

CS3640

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# Network Layer (2): The Internet Protocol

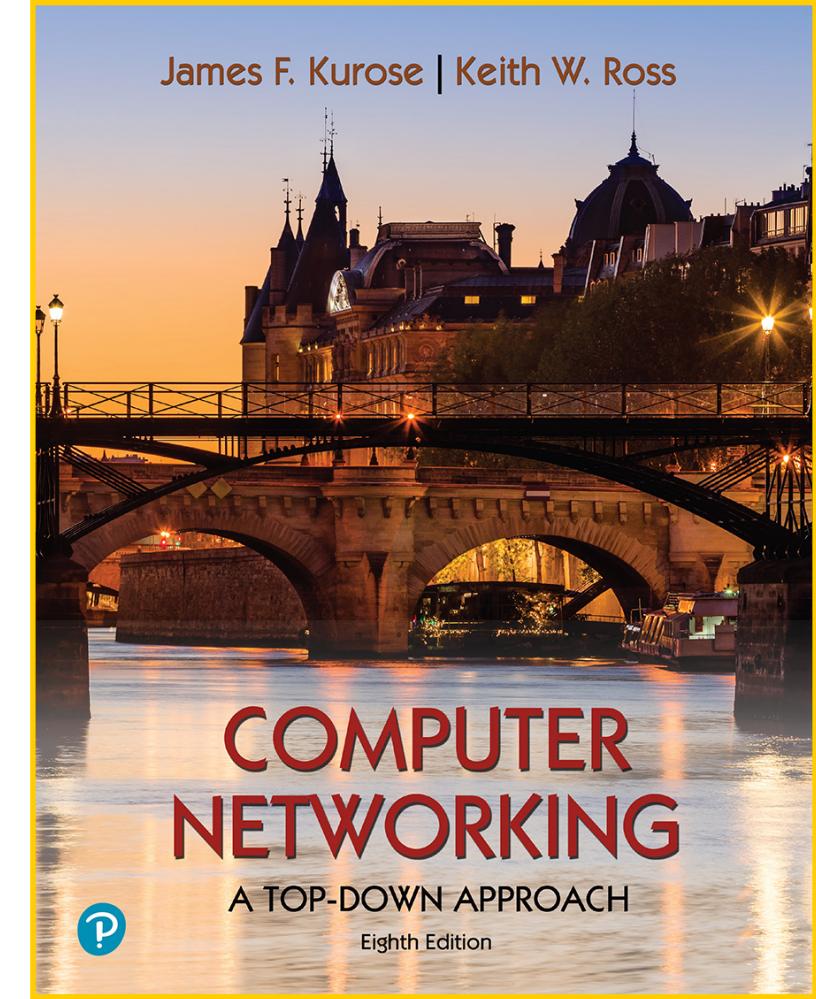
**Prof. Supreeth Shastri**  
*Computer Science*  
*The University of Iowa*

