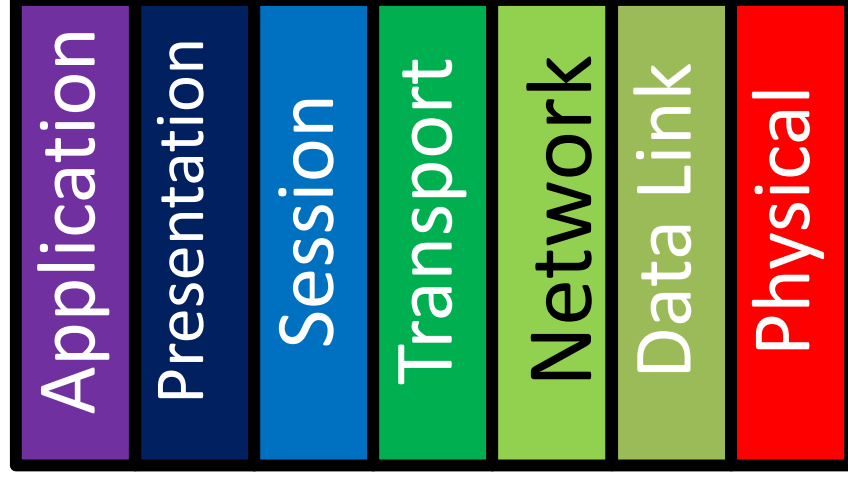# Network Layer

Network Layer

- Two key function:
  - Set up routes (control plane)
  - Forward the packets (data plane)

- In networking layer, we will cover
  - Addressing
  - Forwarding
  - Routing

| Application |
| Presentation |
| Session |
| Transport |
| Network |
| Data Link |
| Physical |

Two key network-layer functions

network-layer functions:

- *forwarding:* move packets from router's input to appropriate router output

- *routing:* determine route taken by packets from source to destination

  – *routing algorithms*

analogy: taking a trip

- *forwarding:* process of getting through single interchange

- *routing:* process of planning trip from source to destination

But first, addressing

Internet Hierarchy

- Internet organized as a three level hierarchy
- First level – autonomous systems (AS's)
  - AS – region of network under a single administrative domain Examples: Comcast, AT&T, Verizon, Sprint, etc.
  - inter-domain routing protocols; Border Gateway Routing (BGP)
- Second level – Within the AS
  - Distance Vector, e.g., Routing Information Protocol (RIP)
  - Link State, e.g., Open Shortest Path First (OSPF)
- Third Level- Local area networks (LANs)
  - Routing at Link layer.

How to represent source and destination addresses?

- What properties do we want?

  – Unique

  – Easy to search

  – Need to mesh with the Internet hierarchy

  – Doesn't necessarily have to be easy to remember

Hierarchical addresses

- The address is divided into two parts: the network part and the host part.

  - The packet is forwarded to the corresponding network

  - Once the packet is within the network, it if forwarded based on the host address

  - Each network has hosts in in LAN; An AS has multiple networks with different IP addresses

IP Address

- Hierarchical, IPv4 uses 32 bit addresses

- "Dotted-Quad" notation

8 bits	8 bits	8 bits	8 bits

aaaaaaaabbbbbbbbcccccccccddddddd ⟷ A . B . C . D

000100010001111100000000000000001 ⟷

223.1.1.1 = 11011111 00000001 00000001 00000001

Class-based addressing

- Classes A, B, C
  - Class A: The first 8 bits used to address the network
  - Class B: The first 16 bits are used to address the network
  - Class C: The first 24 bits are used to address the network

- How many Class A addresses can you have?

