Beyond the IPv4 Internet

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The IETF's ROAD Trip

- By 1990 it was evident that IPv4 was not going to have a large enough address span for long term deployment
- And the routing architecture was not able to scale indefinitely
- The combined ROuting and Addressing effort took up much of the IETF's attention in the period 1991 – 1994
- There were a number of outcomes – some intentional, some accidental

ROAD Outcomes

- Short Term mitigation
  - Drop address classes from the address plan to decrease address consumption rates
  - Adopt provider-based addressing to increased routing aggregation
- Longer Term approach
  - Extend the address size in IP by a factor of 4
- Accidental Outcome
  - NATs

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Transition to IPv6

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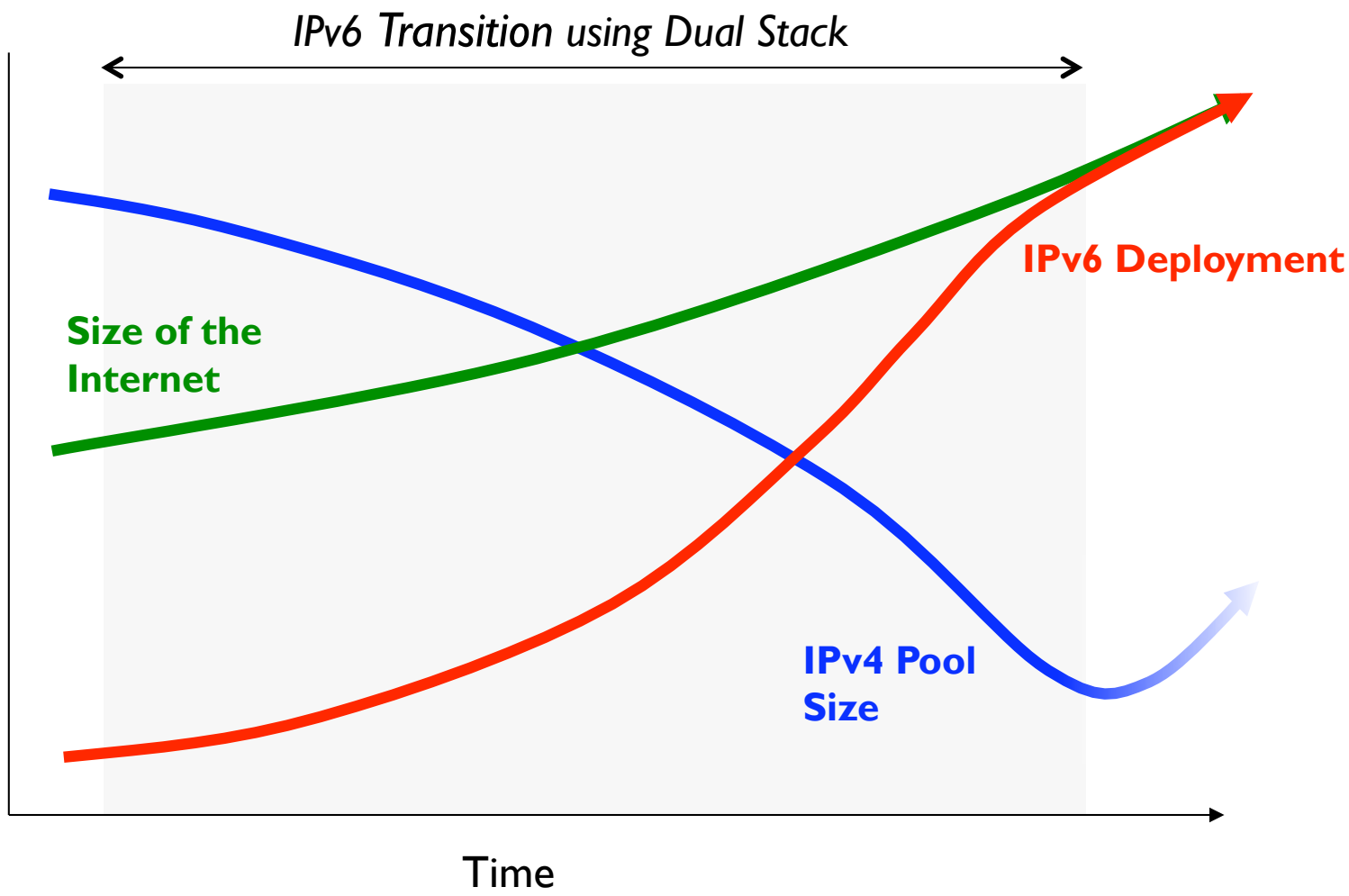
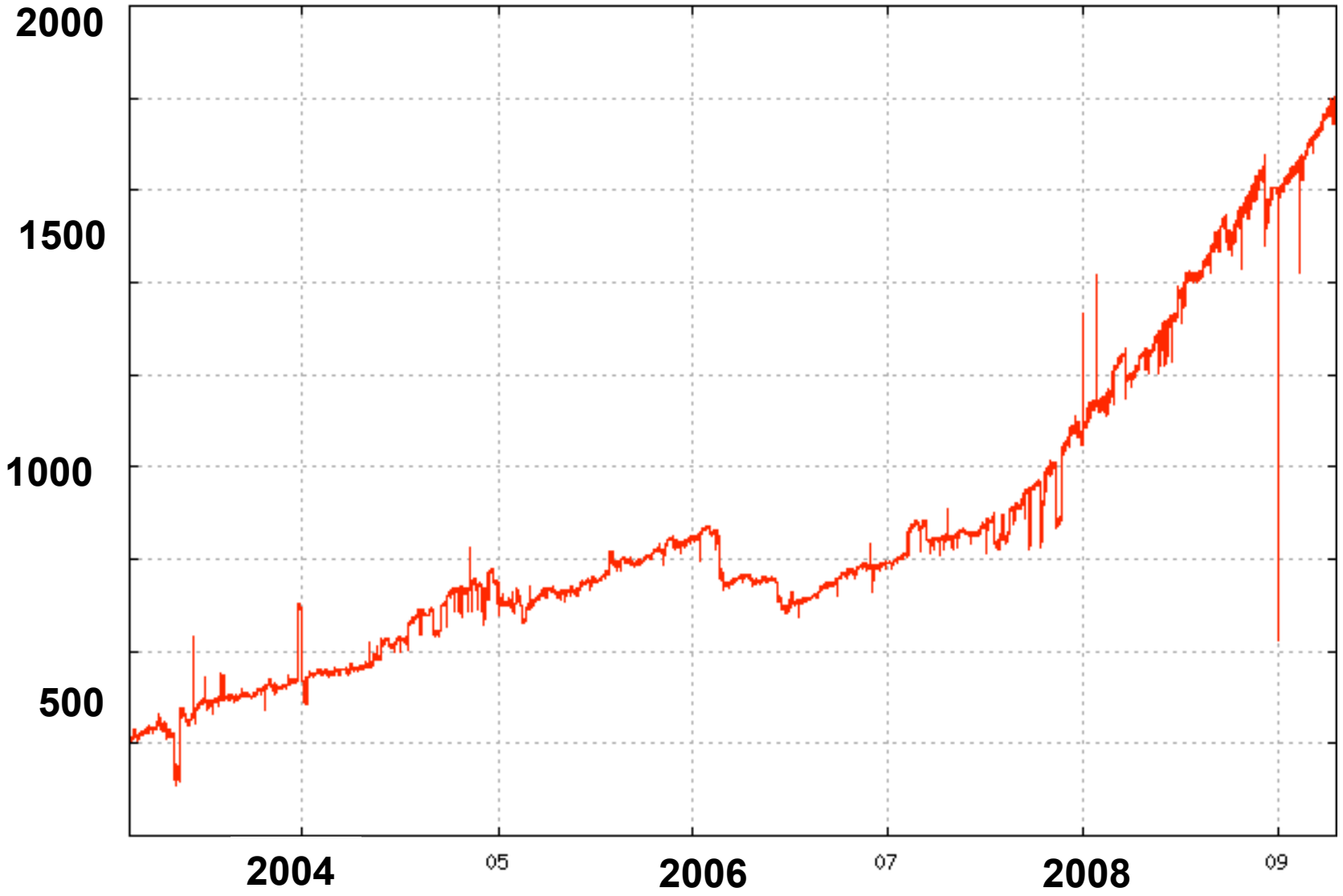
The Original Plan for IPv6 Transition



How are we doing in this plan?

