



University
of Glasgow

Network Layer (2): Addressing

Networked Systems 3
Lecture 9

Lecture Outline

- Addressing
 - Concepts
 - Addressing in the Internet
 - IPv4
 - IPv6
 - The shortage of IPv4 addresses

Addressing

- How to name hosts in a network?
 - Is the address an identity or a location?
 - Does it name the host, or the location at which it attaches to the network
 - How should addresses be allocated?
 - Hierarchical or flat?
 - What is the address format?
 - Human or machine readable?
 - Textual or binary? Structured or unstructured?
 - Fixed or variable length? How large?

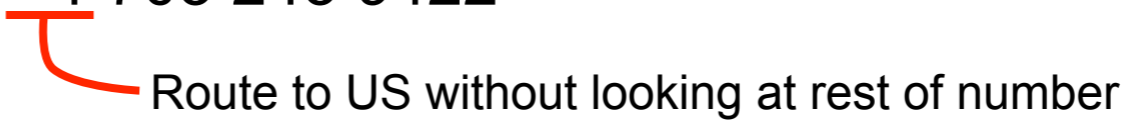
Identity and Location

- Addresses can denote host identity
 - Give hosts a consistent address, irrespective of where or when they attach to the network
 - Simple upper-layer protocols
 - Transport layer and applications unaware of multi-homing or mobility
 - Puts complexity in network layer
 - Network must determine location of host before it can route data
 - Often requires in-network database to map host identity to routable address
 - E.g., mobile phone numbers

Identity and Location

- Alternatively, an address can indicate the *location* at which a host attaches to the network
 - Address structure matches the network structure
 - Network can directly route data given an address
 - E.g., geographic phone numbers: +44 141 330 4256
 - Simplifies network layer, by pushing complexity to the higher layers
 - Multi-homing and mobility must be handled by transport layer or applications – transport layer connections break when host moves

Address Allocation

- Are addresses allocated hierarchically?
 - Allows routing on aggregate addresses
 - E.g., phone call to +1 703 243 9422
Route to US without looking at rest of number
 - Forces address structure to match network topology
 - Requires rigid control of allocations
- Or is there a flat namespace?
 - Flexible allocations, no aggregation → not scalable

Address Formats

- Textual or binary? Fixed or variable length?
 - Fixed length binary easier (faster) for machines to process
 - Variable length textual easier for humans to read
 - Which are you optimising for?

IP Addresses

- IP addresses have the following characteristics:
 - They specify location of a network interface
 - They are allocated hierarchically
 - They are fixed length binary values
 - IPv4: 32 bits
 - IPv6: 128 bits
- Domain names are a separate *application level* namespace

IP Addresses

- Both IPv4 and IPv6 addresses encode location
 - Addresses are split into a *network part* and a *host part*
 - A *netmask* describes the number of bits in the network part
 - The network itself has the address with the host part equal to zero
 - The broadcast address for a network has all bits of host part equal to one (allows messages to be sent to all hosts on a network)
 - A host with several network interfaces will have one IP address per interface
 - E.g., laptop with an Ethernet interface and a Wi-Fi interface will have two IP addresses

IPv4 Addresses

32 bit binary addresses

IP address: 130.209.247.112 = 10000010 11010001 11110111 01110000

Netmask: 255.255.240.0 = 11111111 11111111 11110000 00000000



20 bits → network = 130.209.240.0/20

Broadcast address:

130.209.255.255 = 10000010 11010001 11111111 11111111

Aside: Classes of IP address

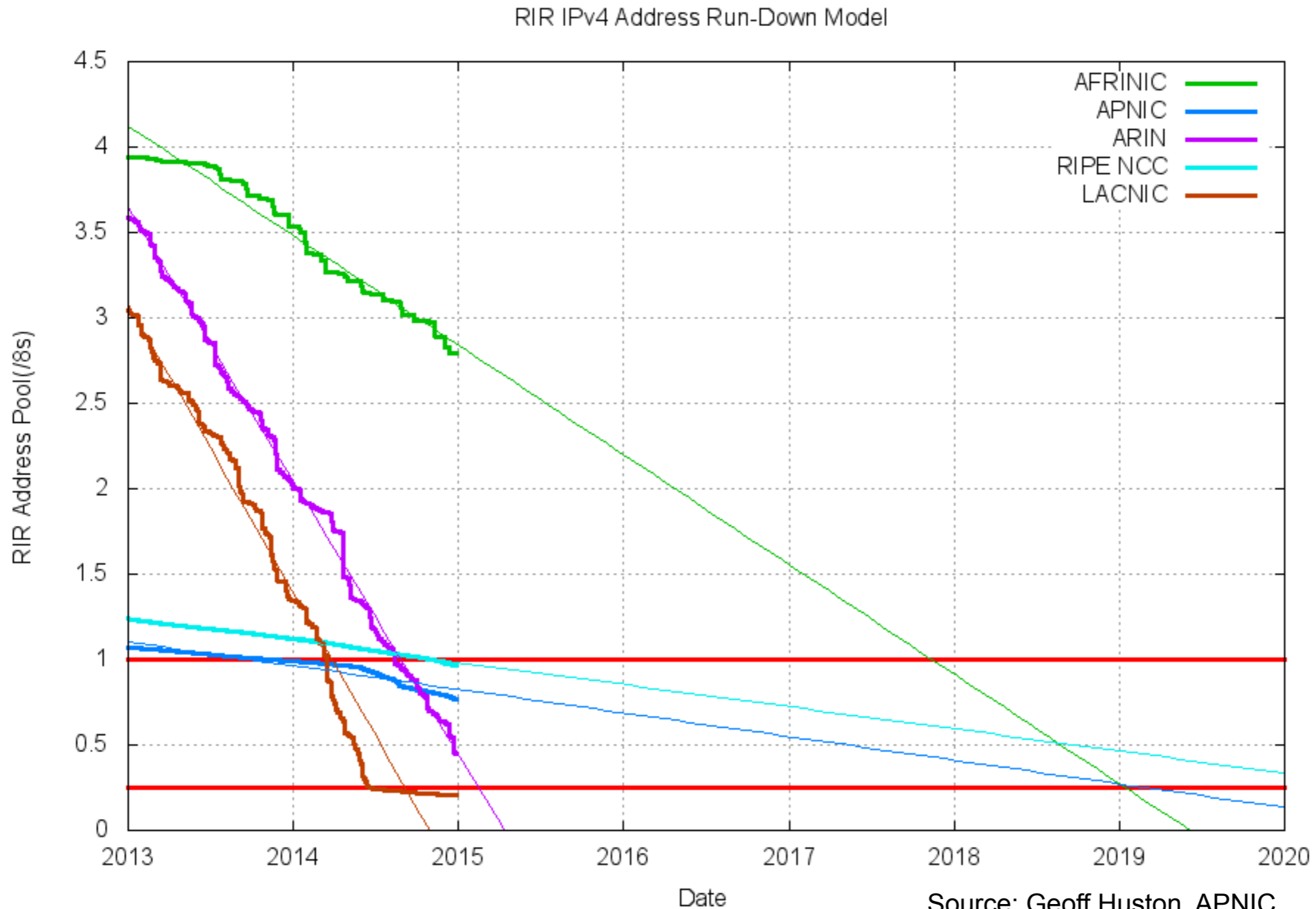
- IP addresses used to be allocated so the netmask was a multiple of 8 bits
 - Class A → a /8 network (~16 million addresses)
 - Class B → a /16 network (65536 addresses)
 - Class C → a /24 network (256 addresses)
- Inflexible, and wasted addresses
- Arbitrary length netmask allowed since 1993:
 - The Glasgow SoCS network is a /20

Old terminology still used sometimes...

IP Address Management

- IPv4 has $2^{32} = 4,294,967,296$ addresses
 - IANA administers the pool of unallocated addresses
 - Historically would assign addresses directly to ISPs, large enterprises, etc.
 - Now, addresses assigned to regional Internet registries (RIRs) as needed:
 - AfriNIC (Africa), APNIC (Asia-Pacific), ARIN (North America), LACNIC (Latin America and Caribbean), and RIPE (Europe, Middle East, Central Asia)
 - Allocations made one /8 ($2^{24} = 16,777,216$ addresses) at a time
 - RIRs allocate addresses to ISPs and large enterprises within their region; ISPs allocate to their customers
 - IANA has allocated all available addresses to RIRs
 - Last allocation made on 3 February 2011