- How many hosts can you have with a Class A address?
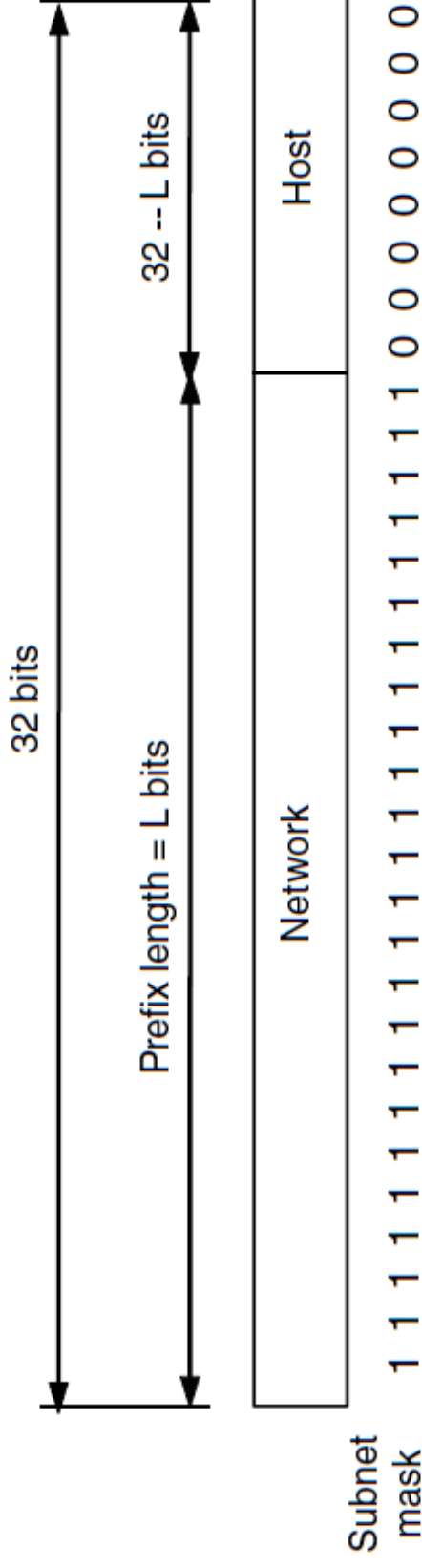
Example class A address

Network Address [A.xxx.xxx.xxx]