# Lecture goals

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

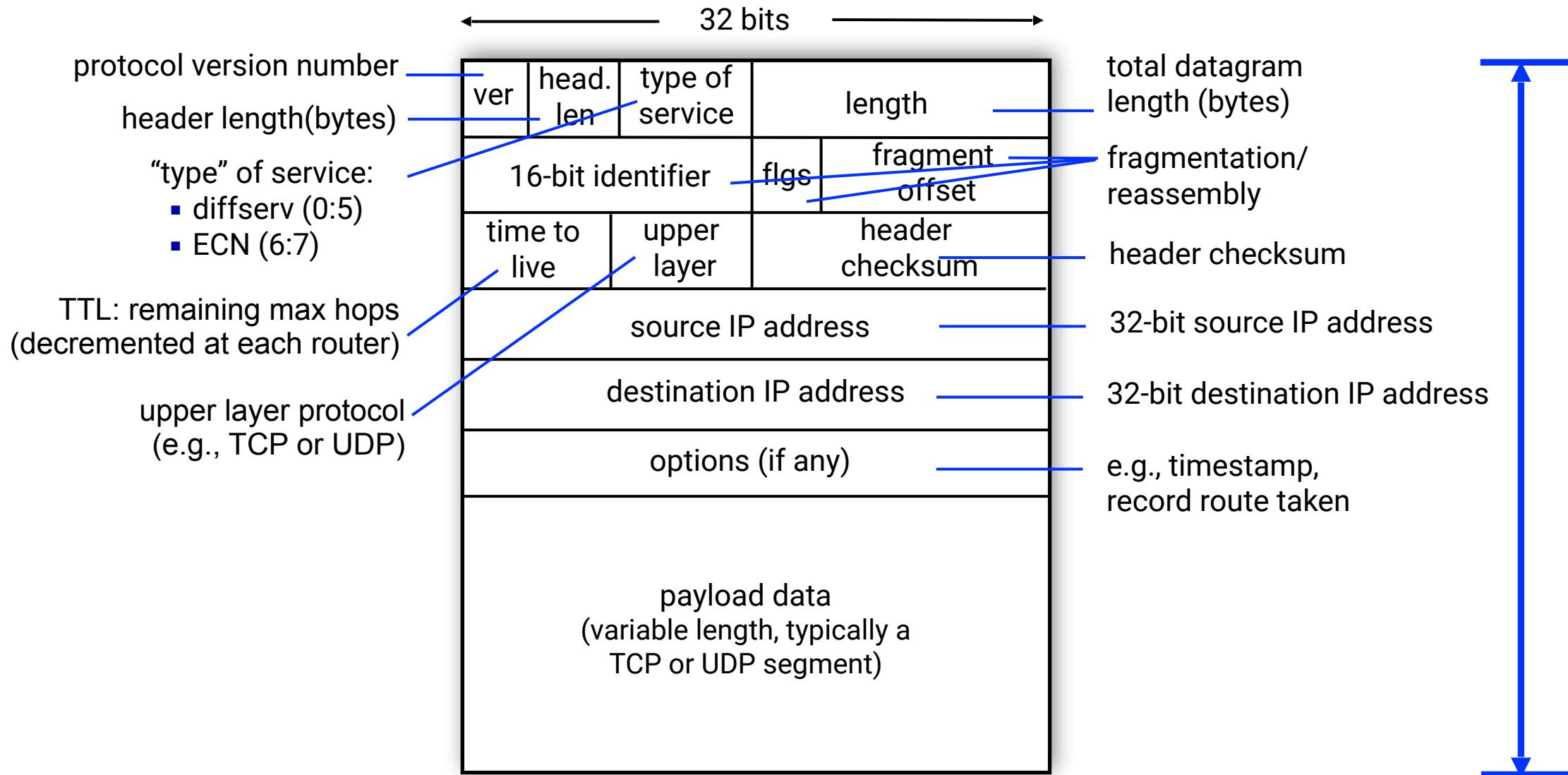
- IPv4 format and addressing
- Address management via DHCP
- NAT and Middleboxes
- IPv6



Chapters 4.3, 4.5

# IP Datagram format

Maximum length: 64Kb  
Typically: ~1500 bytes

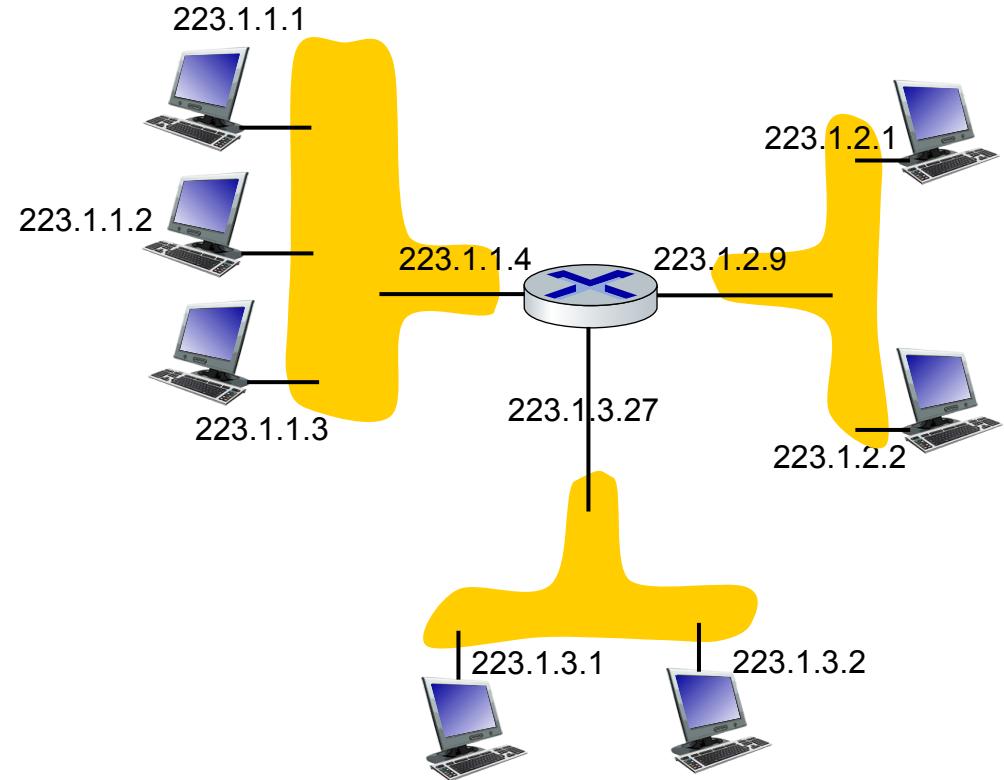


# Primer on IP addressing

**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  
                \u2014        \u2014        \u2014        \u2014  
            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

