Network Layer: Overview

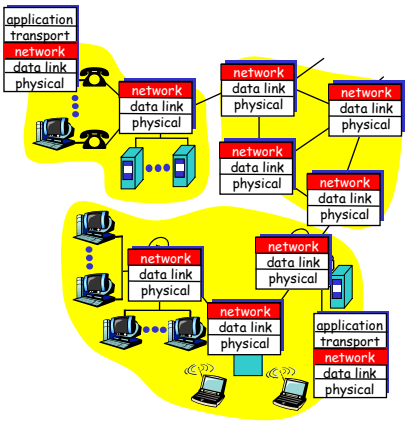
- Network layer functions
- IP
- Routing and forwarding

Network layer functions

- Transport packet from sending to receiving hosts
- Network layer protocols in *every* host, router

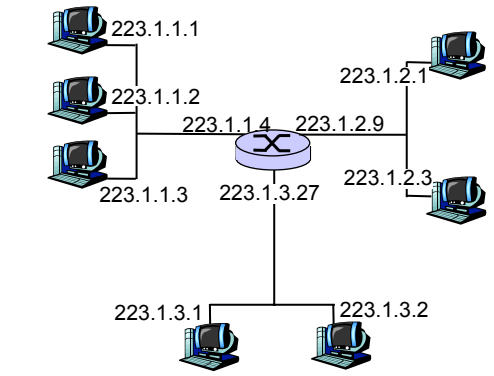
Three important functions:

- *Path determination:* route taken by packets from source to dest. *Routing algorithms*
- *Switching:* move packets from router's input to appropriate router output



IP Addressing

- IP address: 32-bit identifier for host, router *interface*
- *Interface:* connection between host, router and physical link
  - Routers typically have multiple interfaces
  - Host may have multiple interfaces
  - IP addresses associated with interface, not host, router

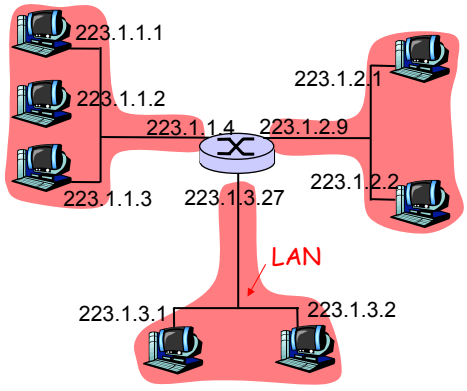


223.1.1.1 = 11011111 00000001 00000001 00000001

223 1 1 1

IP Addressing (2)

- IP address:
  - Network part (high order bits)
  - Host part (low order bits)
- *What's a network?* (from IP address perspective)
  - Device interfaces with same network part of IP address
  - Can physically reach each other without intervening router

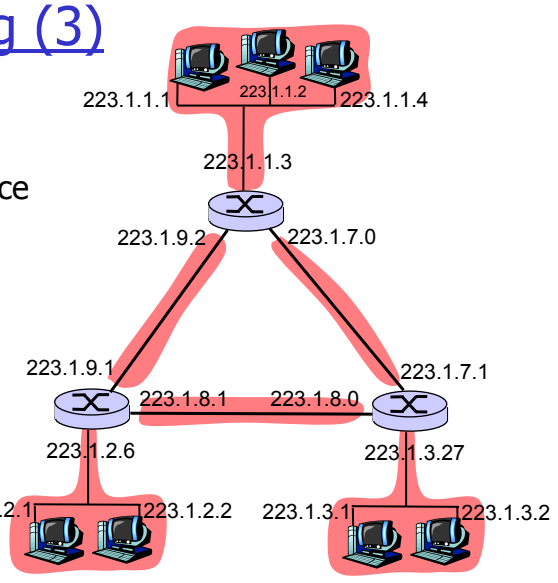


network consisting of 3 IP networks (for IP addresses starting with 223, first 24 bits are network address)

IP Addressing (3)

How to find the networks?

- Detach each interface from router, host
- Create "islands" of isolated networks



Interconnected system consisting of six networks

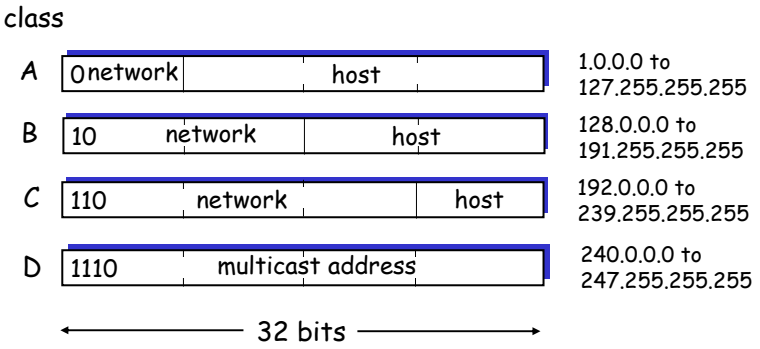
IP Networks: Subnets

- Sub divide address space
  - Network part
  - Host address
- Address format: a.b.c.d/x, where x is # bits in subnet portion of address

11001000 00010111 00010000 00000000

200.23.16.0/24

Fixed Subnetting (classful)



Address Management

- Problem: we are running out of networks
- Solution (a):
  subnetting: e.g., Class B Host field (16bits) is subdivided into <subnet;host> fields
- Solution (b):
  CIDR (Classless Inter Domain Routing)

CIDR

- Classless InterDomain Routing
- Class A is too large, Class C is too small
- Everyone has a Class B address!!!