A.0.0.0

A.0.0.1 .... A.255.255.255

Hosts
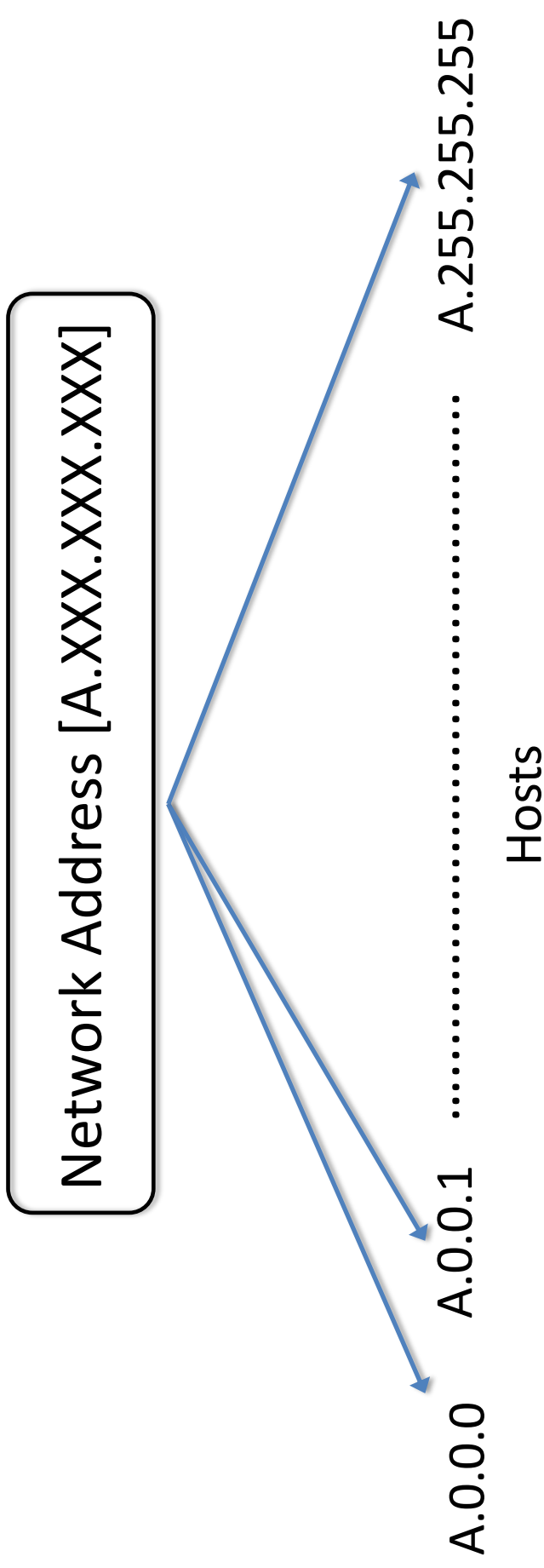
Classless addresses

Addresses are allocated in blocks called prefixes

— Prefix is determined by the network portion

— Has 2^L addresses aligned on 2^L boundary

32 bits

Prefix length = L bits

32 -- L bits

Network	Host

Subnet mask

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0

Classless Inter-Domain Routing (CIDR)

- Variable network and host address length.

  Subnet mask helps get the IP address

  18 bits for the network

  14 bits for the hosts
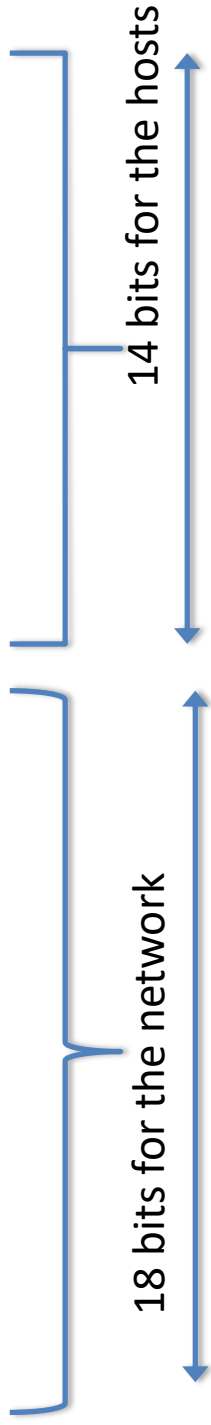
- Subnet mask = 11111111 11111111 11000000
 00000000 = 255.255.192.0

CIDR notation

- /XXX is the typically used notation to represent CIDR addresses

- "/26" (slash 26) means a network address of length 26.
  - What is the subnet mask?
  - How many hosts?

CIDR example

CIDR: Classless InterDomain Routing

- subnet portion of address of arbitrary length
- address format: a.b.c.d/x, where x is # bits in subnet portion of address

subnet
part

host
part

11001000 00010111 00010000 00000000
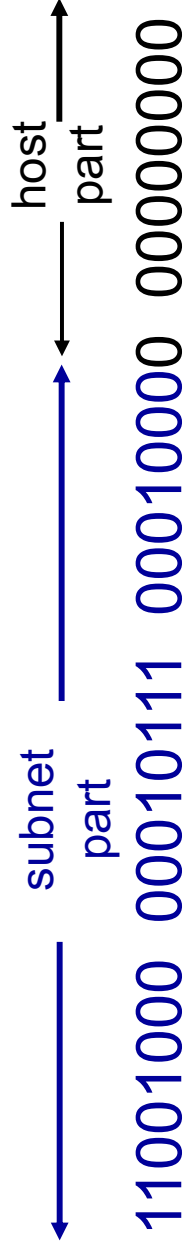
200.23.16.0/23

Subnet Mask Example

Network address **172.19**.0.0 with **/16 network mask**

Network	Network	Host	Host
172	19	0	0

If destination is 172.19.1.0, then apply the subnet mask using an AND to get the network part and the host part.

					Destination address
172	19	1	0		
11111111	11111111	00000000	00000000		/16 subnet mask

IP addresses: how is it allocated?

Q: how does *network* get subnet part of IP addr?

A: gets allocated portion of its provider ISP's address space.

Can be subdivided into more subnetworks.