- Can we provide some measurements about where we are with IPv6 deployment across the entire Internet?
  - What measurements are useful?
  - What data sets are available?

Routing Measurements: The BGP view of IPv6



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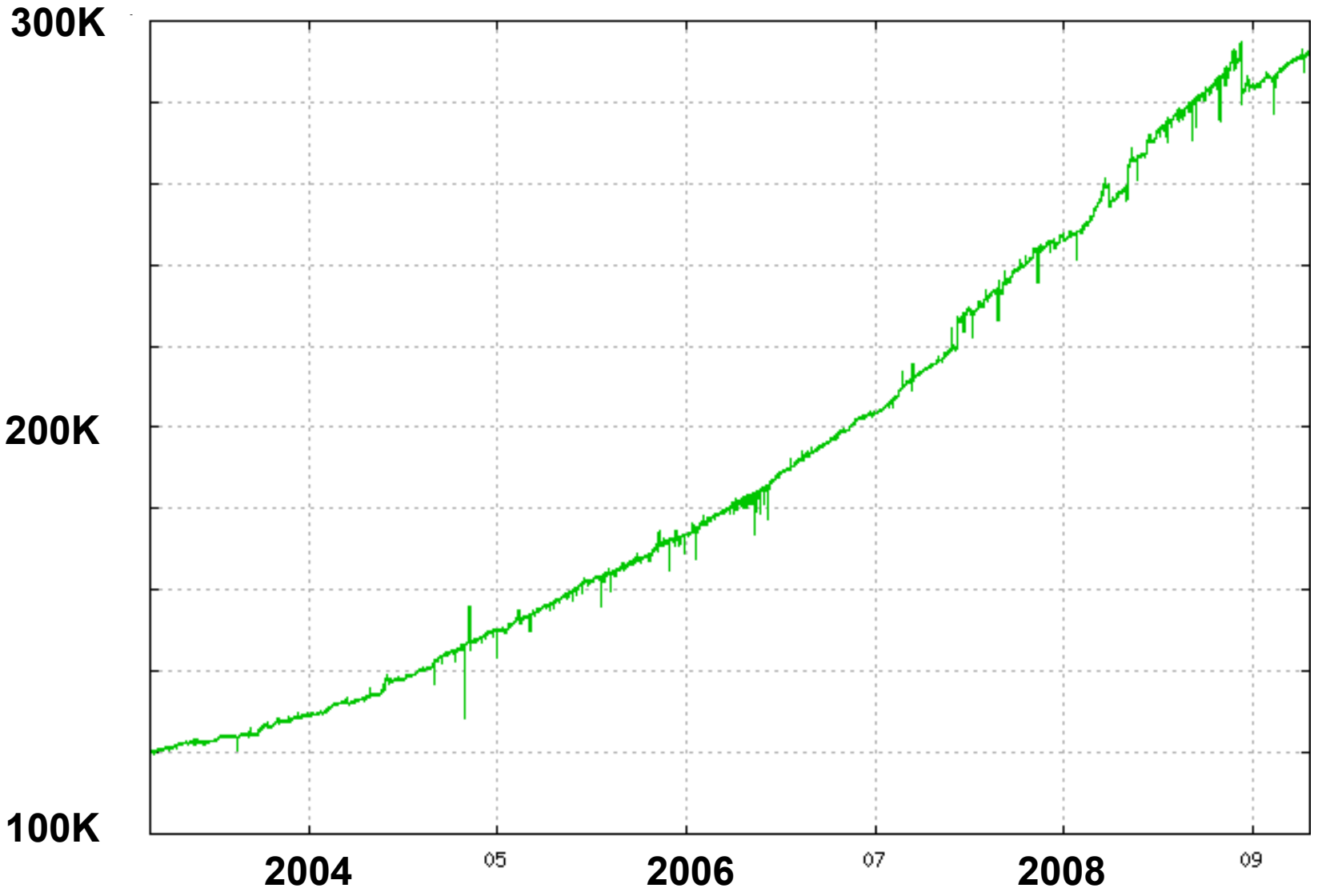
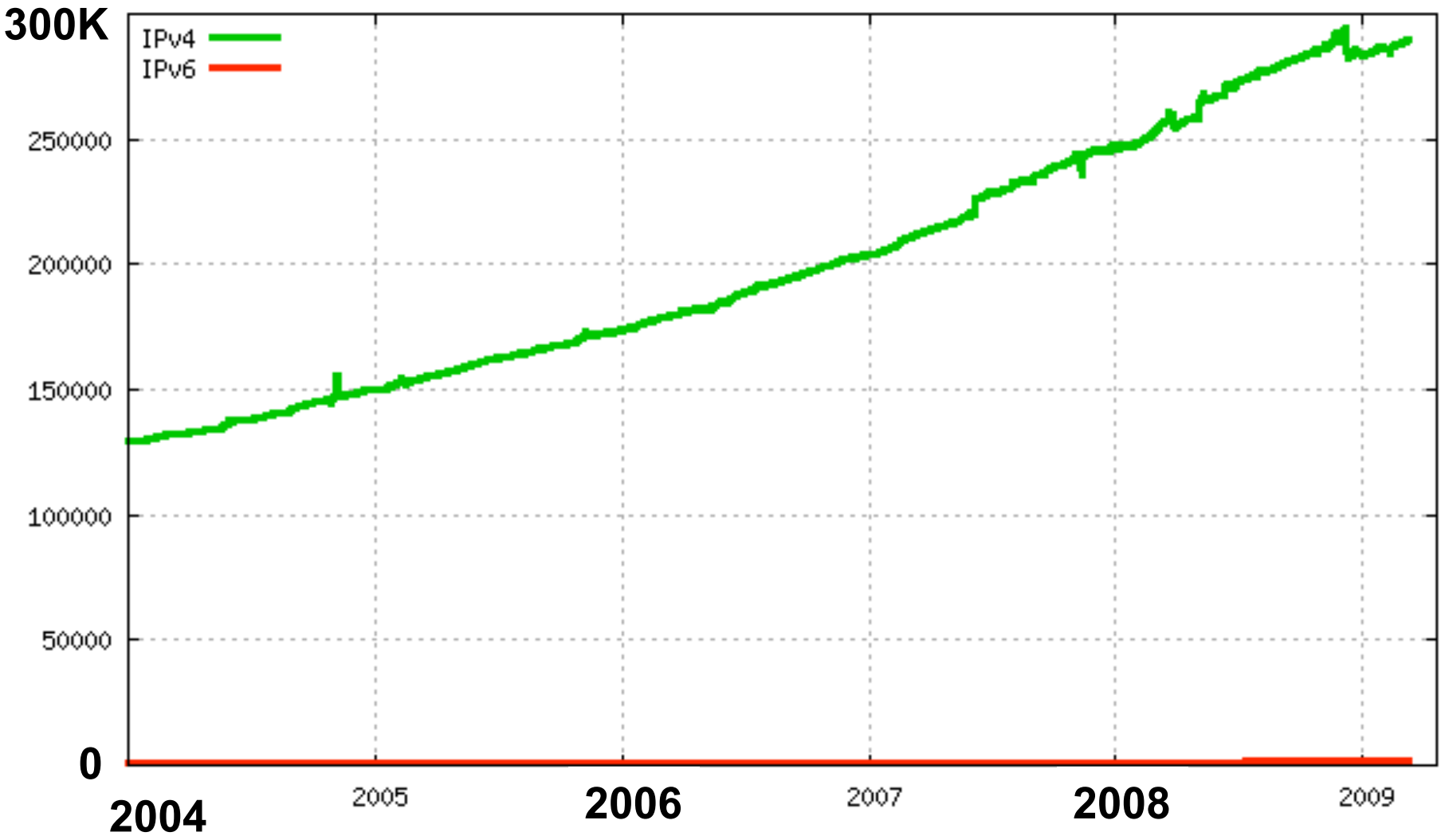


