IPv4 Numerology

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APRICOT 2006

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

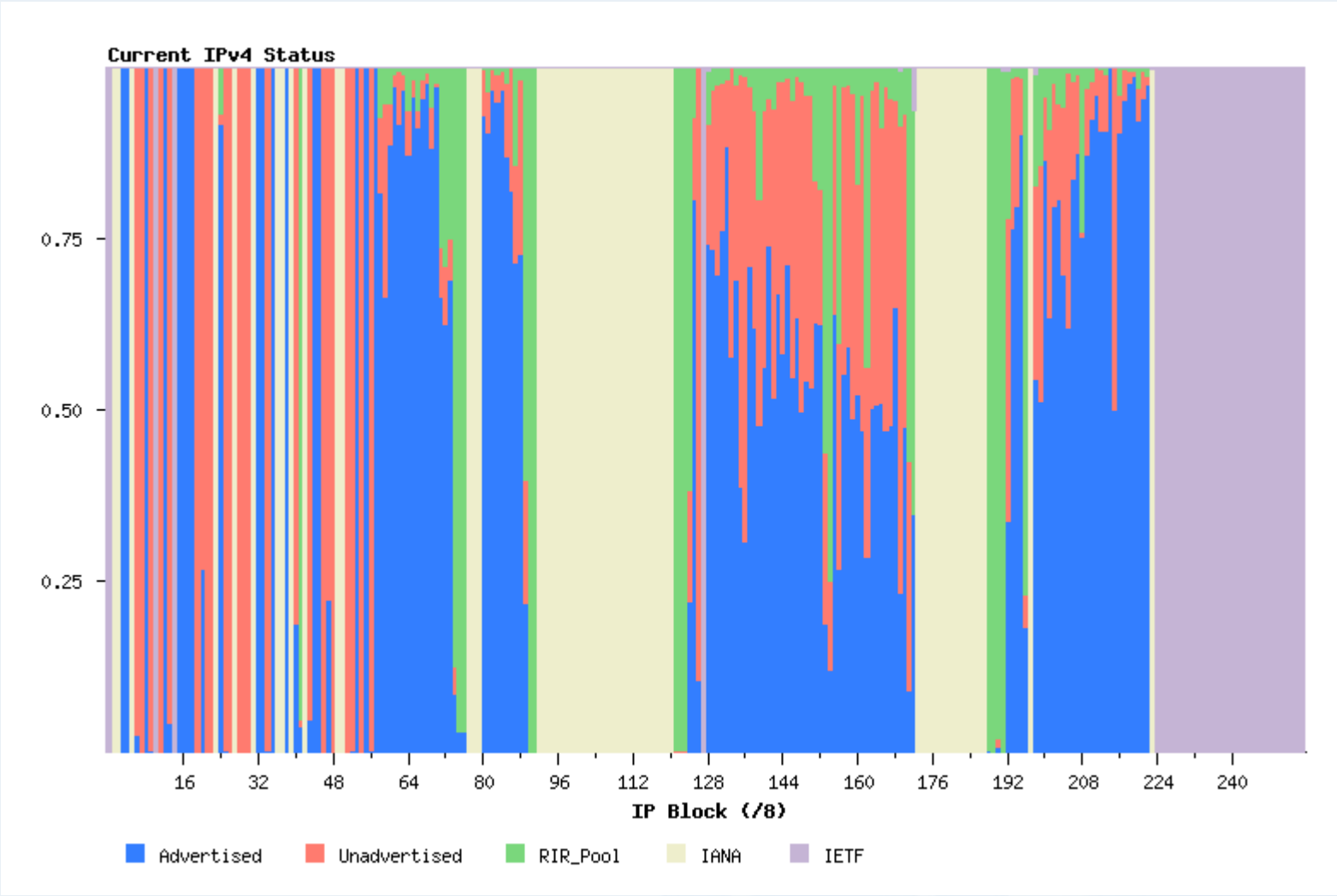
So - to be clear – the question posed in this study is:

