ELEC / COMP 177 – Fall 2016

Computer Networking
→ Future of the Internet

Final Exam

- **Tuesday, December 13th – 8am-11am**
- Same format as midterm
  - Open notes, open computer, open internet
  - 1 programming problem using Python
- Time limited – 3 hours max
- **Bring your Linux laptop/USB key!**

- Topic: Text-only “Wireshark” tool

Future of the Internet

IPv6

IP Versions

ID	Description
0-3	Unused: Development versions of IP
4	Current network-layer protocol
5	Unused: Experimental stream protocol – ST
6	New network-layer protocol (1996)
7-9	Unused: Experimental protocols – TP/IX, PIP, TUBA
10-15	Not allocated

Why Replace IPv4?

- Performance?
  - Quality of Service?
- Security?
  - Authenticating users?
  - Tracking criminals / spammers?
  - Denial of service?
- New applications?
  - Mobile devices?
- Routing is scaling out of control?

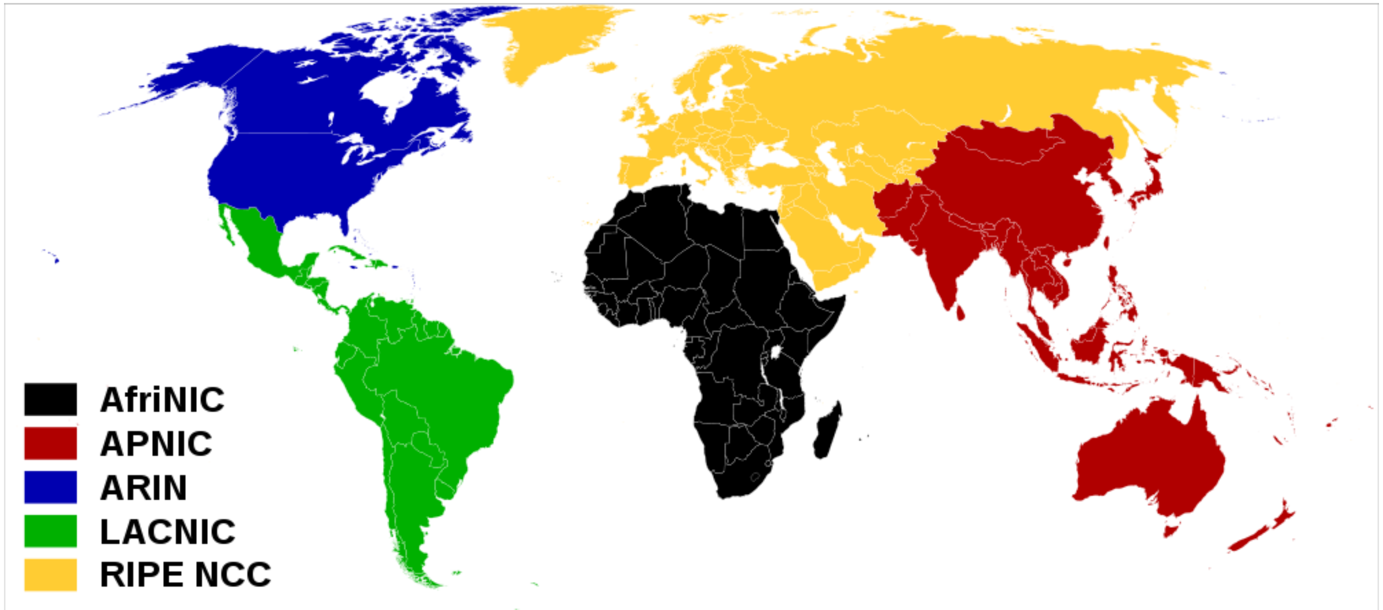
- IPv6 does not attempt to solve all problems with computer networks
  - Actually, it only really solves one of them!

Why Replace IPv4?