BGP: IPv6 and IPv4



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But how significant is a relative growth in IPv6 routing entries from 0.4% to 0.6% over 20 months?

What's this saying?

- V6 is 0.6% of IPv4 in terms of routing table entries
  - Growth is 0.22% p.a., linear
    - IPv6 deployment will reach IPv4 levels in **452** years
  - But the routing domain of IPv4 is heavily fragmented, while IPv6 is not
    - Assuming IPv6 will exhibit 1/3 of the routing fragmentation of IPv4, then IPv6 deployment will fully span the Internet in about **149** years!

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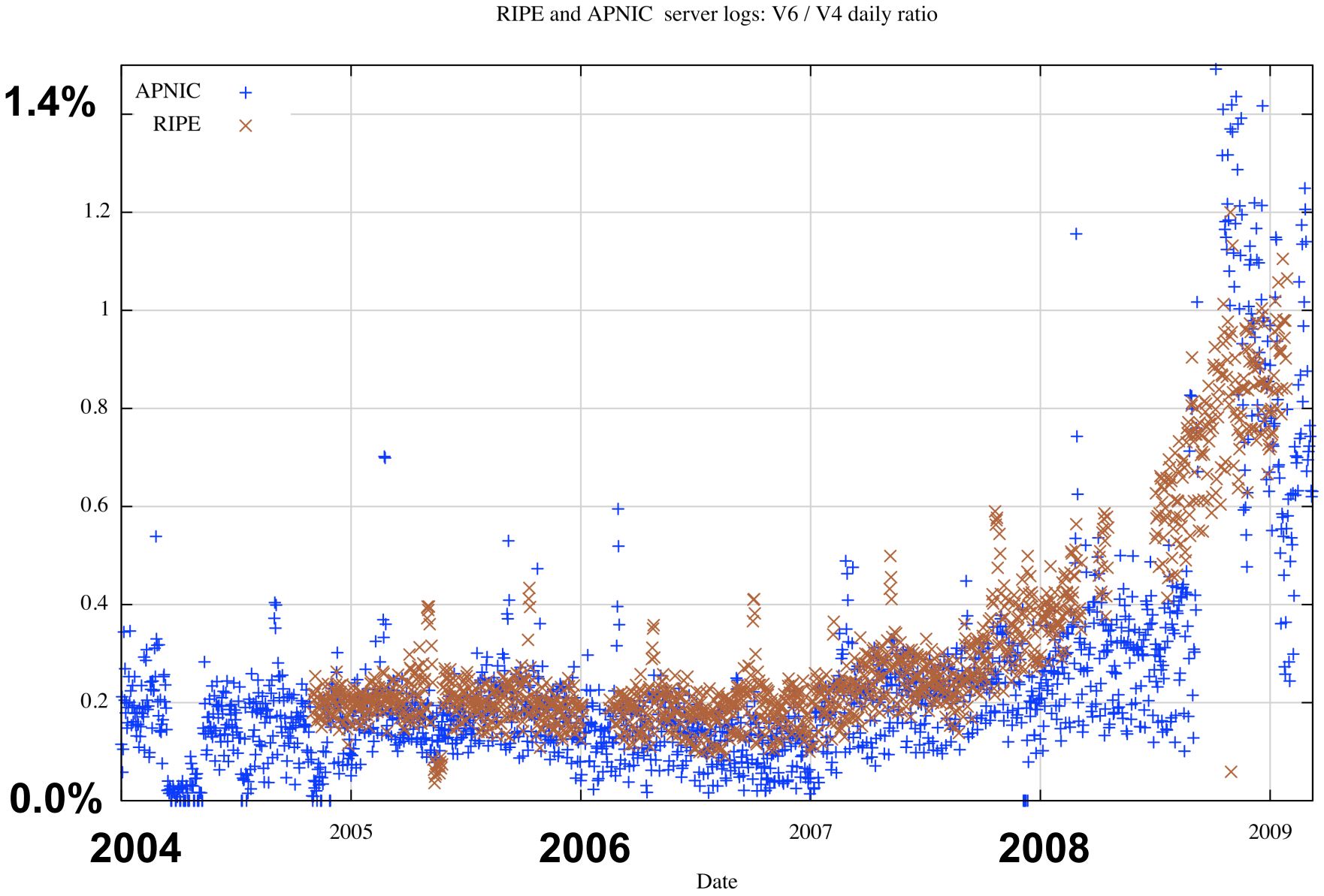
This seems highly implausible!

Web Server IPv6 / IPv4 Stats



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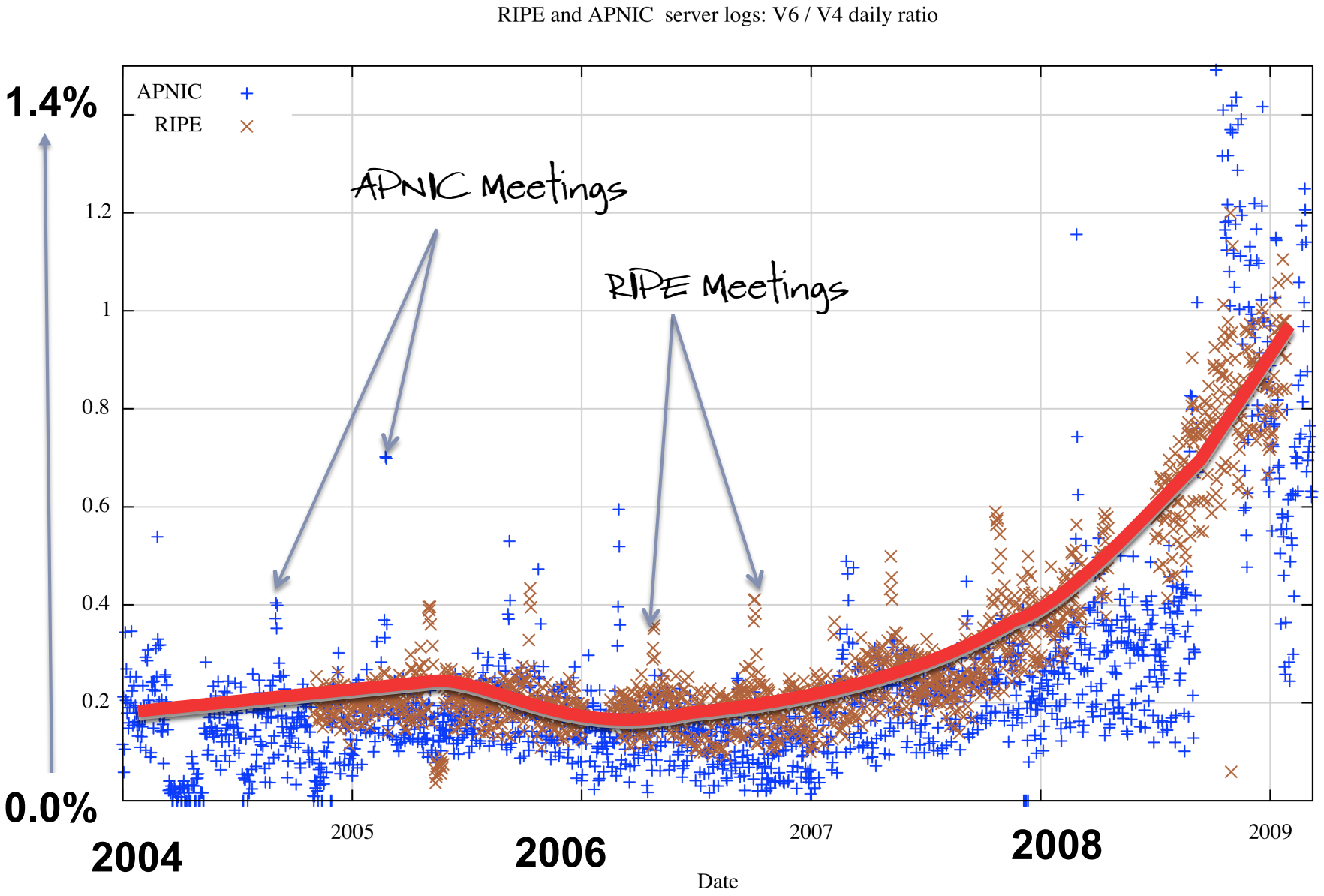

