CPSC 317 COMPUTER NETWORKING

Module 5: Network Layer – Day 2 – IP Addresses and Forwarding

READING

- Reading: 4.3, 4.3.1, 4.3.3 (Before Obtaining a Host Address: The Dynamic Host Configuration Protocol), 4.3.5

LEARNING GOALS

IP addresses and forwarding

- Explain why the network layer functions are divided into forwarding and routing
- Know the format of an IPv4 address and what it names
- Know the difference between classful and classless addressing (CIDR addressing)
- Understand how and why IPv6 is different from IPv4
- Describe the general information contained in network packet headers and the role of this information
- Describe IP protocol header and the purpose of the fields

IP SERVICE MODEL

- Best effort delivery from one network interface to another network interface
- No guarantees
- No (per flow) state in the routers
- Split into two parts
  - Forwarding
  - Routing

TWO KEY NETWORK-LAYER FUNCTIONS

Functionality

- *forwarding:* move packets from router's input to appropriate router output
- *routing:* determine route taken by packets from source to destination
  - *routing algorithms*

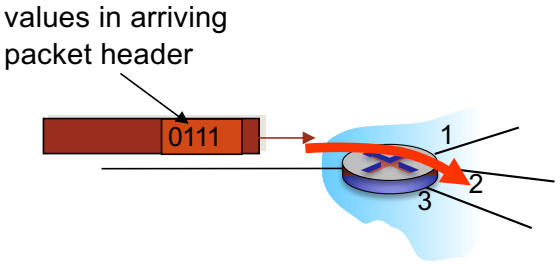
A Road-trip Analogy

- *forwarding:* getting through a single intersection
- *routing:* planning the trip from source to destination

NETWORK LAYER COMPONENTS

Data plane

- local, per-router function
- determines how datagram arriving on router input port is forwarded to router output port
- forwarding function



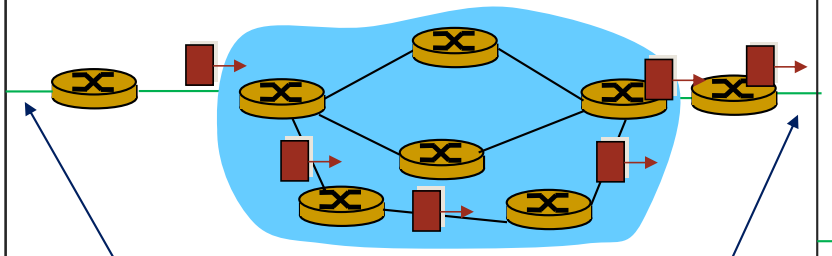
Control plane

- network-wide logic
- determines how datagram is routed among routers along end-end path from source host to destination host
- two control-plane approaches:
  - *traditional routing algorithms:* implemented in routers
  - *software-defined networking (SDN)*: implemented in (remote) servers

HOPPING ACROSS THE NETWORK

Source
192.168.0.45

A router makes forwarding decisions by comparing the addresses of networks in its forwarding table to the destination IP address in the IP header.