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

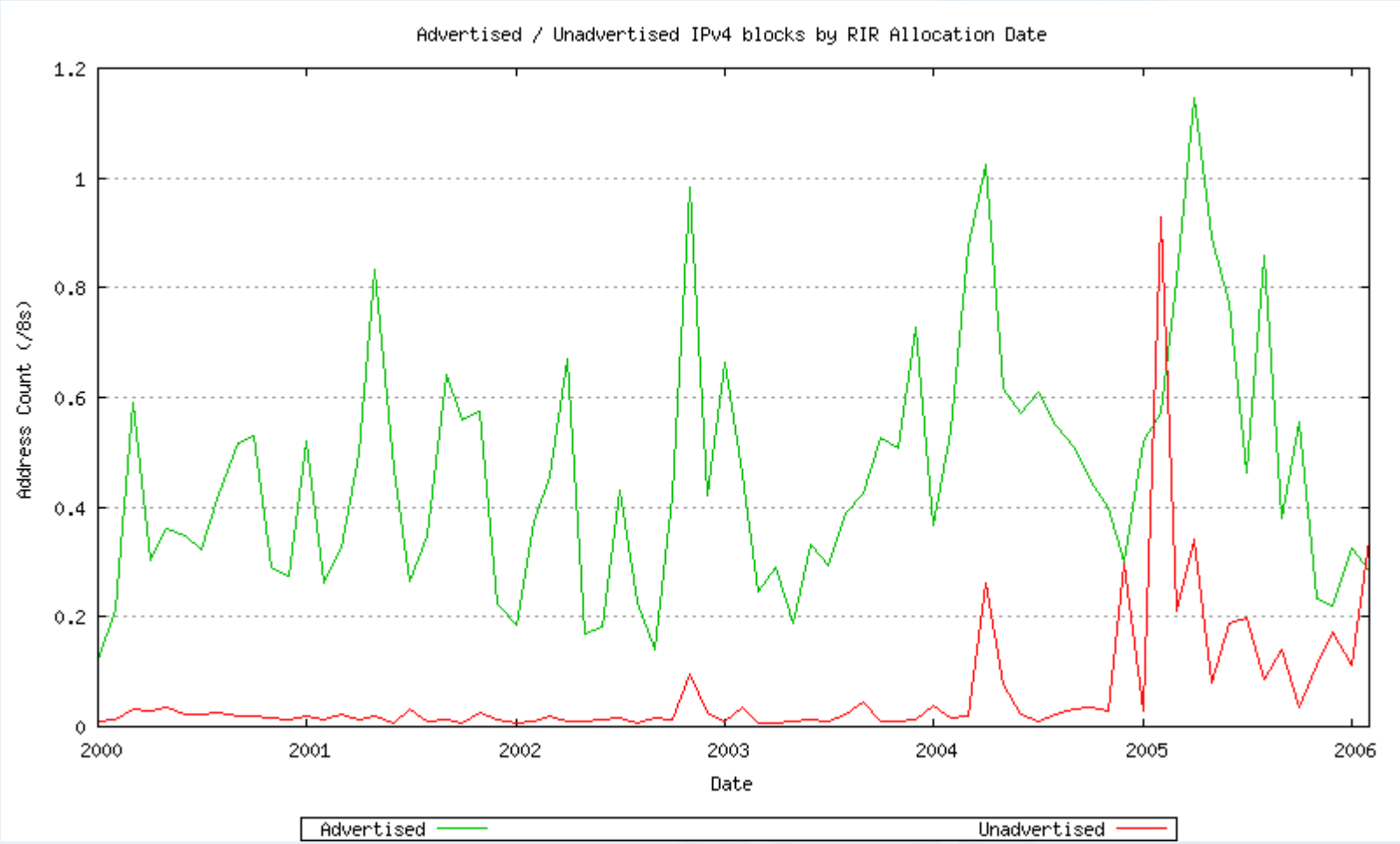
A look at the IPv4 data

- 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



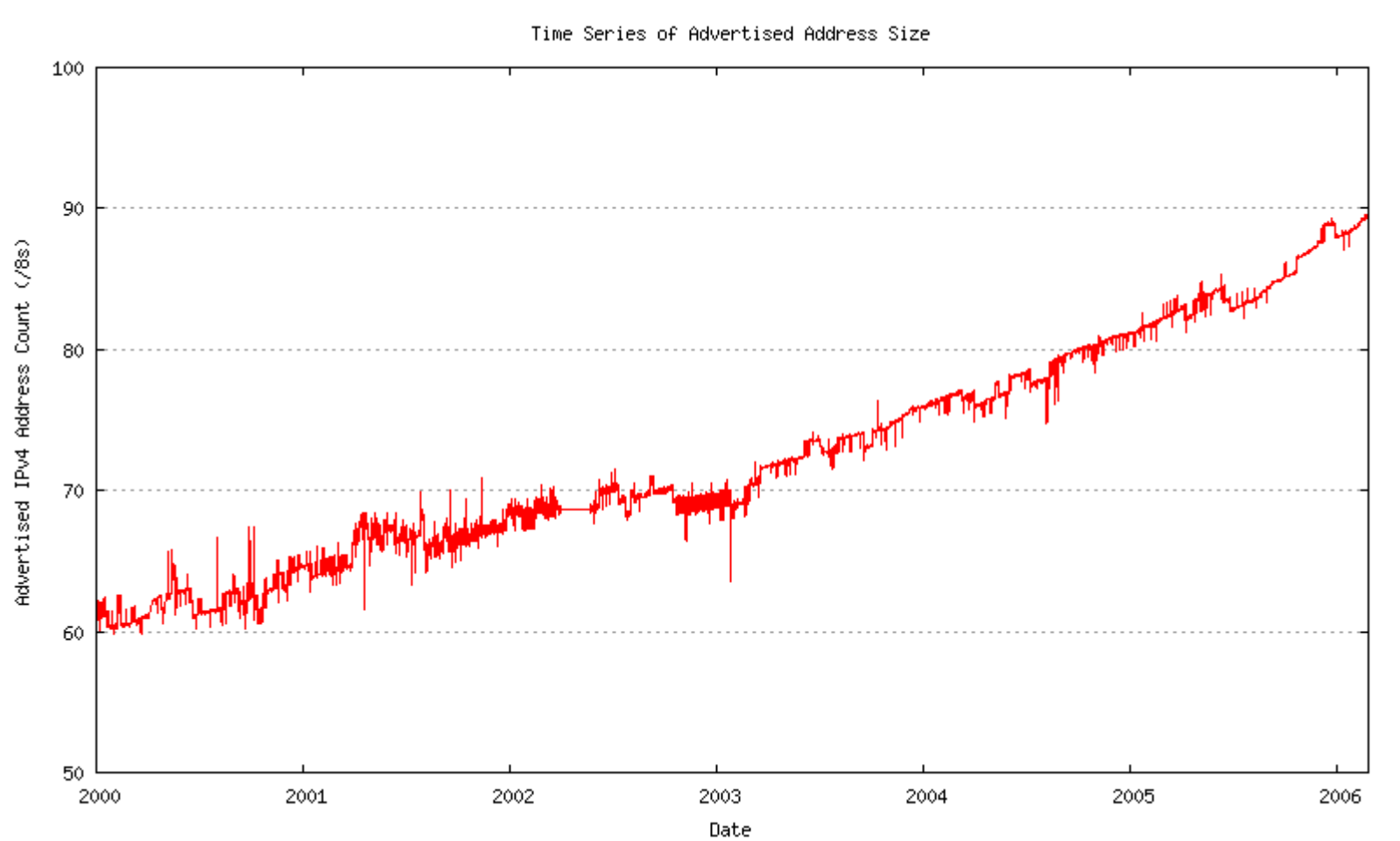
Advertised and Unadvertised Addresses