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What's this saying?

- Relative use of IPv6 when the choice is available is 0.2% in the period 2004 – 2006
- Relative use of IPv6 increased from 2007 to around 1% today
  - Is interest in IPv6 slowing picking up again?
  - Increased use of auto-tunneling of IPv6 on end host stacks?
  - Assuming continuing IPv6 take up at a relative rate of 0.75% p.a., then all hosts will be IPv6 capable in about **152** years!

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Use of V6 Transition Tools (6to4 and Teredo)

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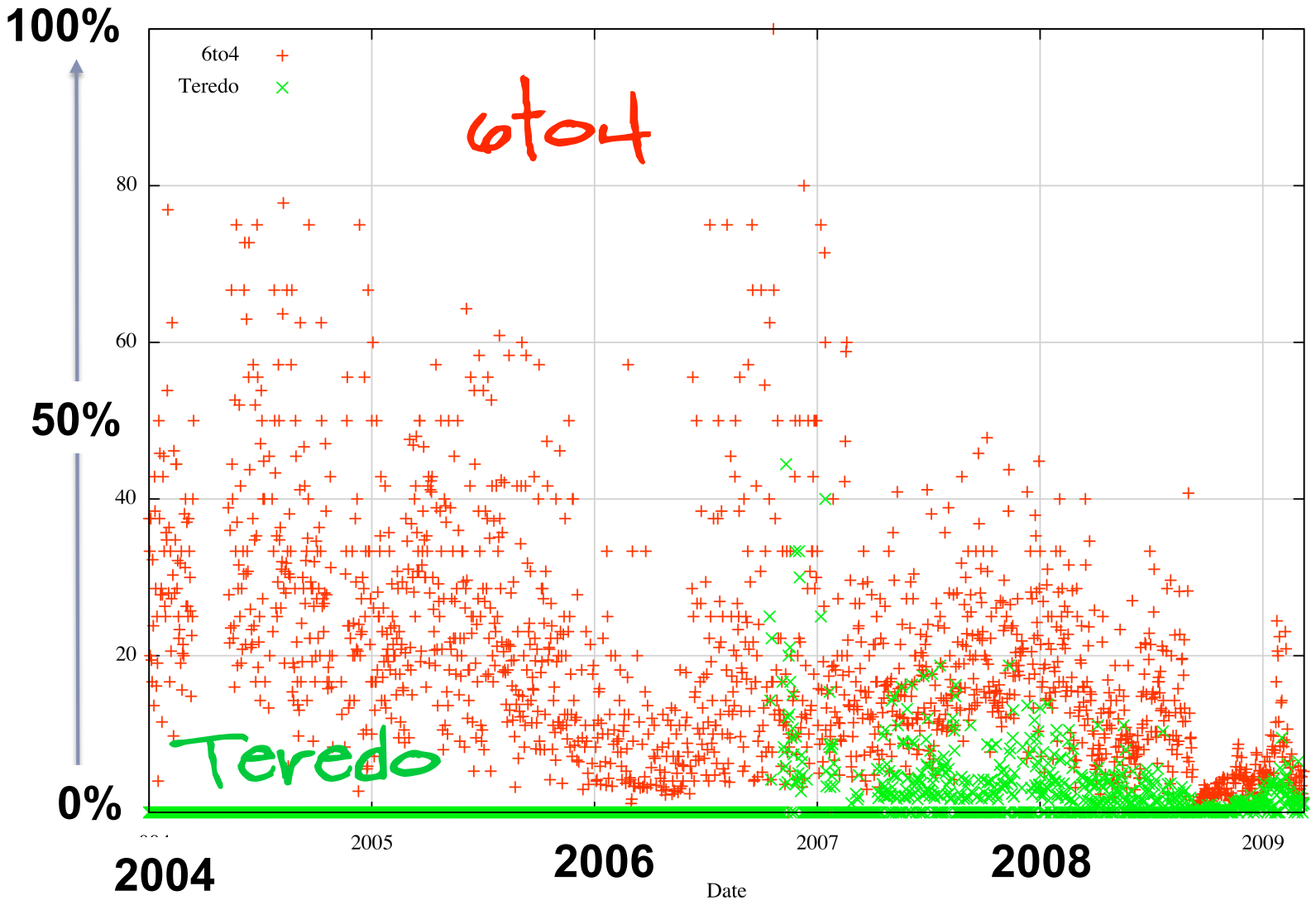