Destination
23.96.1.28

192.168.0.1

23.96.1.1

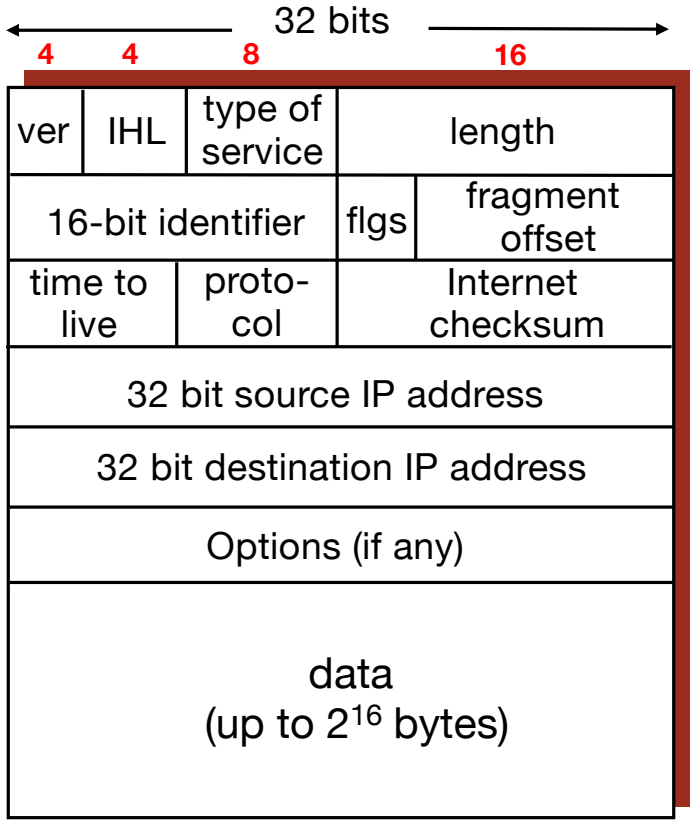
Network Header

192.168.0.45 → 23.96.1.28

Network Payload

IPV4 DATAGRAM HEADER

- ver: IP version
- Internet Header Length (IHL): # of 32-bit **words**.
- Header size: 20 bytes plus options (IHL: ≥ 5)
- Length: total length of the IP datagram including header and payload
- TTL (time-to-live): used to discard packets that live too long in the network
- protocol: upper-layer protocol to deliver to



Words: 32 bits
Byte: 8 bits (a.k.a. octet)
Nibble: 4 bits

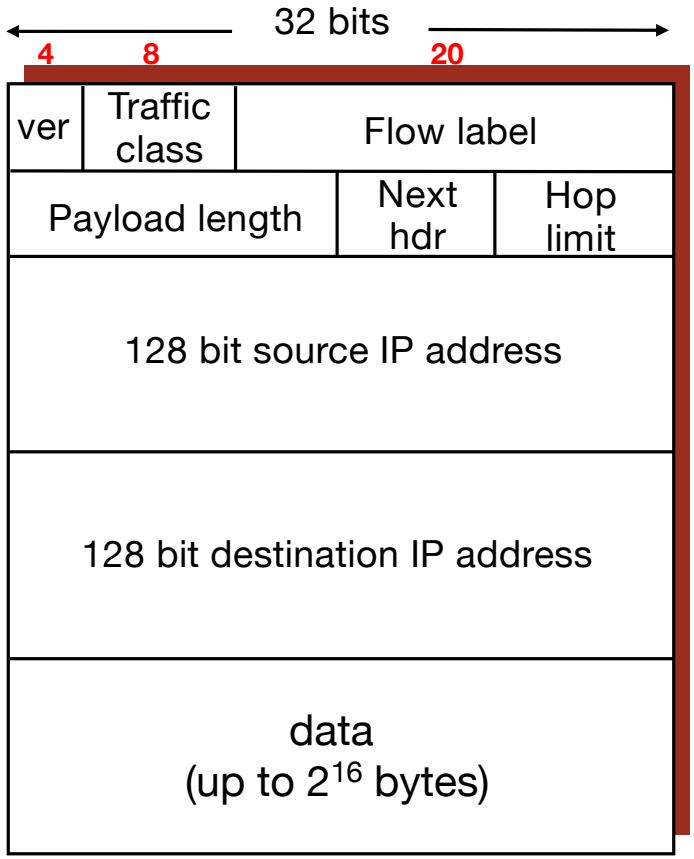
IPV6 DATAGRAM HEADER

Traffic class: similar to IPv4 type of service

Flow label: identification of related packets

Next hdr: similar to IPv4 protocol field (upper layer protocol)

