IOWA

CS3640

Network Layer (2): The Internet Protocol

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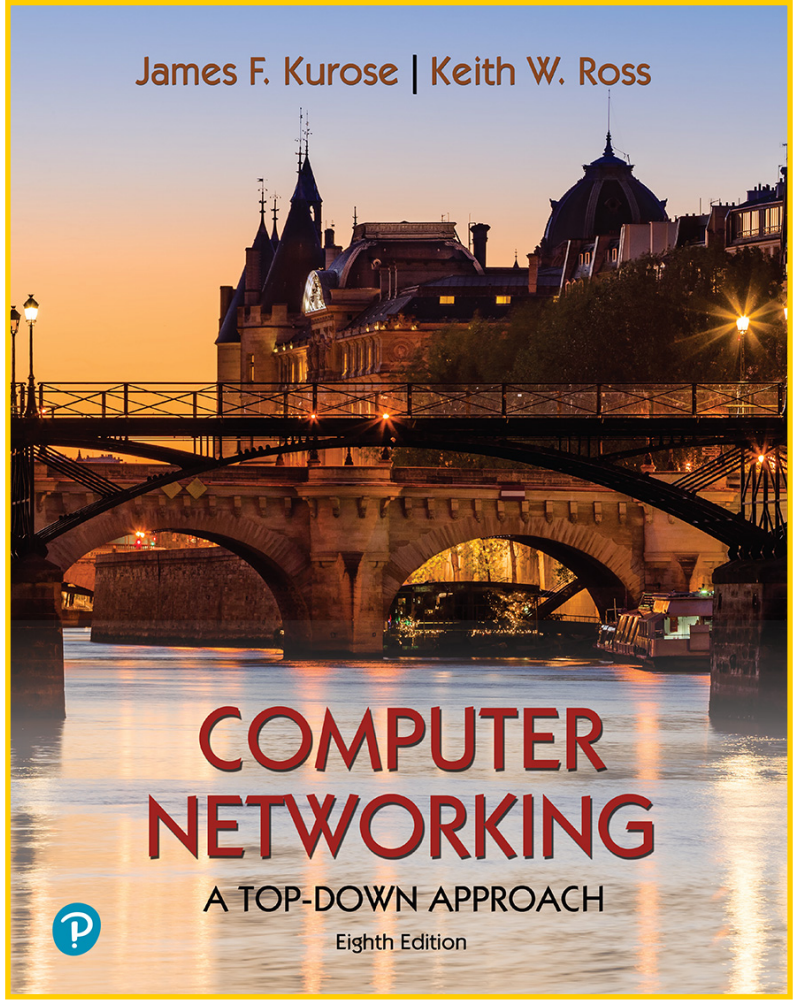
Lecture goals

a two-part discussion on the Internet Protocol, its functionalities, shortcomings, and real-life solutions

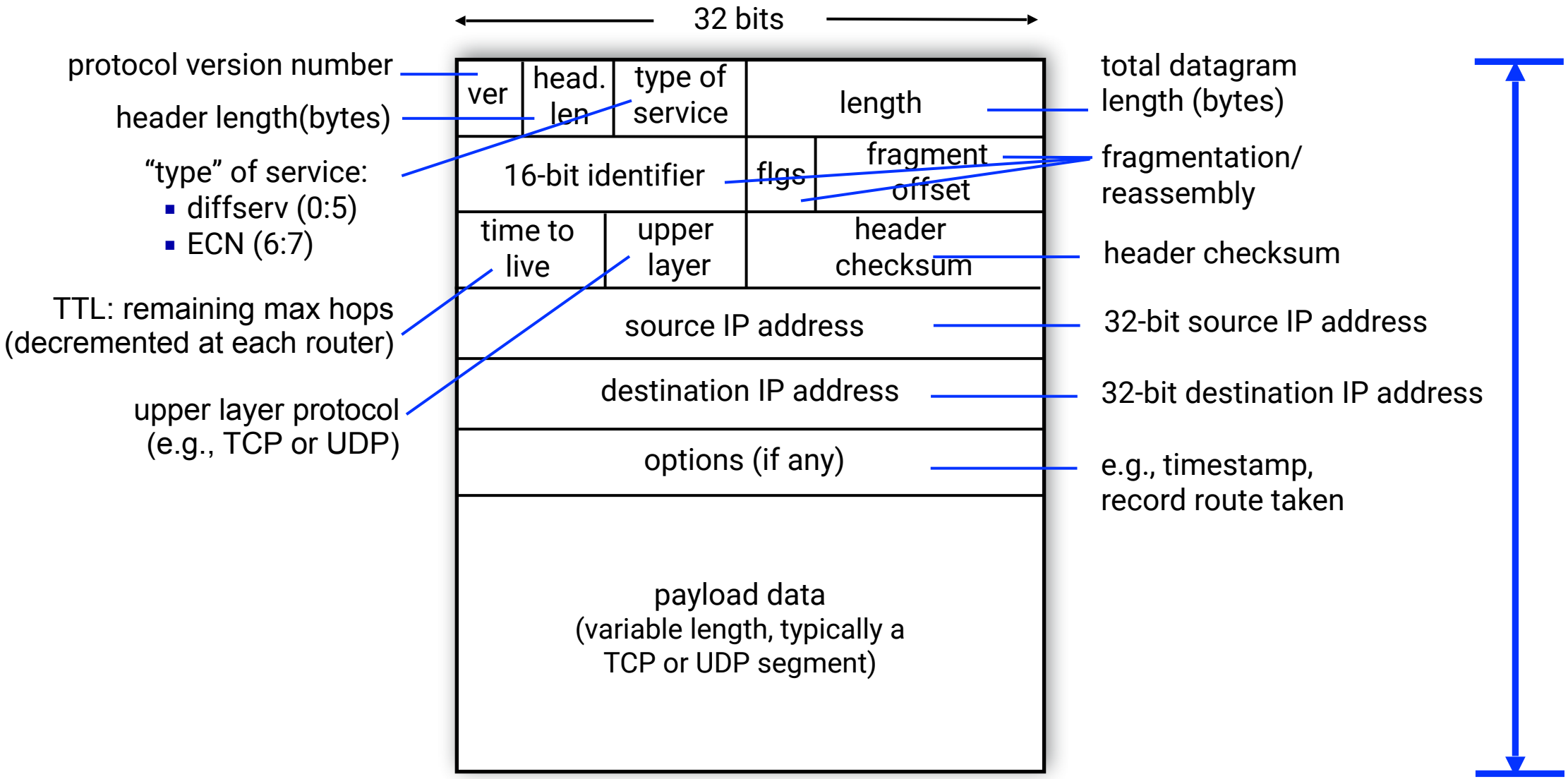
- *IPv4 format and addressing*
- *Address management via DHCP*
- *NAT and Middleboxes*
- *IPv6*