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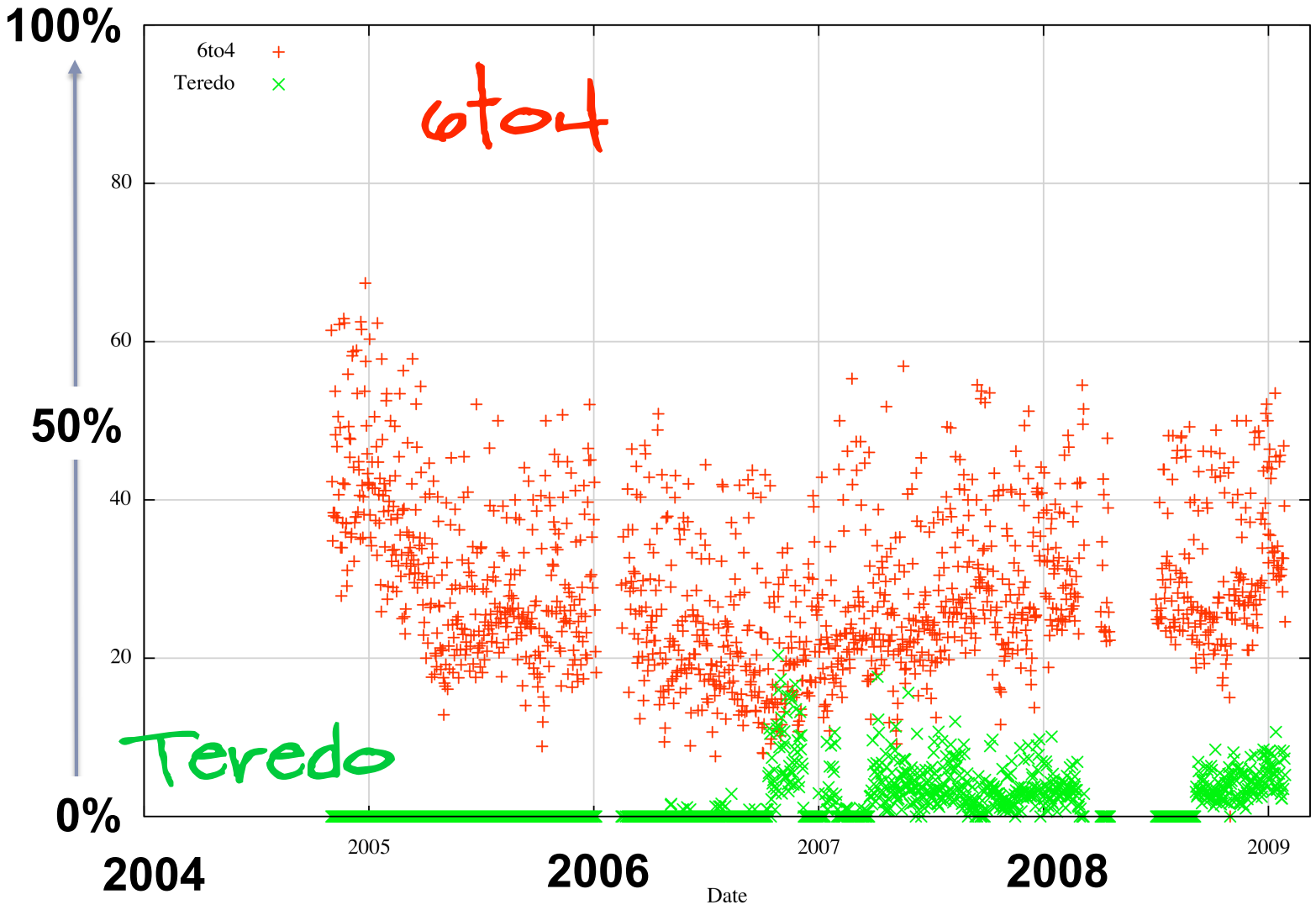
RIPE Web Server Stats



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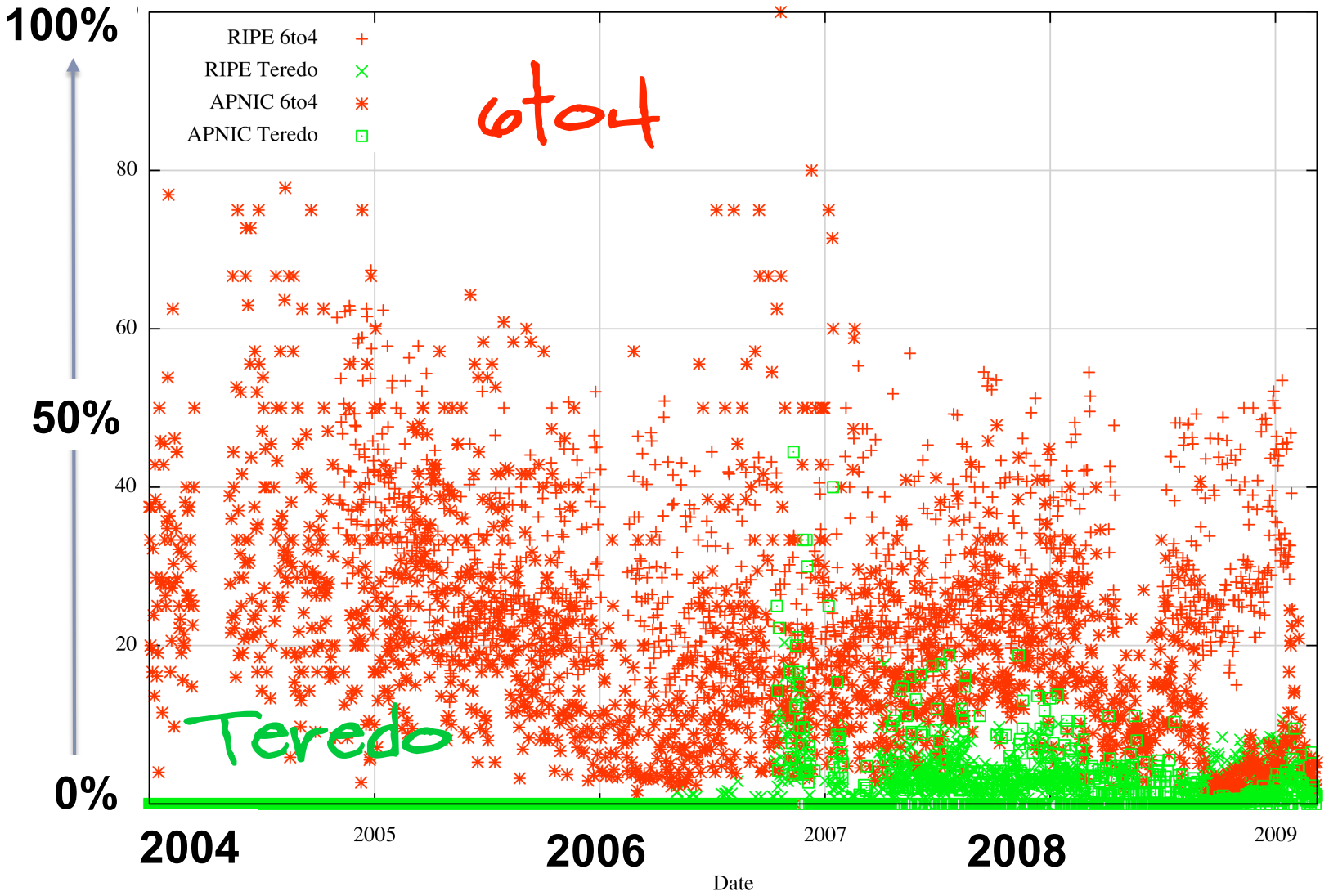