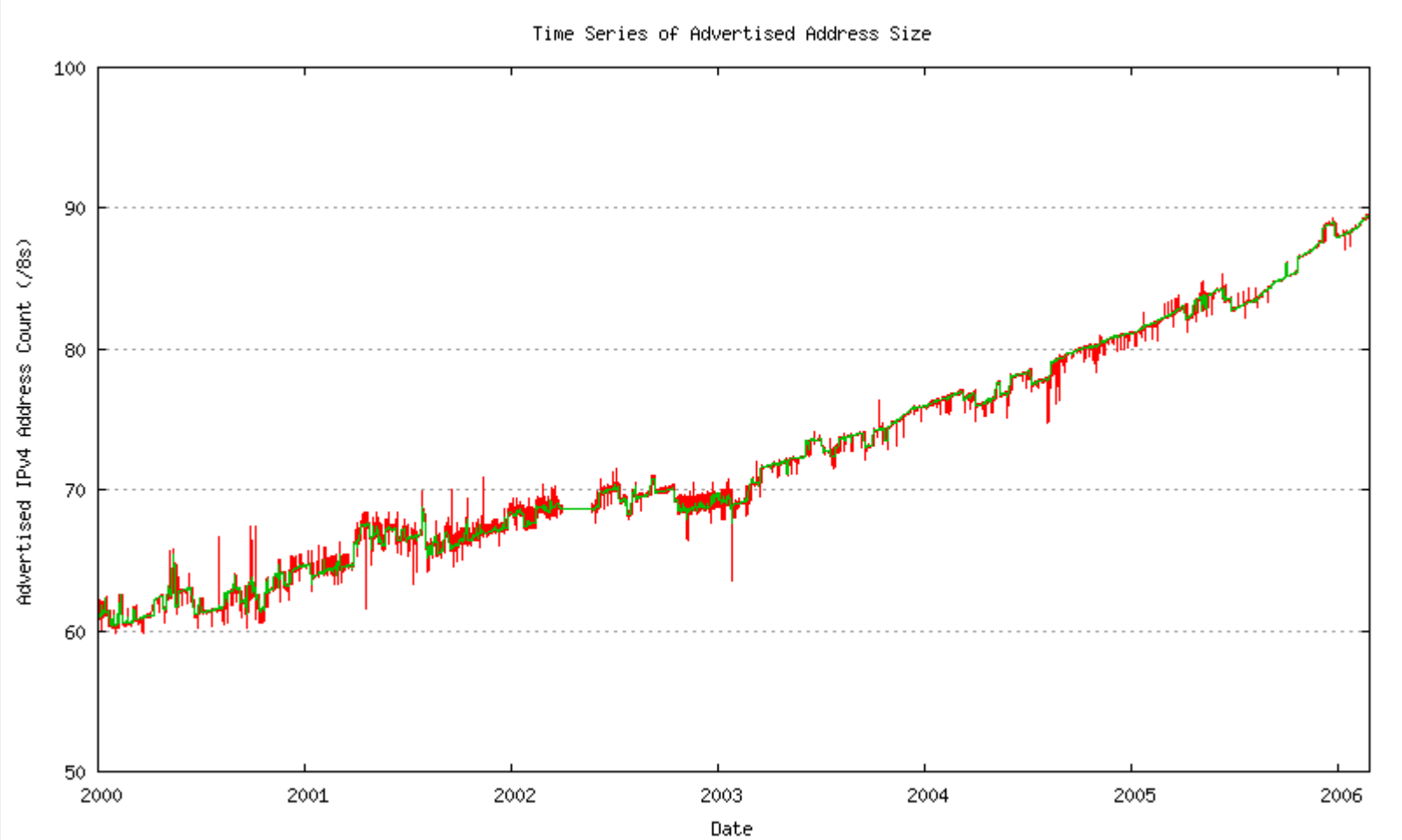
This Approach to Modelling IPv4

- 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



Advertised Address Space



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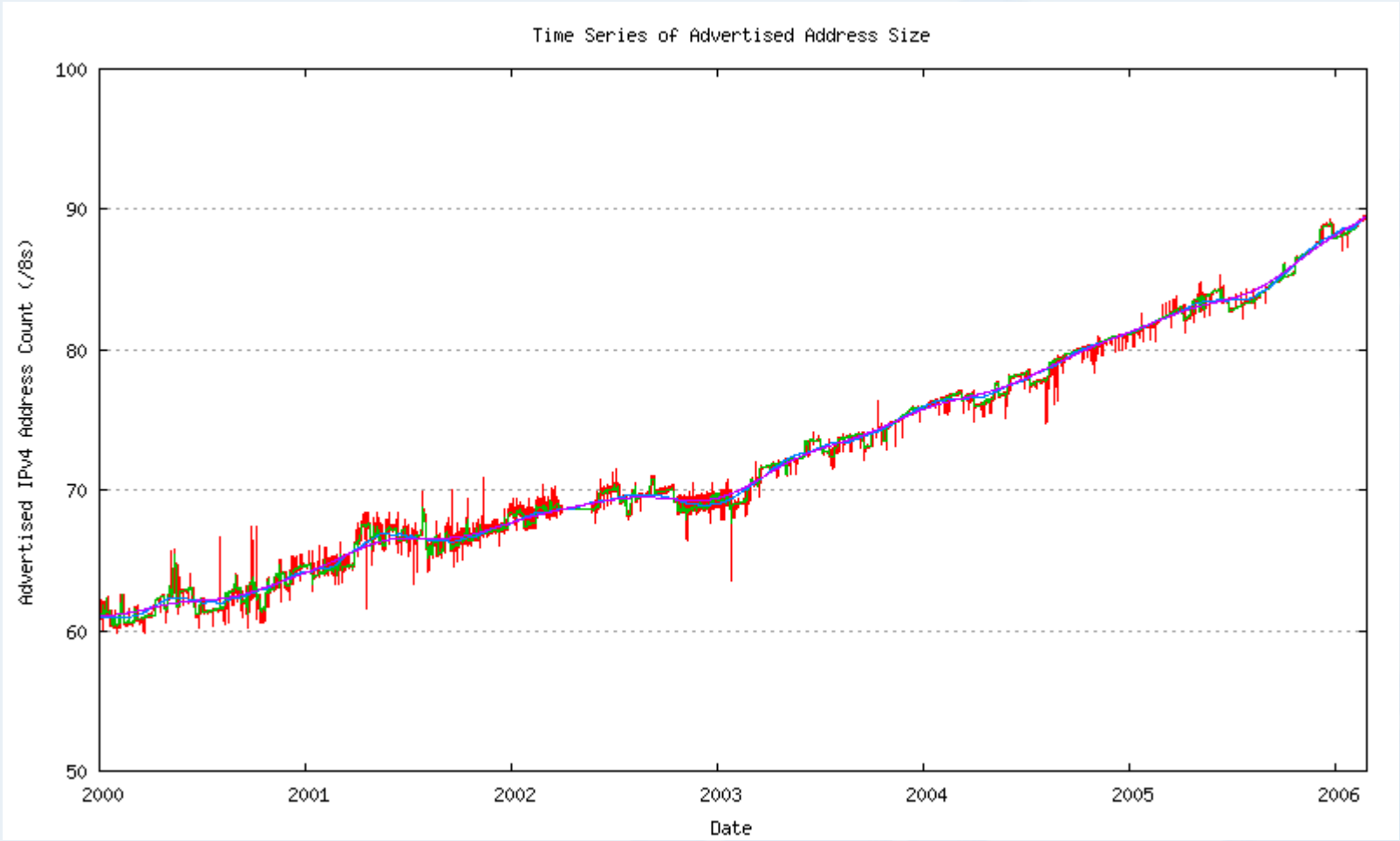