ISP's block   11001000 00010111 00010000 00000000   200.23.16.0/20

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
    ...   .
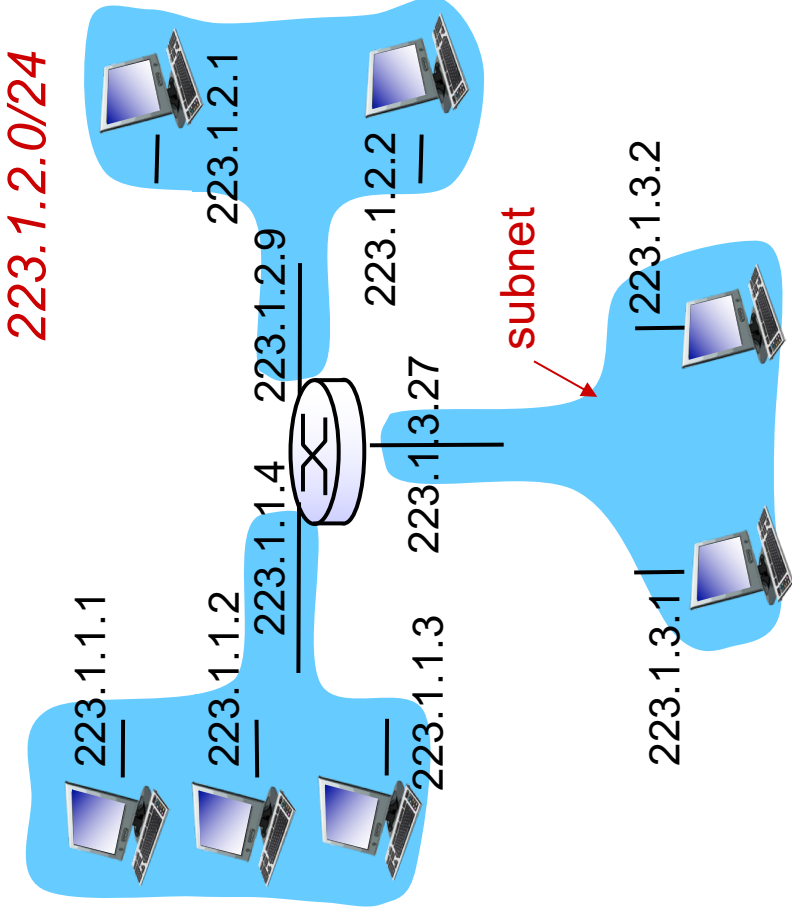Organization 7   11001000 00010111 00011110 00000000   200.23.30.0/23

IP addressing continued

Q: how does an ISP get block of addresses?

A: ICANN: Internet Corporation for Assigned Names and Numbers http://www.icann.org/

- allocates addresses
- manages DNS
- assigns domain names, resolves disputes

Subnetting

recipe

- to determine the subnets, detach each interface from its host or router, creating islands of isolated networks

- each isolated network is called a *subnet*

223.1.2.0/24

223.1.2.1

223.1.2.9

223.1.2.2

subnet

223.1.3.2

223.1.3.27

223.1.3.0/24

223.1.3.1

223.1.3.1

223.1.1.4

223.1.1.0/24

223.1.1.1

223.1.1.2

223.1.1.3

subnet mask: /24

# IP addresses: how do I get one?

Q: How does a *host* get IP address?

- hard-coded by system admin in a file
  – Windows: control-panel->network->configuration->tcp/ip->properties
  – UNIX: /etc/rc.config
- DHCP: Dynamic Host Configuration Protocol: dynamically get address from as server
  – "plug-and-play"