Chapters 4.3, 4.5

IP Datagram format

Maximum length: 64Kb
Typically: ~1500 bytes



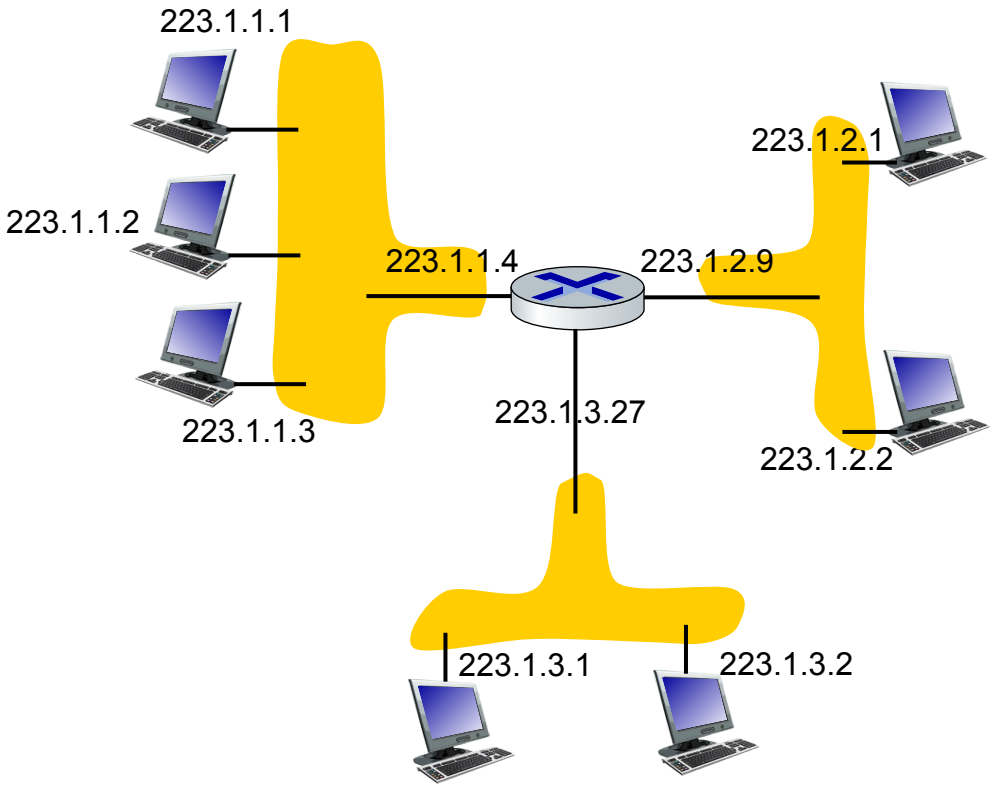
Primer on IP addressing

IP address: 32-bit identifier associated with every addressable entity on the Internet

dotted-decimal IP address notation:

223.1.1.1 = 11011111 00000001 00000001 00000001

223 1 1 1



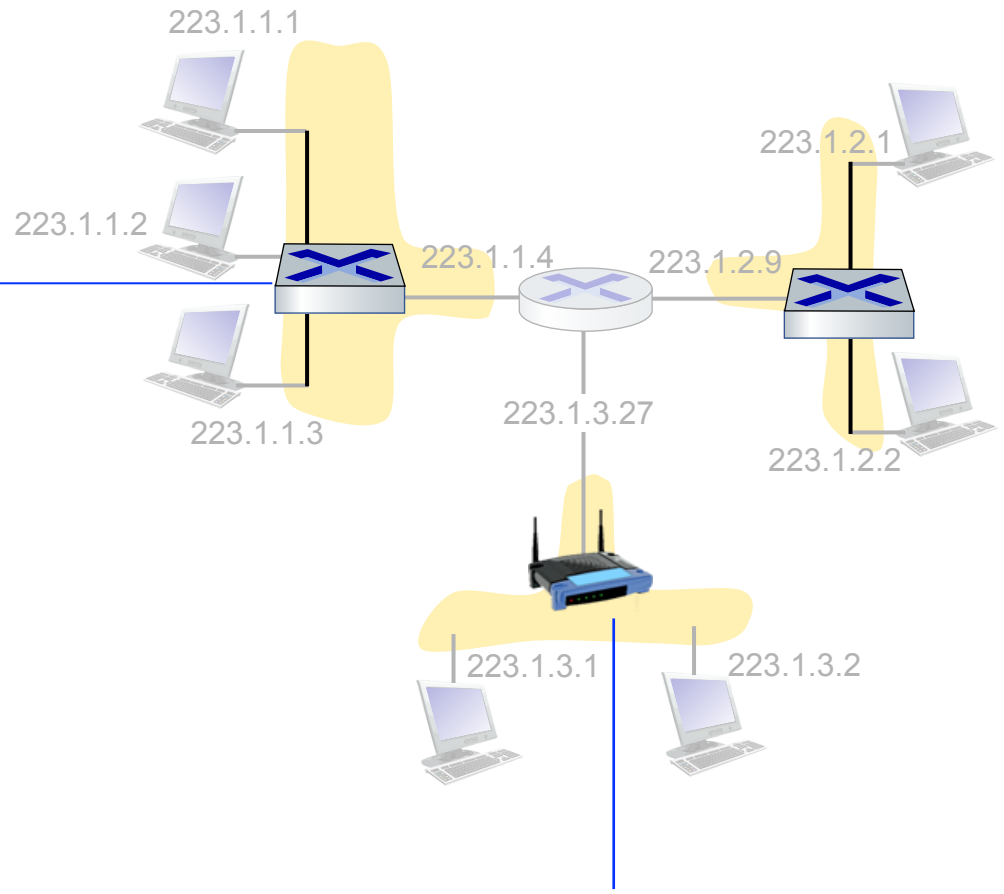
Network interface: *device within a host/router that connects with physical link*