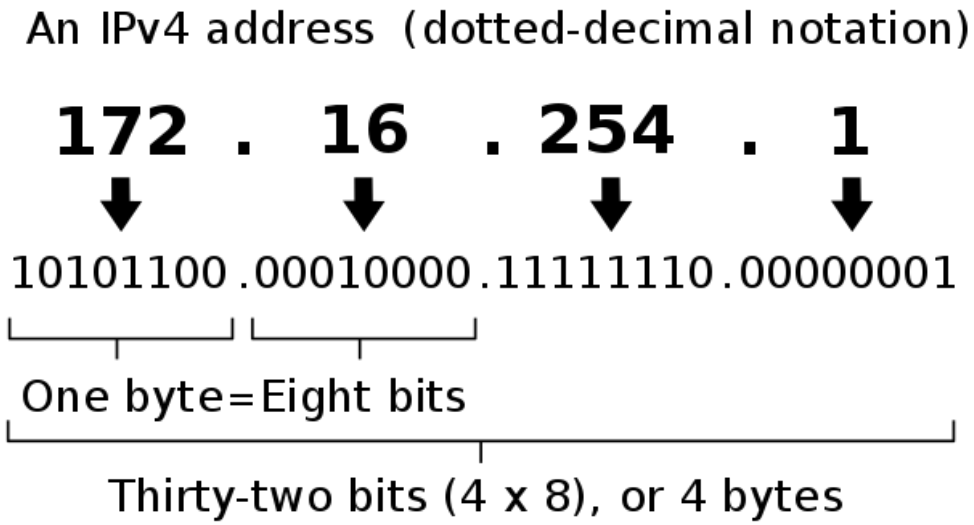
Header size: 40 bytes



IP ADDRESSES

- IPV4 original addresses (obsolete)
- IPV4 class-based addresses (obsolete)
- IPV4 class-less (CIDR) addresses
- IPV6 addresses

IPV4 ADDRESS



An octet is RFC-speak for a byte.
Anciently some computers had different sized bytes, so octet is more precise.

REMEMBER THE HISTORY

- IP addresses were first used in the 1970s
- No one imagined that each person would have multiple IP addresses!
- A few organizations, with a few hundred or thousand computers each
- 32 bits (4 billion addresses) seemed like a lot

ORIGINAL ADDRESSING

- 8 bit network number
- 24 bit host number within the network

- Example: 17.0.0.1
  - The first host on the Apple network

IN ALL IPV4 NETWORKS

- The first and last addresses are never used for an actual host:
  - Generally the first address (host address == all 0s) is used to represent the network and for hosts that don't have an address yet
  - The last address in range (host address == all 1s) is used for broadcast (sending a datagram to all the hosts in the network)

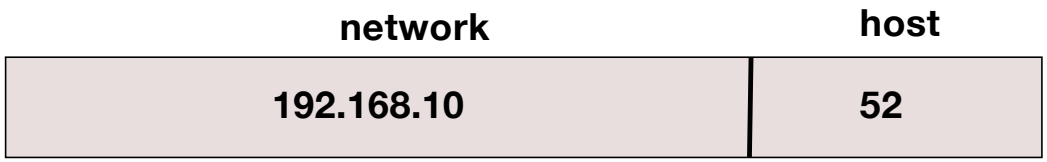
OOPS, WE UNDERESTIMATED THE NUMBER OF NETWORKS WE ARE GOING TO NEED

- So, let's complicate the scheme
- There are a bunch of the network numbers that we haven't given out yet

CLASS BASED ADDRESSING

Prefix	Network Size (bits)	Name
0	8	Class A
10 (128 – 191)	16	Class B
110 (192 – 223)	24	Class C
1110 (224 – 239)	32	Class D - multicast
1111 (240 – 255)	32	Class E (reserved)

What class is 192.168.10.52? 192 = 0b11000000



CLICKER QUESTION

Prefix	Network Size (bits)	Name
10	16	Class B

How many Class B networks are there?

