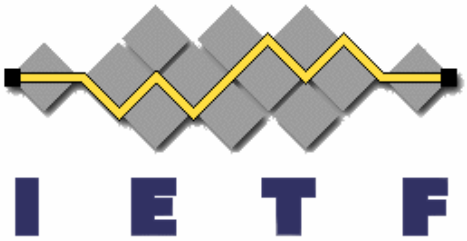

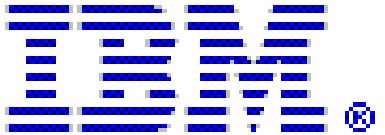

IPv6 - Harvesting a Mature Technology

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Distinguished Engineer

Systems and Technology Group

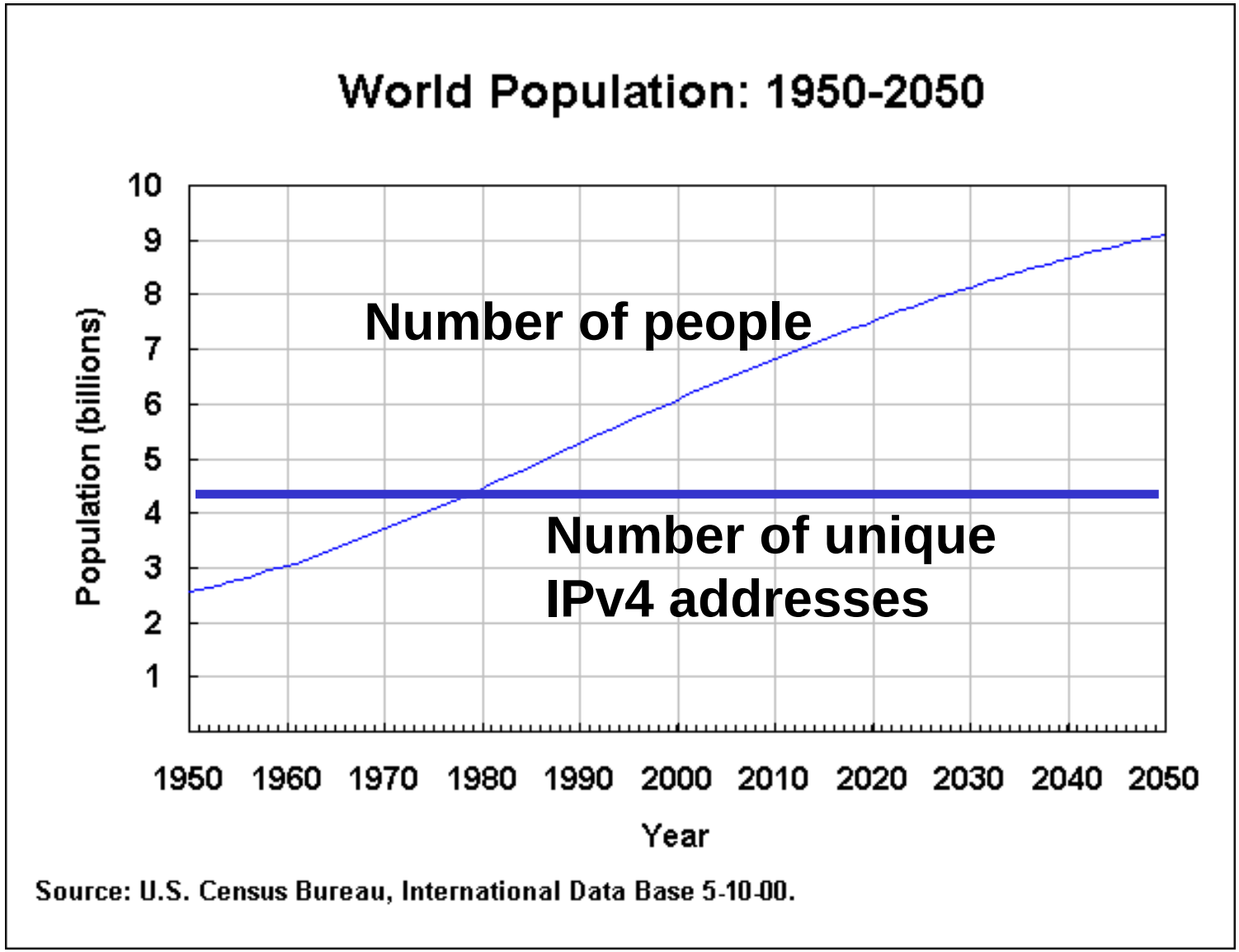
IBM

November 2006

Topics

- Some thoughts about the timeline
- Stable specifications
- Recent developments
- Final thoughts about the timeline