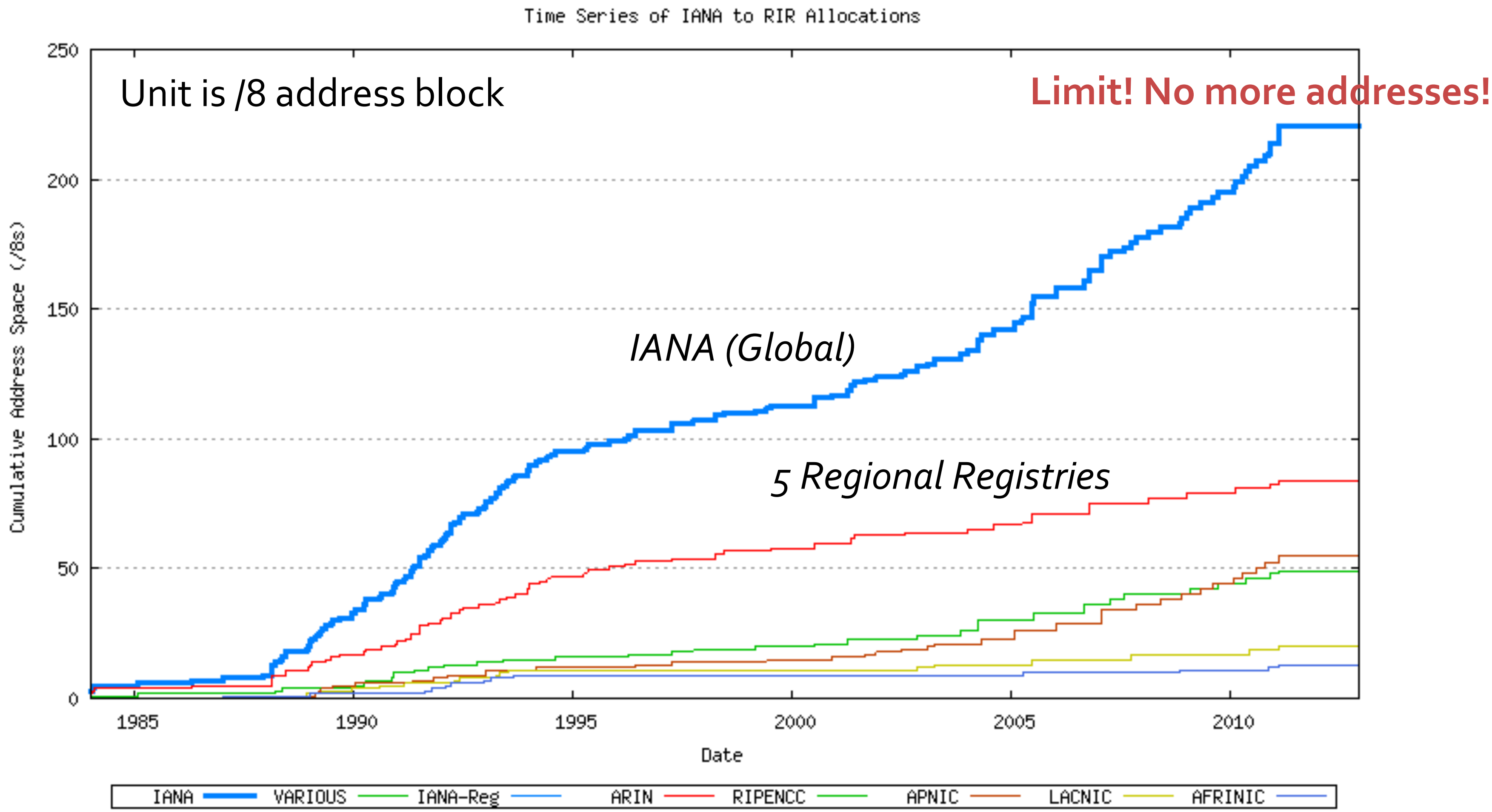
- The problem
  - IPv4 has ~4.3 billion addresses
  - World has ~7.3 billion people!
    - How many internet-capable devices per person?
- IP address exhaustion
  - Internet will not “collapse”, but new devices / networks will not be able to join
- When? Now! *(back in 2011, actually)*
  - Consuming about one /8 block (16.78 million addresses) per month

IP Address Distribution

- Global pool: *Internet Assigned Numbers Authority* (IANA)
- Regional Internet Registry (RIR) <- "Local distributor"
  - ARIN, LACNIC, AfriNIC, RIPE, APNIC