- router's typically have multiple interfaces
- host typically has one or two interfaces (e.g., wired Ethernet, wireless 802.11)
- each interface (*not necessarily the host*) is associated with a unique IP address

Primer on IP addressing

Q: How are interfaces actually connected?

wired interfaces are connected by **Ethernet switch**



wireless interfaces are connected by **WiFi base station**

Local area networks (LANs) are broadcast medium governed by link layer protocols such as Ethernet and WiFi (*we will learn about those in lectures 20-23*).

Our current focus is on **wide area networking (WAN)** i.e., end to end routing of IP packets

Primer on IP addressing

What is a subnet?

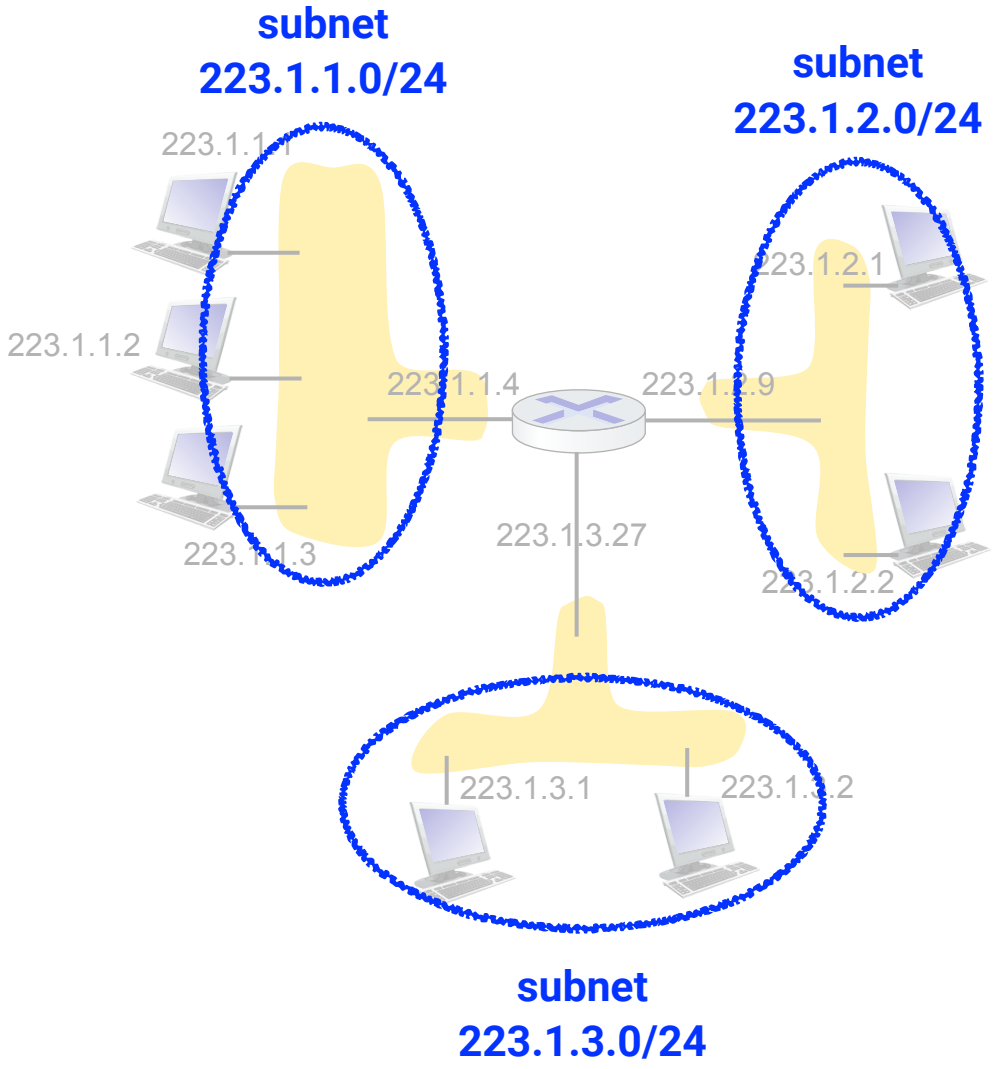
a logical/administrative subdivision of an IP network, where network devices can reach each other without passing through an intervening router

IP address has two parts to it:

all devices in a given subnet will have same high order bits. This is referred to as **subnet mask** (denoted by **/x** notation)

all devices in a given subnet will have unique host part

this network consists of 3 subnets



Reserved IP addresses

Address block	Range of addresses	Scope	Description
0.0.0.0/32	0.0.0.0	within a subnet	placeholder source address until the host learns its assigned address
10.0.0.0/8	10.0.0.0 to 10.255.255.255.255	within a private network	local in-network communications
127.0.0.0/8	127.0.0.0 to 127.255.255.255.255	within a host	loopback addresses
192.168.0.0/16	192.168.0.0 to 192.168.255.255	within a private network	local in-network communications
255.255.255.255/32	255.255.255.255	within a subnet	broadcast to all hosts

IP Address: how to get one?

That's actually two questions:

1. How does a network get its set of IP address (i.e., the subnet part of address)?
2. How does a host get IP address within its network (host part of address)?