DHCP: more than IP addresses

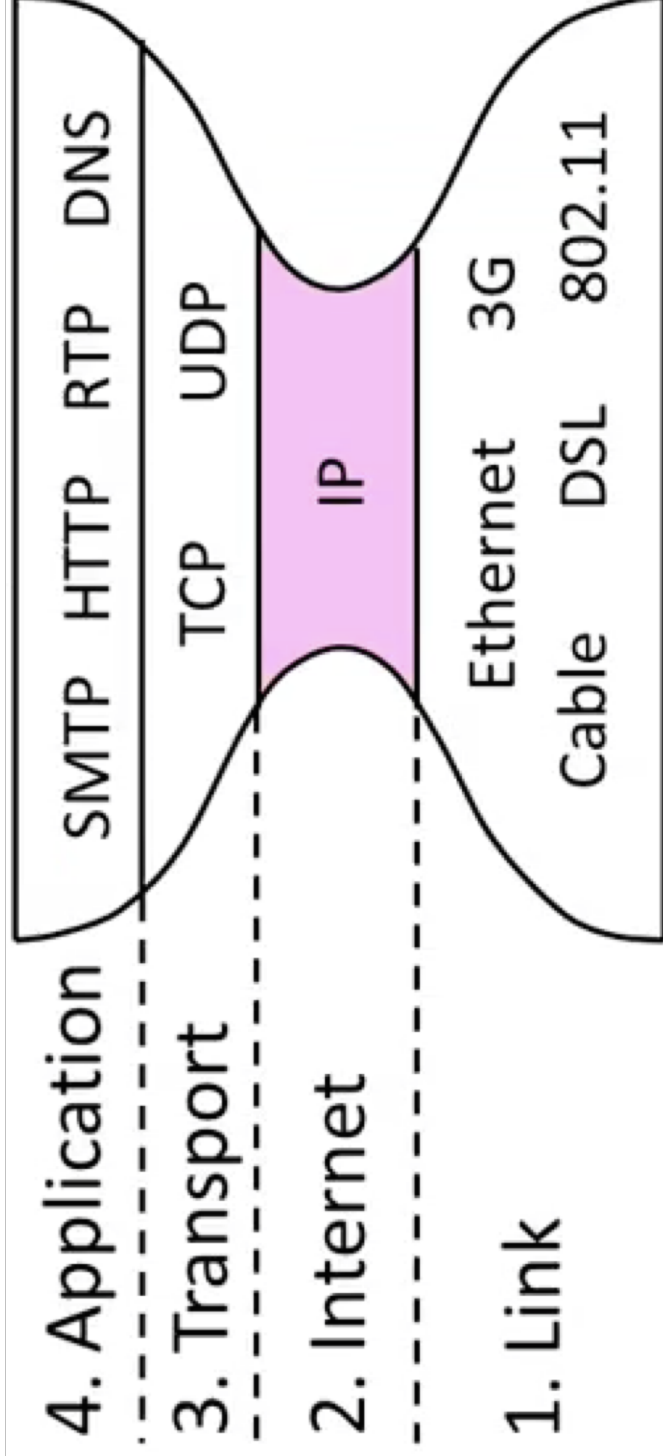DHCP can return more than just allocated IP address on subnet:

- address of first-hop router for client
- name and IP address of DNS sever
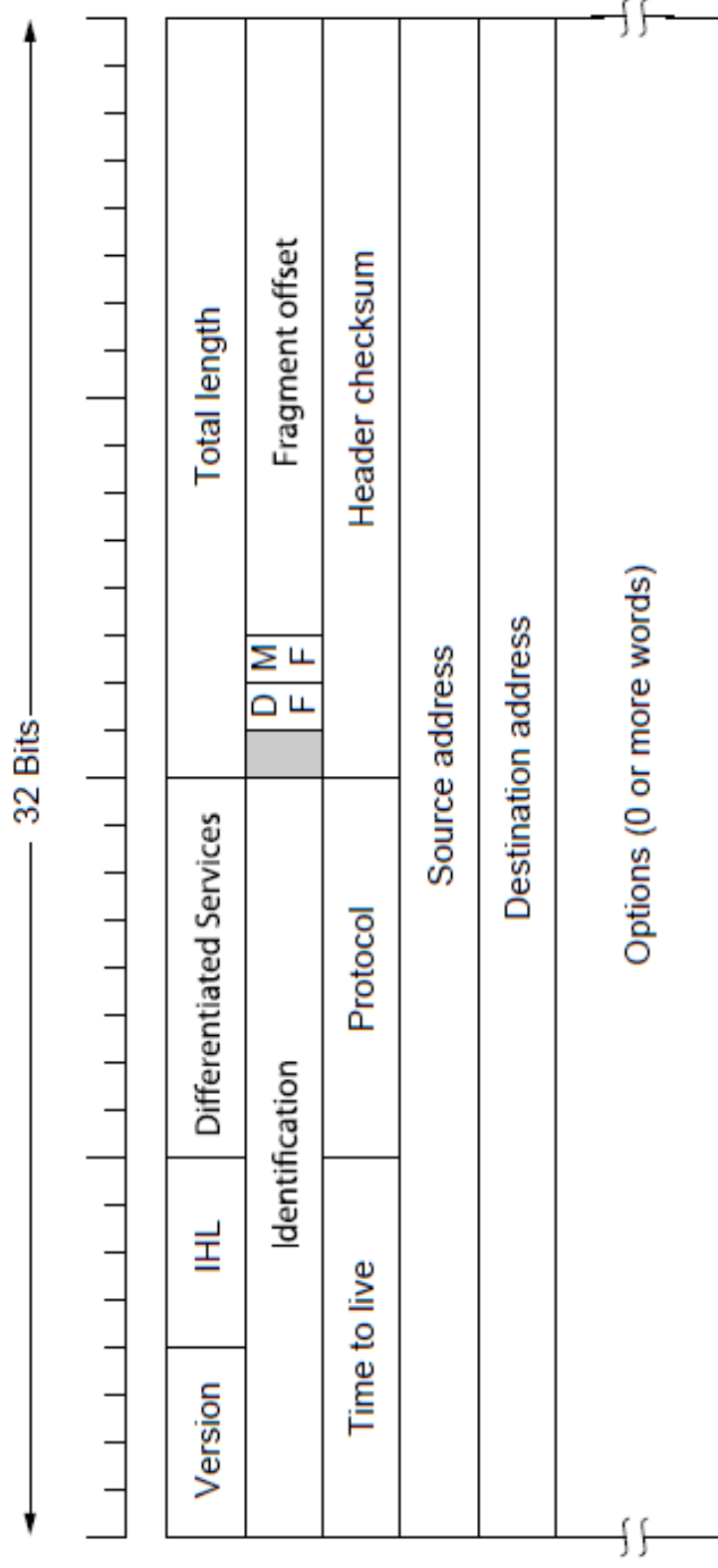- network mask (indicating network versus host portion of address)