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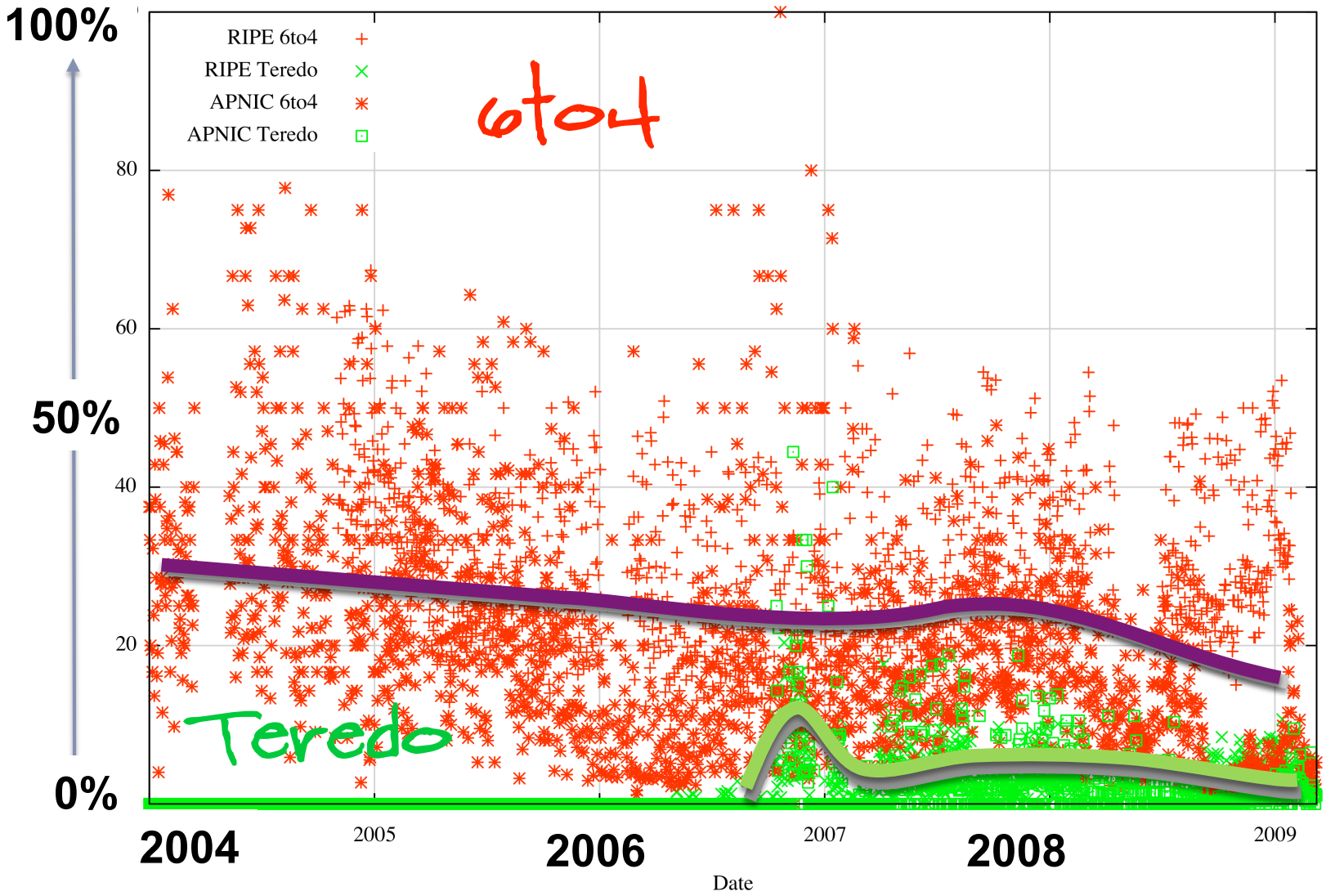

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These last two data measurements are from a pair of relatively small web sites, strongly oriented to an IPv6—interested user base

The general number may be far smaller, and the general tunneling ratio may be far higher than that gathered from the web sites used for these measurements

AS Count IPv6 : IPv4

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What's this saying?

- The number of AS's announcing IPv6 routes has risen from 2.5% to 4.2% from Jan 2004 to the present day

- 4.2% of the networks in the Internet are possibly active in some form of IPv6 activity
  - At a relative rate of update of 0.8% per year, a comprehensive deployment of IPv6 across the network, as measured by ASN uptake with IPv6 is only 120 years away.

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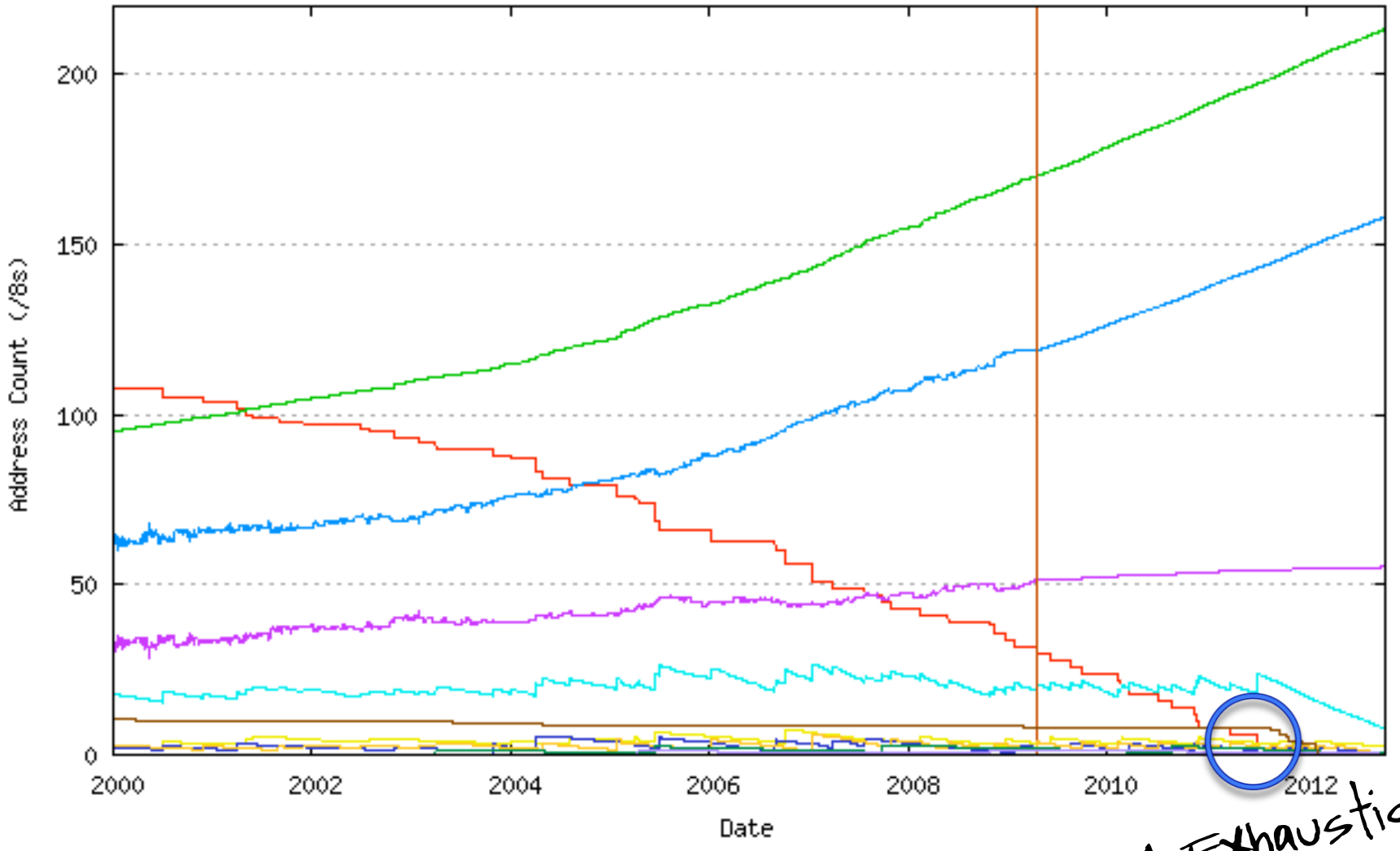
  Actually that's a little bit misleading – here's a better summary:

  17 % of the IPv4 transit ASs (ISPs) announce IPv6

  2% of the IPv4 stub Ass announce IPv6

IPv4 Address Exhaustion Model



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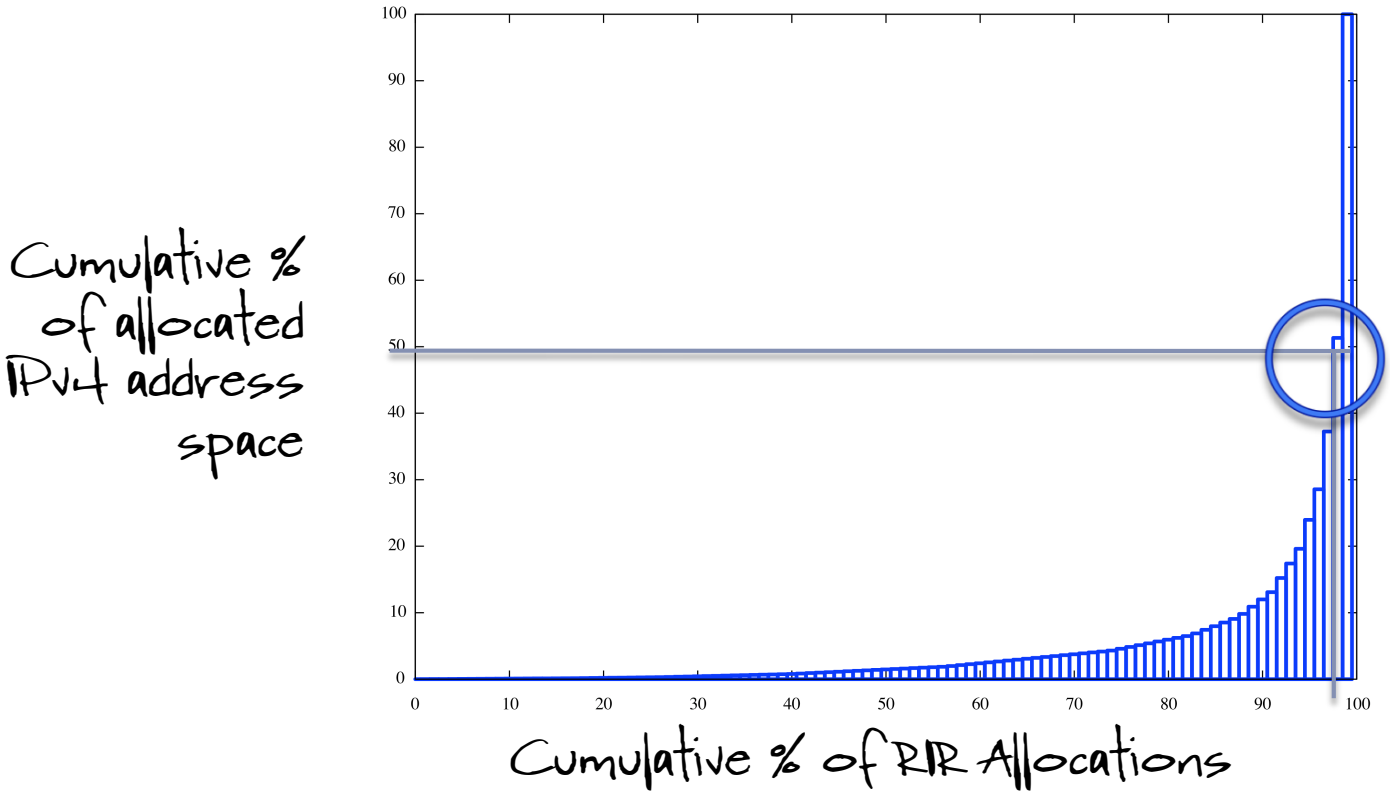
Distribution of IPv4 address allocations 2007 - Present

Of the 15,422 individual IPv4 address allocations since January 2007, only 155 individual allocations account for 50% of the allocated IPv4 address space.
65 of these larger allocations were performed by APNIC, and 22 of these were allocated into China.
54 were performed by ARIN and 52 of these were allocated into the US



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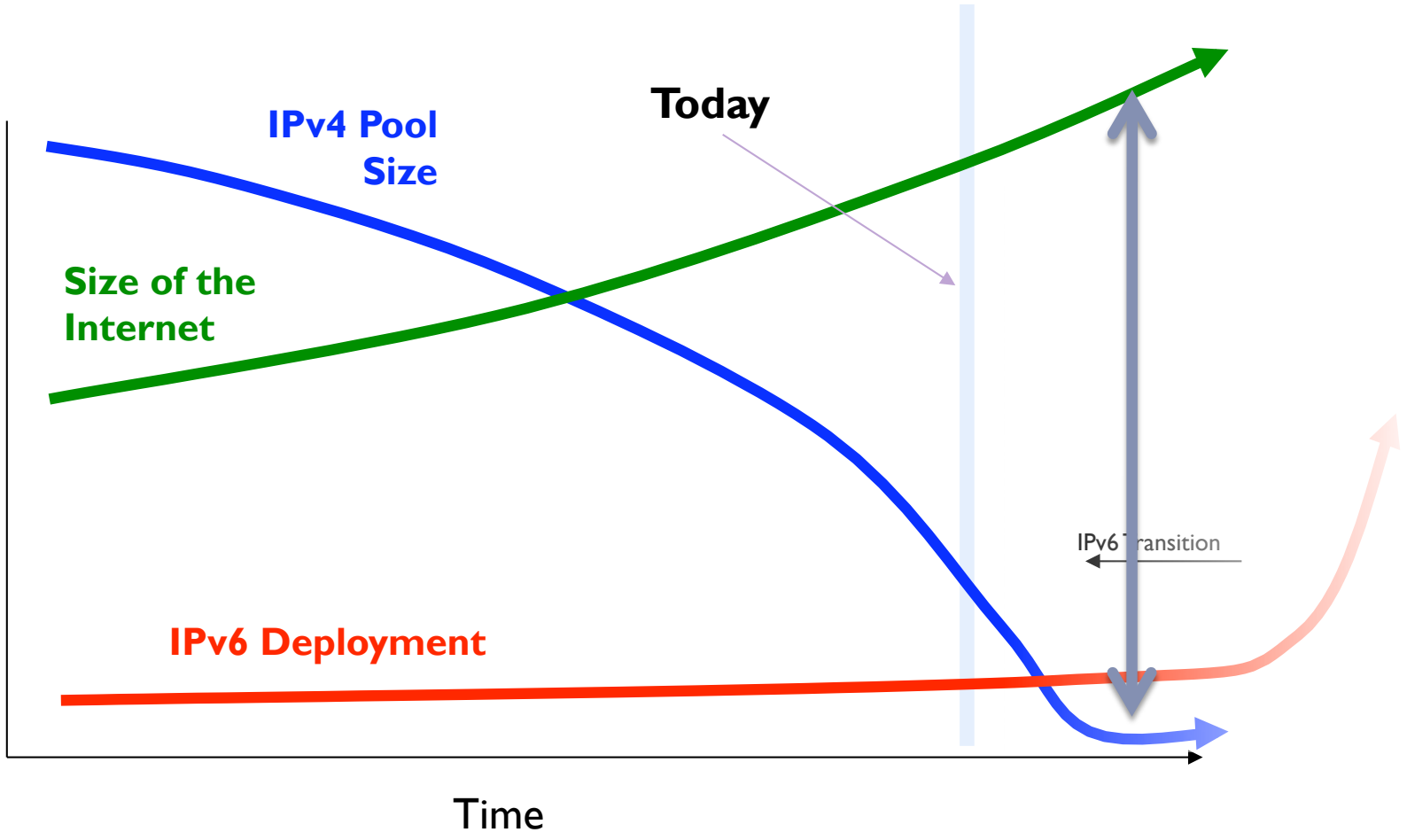
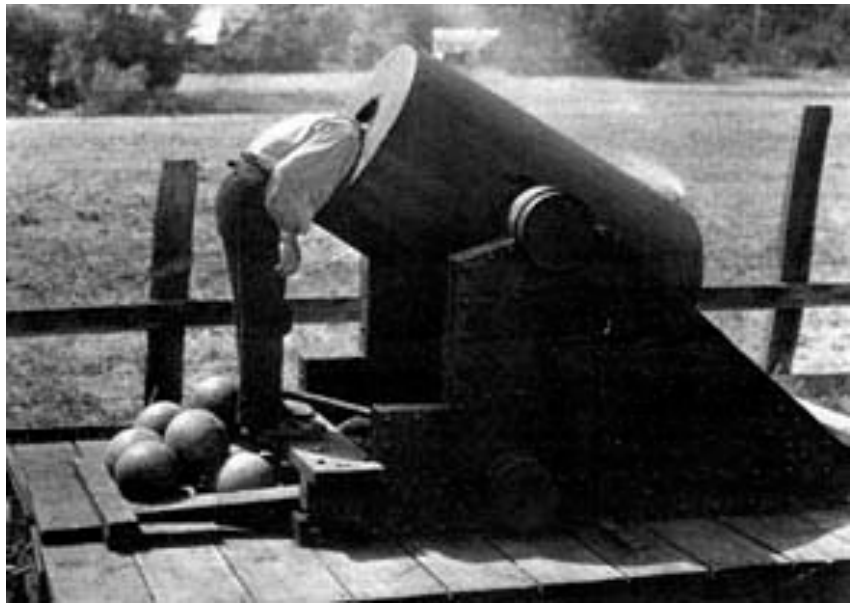
- Large-scale capital-intensive deployments are driving IPv4 demand
- We cannot avoid the situation of IPv4 demand outliving the remaining pool of unallocated IPv4 addresses