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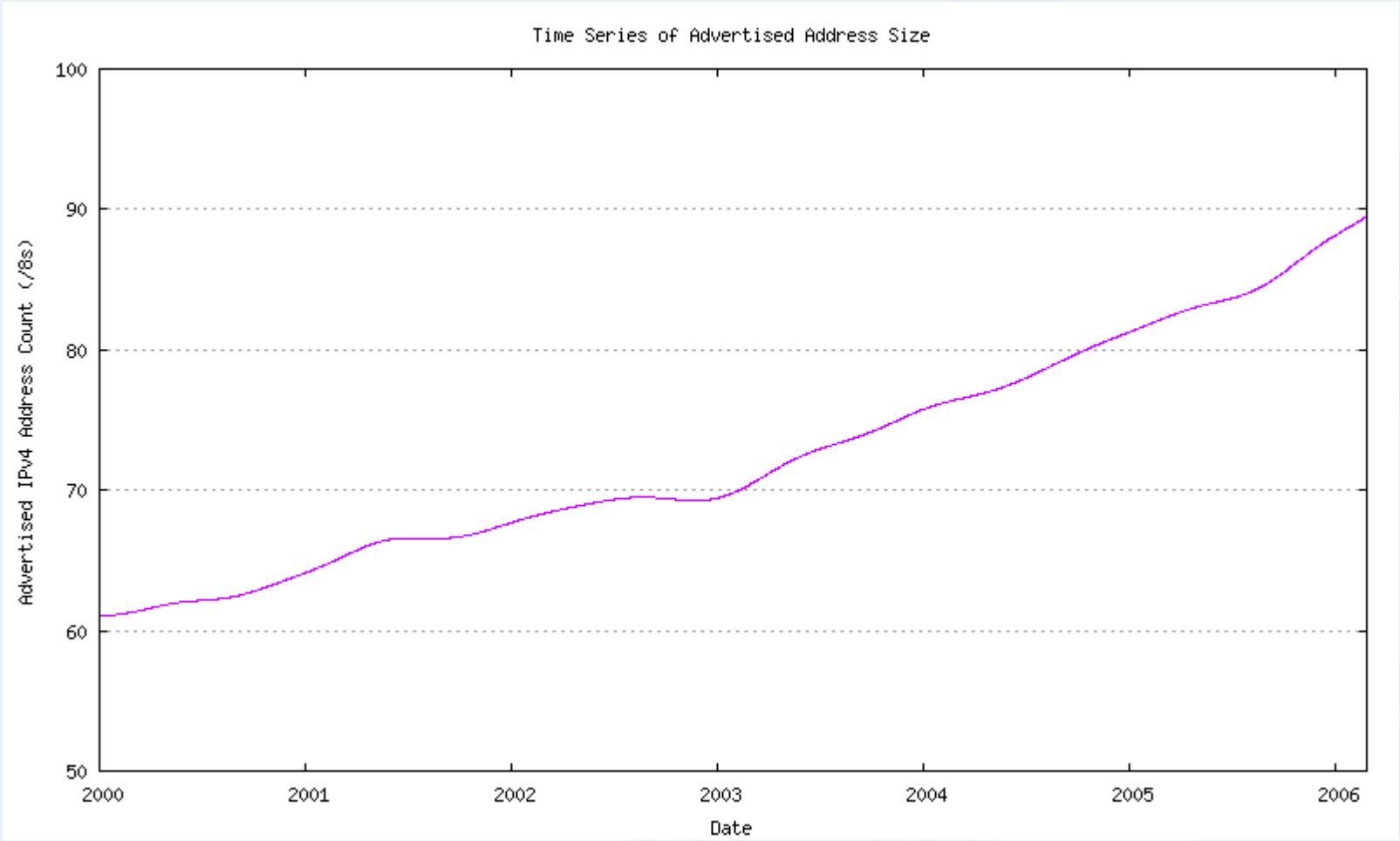
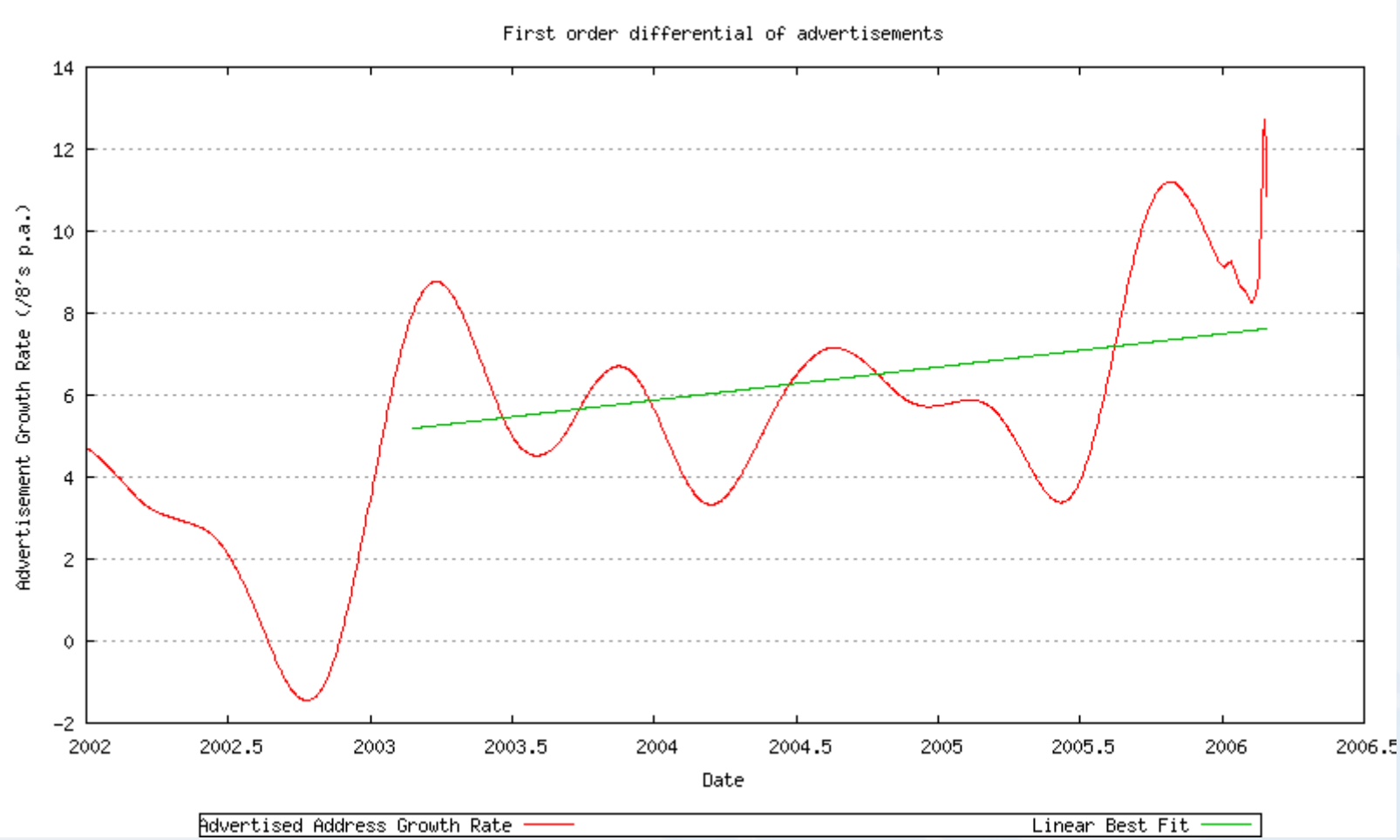
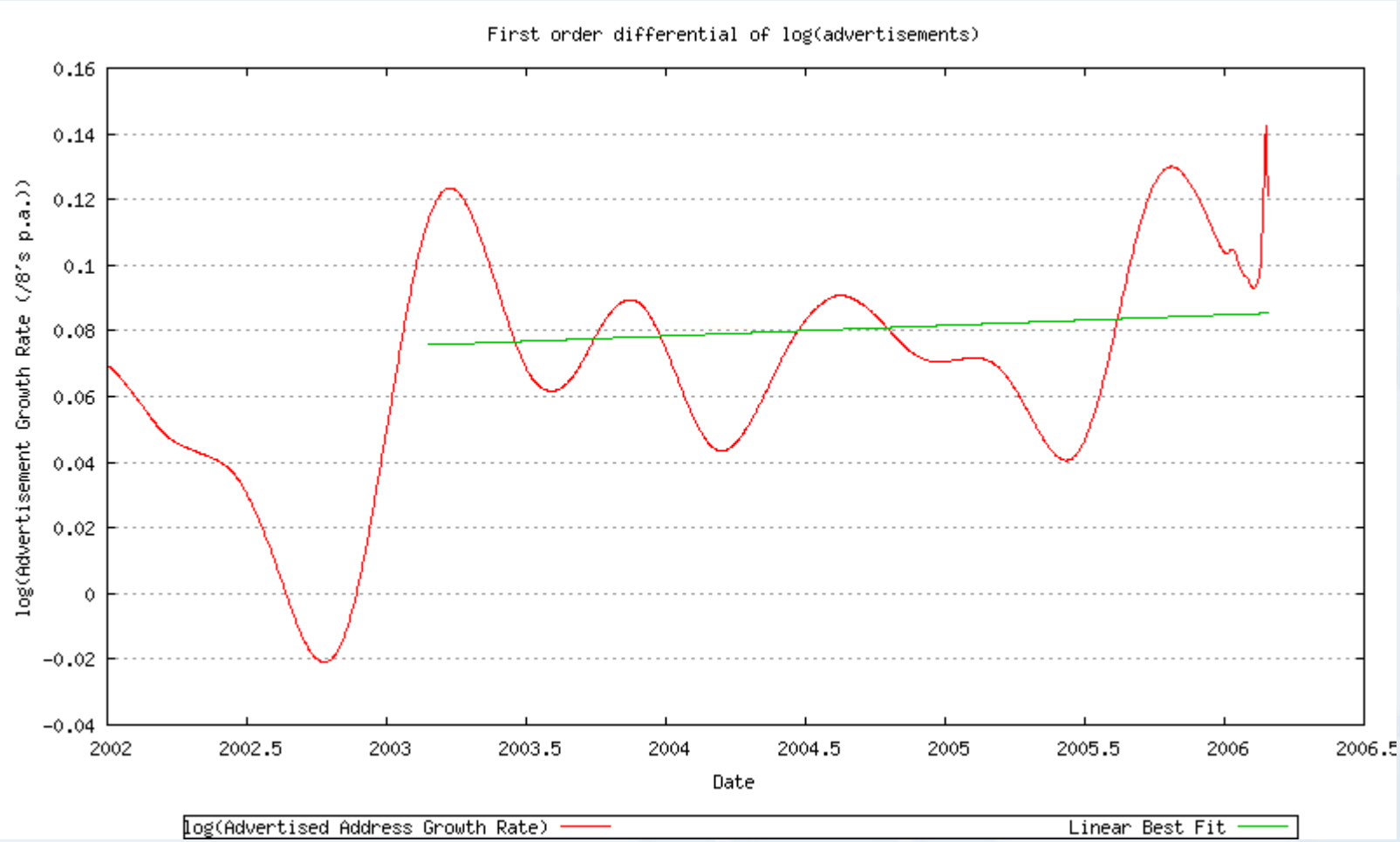