End of IPv4



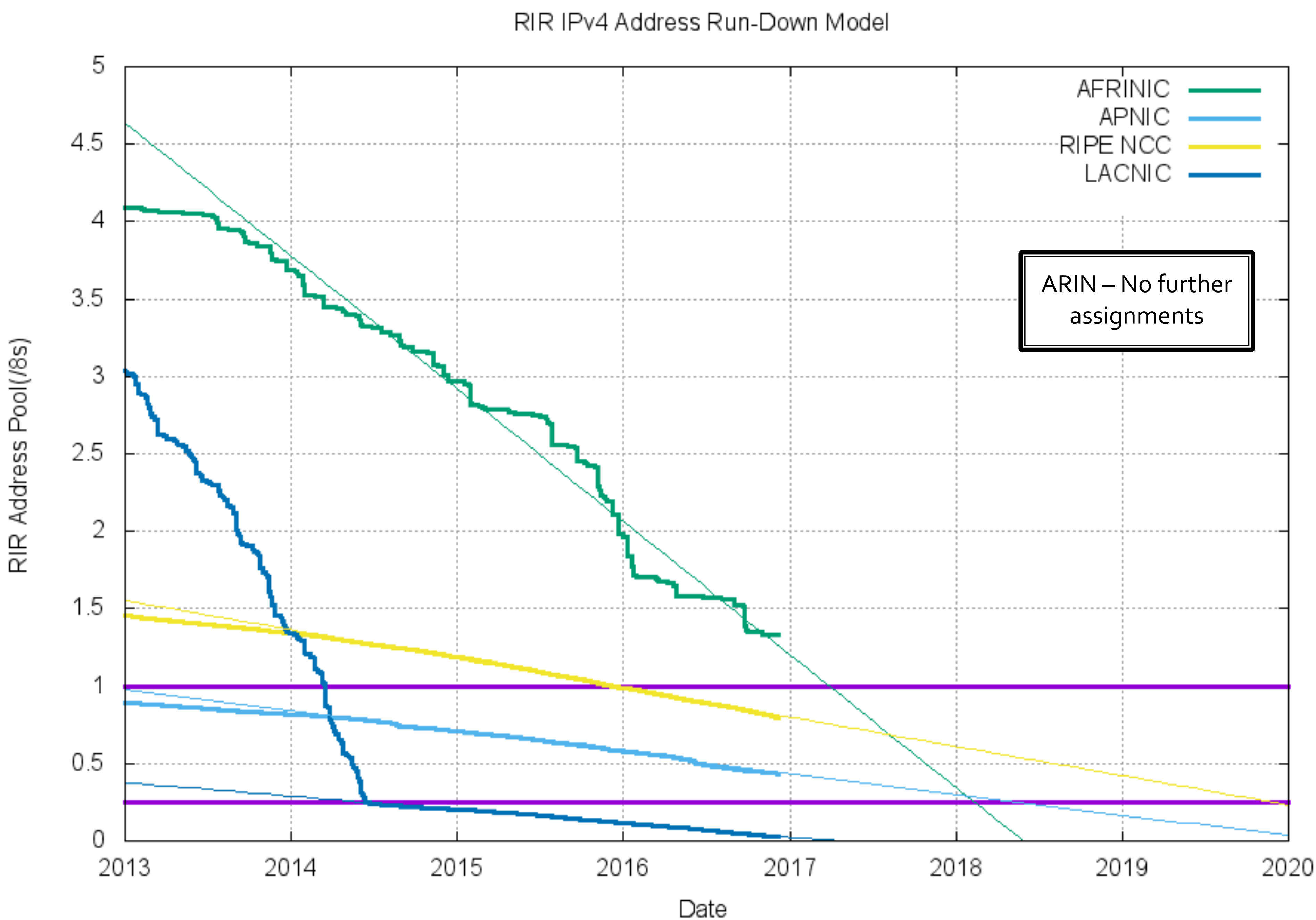
http://www.potaroo.net/tools/ipv4/index.html

End of IPv4

- February 3rd, 2011
  - Internet Assigned Numbers Authority (IANA) distributed final five /8 IPv4 blocks
  - One to each Regional Internet Registry (RIR)
- Registries now only allocate /22 blocks
  - *1024 addresses = tiny!*
- When /22 blocks are exhausted, game over
- **When will the regional internet registries run out of addresses?**

End of IPv4

- Exhaustion Dates
  - APNIC (Asia) – April 14th, 2011
  - RIPE NCC (Europe) – Sept 14th, 2012
  - LACNIC (South/Latin America) – June 10th, 2014
  - **ARIN (North America) – Sept 24th, 2015**
  - AfriNIC (Africa)
    - Slow rate of consumption
    - Several years remaining of supply