Organization and ISPs get address blocks

- Internet Corporation for Assigned Names and Numbers (ICANN)

There are two ways for a host to get its address

- hard-coded by network administrator in config file (e.g., /etc/rc.config in UNIX)
- dynamically allocated from a pool of available addresses (via DHCP)

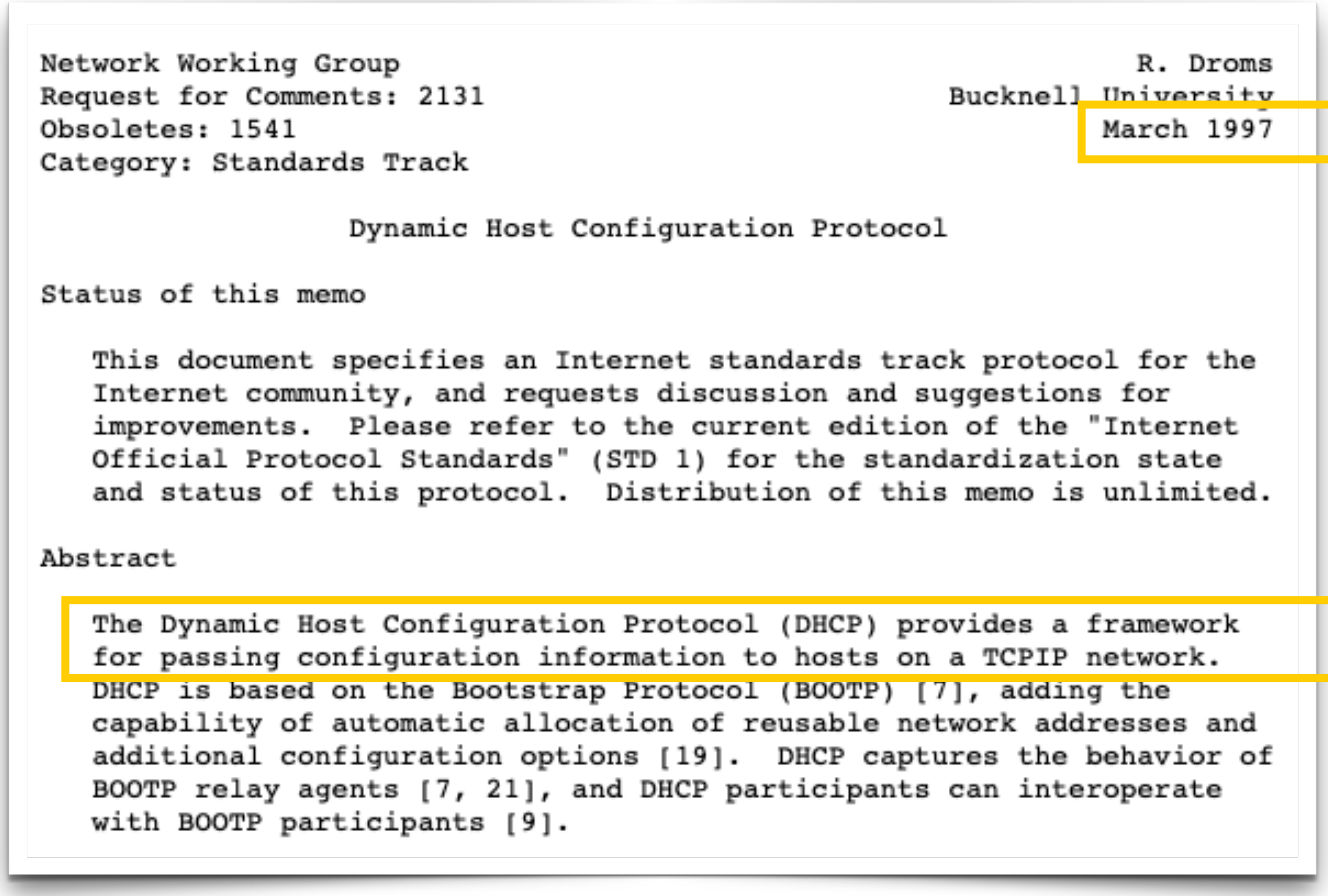
DHCP

(or how my device got its address)

Dynamic Host Configuration Protocol (DHCP)

Goals

- enable hosts to dynamically obtain IP address upon join a network
- zero-configuration network management: allow address reuse, enable user mobility, handle lease renewals etc
- share information about network configuration: network mask, first-hop router, and DNS server



Network Working Group
Request for Comments: 2131
Obsoletes: 1541
Category: Standards Track

