The State of IPv6

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 just as we are gearing up, we are about to stuff it up! We've used up most of the Internet's 32bit address pool and that's a huge problem!
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, as we are gearing up, we are about to stuff it up! We’ve known this looming IPocalypse for the past twenty years... but we’ve used up most of the Internet’s address pool and that’s a huge problem!
Growth in Network Numbers
("Configured" Nets from NSFnet PRDB)
## Depletion Dates

- **Assigned Class "B" network numbers**
  - Mar. 17, 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
The CIDR Fix

Time Series of IANA Allocations

- NSFNET
- A&R networks
- CIDR
- Class-full
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
For a while this did not look to be an urgent problem...
CIDR worked!

Time Series of IANA Allocations

Address Count (/8s)

Date

IANA Allocations


CIDR

Class-full

A&R networks

NSFNET
Meanwhile, we continued to build (IPv4) networks.

![Graph showing time series of IANA allocations with key events such as CIDR, A&R networks, NSFNET, Boom & Bust, Broadband, and Mobiles.]
The rude awakening

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

Time Series of IANA Allocations

- NSFNET
- A&R networks
- CIDR
- Boom & Bust
- Broadband
- Exhaustion!
- Mobiles

Date

IANA 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 Echeberria, 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 affirmative action to deploy IPv6.”

“This is truly a major turning point in the on-going adoption of the Internet,” said Rod Beckstrom, ICANN’s President and Chief Executive Officer. “Nobody was caught off guard by this event. The technical community has been planning for IPv4 depletion for quite some time. But it means the adoption of IPv6 has now 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 worldwide 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 Echeberria. IPv6 address space has been available since 1999. Visit http://www.nro.net/ipv6/ for more information on IPv6, or contact the NRO at info@nro.net.
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!
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 — it's 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 – it's 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
The "inevitability" of technological evolution
The "inevitability" of technological evolution

wires \rightarrow \text{virtual circuits} \rightarrow \text{packets}
The "inevitability" of technological evolution

Each time we shifted the technology base of the network, the cost efficiencies of the "new" technology in effect motivated the shift from the older technology to the new
The "inevitability" of technological evolution: It's just economics!
The "inevitability" of technological evolution

Now let's look at something a little more topical to today!
The "inevitability" of technological evolution?
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 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 IPv4.
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

We're just too late!
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.
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 carriage provider heads off in a completely different direction!
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
Coping with Demand

Global IPv4 supply shortfall is predicted to reach 800m addresses by 2014.
And it's not getting any easier...

The metrics of IPv6 deployment could be a lot higher than they are today..
IPv6 capability, as seen by Google

In November 2012 only 0.9% of users’ access to Google’s dual stack services used IPv6

Where is it?

% of users preferring IPv6 – per country

http://labs.apnic.net/index.shtml
Relatively, where is it?

# Labs.APNIC.NET - IP Resource Per Country Distribution Report

**Date:** 20 Nov 2012

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*Internet Average*
Absolutely, where is it?
United States

IPv6 Preference 30 day moving average
France

IPv6 Preference 30 day moving average

Netherlands

IPv6 Preference 30 day moving average

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 1% 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.

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.

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

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

Non Sequitur

Um... it didn't work... again

But the theory is still sound!

The first economist
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 a 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.
This situation represents a period of considerable uncertainty for our industry. How long will this transition take? If I wait will equipment get cheaper or will the user experience get worse? Is IPv6 really ready for prime time yet? 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? How long should CGNs be? How big should IPv6 be?
Where is this heading?
In the next five years...

we have a choice
In the next five years...

Everything gets squashed into HTTP, IPv4 and CGNs IPv6
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 it's not yet clear which path the internet will take!
And it's 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?

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 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

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!