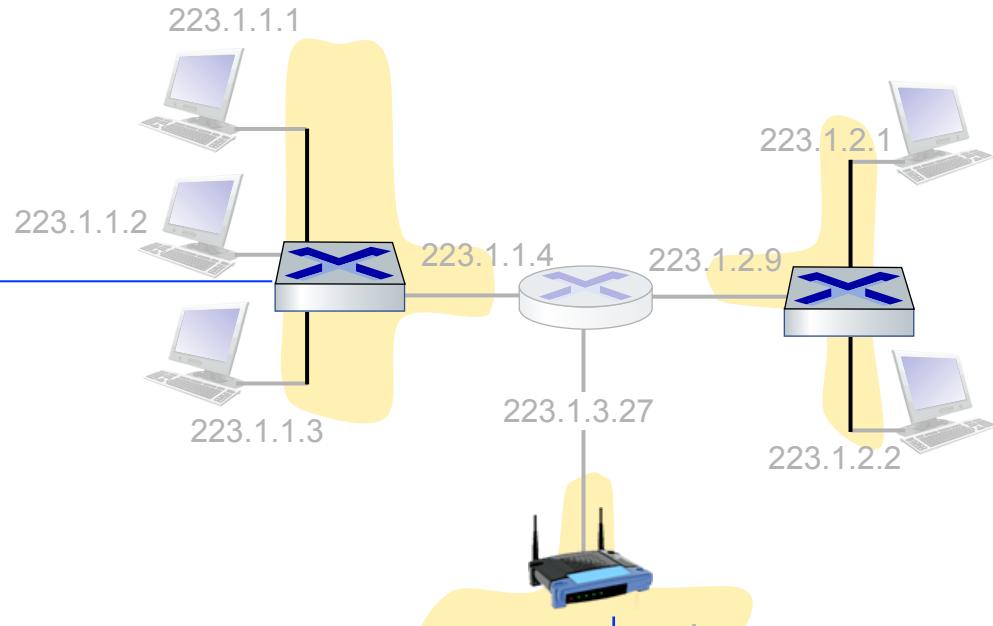
# Primer on IP addressing

Q: How are interfaces actually connected?

wired  
interfaces are  
connected by  
**Ethernet switch**

**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



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

# 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

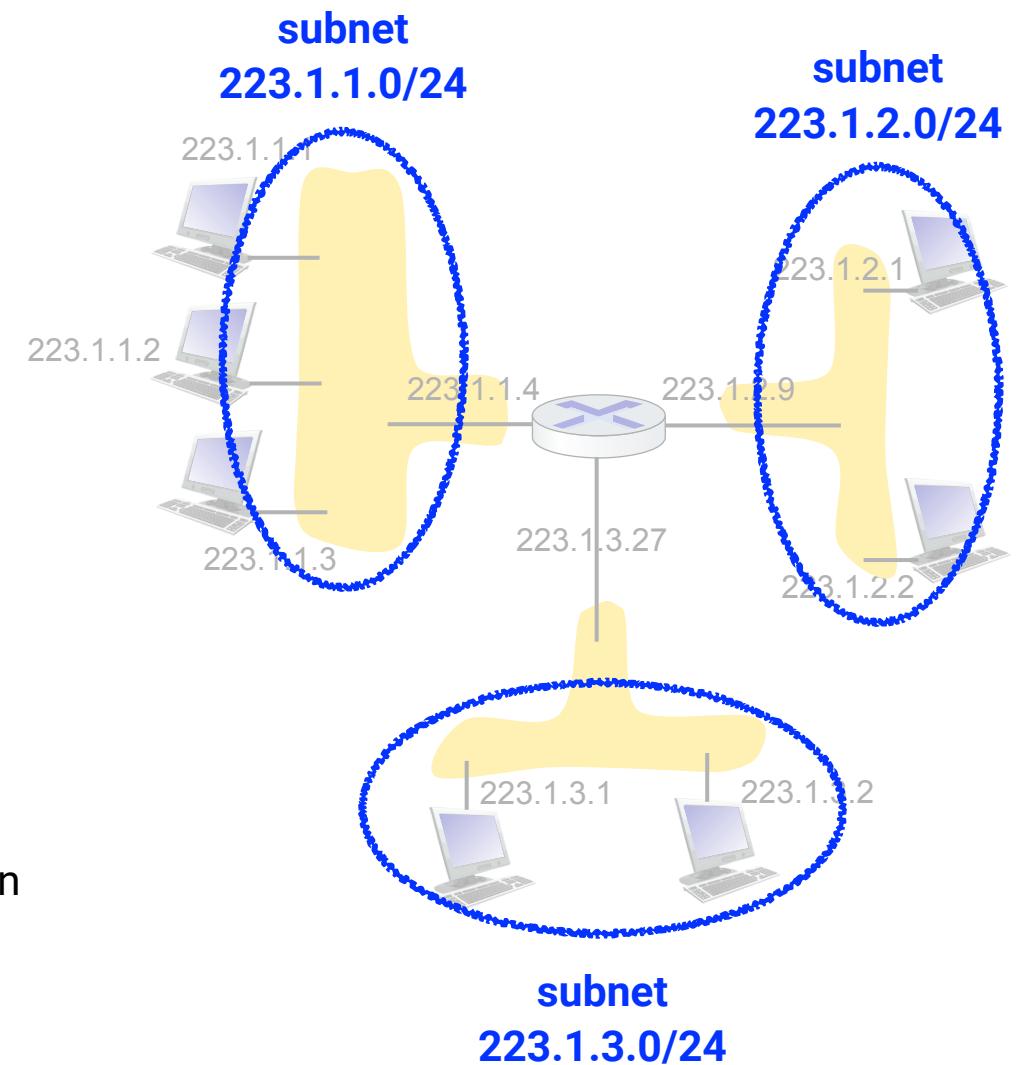
IP address has two parts to it:



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     | within a private network | local in-network communications                                       |
| 127.0.0.0/8        | 127.0.0.0 to 127.255.255.255   | 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

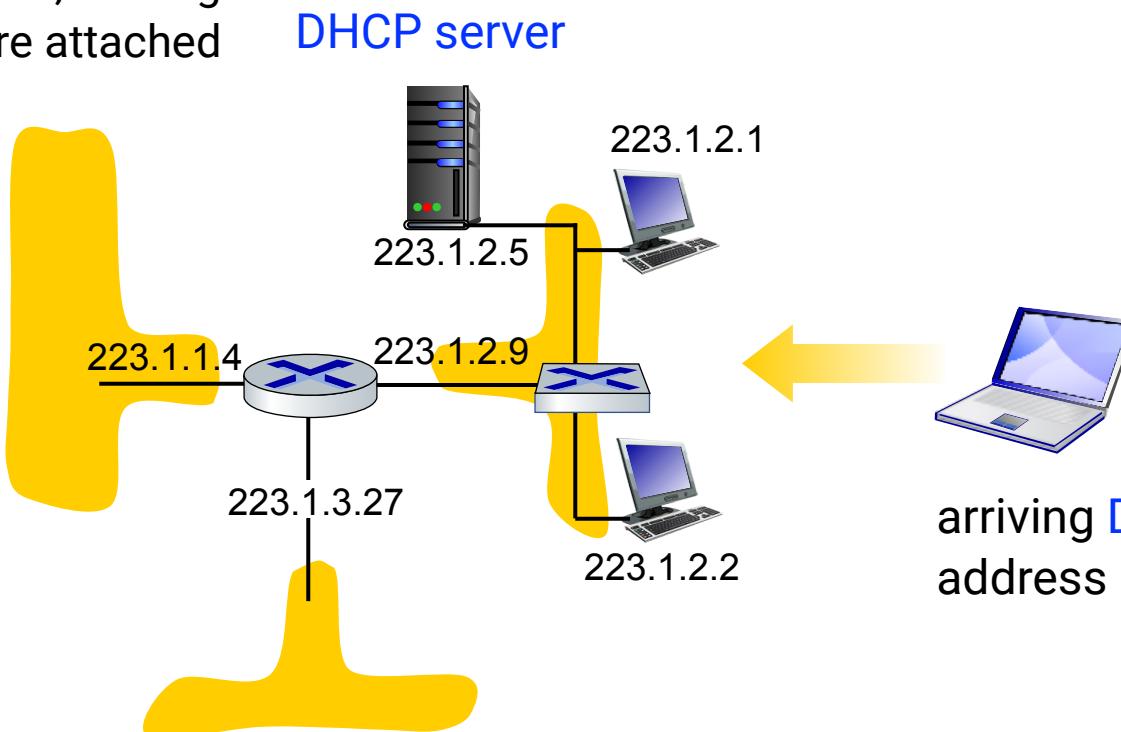
This document specifies an Internet standards track protocol for the Internet community, and requests discussion and suggestions for improvements. Please refer to the current edition of the "Internet Official Protocol Standards" (STD 1) for the standardization state and status of this protocol. Distribution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

Abstract

The Dynamic Host Configuration Protocol (DHCP) provides a framework for passing configuration information to hosts on a TCP/IP 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].