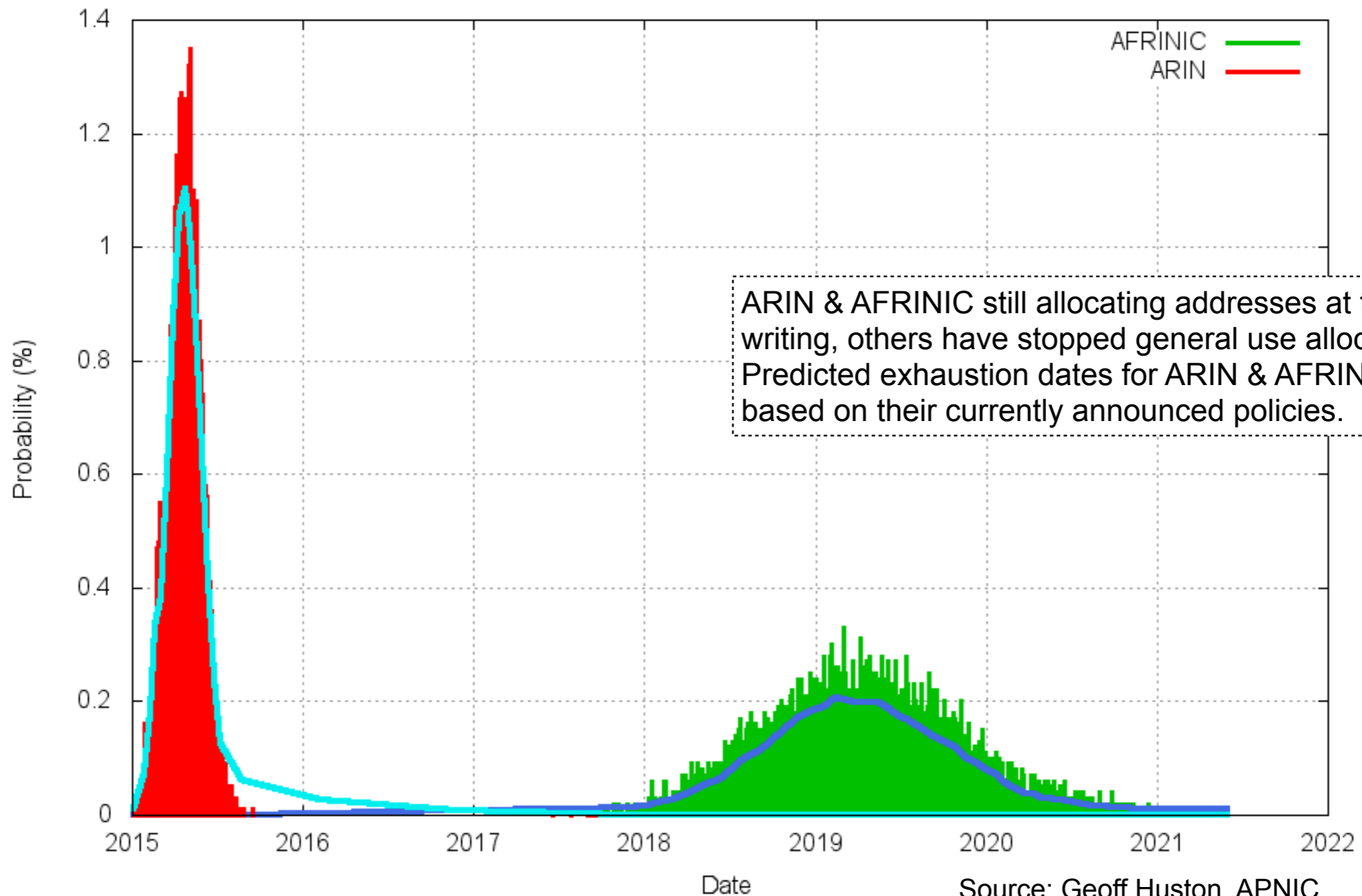
RIR IPv4 Address Exhaustion (1)



Source: Geoff Huston, APNIC
28 Dec 2014 <http://ipv4.potaroo.net/>

RIR IPv4 Address Exhaustion (2)

RIR IPv4 Address Run-Down Model - Variance Analysis



Source: Geoff Huston, APNIC
28 Dec 2014 <http://ipv4.potaroo.net/>

The IPv4 Address Space is Fully Used

- In practical terms, we have run out of IPv4 address space



IPv6

- IPv6 provides 128 bit addresses – if deployed it will solve address shortage for a *long* time
 - $2^{128} = 340,282,366,920,938,463,463,374,607,431,768,211,456$ addresses
 - Approximately 665,570,793,348,866,943,898,599 addresses per square metre of the Earth's surface

IPv6 Addresses

128 bit binary addresses, written as : separated hexadecimal

2001:0db8:85a3:08d3:1319:8a2e:0370:7334

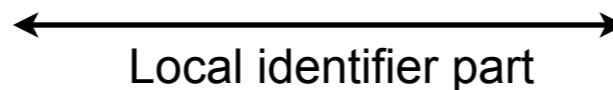
A single run of consecutive zeros can be compressed to a ::

2001:200::8002:203:47ff:fea5:3085

IPv6 Addresses

Local identifier part of IPv6 address is 64 bits:

2001:0db8:85a3:08d3:1319:8a2e:0370:7334



Can be derived from Ethernet/Wi-Fi MAC address:

48 bit IEEE MAC: 0014:5104:25ea

Expand to 64 bits: 0014:51ff:fe04:25ea

Invert bit 6: 0214:51ff:fe04:25ea

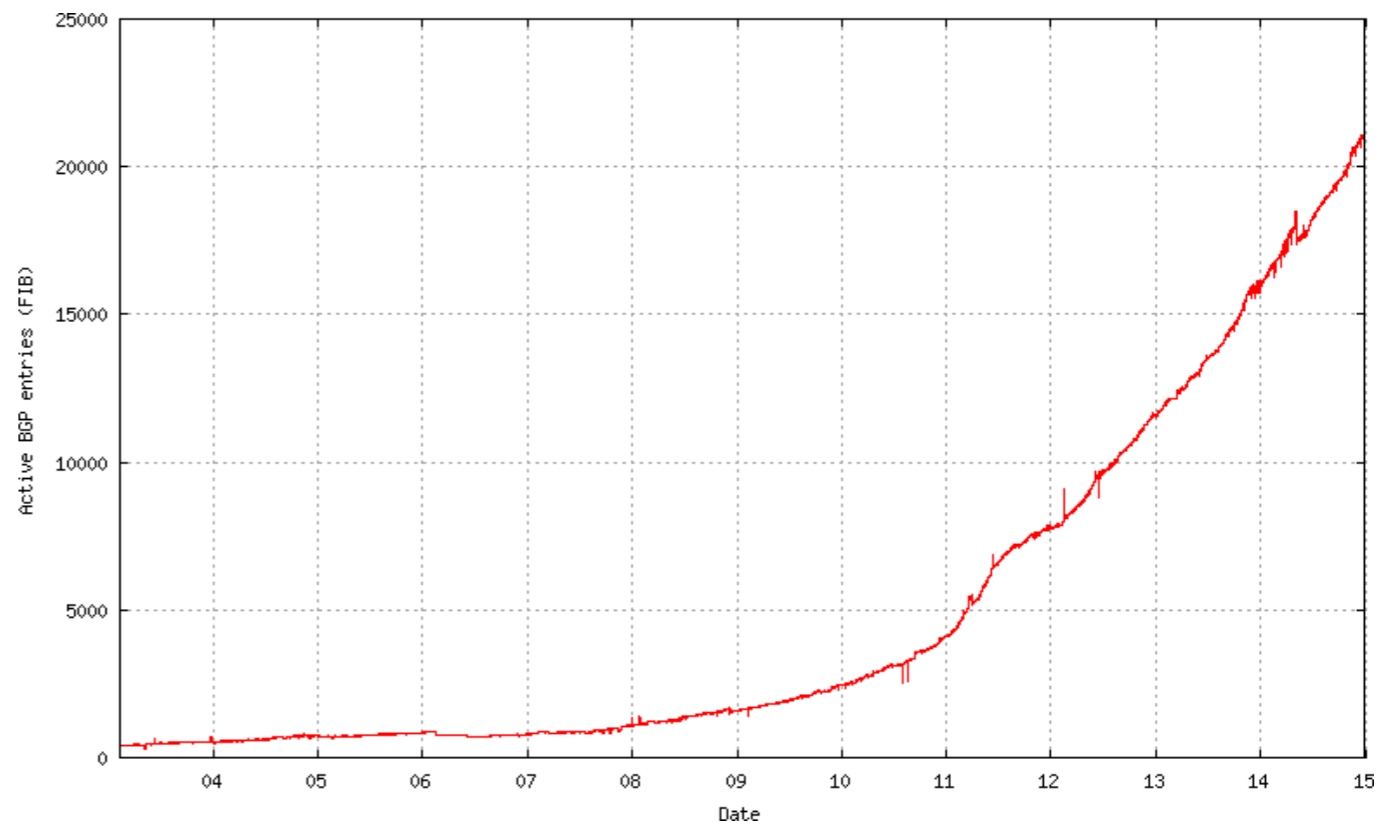
Or randomly chosen, with bit 6 set to zero, to give illusion of privacy

IPv6 Deployment Issues

- IPv6 requires changes to *every* single host, router, firewall, and application...
 - Significant deployment challenge!
 - Host changes done: MacOS X, Windows, Linux, FreeBSD, Symbian, iOS, Android, etc.
 - Backbone routers generally support IPv6, home routers and firewalls (mostly) not yet
 - Many applications have been updated

NAT vs. IPv6

- NAT widely deployed for IPv4
 - Initially seems simple: no host changes; web browsing and email still work
 - But... hugely complicated for peer-to-peer applications → lecture 14
 - Very difficult to debug problems, or deploy new classes of application
- IPv6 starting to see large-scale use:



Source: Geoff Huston, APNIC

28 Dec 2014 <http://bgp.potaroo.net/v6/as2.0/>

Summary

- Addressing: identity vs. location, address formats
- Internet addressing:
 - IPv4 and address exhaustion
 - IPv6