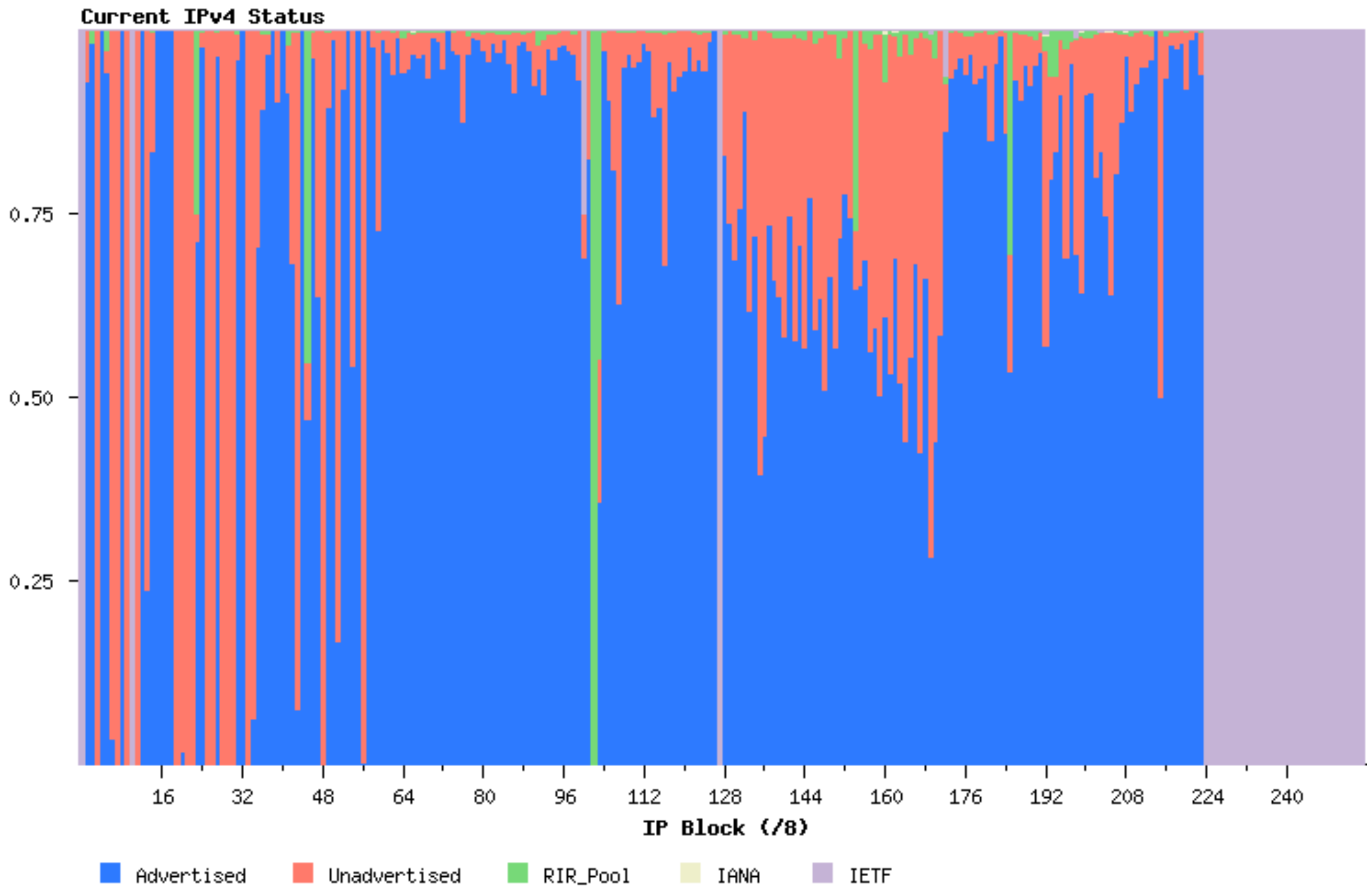


http://www.potaroo.net/tools/ipv4/

IPv4 Address Space

- Unavailable Addresses
  - 10.x – Private Addresses
    - Along with 192.168.x and 172.16.x to 172.31.x
  - 127.x – Local Loopback Addresses
    - Why an entire /8?
  - 224.x to 239.x — Multicast groups
  - 240.x to 254.x — Reserved for "future use"
    - Waste of address space
    - Impossible to re-use today because most IP software flags these addresses as invalid
  - 91 entities with entire class A's (Govt, IBM, GE, HP, MIT, ...)
- Current Allocation
  - http://www.iana.org/assignments/ipv4-address-space

Used –vs– Unused Addresses



http://www.potaroo.net/tools/ipv4/

IPv4 vs IPv6 - Similarities

- Datagram
  - Each packet is individually routed
  - Packets may be fragmented or duplicated
- Connectionless
  - No guarantee of delivery in sequence
- Unreliable
  - No guarantee of delivery
  - No guarantee of integrity of data
- Best effort
  - Only drop packets when necessary
  - No time guarantee for delivery

IPv4 vs IPv6 - Differences

- Address Length
  - IPv4 – 32 bits (2^{32} = ~4 billion)
  - IPv6 – 128 bits (2^{128}= ~340 trillion, trillion, trillion)
- Security – ~~IPSec support required in IPv6~~
  - *Dec 2011: IPSec support "recommended" in IPv6*
  - IPSec encrypts each IP packet independently
- Reliability – No Header Checksum in IPv6
  - Easier for routers – No need to update checksum after decrementing TTL
  - Relies on link-level error checking
- Quality of Service
  - Label data flows for special priority levels at routers
- Simplified Header Format
  - Infrequently used fields are optional

IPv6 Address Notation

- 128 bits – 8 groups of 4 hex digits
  - `2001:0db8:85a3:08d3:1319:8a2e:0370:7334`
- User friendly! Easy to remember!
- "Helpful" Shortcuts:
  - Omit leading zeros in a group (`0005:0db8:`… is equivalent to `5:db8:`…)
  - Collapse groups of all-zeros with :: (`2001:0000:0000:0000:0000:8a2e:0370:7334` is equivalent to `2001::8a2e:0370:7334`)

IPv6 – Routing

- **How can having bigger IP addresses (128 bits) make routing easier?**
  - Larger address space allows more intelligent network organization
    - Addresses match physical network organization
    - Collapse routing table entries
  - Basic idea
    - Use upper 64 bits for routing
    - Use lower 64 bits for interface ID
      (clients pick this randomly or based on MAC address)

Routing

- **Besides the address layout, how does IPv6 make routing easier?**
  - No checksum calculation
  - No fragmentation
  - Infrequently used headers are optional
- **How does IPv6 make routing harder?**
  - Forwarding table entries 2x-4x larger
  - Need to route both IPv4 and IPv6 for the foreseeable future

Deployment

- Why should I deploy IPv6 today?
  - My customers can reach anywhere on the Internet today
  - "Famous services" (e.g. Google) will always be reachable
  - Only new applications / users will suffer
- How do I deploy IPv6?
  - Flip a switch across the internet?
- Legacy routers may not be upgradeable
  - Hardware implementations cannot be changed
  - Software workarounds offer low performance
- Islands of IPv6 in the sea of IPv4
  - Dual network stacks support both IPv4 and IPv6
  - Tunnel IPv6 across IPv4 networks
- Need to upgrade other systems
  - DHCP (DHCPv6)
  - DNS (root servers A-M accessible via IPv6 as of 2016)
  - Firewalls, traffic shapers, etc.