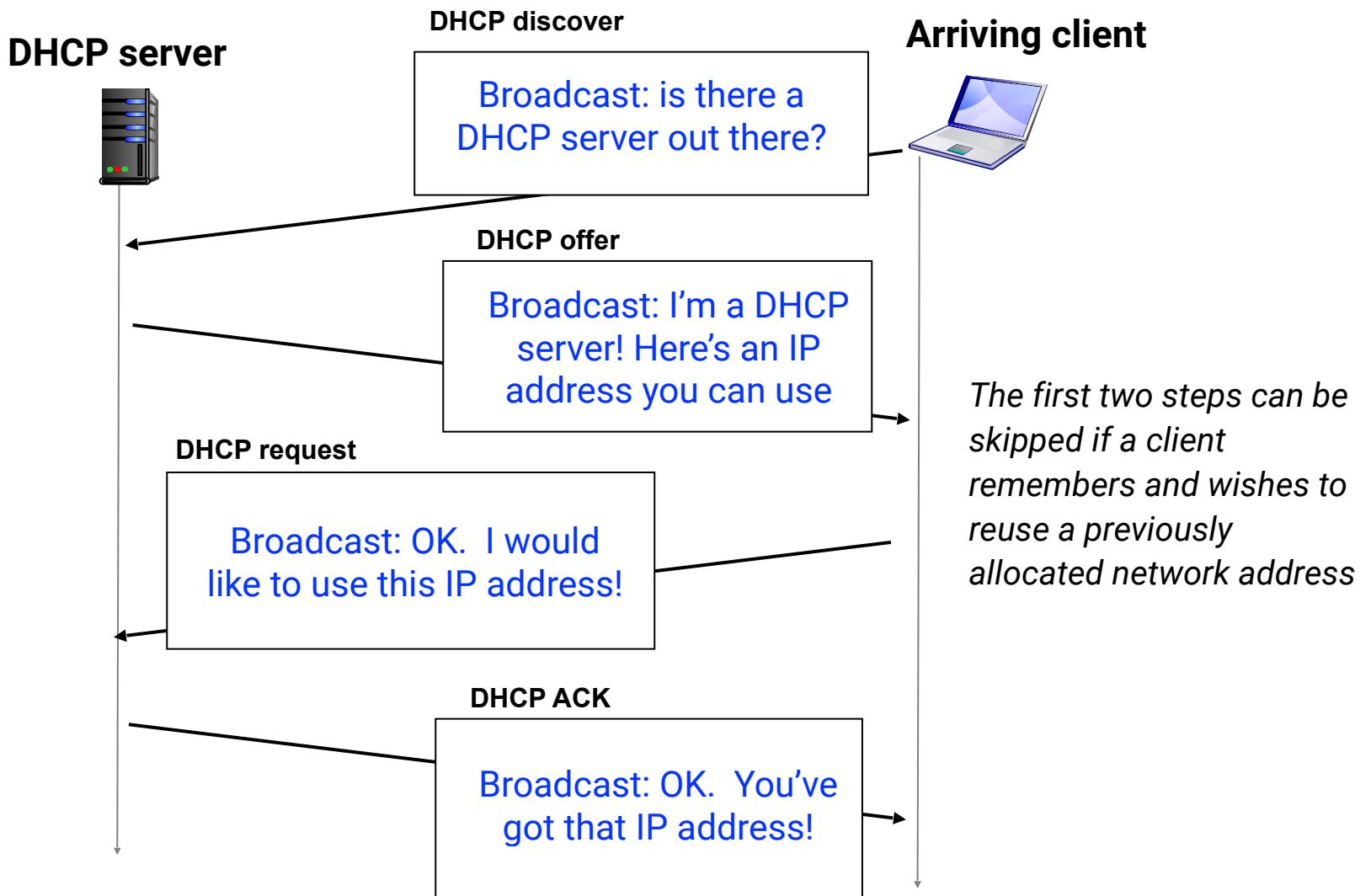
# DHCP is an Application Protocol

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

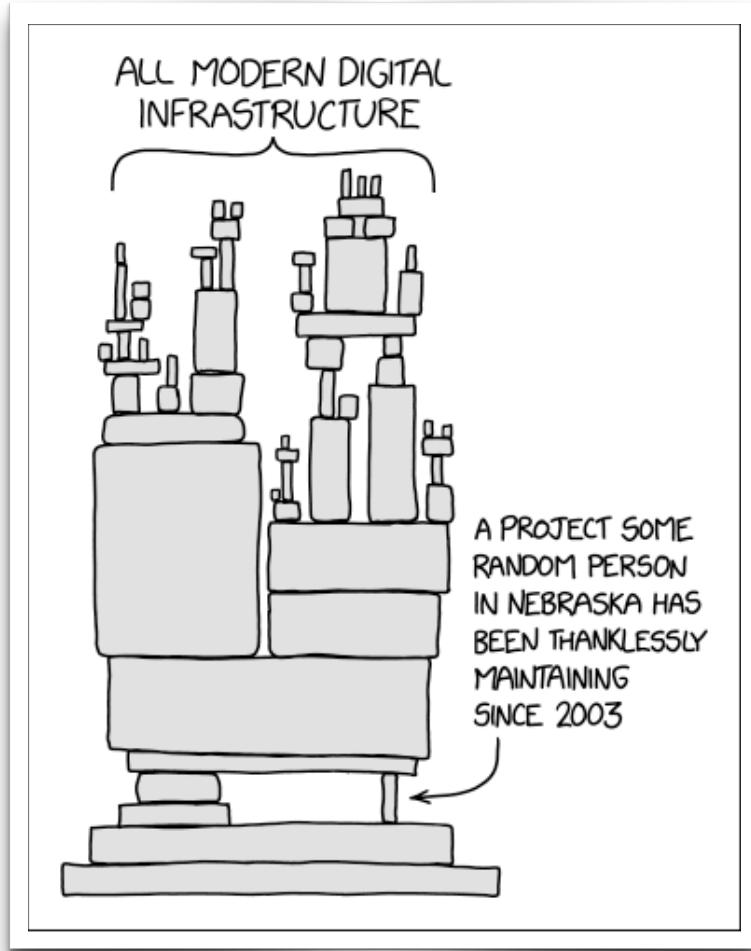




**ICANN**

*(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



**ICANN**

# 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 <u>00010000</u> 00000000 200.23.16.0/20 |
|-------------|---|

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

|                |   |
|----------------|---|
| Organization-0 | 11001000 00010111 <u>00010000</u> 00000000 200.23.16.0/23 |
|----------------|---|