DHCP: example
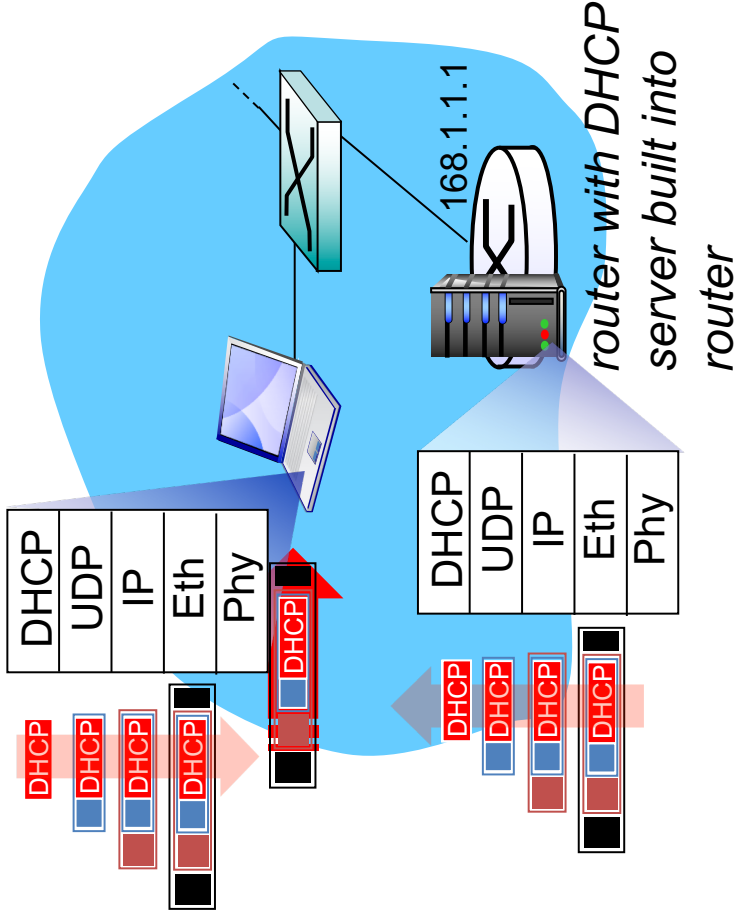
- connecting laptop needs its IP address, addr of first-hop router, addr of DNS server: use DHCP

- DHCP request encapsulated in UDP, encapsulated in IP, encapsulated in 802.1 Ethernet

- But how can I contact the DHCP without an IP address? We will discuss this in the next layer.