IPv6 – Original Plan

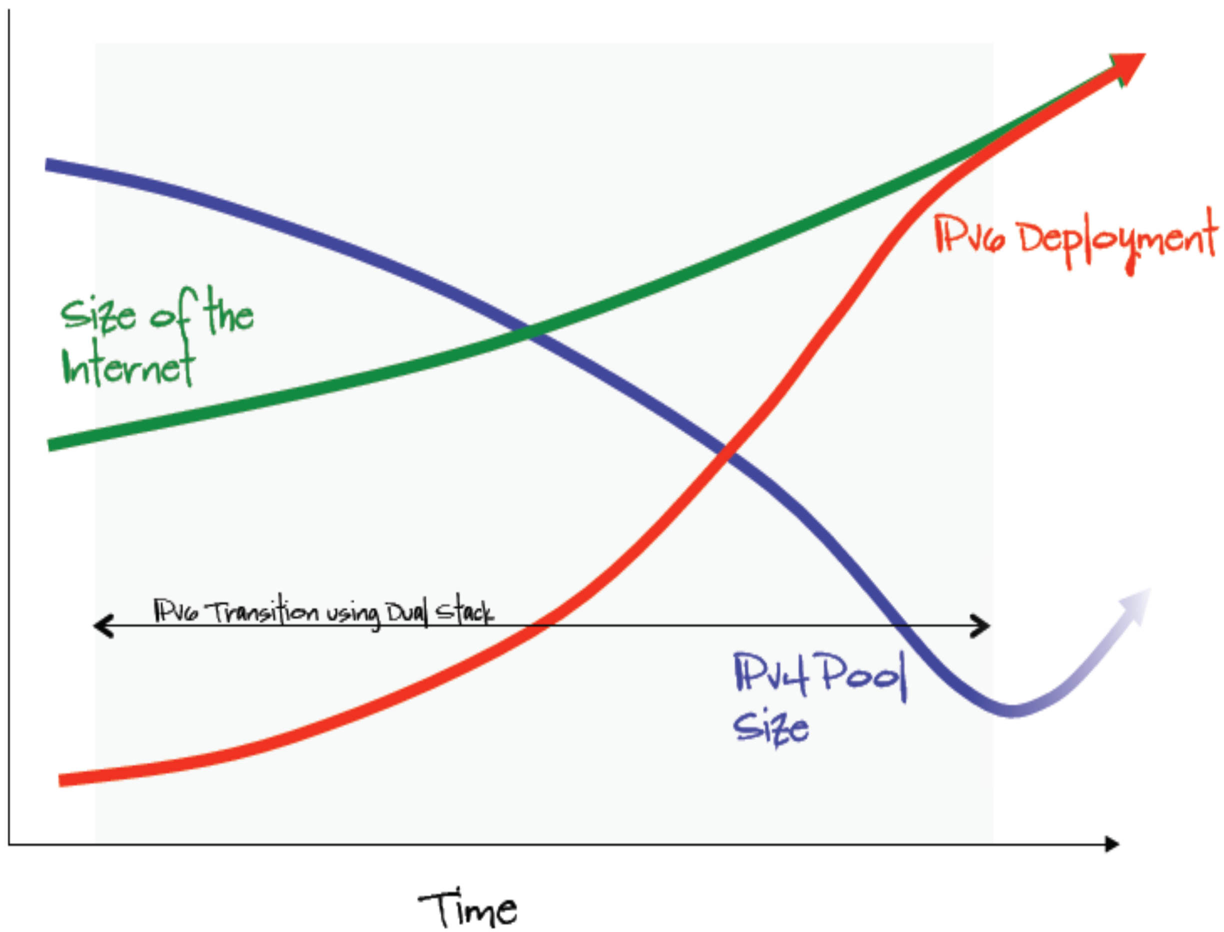
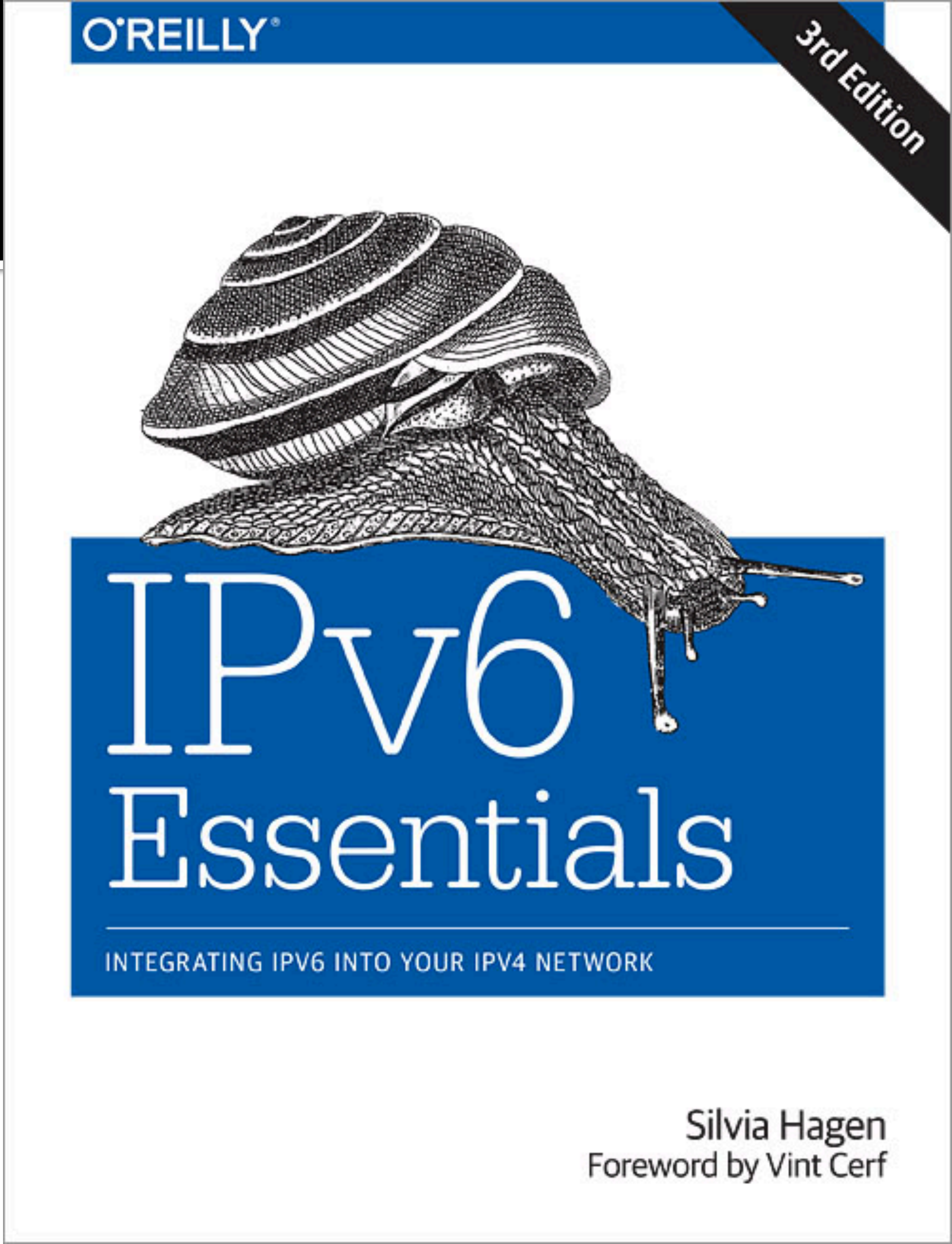


