IPv4 Numerology

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If 42 is the answer …
Then what was the question?

– Part of the reason for differences in outcomes in this area lies in the difference of the question being posed

So - to be clear – the question posed in this study is:

When can we expect that the current address allocation policies for IPv4 will no longer apply?
A look at the IPv4 data

• Use the fundamental assumption that **the driver for address consumption is the Public Internet**, and that the growth of the Internet itself is reflected in address consumption demands

• This is based on the growth of advertised address span in the public Internet

• Adjust the model to include each individual RIR’s allocation behaviour over time

• Set the ‘exhaustion’ date at the point when any RIR cannot honor an address request
Current Status of IPv4

![Current IPv4 Status Diagram]
Advertised and Unadvertised Addresses
This Approach to Modelling IPv4

- The post-2000 data indicates that more than 95% of all allocated address space is advertised in BGP on the public IPv4 Internet

- This implies that the drivers for address consumption can be found in the advertised address pool behaviour

- From the advertised data time series, first remove the high frequency noise components, generate a best fit trend, then model interactions with unadvertised and RIR address pools

- Perform forward extrapolation from this model
Advertised Address Space

Time Series of Advertised Address Size

Date

Advertised IPv4 Address Count (\times 10^6)
Advertised Address Space
Advertised Address Space
Advertised Address Space

Time Series of Advertised Address Size

- Advertised IPv4 Address Count (0s)
- Date

- 2000
- 2001
- 2002
- 2003
- 2004
- 2005
- 2006
Advertised Address Growth
First Order Differential

First order differential of advertisements

Date

Advertised Address Growth Rate

Linear Best Fit
Advertised Address Growth
First Order Differential of Log

First order differential of log(advertisements)

Log(Advertised Address Growth Rate)  Linear Best Fit
Advertised Address Growth

• Exponential growth model provides a best fit to the 3 year data series of advertised address span
• Now find a reasonable correlation between advertised and unadvertised address space
• Then project RIR allocation demands
Unadvertised Address Space

Time Series of Advertised and Unadvertised Addresses

Date

IP4 Address Count (GB)

2000 2001 2002 2003 2004 2005 2006

Advertised Unadvertised

APNIC
Asia Pacific Network Information Centre
Unadvertised / Advertised Ratio
Modelling Advertised Growth

• Best fit to previous 3.5 years data appears to be a compound rather than constant growth rate
  – Use an exponential growth model in underlying address demand function ( $adv = e^{ax + b}$ )

• Average network growth of some 7 /8’s per year – accelerating at a rate of 0.3 /8’s per year

• To reach an ‘exhaustion point’ the model uses:
  – an exponential growth trend model based on previous 1,200 days (~ 3.5 years) advertised address data
  – a decreasing linear trend model of the ratio of unadvertised to advertised addresses
The Address Consumption Model

• Advertised Address span grows at an exponential rate
Unadvertised Addresses

• Unadvertised address pool continues to grow (at a slower rate than advertised)
• This implies that reuse, reclamation and return rates for addresses have had no significant impact on overall address consumption.
• This model assumes no change in address return and reuse rates
The Address Consumption Model

- Advertised and Unadvertised Addresses
The Address Consumption Model

- Total address demand projection
RIR Allocation Model

- Assumes that the relative rate of RIR allocation across the RIRs varies according to relative allocation trend rates in previous 3.5 years
- Absolute rate of RIR allocation is driven by the total address consumption growth
- The point of address exhaustion occurs when any single RIR’s address pool drops to zero
The Address Consumption Model

- Combined RIR Model
The Address Consumption Model

- IANA Pool Consumption
Projections from this Model

• IANA Pool exhaustion
  – 04 January 2012

• RIR Pool exhaustion
  – 08 January 2013
Comments

• This model assumes an orderly procession right up to the point of effective exhaustion of the unallocated address pool
  – This is **highly unlikely** to eventuate

• A more likely industry response will be accelerating demands as imminent address exhaustion becomes more ‘visible’
  – A “last chance” rush on remaining resources

• It is not possible to model such industry ‘rush’ behaviours using the historical address allocation and BGP data
  – Some other form of modelling of social and market behaviour would be better positioned to make some guesses estimates here
Comments

• Exhaustion of the IPv4 unallocated address pool does not imply complete unavailability of IPv4 address resources to industry players.

• The exhaustion of the unallocated IPv4 address pool does not appear to imply a forced IPv6 conversion onto the industry at that point in time.

• There is reason to believe that the Internet industry will continue to use IPv4 as a base protocol well after this IPv4 unallocated address pool exhaustion date comes and goes.
Some Speculation on Address Policies and an IPv4 Address Market

• In the absence of the imposition of specific external control functions, a conventional economic response would be the emergence of various forms of trading markets in address resources

• In conventional markets scarcity tends to operate as a pricing premium factor

• Market behaviours would then imply an entirely different behaviour in terms of IPv4 address distribution functions
More Speculation

• Unadvertised address pools, and release of current address holdings based on conversion to address compression technologies could come into play within a market-based pricing dynamic

• What form of market regulation would be appropriate? How would it be applied? Who would apply it? Why would it be useful to have?

• How can we preserve address utility (the integrity of address uniqueness) in an environment of market-based trading?
Food for Thought

• RIR Allocation Policies:
  – What is the threshold point where the application of different IPv4 address allocation policies may be appropriate?
  – Or is “no change” a wiser course of action?
  – Or should the RIRs establish “strategic reserve address pools? Why?
Food for Thought

- Emergence of IP Address Markets:
  - Is the emergence of such markets Good or Bad? Avoidable or Inevitable? Appropriate or Inappropriate? Fair or Unfair?
  - Are there any practical alternatives for the industry?
  - How would address trading markets be best supported?
  - Would such markets be regulated? How?
  - What is the RIR role in such an environment?
Food for Thought

• Global Implications:
  – What about “Equity”, “Affordability”, “Fairness” of access to address resources at a global level?
  – And in what venue are such concerns best expressed?
  – And how would they be expressed within the overall model?
Address Policy Questions

What are most appropriate address management policy measures that will support the continued well-being of the global Internet and its users?

And when will they be needed?
The Daily Report

http://ipv4.potaroo.net
Thank You