A. 2^8

B. 2^{16}

C. 2^{14}

D. 2^{10}

E. 2^{12}

CLASS A RESERVED ADDRESSES

Network	Purpose
0	Local identification
10	Private networks
127	Local host (loopback)

CLASS A ALLOCATIONS

Network	Purpose
12	AT&T
17	Apple
19	Ford
38	PSINet (now Cogent)
48	Prudential
56	US Post Office
73	Comcast
6, 7, 11, 21, 22, 26, 28, 29, 30, 33, 55	US Military

OOPS, WE UNDERESTIMATED THE NUMBER OF NETWORKS WE ARE GOING TO NEED

- So, let's complicate the scheme (again)

CLASSLESS INTER-DOMAIN ROUTING ADDRESSES (CIDR) (PRONOUNCED CIDER)

- How can we represent a larger number of networks with a wider range of sizes?
- Allow any number of bits in the network number (practically, between 8 and 31)
  - Call these the fixed bits
- The rest of the bits name the host within the network
- The boundary position is indicated after a / (the number of fixed bits)

IP ADDRESSING: CIDR EXAMPLE

CIDR Address: 200.23.18.4/22

```
200       23        18        4
11001000 00010111 00010010 00000100
11001000 00010111 000100  1000000100
```

Network address (22 bits)

Host address
(10 bits)

ALTERNATIVE FORMAT: NETMASK

CIDR Address: 200.23.18.4/22

```
200         23          18          4
11001000    00010111    00010010    00000100
11001000    00010111    000100 10   00000100
```

Network address

Host address

```
11111111    11111111    11111100    00000000
255         255         252         0
```

200.23.18.4/255.255.252.0 or 200.23.18.4 netmask: 255.255.252.0

IP NETWORK ADDRESS

Replace the host bits with zero (don't cares)

Routers only care about the network part

Example: What is the network address of the host 200.23.18.4/22?

11001000 00010111 000100 10 00000100

11001000 00010111 000100 00 00000000

200.23.16.0/22 or 200.23.16/22

IP NETWORK ADDRESS (NETMASK)

Replace the host bits with zero (don't cares)

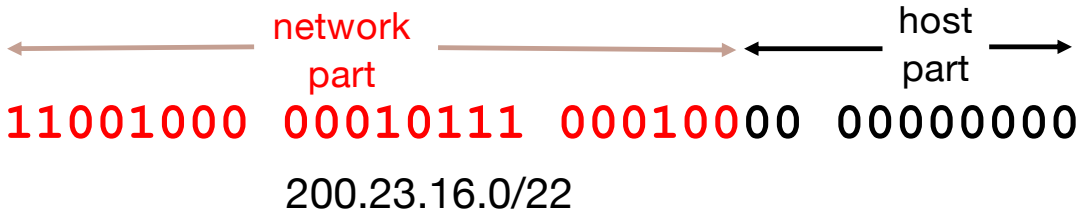
You can compute this by AND-ing with the netmask

Example: What is the network address of the host 200.23.18.4 netmask 255.255.252.0?


```
11001000  00010111  000100 10 00000100
11111111  11111111  111111 00 00000000   netmask
11001000  00010111  000100 00 00000000
```

200.23.16.0/22 or 200.23.16/22

NETWORK SIZE



How many hosts can exist on this network?:

host number (smallest) 200.23.16.0

host number (largest) 200.23.19.255

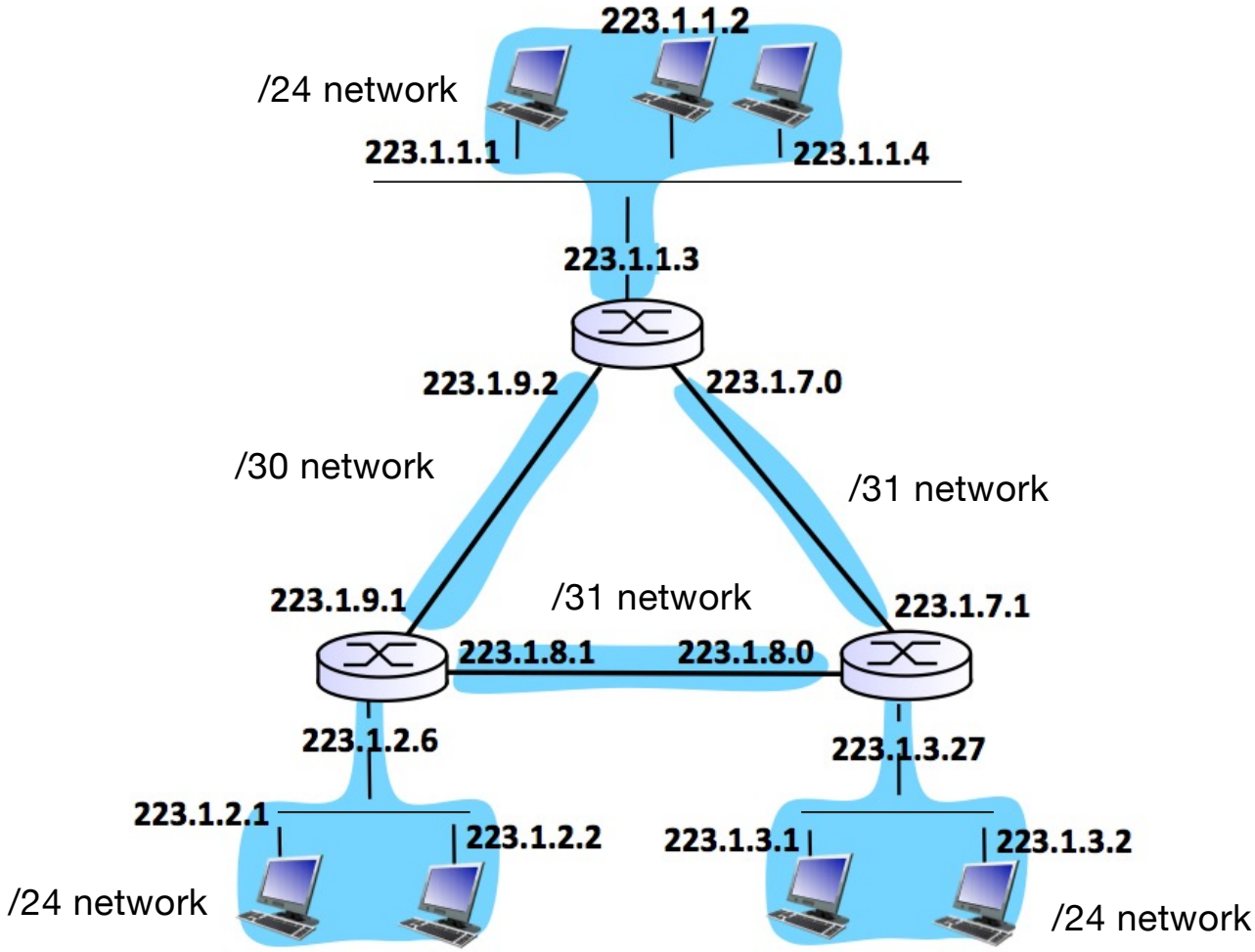
But avoid host numbers of all zeros and all ones:

200.23.16.1 to 200.23.19.254, or

$2^{10} - 2 = 1024 - 2 = 1022$

Note: All ones and all zeros avoided (all zeros is the IP address machines use when they haven't been assigned an address, and broadcast uses all ones).