The Future Situation





Its just not looking very good is it?

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- We cannot expect any new technology to assist us here in the short or medium term
- We are going to have to use IPv4 to span an Internet that will be very much larger than today during the final stages of this transition to IPv6
- We must support uncoordinated piecemeal deployment of transitional tools, intense use of NATs and various hybrid IPv4 and IPv6 elements in the Internet for many years to come

Constraints

- Its also clear that the focus of any transitional effort to IPv6 will fall on the large scale deployments, and not on the more innovative small scale networked environments

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- Its also clear that the brunt of any transitional effort will fall on the large scale deployments, and not on the more innovative small scale networked environments
- We have to recognize that IPv6 is an option, not an inevitable necessity, and it is competing with other technologies and business models for a future

Challenges

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  - It requires additional large-scale capital investment in switching infrastructure and service delivery mechanisms

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  - It requires additional large-scale capital investment in switching infrastructure and service delivery mechanisms
  - There is no corresponding incremental revenue stream to generate an incremental return on the invested capital
  - Displaced costs and benefits - the major benefits of the IPv6 investment appear to be realized by new market entrants at the services and application layer rather than existing large scale infrastructure incumbents, yet the major costs of transition will be borne by the existing large scale incumbent operators in the market

The Current Situation

- No clear consumer signals
  - User needs are expressed in terms of services, not protocols
  - No value is being placed on IPv6 by the end consumer

The Current Situation

- Lack of business imperatives
  - No immediate underlying business motivation to proceed with this transition for established service enterprises with a strong customer base
  - Perception that the costs and benefits of investment in IPv6 transition are disconnected

The Current Situation

- No clear Public Policy stance
  - Uncertainty: Having deregulated the previous structure of monopoly incumbents and encouraged private investment in communications services there is now no clear stance from a regulatory perspective as to what actions to take
  - Risks of Action: No desire to impose additional mandatory costs on incumbent operators, or to arbitrarily impose technology choices upon the local industry base
  - Risks of Inaction: No desire to burden the local user base with inefficient suppliers and outmoded technologies as a result of protracted industry inaction

What to Do?

- A Conservative View:

  Do Nothing!

  - Risk inaction for a while longer until clearer signals emerge as to the most appropriate investment direction
  - Wait for early adopters to strike a viable market model to prompt larger providers enter the mass consumer market with value and capital

What to Do?

- A more Radical View:

  Act Now!

  - Take high risk decisions early and attempt to set the market direction with IPv6 through market leadership
  - Deploy IPv6 services quickly and attempt to gain an unassailable market lead by assuming the role of incumbent by redefining the market to match the delivered service

Further Thoughts

- A Public Sector Regulatory View

  Think about it some more!

A Broader View

- Its about balance, efficiency and productive private and public sector infrastructure investments that enable leverage to economic well-being
- Its about leveraging continued value from existing infrastructure investments for as long as possible while being competitive with new infrastructure models
- Its about balance between:
  - industry regulatory policies for the deployment of services to meet immediate needs of local users and local industry, with
  - public fiscal policies to support capital investments to sustain competitive interests in the short term future, with
  - economic developmental policies to undertake structural investments for long term technology evolution

What to do?

- What can we do about this transition to IPv6?
  - Is the problem a lack of information about IPv4 and Ipv6? Do we need more slidepacks and conferences to inform stakeholders?
  - Should we try to energise local communities to get moving?
  - Should we try to involve the public sector and create initial demand for IPv6 through public sector purchases?
  - Should we try to invoke regulatory involvement?
  - Should we set aspirational goals?
  - Should we attempt to get the equipment vendors and suppliers motivated to supply IPv6 capability in their products?
  - Should we try to invent new transitional technologies?
  - Or should we leave all this to market forces to work through?

What to do?

- Maybe this is not an accidental problem
- Maybe the shortcoming lies in the architecture of IP itself
- And maybe this situation represents an opportunity to do something about it

I have a couple of my own modest suggestions about what to do, as a result of these considerations ...

Today's Agenda

1. Get moving on today's issues

Operational Tactics: Tomorrow's Dual Stack Internet

- Can we leverage investments in IPv6 transitional infrastructure as a 'natural' business outcome for today's Internet?
- How do we mitigate IPv4 address scarcity? By attempting to delay and hide scarcity or by exposing it as a current business cost?
- Do we have some viable answers for the near term? Do the emerging hybrid V4/V6 NAT models offer some real traction here in terms of scaleable network models for tomorrow's networks?
- What's the timeline to deployment for these hybrid NAT approaches?

More Agenda Items for Today

1. Get moving on today's issues
2. And do not forget about tomorrow

Overall Strategy

- How do we evolve our current inventory of wires, radios and switches into tomorrow's flexible and agile network platforms to allow for innovation in services to meet the demand of an increasingly diverse application portfolio?

- Or should we consider more capable applications layered across a heterogenous network substrate?

Overall Strategy: Where is this leading?

- What's the research agenda?
- What can we learn from this process in terms of architectural evolution of networking services?
- What's **really** important here?
  - IPv6?
  - Or a service evolution that exploits a highly heterogenous networked environment?
  - Why do today's services need protocol uniformity in our networks?
  - Can we build a stable service platforms using hybrid IP protocol realms?

One evolutionary view of network architecture – moving up the stack

circuit networking - yesterday

- shared capable network with embedded applications
- simple 'dumb' peripherals
- single simple application

packet networking - today

- simple datagram network
- complex host network stacks
- simple application model

identity networking - tomorrow

- realms of simple datagram networks
- locator–based simple host network stacks
- identity–based complex application overlays

Where Next?

- Perhaps all this is heading way further than just IPv6
- Perhaps the real opportunity here is about breaking away from the two-party communications model as an overlay above a uniform protocol substrate and looking at a model of peer-networking application architectures with relay and rendezvous agents layered on a heterogenous base
- Perhaps we are starting to work on the challenges involved in a new generation of identity-based networked services as a further evolutionary step in networking service architecture

Thank You