- Solution: sites are given contiguous blocks of class-C addresses (256 addresses each) and a mask or parts of former class A/B networks.

CIDR

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

200.23.16.0/23

IP addresses: how to get one?

Q: How does *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"
- IP / Subnets allocated by provider (RIPE/ARIN/…)

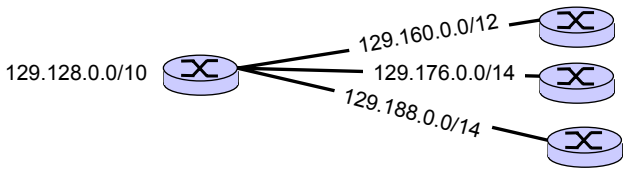
Hierarchical address structure

- Recall: CIDR

18 relevant bits

128.119.48.12/18 = 10000000 01110111 00110000 00001100

  - High order bits form the **prefix**
  - Once inside the network, can **subnet**: divide remaining bits
  - Subnet example:



Note: Picture shows prefix masks, not interface addrs!

- **Forwarding decision: longest prefix match**

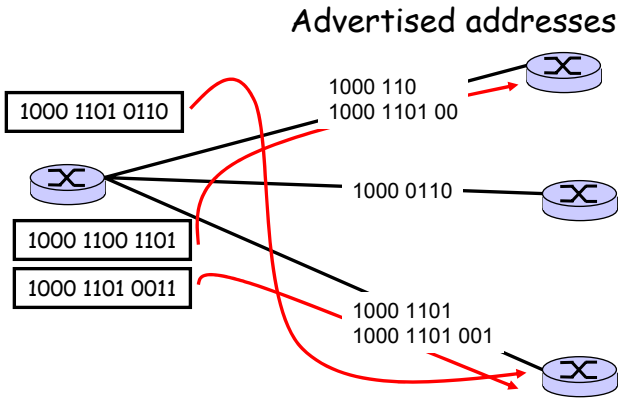
Forwarding vs. Routing

- Forwarding: the process of moving packets from input to output
  - The forwarding table
  - Information in the packet
- Routing: process by which the forwarding table is built and maintained
  - One or more routing protocols
  - Procedures (algorithms) to convert routing info to forwarding table.

  (Much more later …)

Forwarding with CIDR

- Packet should be sent towards the interface with the **longest matching prefix**

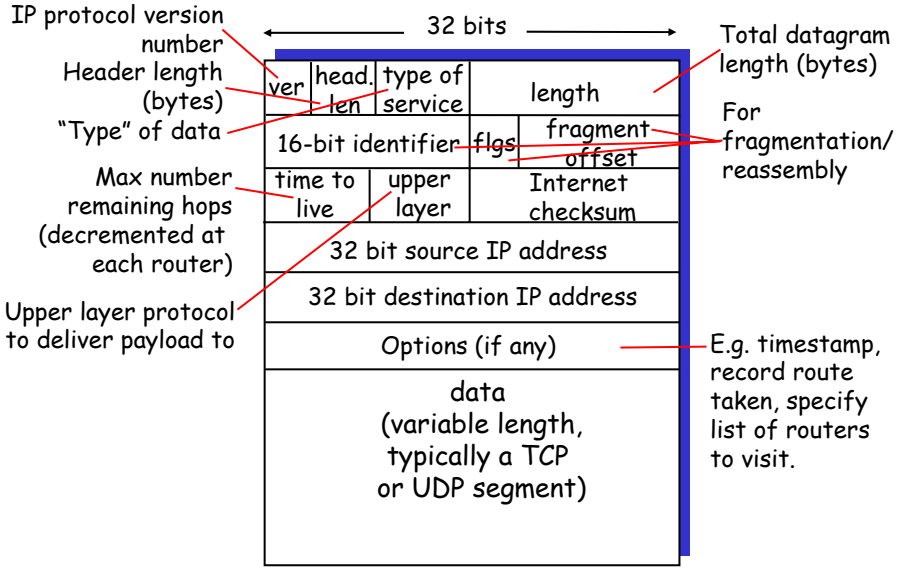


Lookup (longest prefix match):

- Forwarding table:
  <Network>/<mask> <next-hop>
- IP Packets: destination IP address
  - Find next-hop
- Example:

Forwarding table		Packets
134.96.252.0/24	A	134.96.252.200
134.96.0.0/16	C	134.96.254.2
134.96.240.0/20	B	134.96.239.200
134.96.252.192/28	B	134.97.239.200
134.96.252.128/28	A	134.96.252.191

IPv4 datagram format



ICMP: Internet Control Message Protocol

- Used by hosts, routers, gateways to communication network-level information
  - Error reporting: unreachable host, network, port, protocol
  - Echo request/reply (used by ping)
- Network-layer "above" IP:
  - ICMP msgs carried in IP datagrams
- ICMP message: type, code plus first 8 bytes of IP datagram causing error

Type	Code	description
0	0	echo reply (ping)
3	0	dest network unreachable
3	1	dest host unreachable
3	2	dest protocol unreachable
3	3	dest port unreachable
3	6	dest network unknown
3	7	dest host unknown
4	0	source quench (congestion control – not used)
8	0	echo request (ping)
9	0	route advertisement
10	0	router discovery
11	0	TTL expired
12	0	bad IP header

Network Layer: Summary

- Network layer functions
- IP
- Routing and forwarding