Advertised Address Growth
First Order Differential



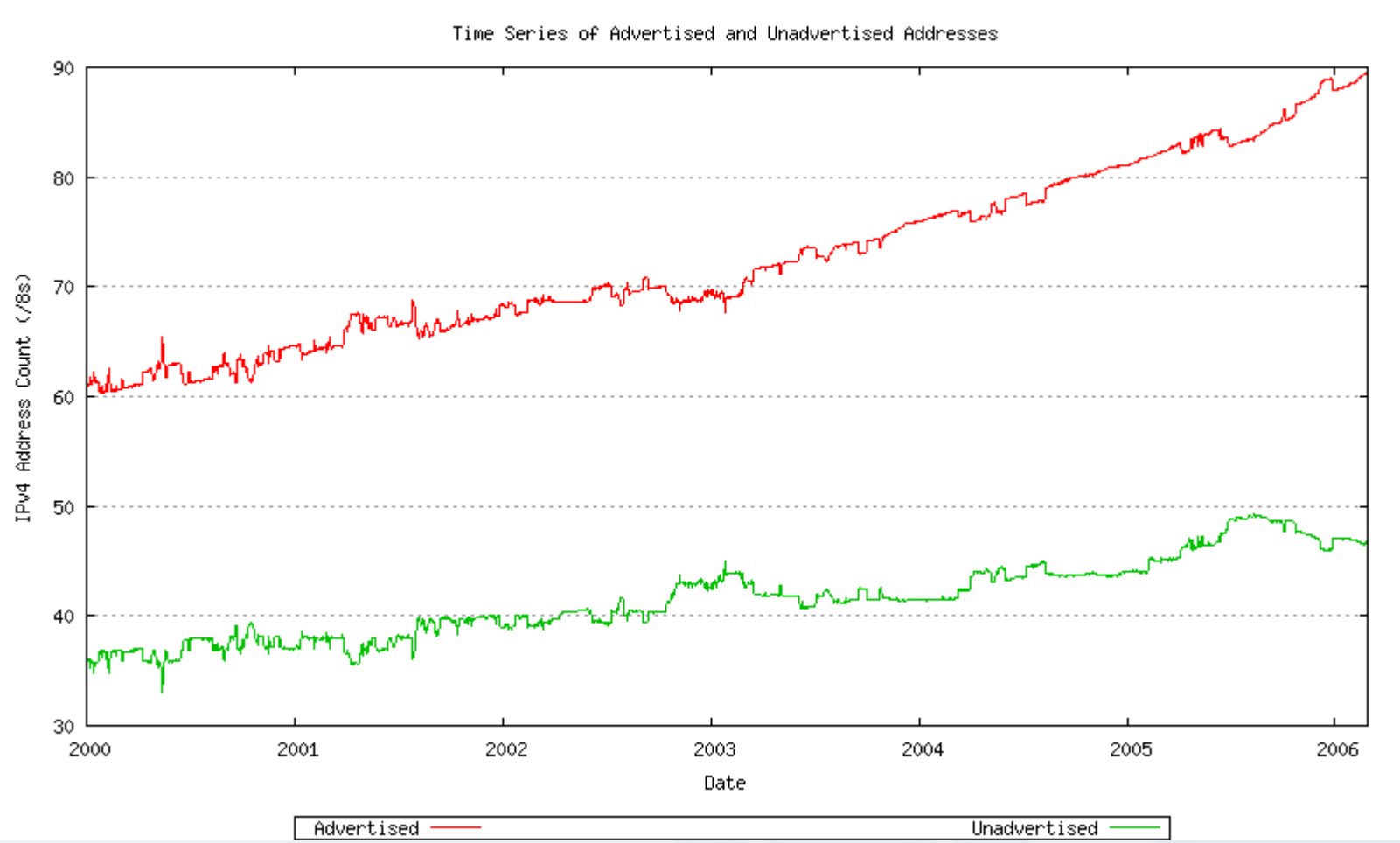
Advertised Address Growth
First Order Differential of Log