|                |   |
|----------------|---|
| Organization-1 | 11001000 00010111 <u>00010010</u> 00000000 200.23.18.0/23 |
|----------------|---|

|                |   |
|----------------|---|
| Organization-2 | 11001000 00010111 <u>00010100</u> 00000000 200.23.20.0/23 |
|----------------|---|

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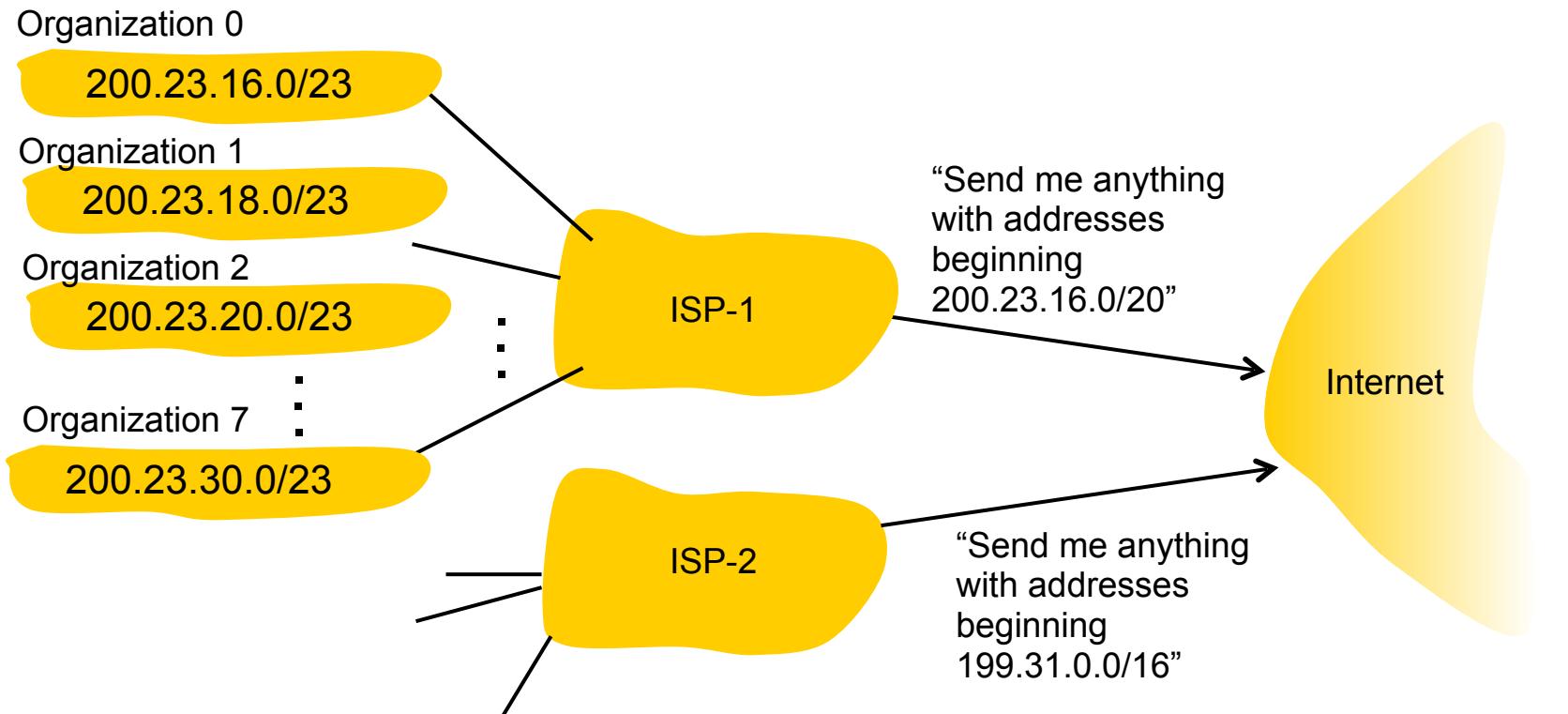
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|                |   |
|----------------|---|
| Organization-7 | 11001000 00010111 <u>00011110</u> 00000000 200.23.30.0/23 |
|----------------|---|

