IPv6 – A 10,000m Perspective

Geoff Huston
Chief Scientist, APNIC
Why?
Because we’ve run out of addresses!
again!
A bit of history...

The original ARPAnet design of 1969 used the NCP protocol, which used 8 bit addresses

- Maximum network size of 256 nodes
- Enough, yes?
ARPAnet IMP - 1970’s
ARPAnet - September 1978
• Turns out that 8 bits of addresses was not enough for the next generation of mini computers
• ARPAnet undertook a transition from NCP to a new protocol: TCP/IP
  – Expansion from 8 to 32 bit addresses
  – Flag Day: 1 January 1983
  – Shutdown and reboot every node into the new protocol
“This time, for sure!”

* Actually Vint didn’t say this!
IP Version 4

• 32 bit address field
  – That’s 4,294,967,296 addresses

• A triumph of minimalism
  – Basic datagram architecture
  – Stateless network with admission control and without active resource management
  – Variable packet size with fragmentation on the fly
  – Basic header set: Source, Destination, Fragmentation Control, checksums, all in 20 octets
  – Decoupled framework of related functions
It Worked!

• The minimal approach allowed for more efficient use of the common network
  – It was cheap
  – It was easy
  – It scaled
It Worked too well!

• Back in 1983 no one ever truly believed that IP would be the single communications protocol for the 21\textsuperscript{st} century
  – And you would be mad for thinking that
  – OSI was meant to be the answer
  – And we understood so little about computing and communications that it was equally possible that we would find something better than packet switching pretty soon
  – So 32 bits of address space was looking like a decent engineering tradeoff
Frank Solensky, IETF, August 1990
Doomsday – Mk 1

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.

Frank Solensky, IETF, August 1990
IPv4 Address Allocations

Time Series of IANA Allocations

Address Count (/8s)

Date

1985
1990
1995
2000
2005
2010

A&R networks
NSFNET

Class B Nets

IANA Allocations
The CIDR Band-Aid

• It was clear by 1991 that we needed a new protocol
  – There was just no way we could hack extra bits of address space into the IPv4 header
  – And maybe we should think about what should/and should not be in the packet header at the same time as we enlarged the address size

• So we needed to buy a few years of breathing space
  – We did this by removing the fixed network/host boundary points
  – Classless Inter-Domain Routing was rushed in as a quick fix
The CIDR Fix

Time Series of IANA Allocations

- Class-full
- CIDR

A&R networks

NSFNET
And the long term plan?

IPng

– There was no OSI any more, so this had to be the one and only protocol in the eyes of the protocol designers

– It was envisaged to have a lifespan of 30 – 100 years

– And encompass ubiquitous deployment to the order of trillions of connected nodes
Problem Solved!

• We set the protocol designers onto the problem
  – we were naive enough to think that a committee could engineer a better architecture
• We planned to worry about transition on a later day once the protocol design had been worked out
• And we turned back to building the network
  – and making money
  – a LOT of money, as it turned out
For a while the problem of the need for a new protocol became LESS urgent

– The network grew at ever faster rates
– But CIDR allowed us to use vastly fewer addresses
– And then consumer NATS allowed us to use even fewer addresses
– So IPv6 became a perennial “sometime” issue that never quite became a “now” item
IPv4 + CIDR + NATs worked!

Time Series of IANA Allocations

- A&R networks
- NSFNET
- CIDR
- Class-full
And worked...

Time Series of IANA Allocations

- NSFNET
- A&R networks
- CIDR
- Boom & Bust
- Broadband
And worked!

Time Series of IANA Allocations

- NSFNET
- A&R networks
- CIDR
- Boom & Bust
- Broadband
- Mobiles
Until it didn’t work any more!
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 joint initiative to deploy IPv6.”

“This is truly a major turning point in the on-going development of the Internet,” said Rod Beckstrom, ICANN’s President and Chief Executive Officer. “Nobody was caught off guard. In fact, the Internet community has been planning for IPv4 depletion for quite some time. But it means the adoption of IPv6 is now a Clement reality, and 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 Echeberría. IPv6 address space has been available since 1999. Visit [http://www.nro.net/ipv6](http://www.nro.net/ipv6) for more information on IPv6, or [http://www.iana.org](http://www.iana.org) for details on the IANA pool.
IPocalypse?
Maybe not

• It's a massive industry
• And exhaustion is not a sudden state change

• But the network grew by more than 280 million services in 2011
  • Which was the largest year so far for the Internet
It’s more like this!
Transition is hard!
Switchover?

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

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!
Piecemeal Switchover?

One-by one networks switchover to IPv6, switching off IPv4 when they complete their transition.
Piecemeal Switchover?

One-by-one networks switchover to IPv6, switching off IPv4 when they complete their transition.
One-by-one networks and hosts have IPv6 added to IPv4.

Switching off ipv4 when every element has both IPv4 and IPv6.
Dual Stack Transition

For this to work we have to start early and finish BEFORE IPv4 address pool exhaustion.
Dual Stack Transition

We're just too late!

One-by one networks and hosts have IPv6 added to IPv4 Switching off ipv4 when every element has both IPv4 and IPv6
More Band Aids!