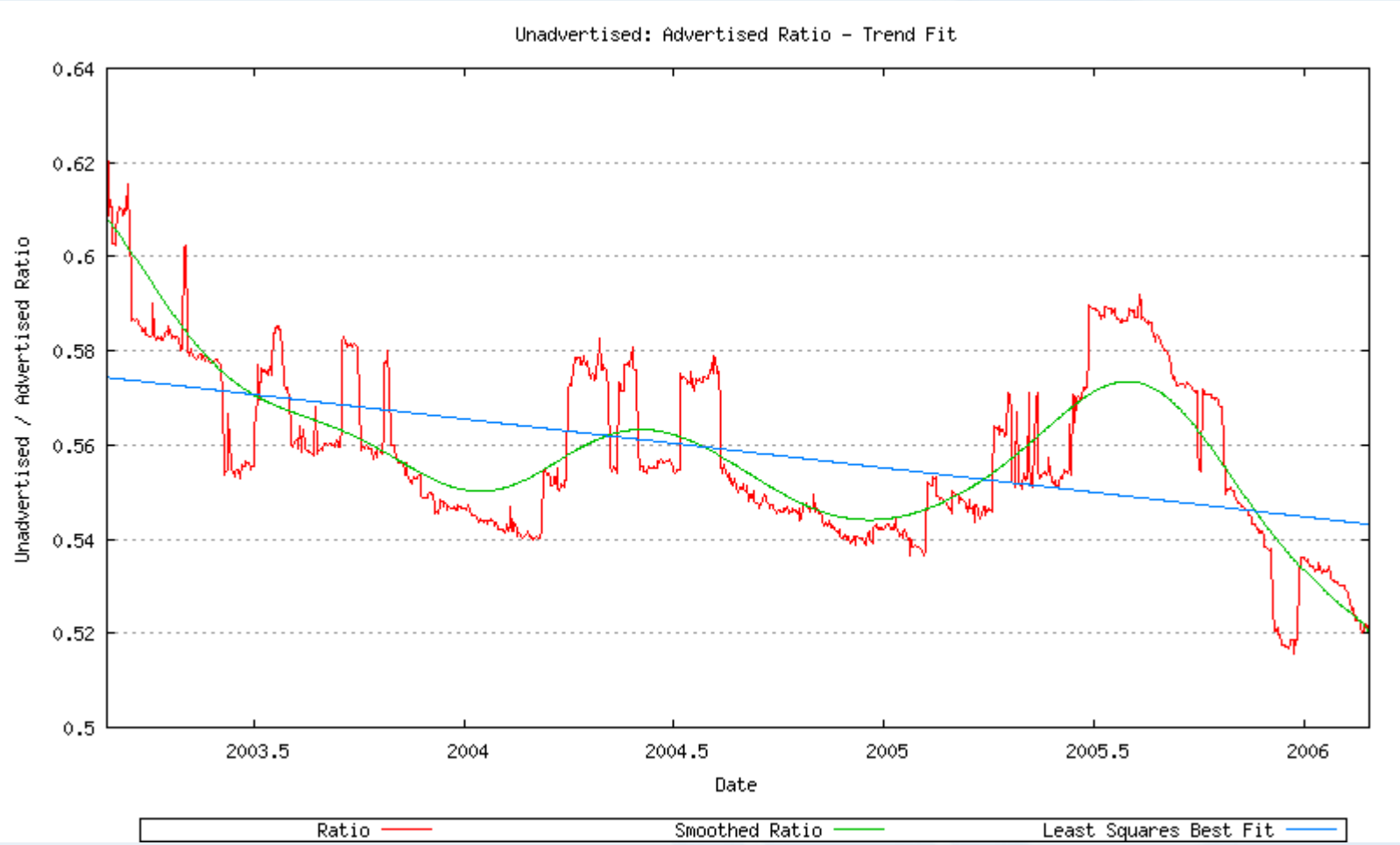
Advertised Address Growth

- 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



Unadvertised / Advertised Ratio

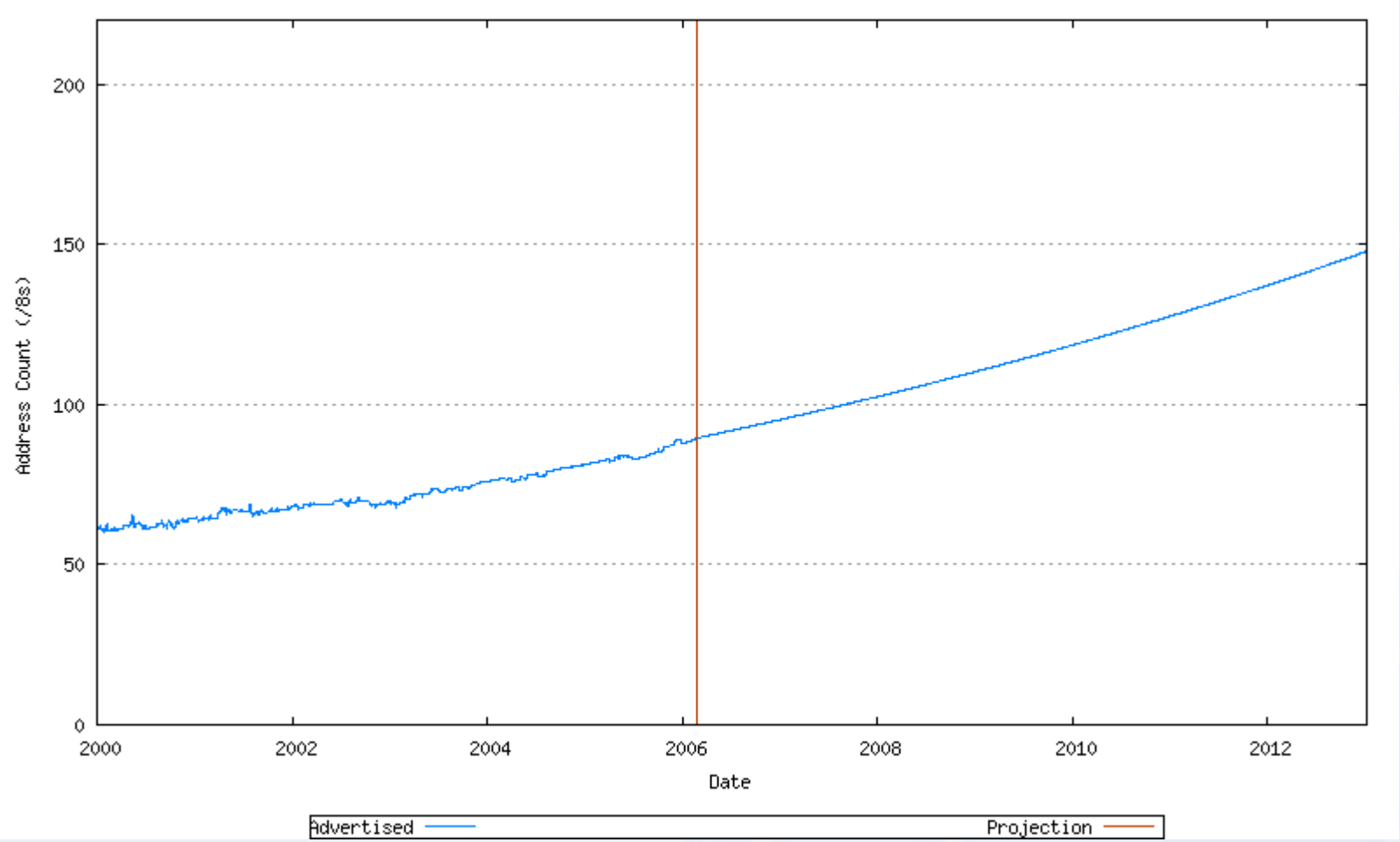


Modelling Advertised Growth

- 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 ($adv = e^{a*x+b}$)
- 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