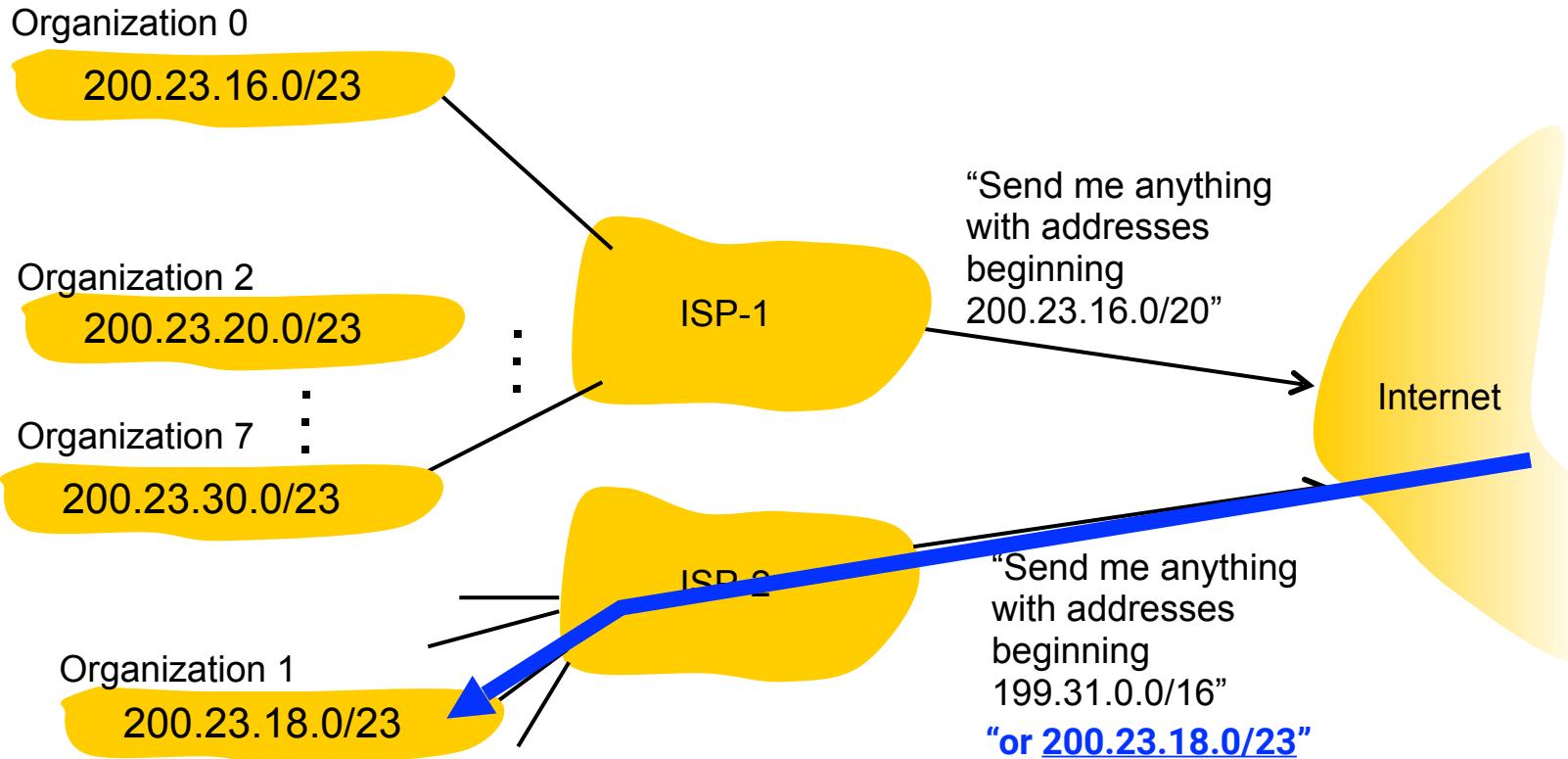
# Hierarchical Addressing: Route Aggregation