168.1.1.1

router with DHCP server built into router

| DHCP |
| UDP |
| IP |
| Eth |
| Phy |

| DHCP |
| UDP |
| IP |
| Eth |
| Phy |

IP: Internet Protocol

4. Application — SMTP HTTP RTP DNS
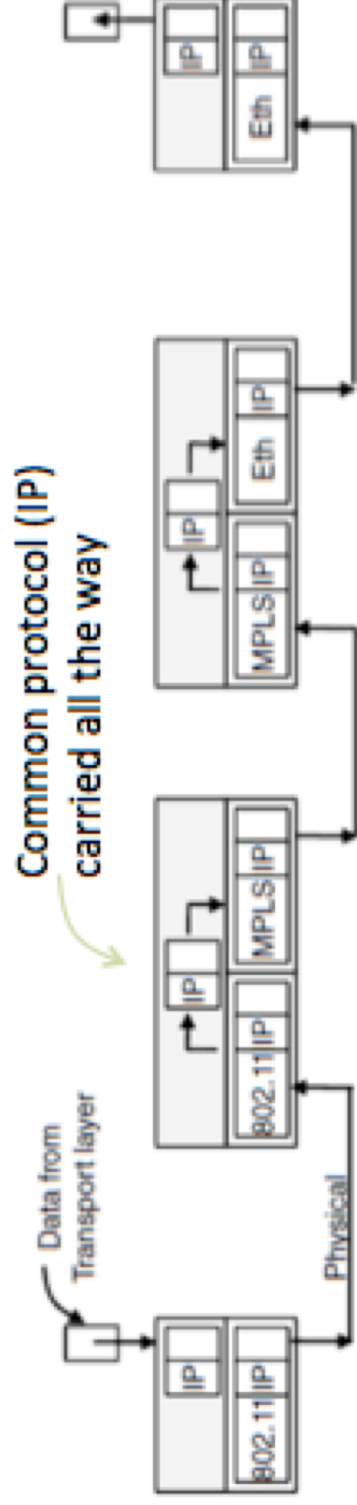
3. Transport — TCP UDP

2. Internet — IP

1. Link — Ethernet 3G / Cable DSL 802.11

IP Version 4 Protocol

IPv4 (Internet Protocol) header is carried on all packets and has fields for the key parts

32 Bits

Version	IHL	Differentiated Services	Total length
Identification			D M F F	Fragment offset
Time to live		Protocol	Header checksum
Source address			
Destination address			
Options (0 or more words)			

How Networks Can Be Connected

Internetworking based on a common network layer – IP

Data from Transport layer

Common protocol (IP) carried all the way

Physical

| 802.11 | IP |
| IP |

| 802.11 | IP | MPLS | IP |
| IP |

| MPLS | IP | Eth | IP |
| IP |

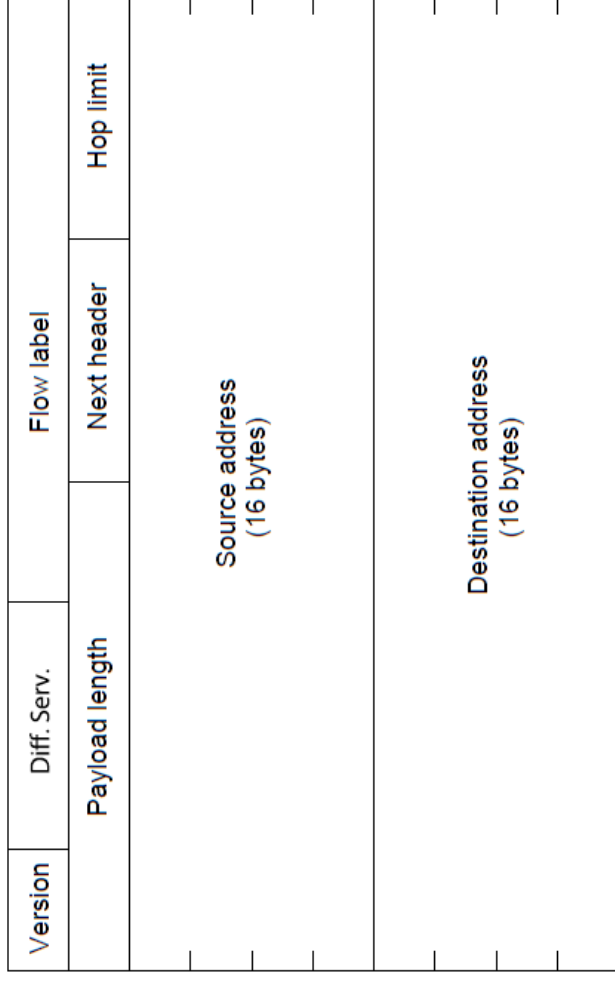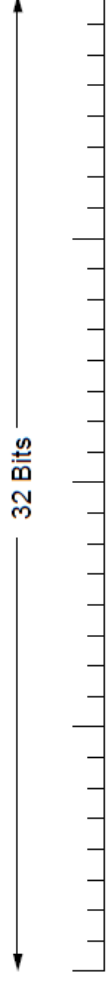| Eth | IP |
| IP |