Why we need IPv6

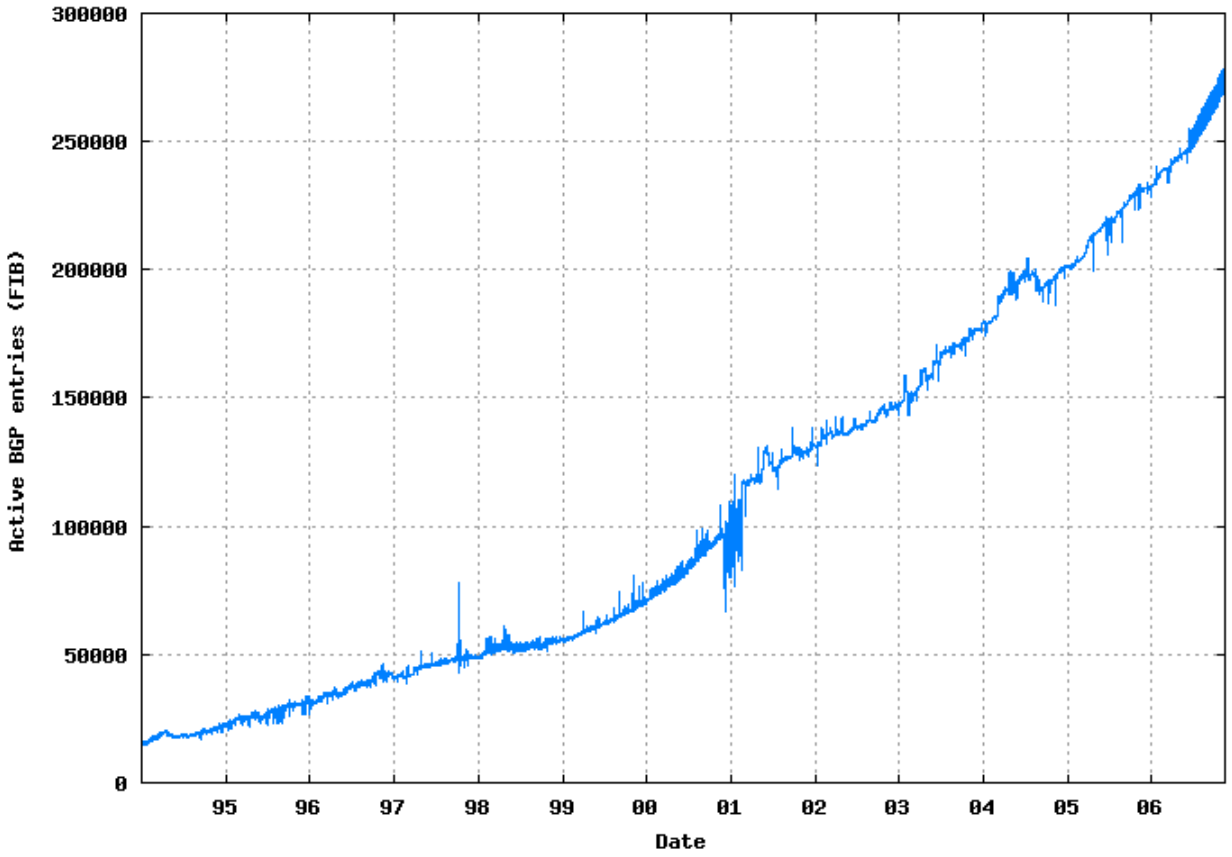


The Internet as a platform for innovation must scale up

- A reasonable goal is 10 billion Internet nodes
  - One node per human in 2050
  - 10 billion nodes squeezed into 4 billion IPv4 addresses – why would we do that?
- Immediate benefit for applications actively hurt by NAT today
  - release the known potential
- Strategic benefit for the next 50 years at least
  - avoid the opportunity cost of staying with IPv4

Scaling since we started measurements

WAN routing table size



1994 2006

Strategic timescales

- 1962: **PACKET SWITCHING INVENTED**
- 1974: internet (catenet) concept invented
- 1981: **TCP/IP standardised**
- 1992: Internet scaling problem identified
  - We've used almost 15 years to be ready to scale the address space with IPv6
  - We need some more years to scale the routing system
- 2050: Internet for everyone
  - Think in terms of a 90 year process