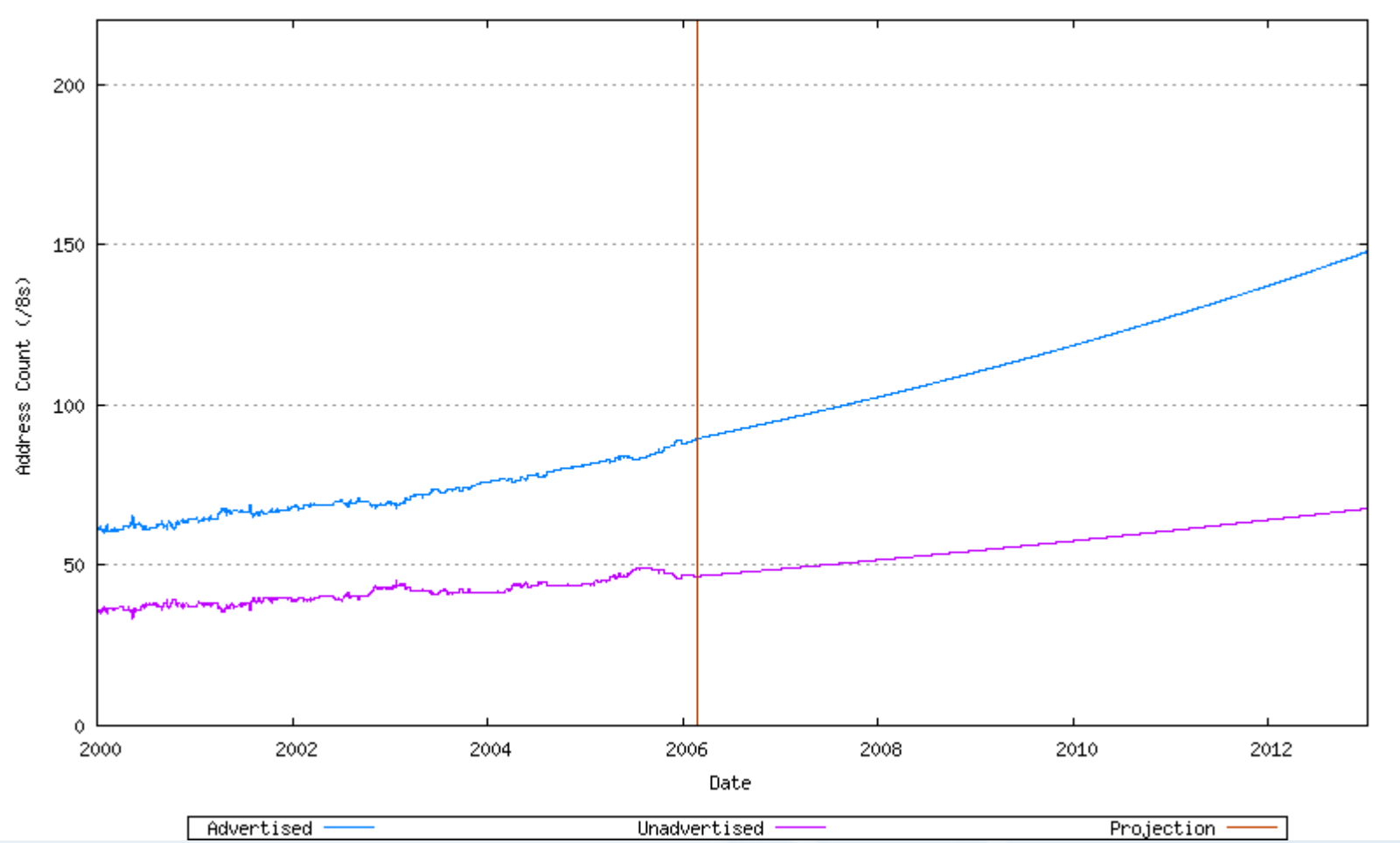


Unadvertised Addresses

- 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

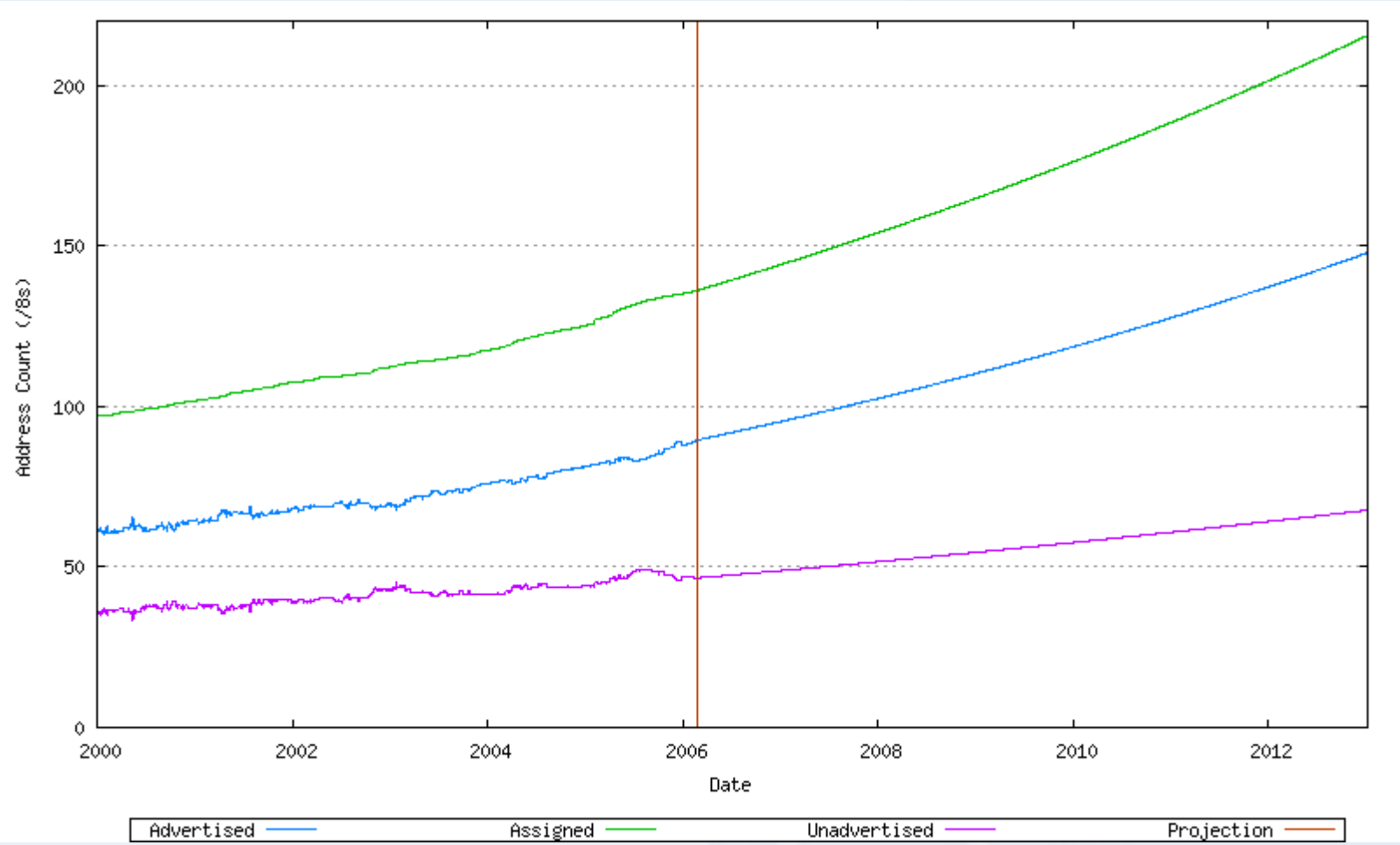
The Address Consumption Model

- Advertised and Unadvertised Addresses



The Address Consumption Model

- Total address demand projection

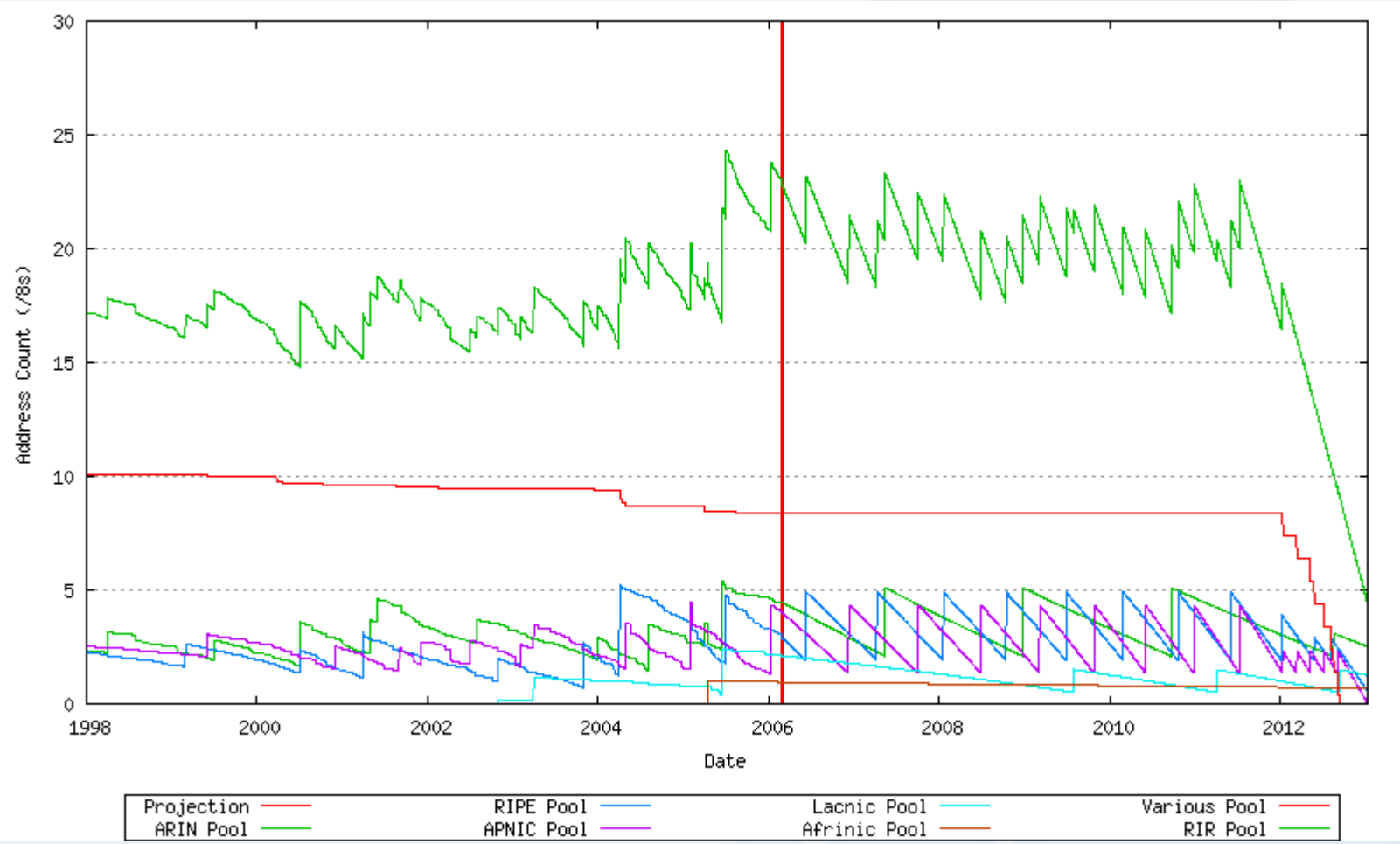


RIR Allocation Model