IP Version 6

Major upgrade in the 1990s due to impending address exhaustion, with various other goals:

- Support billions of hosts
- Reduce routing table size
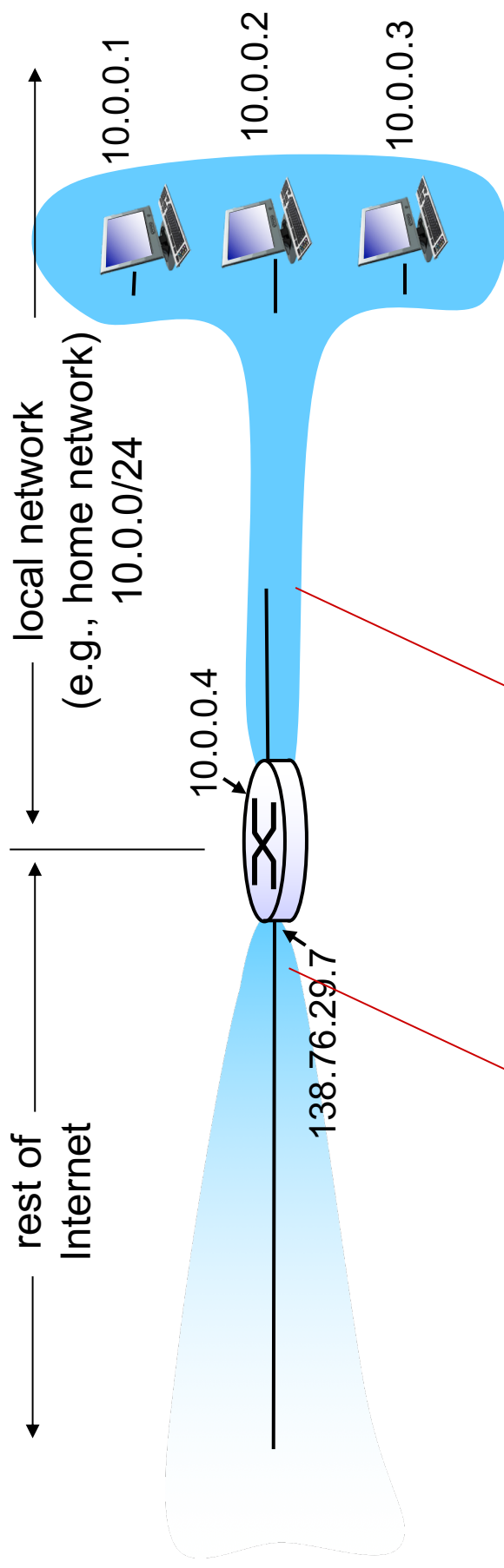- Permit coexistence of old, new protocols, ...

Use 128 bit address space rather than 32 bits

IPv6 packet

IPv6 protocol header has much longer addresses (128 vs. 32 bits) and is simpler

32 Bits

Version	Diff. Serv.	Flow label		
Payload length		Next header	Hop limit
Source address (16 bytes)				
Destination address (16 bytes)				

NAT: network address translation

local network
(e.g., home network)
10.0.0/24

rest of
Internet

10.0.0.1

10.0.0.2

10.0.0.3

10.0.0.4

138.76.29.7

datagrams with source or
destination in this network
have 10.0.0/24 address for
source, destination (as usual)

all datagrams *leaving* local
network have *same* single
source NAT IP address:
138.76.29.7,different source
port numbers

What does a NAT address mean?

- If behind a NAT, I have a private IP address
  - No one can contact me, but I can contact public IPs

- In class example of assignment 1 public/private IPs