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Basic specs are stable

- Basic protocol (RFC 2460) published 1998
  - Flow label spec (RFC 3697) added 2004
- Basic socket API (RFC 2553) published 2003
- Address architecture (RFC 4291) stable, minor revision in 2006
- Node requirements (RFC 4294) published 2006
- Mobile IPv6 (RFC 3775) published 2004
- DHCPv6 (RFC 3315) published 2003
  - and dozens of other RFcs

Coexistence Mechanisms (1)

- Dual stack (RFC 2893)
  - Socket API (RFC 3493)
  - DNS supports IPv4 and IPv6 (RFC 1886)
- IPv6 in IPv4 tunnels (RFC 2893)
- NAT-PT translation (RFC 2766)
  - IETF likely to deprecate this
- Tunnel Broker (RFC 3053)
- 6to4 implicit tunnels (RFC 3056)

Coexistence Mechanisms (2)

- Less favored in IETF
  - Bump in the Stack (RFC 2767)
  - Bump in the API (RFC 3338)
  - SOCKS (RFC 3089)
  - Transport relay (RFC 3142)
  - 6over4 using IPv4 multicast (RFC 2529)
  - ISATAP (RFC 4214)
  - Teredo (RFC 4380)
  - DSTM (draft expired)

Implementation status

- All significant operating systems and router vendors now support dual IPv4/IPv6 stacks and socket APIs
  - Vista and Longhorn prefer IPv6 to IPv4
- BIND DNS, PowerDNS, etc. support IPv6
- Java 1.4 and later supports IPv6
- Many public domain applications support IPv6
- The conversion of commercial applications is progressing
  - 35 IBM software products listed as compliant now
  - 49 more intended by 2008-01-01

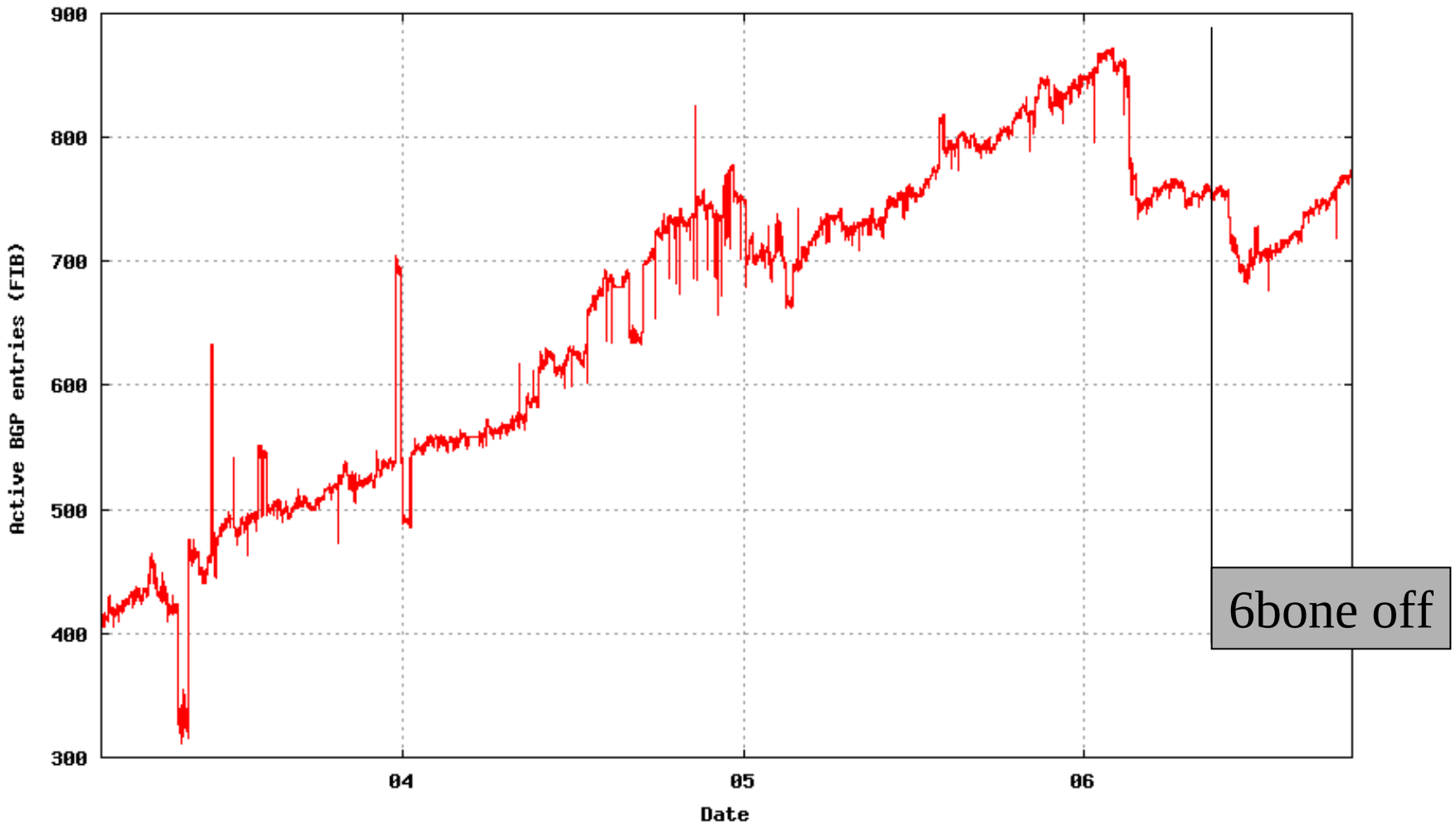
Deployment status (1)