hierarchical addressing allows efficient advertisement of routing information



# Hierarchical addressing: more specific routes

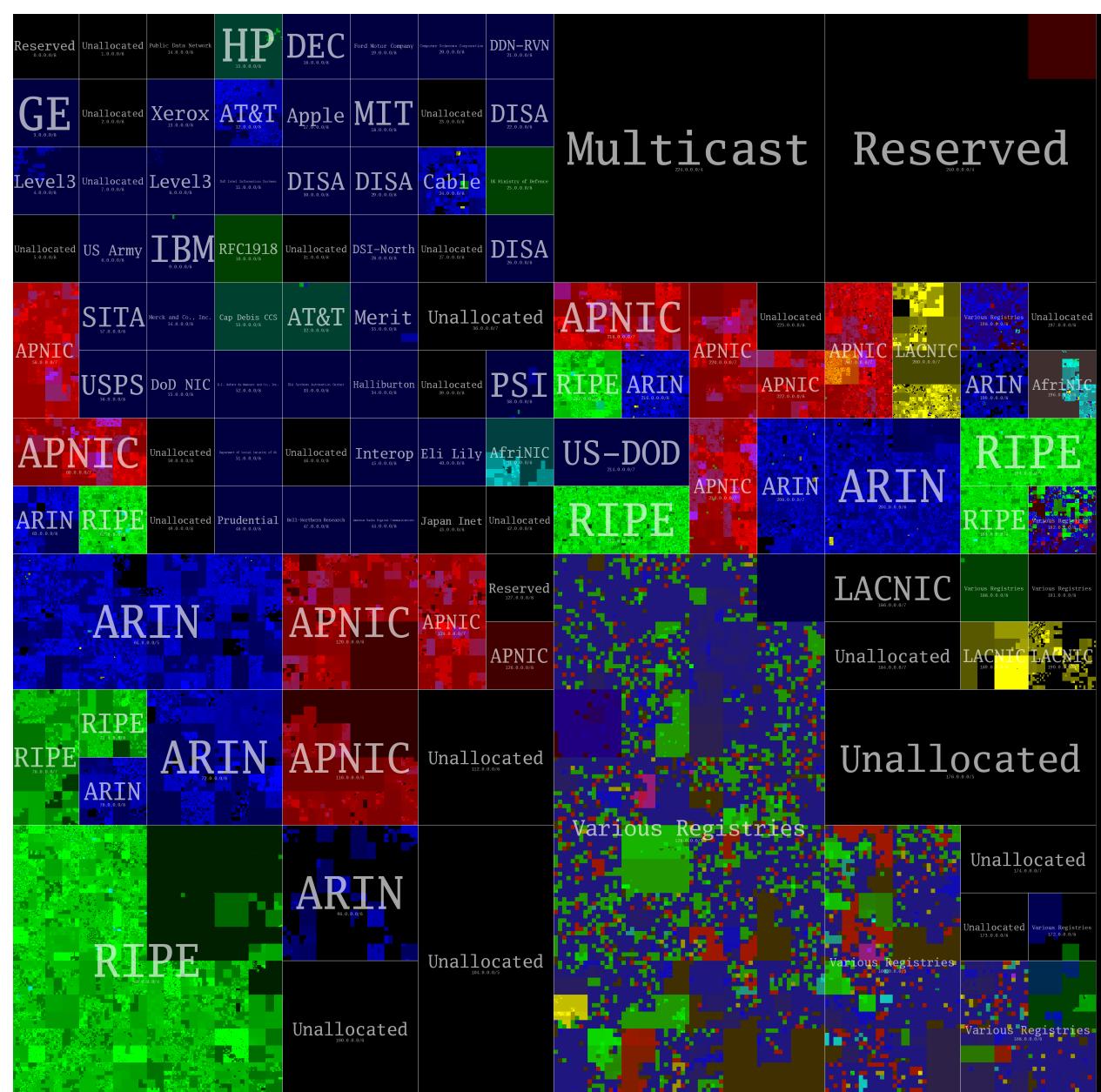
- Organization 1 moves from ISP-1 to ISP-2, taking its block of addresses
- ISP-2 begins to advertise a more specific route to Organization 1; however, ISP-1 continues to advertise for its original /20 block



# 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?*



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

# **Spot Quiz (ICON)**