Lessons from IPv6

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History

- Effort started in 1992-1993
- Original primary purpose: more IP addresses
- Several competing proposals

Context

- Internet security starting to be noticed
  - Note: security ≠ cryptography!
- No deployed autoconfiguration – DHCP dates to 1993
- No NAT; first RFC was 1994
- OSI vs TCP/IP wars
- Routing table size an issue

Basic Decisions

- Do not change basic semantic model of IP; keep it simple
  - Slightly modified over time...
- Support other things seen as necessary
  - Mobility
  - Renumbering
  - Multicast
- Add security: IPsec
- Do not change TCP

What Happened

- Near-stalemate in the IETF among different proposals
  - IPng area and directorate formed
- Arguments over cryptography (vs. U.S. export laws)
- Routing table size was seen as not a primary issue
  - Use CIDR and easy renumbering
- Engineering took a lot longer than expected

Second System Effect

- Many features were added to IPv6
- Scoped addresses
  - Required changes to the socket API
- Neighbor Discovery replaced ARP
  - Includes basic autoconfiguration
- Flow labels (but usage wasn't specified)
- Early decision on stateless autoconfiguration froze part of the address format

The Claims for V6

- Bigger addresses
  - True, but doesn't attract end users
- Autoconfiguration
  - We now have DHCP for client configuration
- More secure
  - IPsec exists for IPv4, too

Engineering is Hard

- Some features were much more complex than people thought
  - Neighbor Discovery couldn't be secured with IPsec
  - Site-local addresses interacted poorly with the DNS
- Finishing the design took a lot longer than expected
- Renumbering is easier, but still not easy; there are too many addresses in configuration files, access control lists, etc.
- Multihoming is still unsolved

What Happened?

- The opportunity attracted too many feature creatures
- During that time, IPv4 didn't stop evolving
  - Many of the putative advantages of IPv6 became part of IPv4
- Tighter allocation controls by the RIRs helped
- NATs solved a large part of the address space crunch

The World Changed under IPv6

- Mobility hasn't been that important at the IP layer
  - Layer 2 mobility often works well: 802.11 access points, cell phones, etc
- Firewalls and VPNs have eroded much of the application base for mobility
- ISP-based multihoming has become increasingly important – and it was explicitly ignored in the IPv6 design

What are the Lessons?

- The devil is in the details – you generally don't know what will work, or how well it will work, until you've built it
- Understand what the real issues are
  - IPv6 got big addresses right; it didn't understand multihoming and looked too much at mobility
- Understand what will motivate users to adopt it
  - NAT made big addresses irrelevant for most end users