R. Droms
Bucknell University
March 1997

Dynamic Host Configuration Protocol

Status of this memo

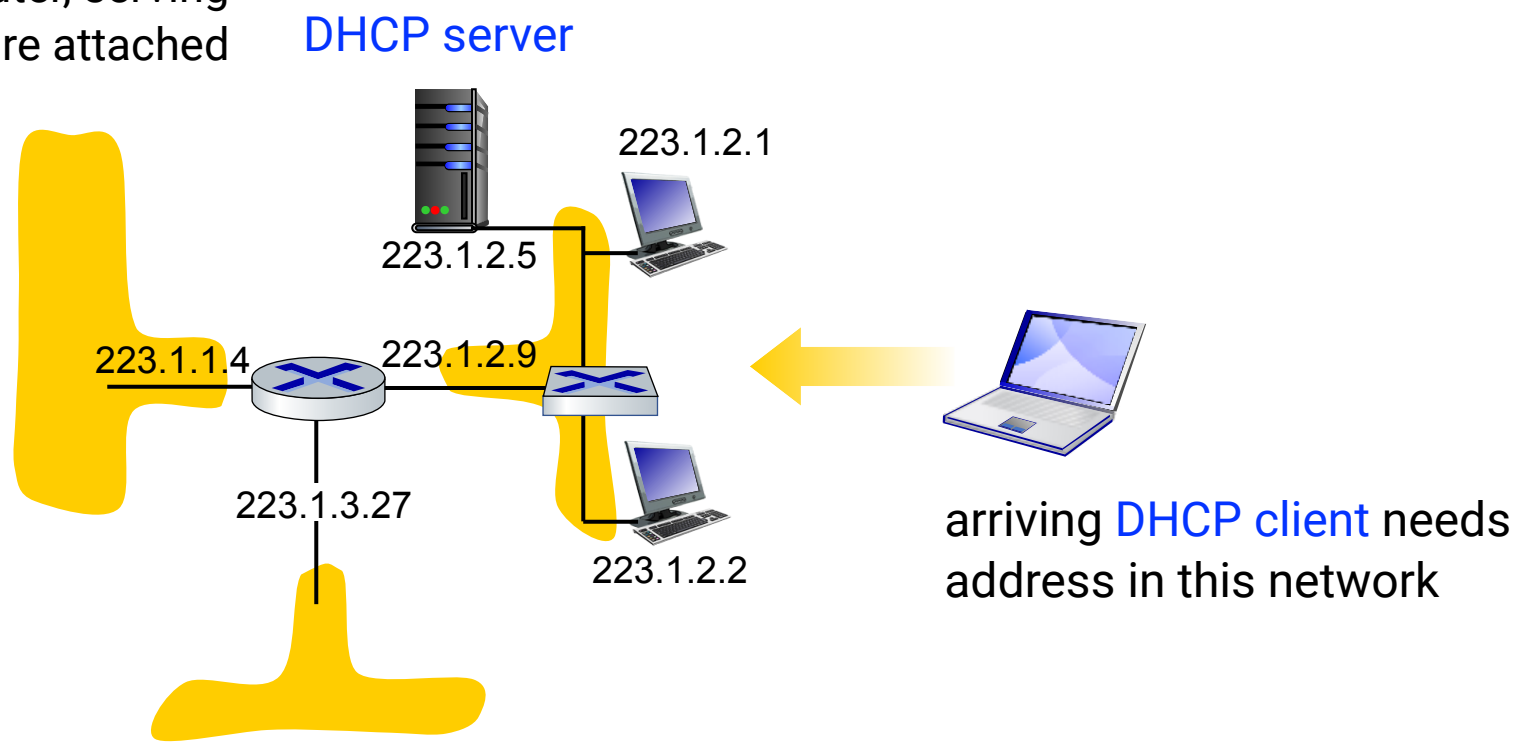
This document specifies an Internet standards track protocol for the Internet community, and requests discussion and suggestions for improvements. Please refer to the current edition of the "Internet Official Protocol Standards" (STD 1) for the standardization state and status of this protocol. Distribution of this memo is unlimited.

Abstract

The Dynamic Host Configuration Protocol (DHCP) provides a framework for passing configuration information to hosts on a TCPIP network. DHCP is based on the Bootstrap Protocol (BOOTP) [7], adding the capability of automatic allocation of reusable network addresses and additional configuration options [19]. DHCP captures the behavior of BOOTP relay agents [7, 21], and DHCP participants can interoperate with BOOTP participants [9].

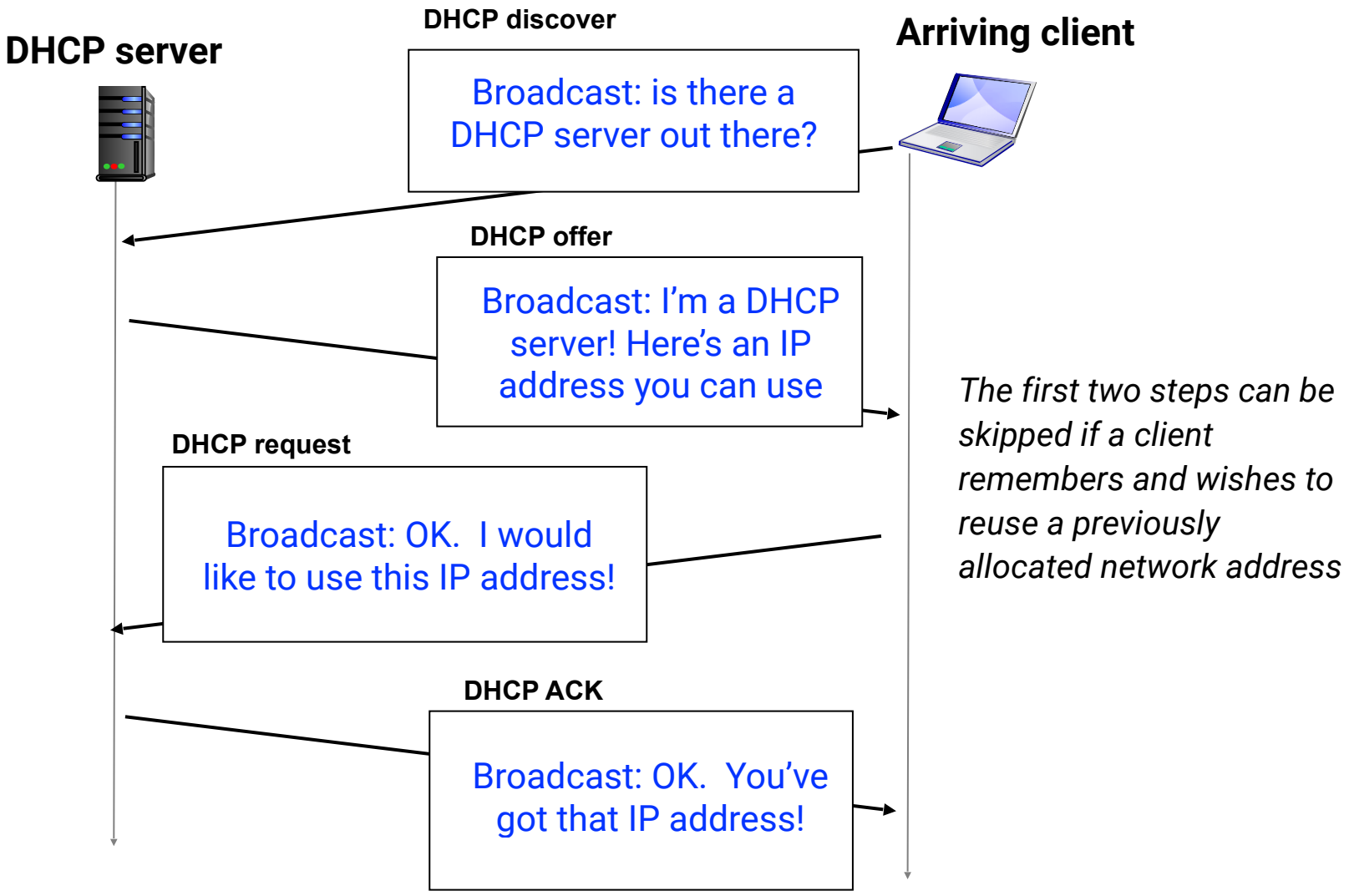
DHCP is an Application Protocol

DHCP server could be standalone or co-located in a switch/router, serving all subnets to which they are attached