- 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

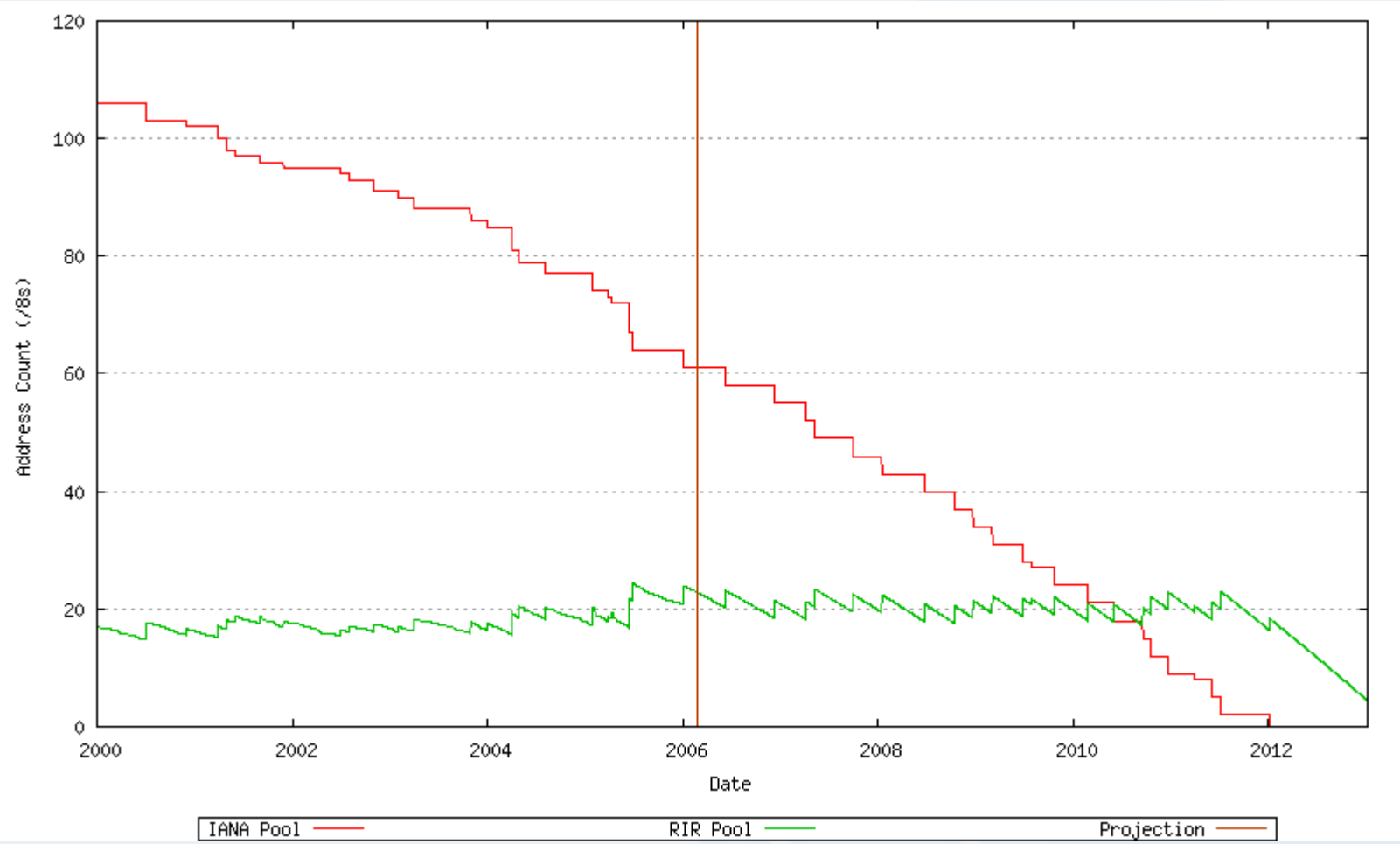
The Address Consumption Model

- Combined RIR Model

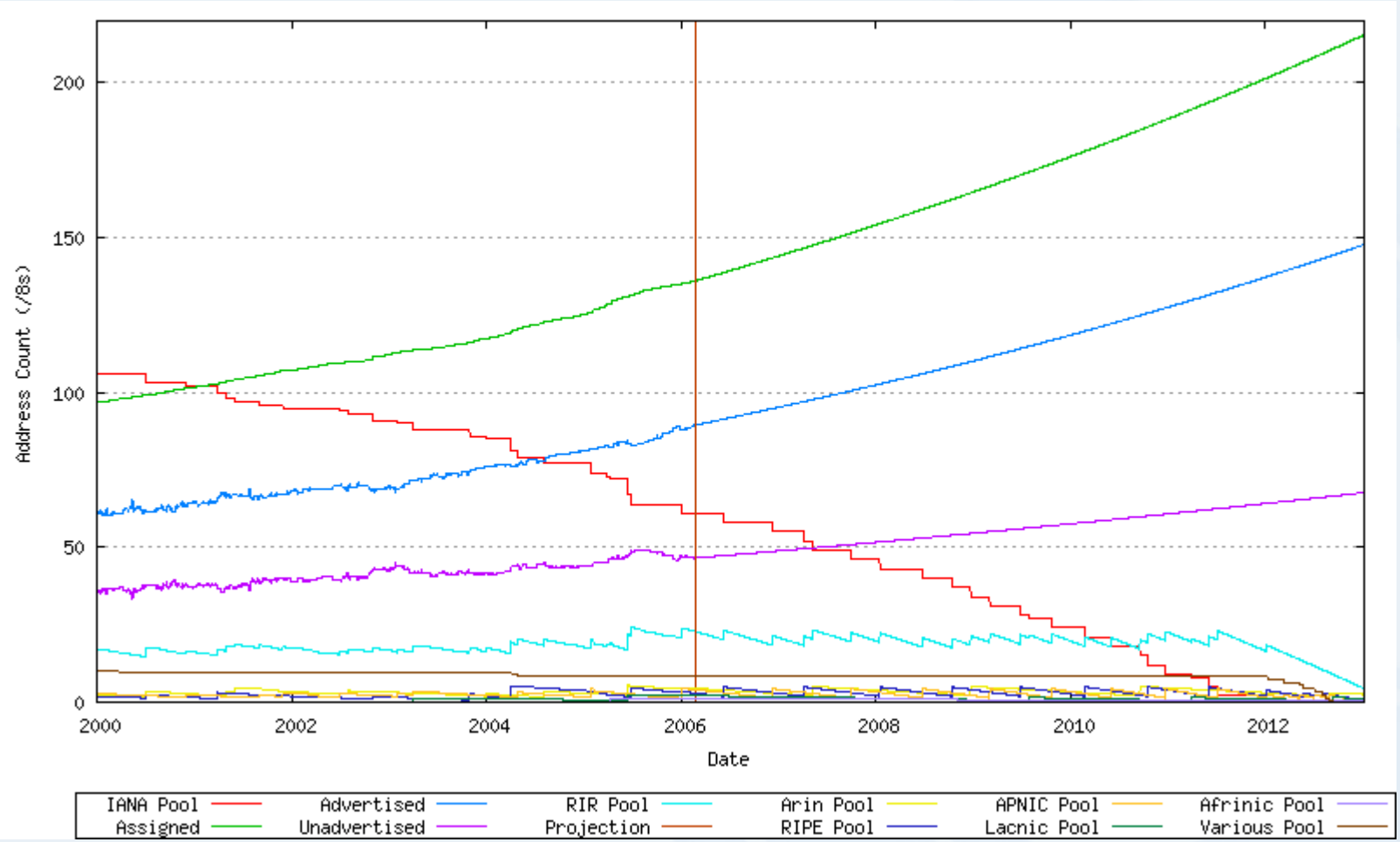


The Address Consumption Model

- IANA Pool Consumption



The Address Consumption Model



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 guesstimates 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