- Multiple R&E networks running IPv6 services around the world
- Numerous commercial IPv6 services on offer, but we have a classical chicken/egg deadlock
  - when will enterprises see the business case?
- Numerous IPv6 Task Forces worldwide.
- Emerging requirement in RFPs
  - Required by ITU NGN
  - US DoD requirement since 10/03
  - USG mandate for 2008.

Deployment status (2)

- About 770 IPv6 prefixes announced in BGP, which mainly belong to ISPs.
  - Hard to know how many offer commercial IPv6 (certainly at least 25, of which ~10 in Japan)
  - Remember that customer prefixes are mainly aggregated behind ISP prefixes: a small number is good news!
  - The pre-production 6BONE officially switched off 6/6/06
  - Connectivity is real, e.g., see
    http://net-stats.ipv6.tilab.com/bgp/
    http://bgp.potaroo.net/index-bgp.html

IPv6 routing history



2003

2006

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IPv6 WG in the last 2 years: mainly consolidation

- TCP MIB [update] (RFC 4022)
- IP Tunnel MIB [update] (RFC 4087)
- IPv6 Scoped Address Architecture (RFC 4007)
- Unique Local IPv6 Unicast Addresses (RFC 4193)
- Default Router Preferences (RFC 4191)
- Host-to-Router Load Sharing (RFC 4311)
- IPv6 Addressing Architecture [update] (RFC 4291)
- ICMPv6 [update] (RFC 4443)
- IPv6 Node Requirements (RFC 4294)
- IP MIB [update] (RFC 4293)
- IP Forwarding Table MIB [update] (RFC 4292)
- Neighbor Discovery Proxies (RFC 4389)
- Link-Scoped IPv6 Multicast Addresses [update] (RFC 4489)
- IPv6 Node Information Queries (RFC 4620)

V6OPS WG in the last 2 years: mainly deployment issues

- Security Considerations for 6to4 (RFC 3964)
- Application Aspects of IPv6 Transition (RFC 4038)
- Introducing IPv6 into ISP Networks (RFC 4029)
- IPv6 Enterprise Network Scenarios (RFC 4057)
- Renumbering an IPv6 Network (RFC 4192)
- IPv6 Transition in 3GPP Networks (RFC 4215)
- Basic Transition Mechanisms for IPv6 [update] (RFC 4213)
- VLANs for IPv4-IPv6 Coexistence in Enterprise Networks (RFC 4554)

IPv6 multihoming in the last 2 years

- MULTI6 WG
  - IPv4 Multihoming Practices and Limitations (RFC 4116)
  - Architectural Approaches to Multi-Homing for IPv6 (RFC 4177)
  - Threats relating to IPv6 Multihoming Solutions (RFC 4218)
  - Things MULTI6 Developers Should Think About (RFC 4219)
- SHIM6 WG
  - Working on shim in host IPv6 stack to conceal multihoming events (changes of address) from transport layer
  - No RFCs so far
  - Controversial approach among ISPs

Other IPv6 WGs in progress

- 6lowpan: IPv6 over Low power WPAN
- mip6: Mobility for IPv6
- monami6: Mobile Nodes and Multiple Interfaces in IPv6
- softwire: Softwires
- *plus increasing attention to IPv6 in all other current protocol designs*