arriving DHCP client needs address in this network

DHCP client-server interaction

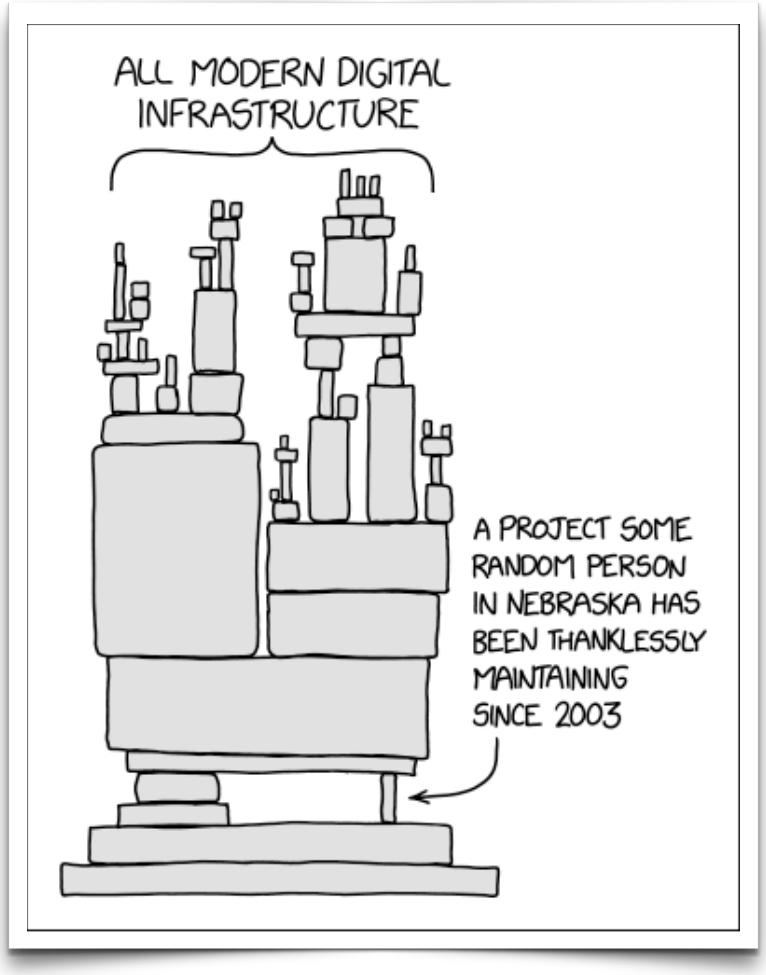


The first two steps can be skipped if a client remembers and wishes to reuse a previously allocated network address

ICANN

(or how my network got its block of addresses)

Internet Assigned Numbers Authority (IANA)



Courtesy: https://xkcd.com/2347/

Jon Postel

- the one man IANA from 1970 - 1997
- oversaw all IP address allocations and name mappings (as a hobby)
- creator of DNS (and co-authored 200+ RFCs)
- So, in early days of the Internet, a DNS lookup just meant reading the Internet mapping file on Jon's machine!

Transition

in 1998, the US Department of Commerce created ICANN to take over this responsibility

Internet Corporation for Assigned Names and Numbers

- allocates IP address blocks to 5 global registries, who may then sub-allocate to national and local registries.
- manages DNS root zone, including delegation of individual TLD (.com, .edu, etc)
- ISPs and organization procure IP address blocks from their regional/local registries (for a fee)

Service Category	Fee	IPv4 Block Size	IPv6 Block Size
3X-Small*	$250	/24 or smaller	/40 or smaller
2X-Small	$500	Larger than /24, up to and including /22	Larger than /40, up to and including /36
X-Small	$1,000	Larger than /22, up to and including /20	Larger than /36, up to and including /32
Small	$2,000	Larger than /20, up to and including /18	Larger than /32, up to and including /28
Medium	$4,000	Larger than /18, up to and including /16	Larger than /28, up to and including /24
Large	$8,000	Larger than /16, up to and including /14	Larger than /24, up to and including /20
X-Large	$16,000	Larger than /14, up to and including /12	Larger than /20, up to and including /16
2X-Large	$32,000	Larger than /12, up to and including /10	Larger than /16, up to and including /12
3X-Large	$64,000	Larger than /10, up to and including /8	Larger than /12, up to and including /8
4X-Large	$128,000	Larger than /8, up to and including /6	Larger than /8, up to and including /4
5X-Large	$256,000	Larger than /6	Larger than /4