The increasing scarcity of IPv4 will force carriage providers to add address sharing mechanisms into the IPv4 network.
Plan F – The Kitchen Sink Approach!

To get from “here” to “there” requires an excursion through an environment of CGNs, CDNs, ALGs and similar middleware ‘solutions’ to IPv4 address exhaustion.
Where are we with IPv6?

It’s a mixed story

– Some components of the Internet have had IPv6 for many years
  • There is far more IPv6 out there in the Internet if you know where to look
  • About one half of today’s Internet devices show that they have an active IPv6 stack

– But some critical parts of the Internet are still determined not to make any shift away from IPv4
  • While one half of the Internet’s devices have IPv6, less that 1 in a hundred devices can actually use IPv6 on the Internet
Where are we with IPv6?

• Every Host?
  – 50% do, 50% do not
  – Strong Points:
    • Microsoft Windows Vista and 7 with IPv6 on by default
    • Mac OSX with IPv6 on by default
    • Unix servers with IPv6 on by hand
  – Weak points:
    • Mobile devices do NOT have IPv6 in their radio systems
      – Any many do not have it at all so far
    • Waiting for the world to turn off XP
Where are we with IPv6?

• Every Network?
  – 50% of the transit networks do, 50% do not
  – 4% of the access networks (or less) do
    • Weak points:
      – DSL deployments with customer-owned CPE are a major impediment to transition
      – BRAS / BFLETs IPv4 only
      – CPE IPv6 story is patchy to bad
      – 3G networks are a problematical in GGSN services
      – 4G networks – still early days
  – Server / Data centre infrastructure weak
    • Not many of the load management products support IPv6
    • And dual stack in a data centre is messy
    • IPv6 internals with a dual stack external presentation is an efficient approach for a data centre – but few centres are willing to make the call and transition to Ipv6 yet
Where are we with IPv6?

In April 2012 only 0.5% of users access Google’s dual stack services using IPv6.

# Where is Australia with IPv6?

## IPv6 Users by Country

<table>
<thead>
<tr>
<th>Index</th>
<th>ISO-3166 Code</th>
<th>Internet Users</th>
<th>V6 Use ratio</th>
<th>V6 Users (Est)</th>
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These are low numbers

• Less than 1% of the Internet’s user base with IPv6 active in 2012 is a very weak position
• And time is running out
• This cannot be an extended transition
  – Either we all move and move the entire Internet to supporting IPv6 by around 2015
  – Or we’ll lose focus and momentum and turn our collective attention to engineering insane adornments for CDNs, ALGs and similar active middleware in an all-IPv4 network
This was always going to be tough

- Deregulated industry structure
- Commoditization of carriage provision
- Dominance of content services
- Disjoint cost and benefit in V6 deployment for access provider industry
- Significant resistance from the carrier sector
- No clear consumer benefits in cost or utility
Why should you care?

• No perceived need - already have IPv4 for enterprise
• Few IPv6 enterprise products available
• No IPv6 expertise in IT management and operations units

• Difficult, costly, and it addresses no perceived need
BUT

Why did you deploy IPv4 in the first place?

Everyone else was using it

It was cheap

Our customers and providers were using it
Why did you deploy IPv4 in the first place?

Everyone else was using it

It was cheap

Our customers and providers were using it
If not IPv6 ...

There is no other plan!
The path with IPv4 leads to Carrier NATS, Application Level Gateways and ultimately to fragmentation and piecemeal networks
The major benefits of IPv4 lie in its openness and universality
  – neither of these are sustainable attributes for more than 2 – 3 years at most!
  – After that expect to see IPv4 segment itself into a set of carrier-limited islands
Timing is everything

• What’s your threshold for IPv6?
• There are no clear first adopter advantages
• So “wait and see” is a pervasive attitude
• But there are clear long term common risks of inaction in terms of cost, efficiency, openness and utility of the common network platform
• “when” is a big question here if we all want to avoid these risks
A Modest Suggestion

• Start **small**, but start **now**
  – Dual Stack the external front of house
    • Contract with your data centre / service provider for front-side IPv6 access
    • Put IPv6 on your front of house service platforms
    • Enable Dual stack your server application
    • Add AAAA records to your DNS
    • Include IPv6 monitoring in your operational monitoring
    • Measure the results
And while you are at it...

- No more purchasing “IPv4 only” products
- Dual stack should be a mandatory purchase criteria
  - It's a simple case of ensuring a reasonable service life for your equipment
  - And it also exposes your operational environment to introducing dual stack services internally
  - And allows you to flexible in adjusting to the moves of your suppliers, peers and customers
What changes with IPv6?
What changes with IPv6?

• Not much
  – Most users never notice when they connect to a dual stack access network
  – It’s still the Web, its still the Internet, and things work much the same as ever

• But that’s what we intended – if nothing changes then we’ve succeeded!
However, it’s not perfect

• We learned a huge amount as we deployed IPv4
• And it’s clear that IPv6 still has its wrinkles
• And doubtless many network operators and their customers will encounter new issues in this deployment
• But that’s no excuse to wait...
We need to move quickly with IPv6
as there is just no more IPv4!
Thank You