Figure from http://www.potaroo.net/presentations/2008-11-17-ipv6-failure.pdf

IPv6

Current Status

Actual book cover!



IPv6 – The New "Plan" (?)

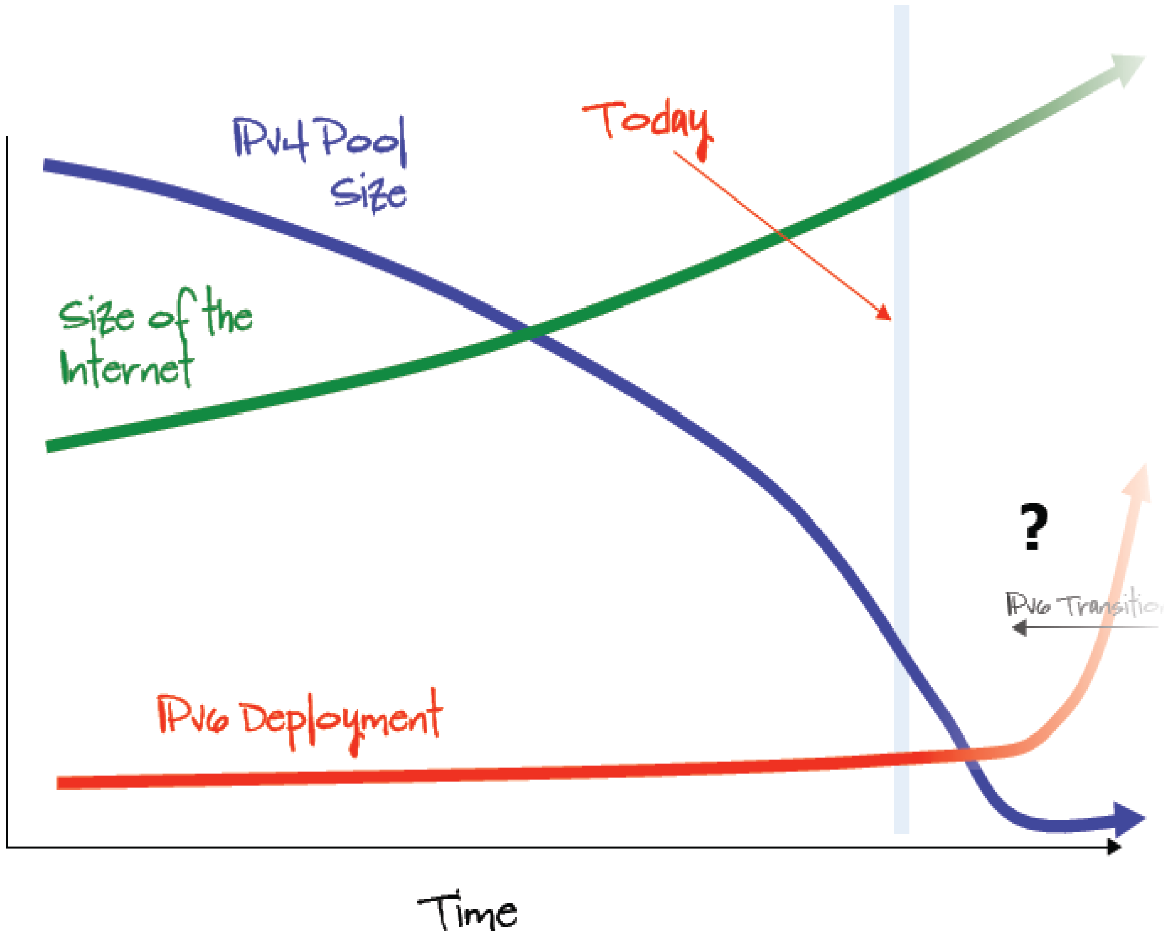
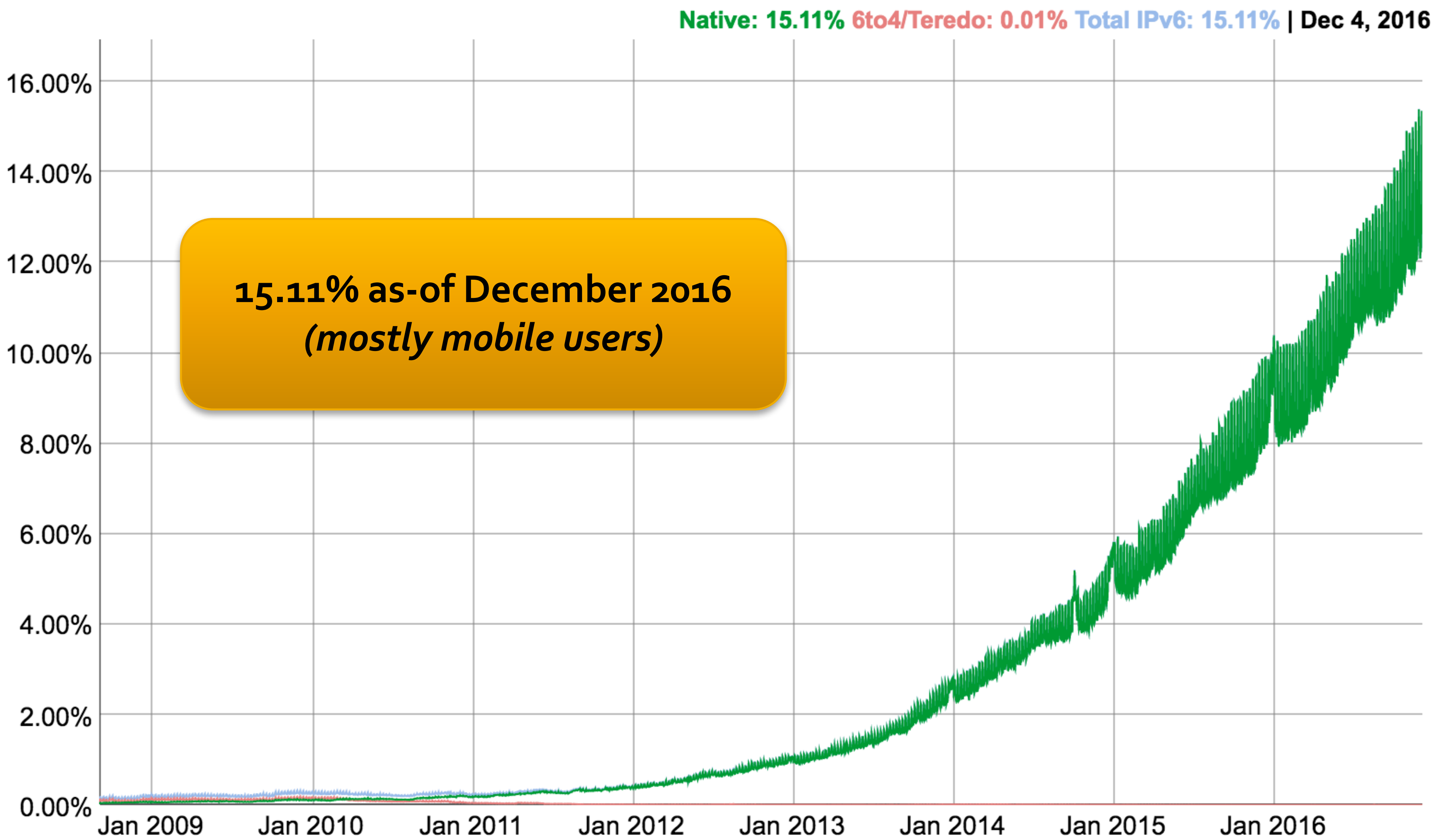