Address allocation: an ISP example

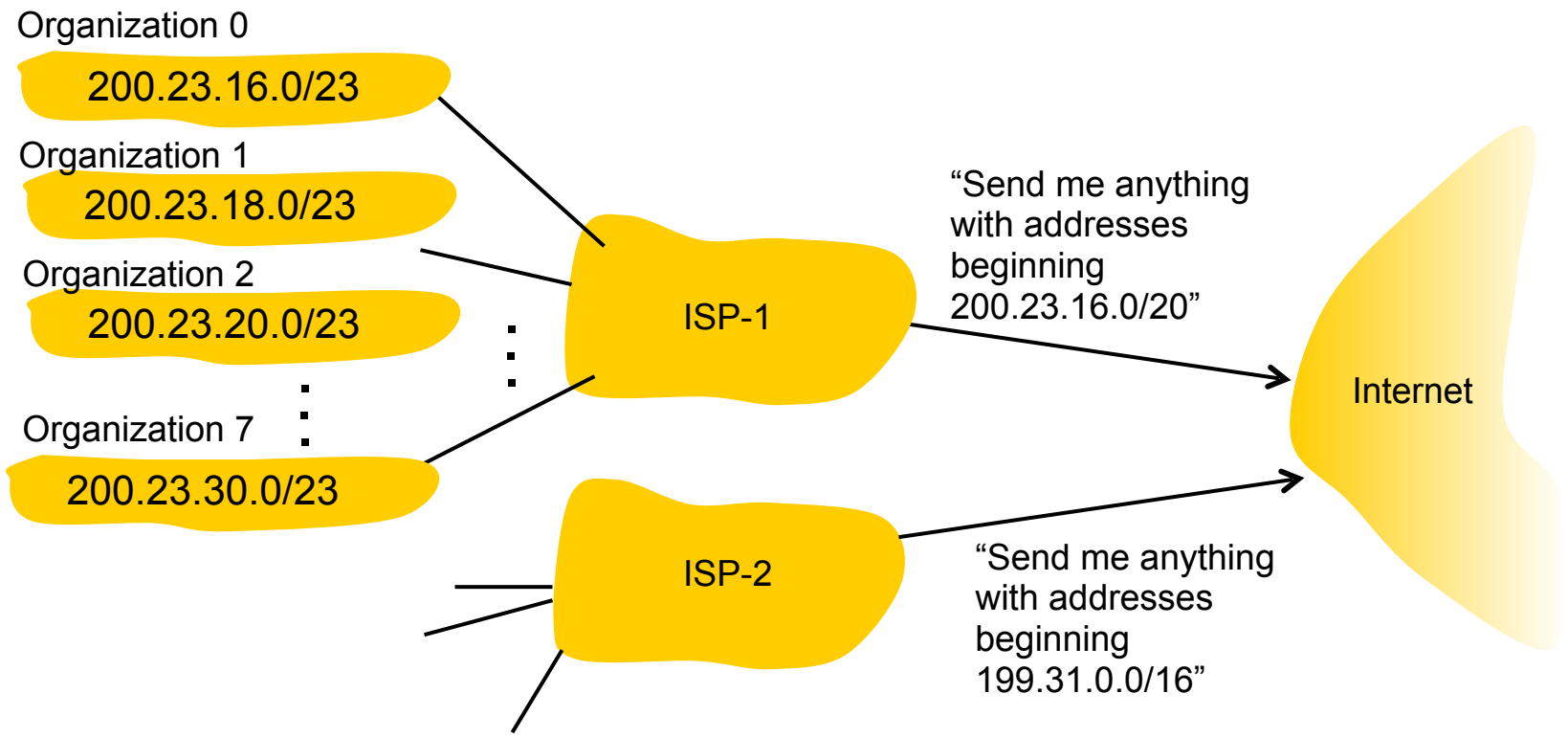
ISP's block	11001000 00010111 00010000 00000000	200.23.16.0/20

ISP can then allocate out its address space in 8 blocks:

Organization-0	11001000 00010111 00010000 00000000	200.23.16.0/23
Organization-1	11001000 00010111 00010010 00000000	200.23.18.0/23
Organization-2	11001000 00010111 00010100 00000000	200.23.20.0/23
...	....	
Organization-7	11001000 00010111 00011110 00000000	200.23.30.0/23

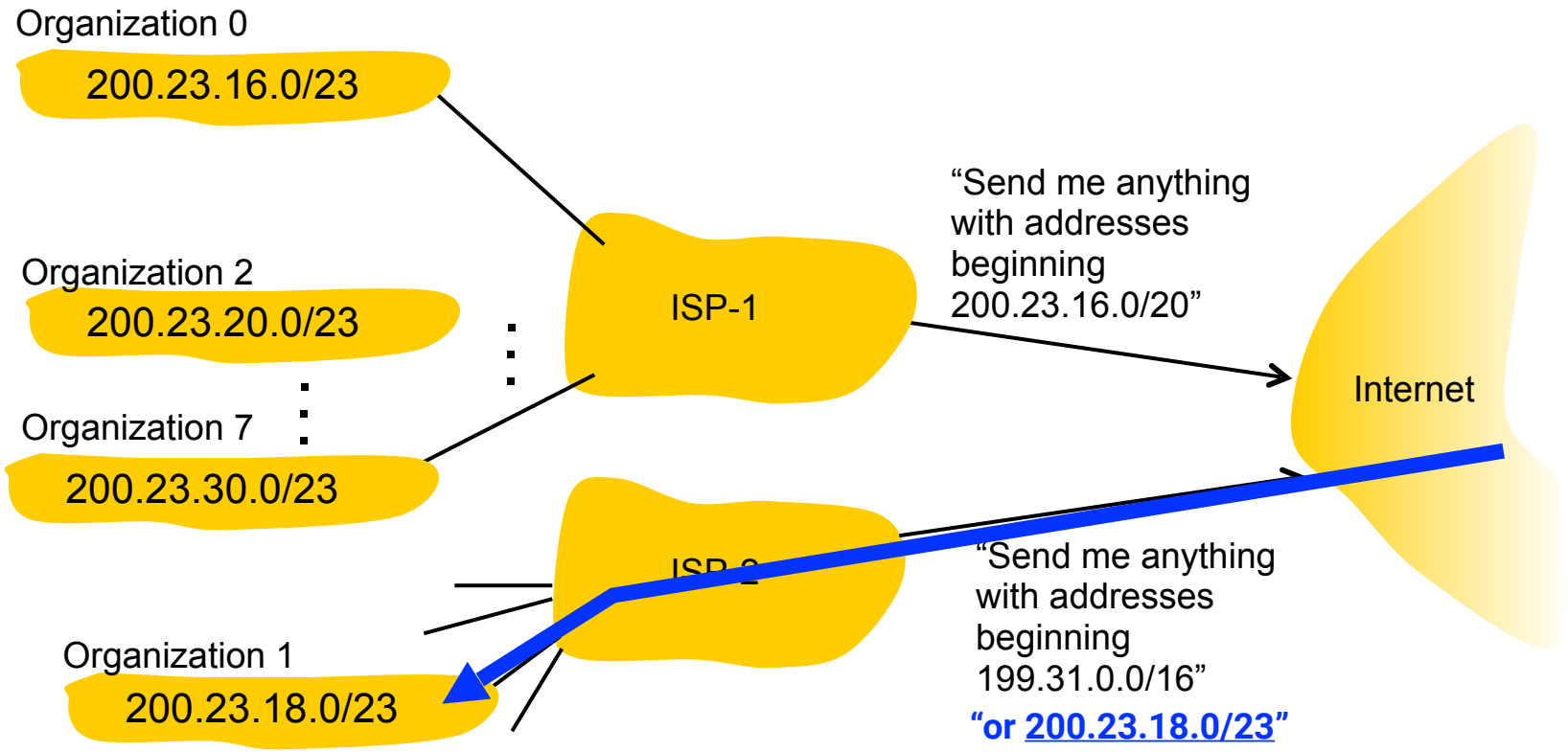
Hierarchical Addressing: Route Aggregation

