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