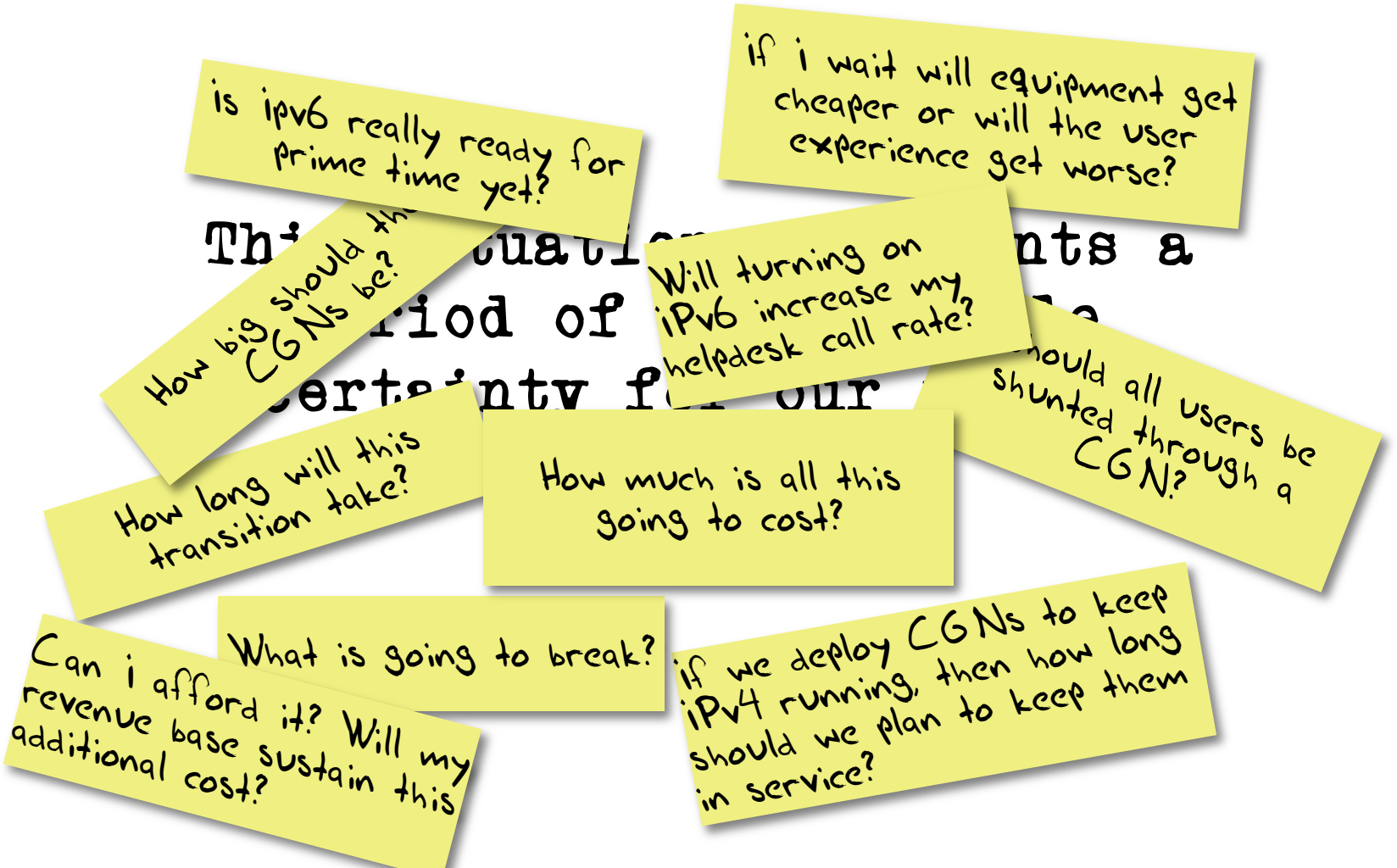
Economics!

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 only yields benefits in another

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 the CGNs be?
Will turning on IPv6 increase my helpdesk call rate?
should all users be shunted through a CGN?
How long will this transition take?
How much is all this going to cost?
What is going to break?
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?

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It's possible that within the next 10 years or so we will complete this dual stack "transition" and folk will feel sufficiently confident to deploy IPv6-only services in which case IPv4 will rapidly decay

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Its possible that within the next 10 years or so we will complete this dual stack "transition" and folk will feel sufficiently confident to deploy IPv6-only services in which case IPv4 will rapidly decay

It's equally possible this won't happen, because we've changed the Internet so much that the choice of which IP address space to use simply won't matter any more!

And its not yet clear which of these paths the internet will take!

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

market forces

You see, there us an Alternate View of where we are today

The Internet, as we knew it, is over.

An Alternate View

The Internet as we knew it, is over.

We don't use the network to reach far-away content and services any more.

Content and services have come to our front door through the intense levels of investment in Content Data Networks

If you look at the dominant traffic volumes "The Internet" is no more than a collection of discrete access networks that use a common technology

What would that mean?

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

What do we need?

And its not clear that we need a single massive address space any more!

Maybe all we need now is a common name space

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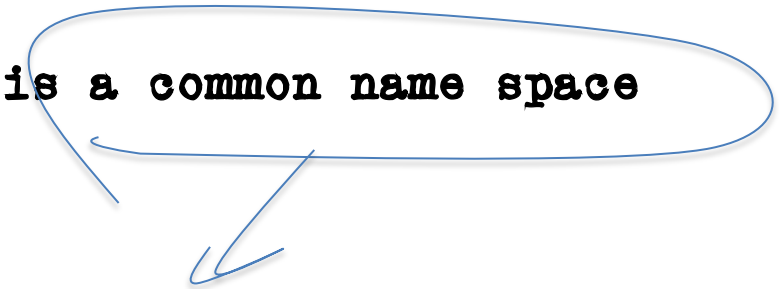

Yes, we didn't realise it at the time, but it IS all about the DNS after all!

What do we want?

Why were we so keen about IPv6 anyway?

IPv6 represented an open and accessible platform for further network growth and innovation

Our common public interest lies in a continuing open and accessible network

And that needs to be expressed within the dynamics of market pressures.

Today's question is:

How can we do this?

How can we "manage" this period of transition?

To ensure that the industry maintains a collective focus on continued innovation and openness as the ultimate objective of this exercise!

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To ensure that the industry maintains a collective focus on continued innovation and openness as the ultimate objective of this exercise!

And ensure that we do not get trapped in a new round of entrenched monopolies that will resist all forms of further innovation!

How can we "manage" this period of transition?

To ensure that the industry maintains a competitive focus on continued innovation and openness as the ultimate objective of this exercise!

And ensure that we do not get trapped in a new round of entrenched monopolies that will resist all forms of further innovation!

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

How can we "manage" this period of transition?

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 coherent digital environment that remains open, neutral, and accessible

Secondly

Stop trying to make yesterday perfect!

We are moving on in trying to make the Internet bigger, faster, cheaper and better

And the effort has changed focus to concentrate on applications and services

If application-centric networking and CDNs make bigger, faster, cheaper and better services then that's what we should be doing!

Finally...

Bring it on!

Resisting further innovation will simply entrench today's incumbents and will recreate the old stifling vertically bundled carriage monopolies of the telephone era!

And at that point we've lost everything!

Thanks!