hierarchical addressing allows efficient advertisement of routing information



Hierarchical addressing: more specific routes

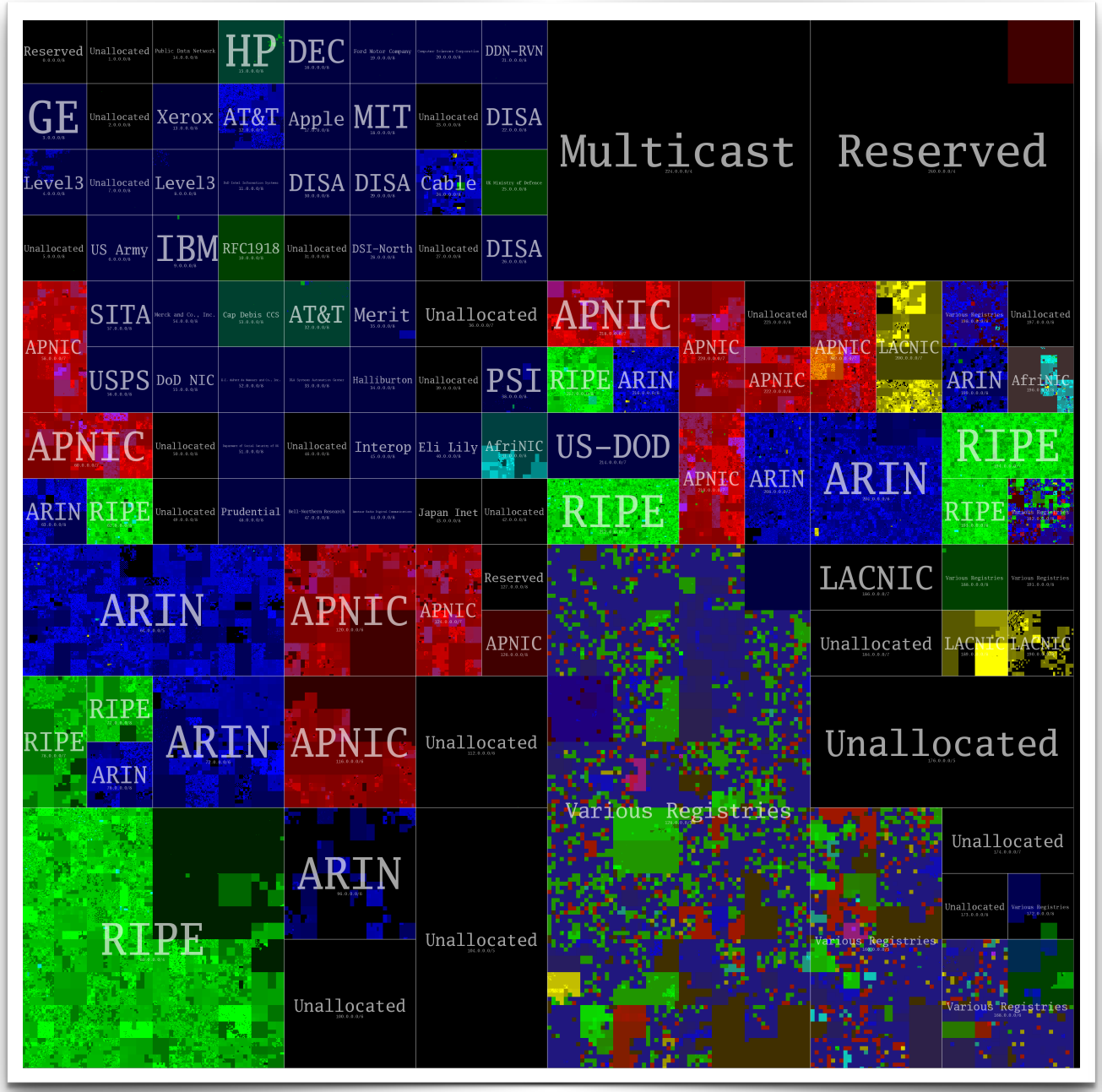
- Organization 1 moves from ISP-1 to ISP-2, taking its block of addresses
- ISP-2 begins to advertise a more specific route to Organization 1; however, ISP-1 continues to advertise for its original /20 block



IPv4 address allocations

ICANN allocated the last chunk of IPv4 addresses in 2011

Does this mean no new host could join the Internet after 2011?



RIRs IPv4 Whois Map

October 2007

/8 /16 /24 /32

AFRINIC

APNIC

ARIN

LACNIC

RIPE

This map shows the characteristics of IPv4 "whois" data from the Regional Internet Registries.

Each pixel in the full-size image represents a single /24 network containing up to 256 hosts. The color of each pixel corresponds to the RIR(s) where the address space is listed.

Areas are shaded with varying levels of transparency. Larger blocks of address space are more transparent, which also makes them darker. Thus, varying shades of a color indicate different-sized blocks of addresses appearing in the whois data.

Courtesy: https://www.caida.org/research/id-consumption/whois-map/

Spot Quiz (ICON)