Special exemption for /31 addresses, you can use both of the addresses for hosts

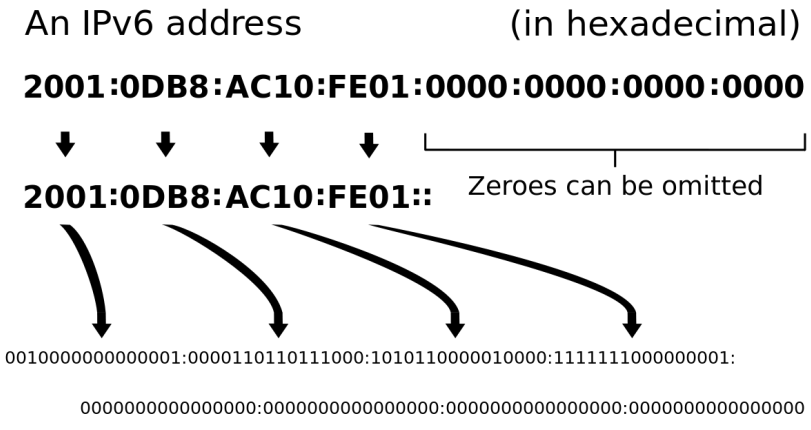

223.1.1.2
/24 network
223.1.1.1
223.1.1.4
223.1.1.3
223.1.9.2
223.1.7.0
/30 network
/31 network
223.1.9.1
/31 network
223.1.7.1
223.1.8.1
223.1.8.0
223.1.2.6
223.1.3.27
223.1.2.1
223.1.2.2
223.1.3.1
223.1.3.2
/24 network
/24 network

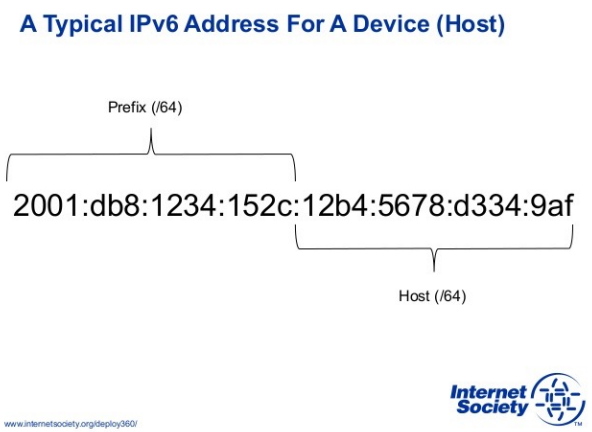
OOPS, WE UNDERESTIMATED THE NUMBER OF NETWORKS WE ARE GOING TO NEED (AND THE NUMBER OF HOSTS, TOO)

- So, let's start over

IPV6 FORMAT

- 128 bits, 32 Hex-digits (8 hextets) separated by colons
- Zero suppression
- Separated into network+subnet (48+16), host (64)





Zero compression and suppressing leading zeros

BUT FOR NOW, WE USE CIDR ADDRESSES

- For the rest of this module, we'll concentrate on IPv4 and CIDR
  - They are the dominant addressing form in use now

GETTING FAMILIAR WITH CIDR ADDRESSES

- Questions we need to be able to answer
  - How big can a network be?
  - Is a given address on a given network?
  - Which of many networks is a given address on?
  - Are two addresses on the same network?

CLICKER QUESTION

Network A has address 200.0.0.0/17

Network B has address 201.0.0.0/18

Choose the true statement (or the one that is closest to being true)

A. Network A has one more host address than network B
B. Network A has twice as many host addresses as network B
C. Network B has one more host address than network A
D. Network B has twice as many host addresses as network A

CLICKER QUESTION

What is the netmask for a CIDR block that ends with /8?

i.e., 17.0.0.0/8

A. 255.255.255.0
B. 255.255.0.0
C. 255.0.0.0
D. Something else
E. There is insufficient information to determine

CLICKER QUESTION

What is the netmask for a CIDR block that ends with /30?

A. 255.255.255.192
B. 255.255.255.240
C. 255.255.255.248
D. 255.255.255.252
E. 255.255.255.254

```
Binary        Decimal
--------------------
00000000 == 0
10000000 == 128
11000000 == 192
11100000 == 224
11110000 == 240
11111000 == 248
11111100 == 252
11111110 == 254
11111111 == 255
```

CLICKER QUESTION

How many different host addresses are there in the CIDR range for 204.33.109.0/29?

(provide your answer as a number)

INCLASS ACTIVITY

- ICA52