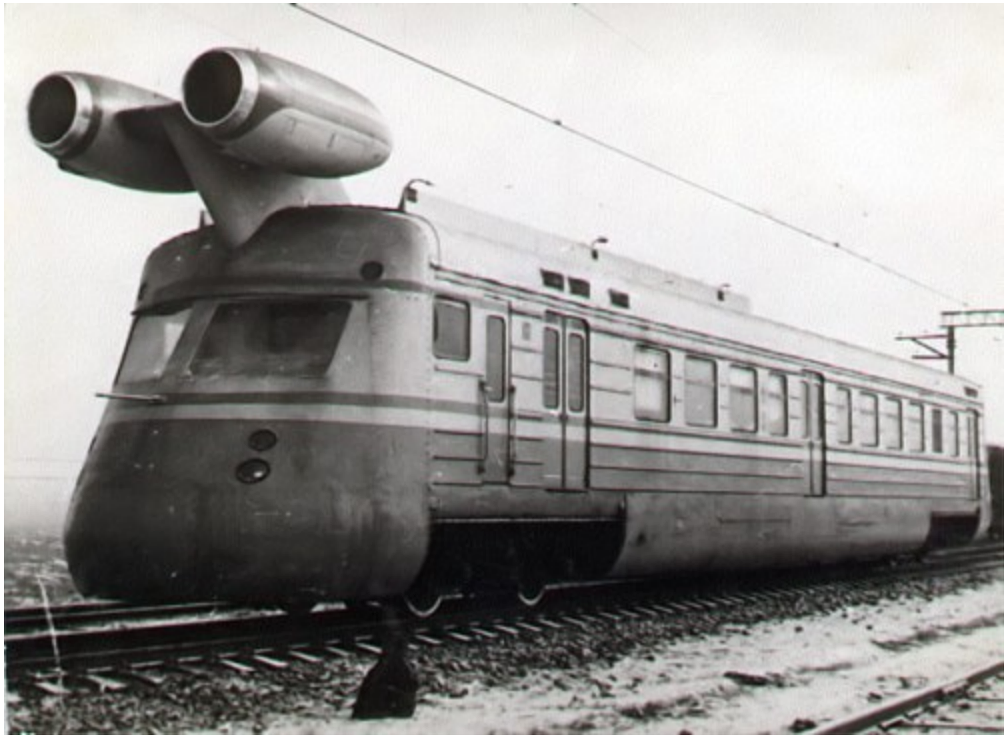
Figure from http://www.potaroo.net/presentations/2008-11-17-ipv6-failure.pdf

Google IPv6 Usage



http://www.google.com/intl/en/ipv6/statistics.html

IPv6 – Failure is an Option



Is this IPv6?

IPv6 – Failure is an Option

- What happens if IPv6 "fails"?
  - Failure is defined as anything less than a complete migration from IPv4 to IPv6
  - Do we stop allowing new hosts to connect to the internet?
- What about using NAT? (address translation)
  - Observation: Only 5-20% of assigned IPs are actually used by hosts.
  - Solution: Use lots of NAT to reclaim unused addressed
- What happens if this works, and we build "carrier-grade" NAT everywhere?
  - No more end-to-end connectivity?
  - Need coordination with ISP to deploy new services?
  - New opportunities for ISPs to filter traffic and charge for services?

http://www.potaroo.net/presentations/2008-11-17-ipv6-failure.pdf

IPv6 – Failure is an Option

- If an organization deploys NAT extensively, how can you get them to give up the reclaimed addresses?
- IP Address Marketplace
  - Can we create a marketplace? (Currently "forbidden" to sell IP blocks)
  - Imagine: *"For Sale: One Lightly-Used IP Block (only used by grandma to check email on Sunday)"*
  - Same problems as buying a used car:
    - Does the person selling the IP block actually "own" it?
    - What is the condition of the IP block? (If used for spam or illicit activity, IP block may be in blacklists worldwide)

http://www.potaroo.net/presentations/2008-11-17-ipv6-failure.pdf