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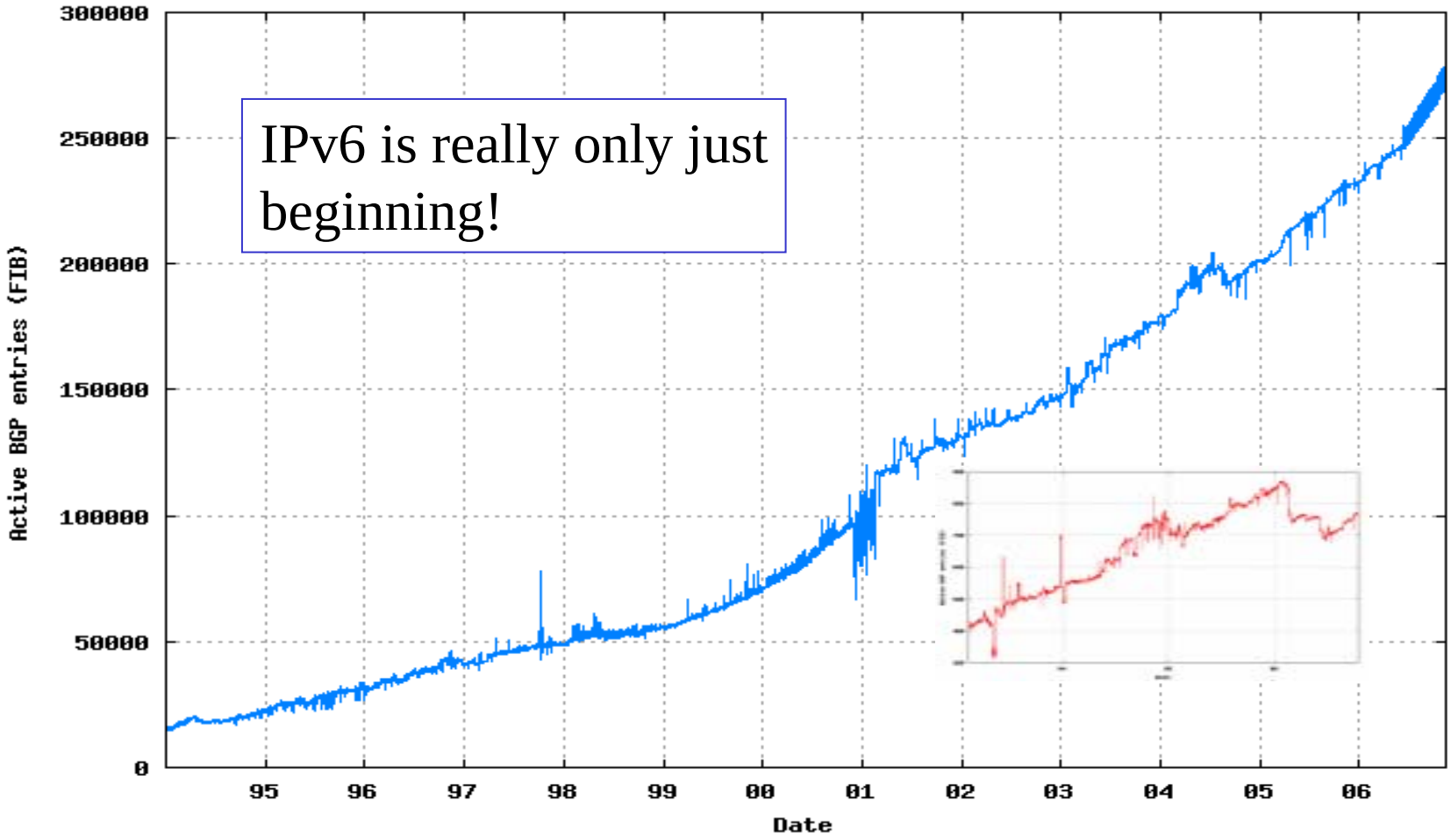
What's left to do?

- Obviously, deploy and exploit IPv6
  - remembering that Internet time really means 50 years for the full harvest
- A big problem known since about 1992 remains - how to make Internet-wide area routing scale adequately for a ten billion node network?
  - serious concern that BGP4 (the inter-ISP routing protocol) will run out of steam within ~5 years
  - IPv6 does nothing to fix this
- So IPv6 is not the end of the story
  - Expect more change in the future

Compare the curves



Thanks to Geoff Huston for both graphs

Pointers

- IETF WGs

www.ietf.org/html.charters

(drafts and RFCs are linked from these sites)

- IPv6 Forum

www.ipv6forum.org

- IBM

www.ibm.com/software/info/ipv6

IETF: brc@zurich.ibm.com
IBM: bcar@ch.ibm.com