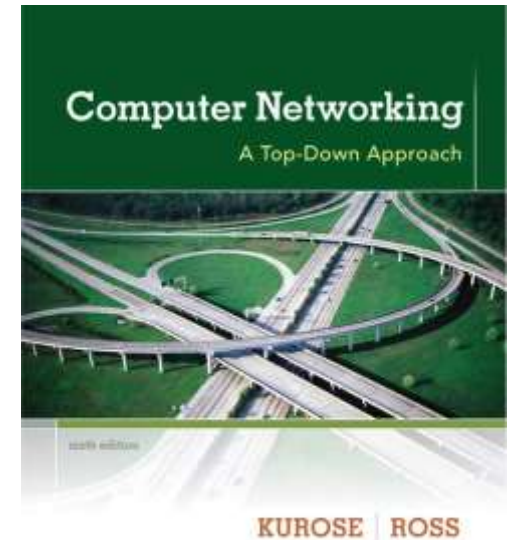


Chapter 4

Network Layer



*Computer
Networking: A Top
Down Approach*
6th edition
Jim Kurose, Keith Ross
Addison-Wesley
March 2012

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Chapter 4: network layer

chapter goals:

- ❖ understand principles behind network layer services:
 - network layer service models
 - forwarding versus routing
 - how a router works
 - routing (path selection)
 - broadcast, multicast
- ❖ instantiation, implementation in the Internet

Chapter 4: outline

4.1 introduction

4.2 virtual circuit and datagram networks

4.3 what's inside a router

4.4 IP: Internet Protocol

- datagram format
- IPv4 addressing
- ICMP
- IPv6

4.5 routing algorithms

- link state
- distance vector
- hierarchical routing

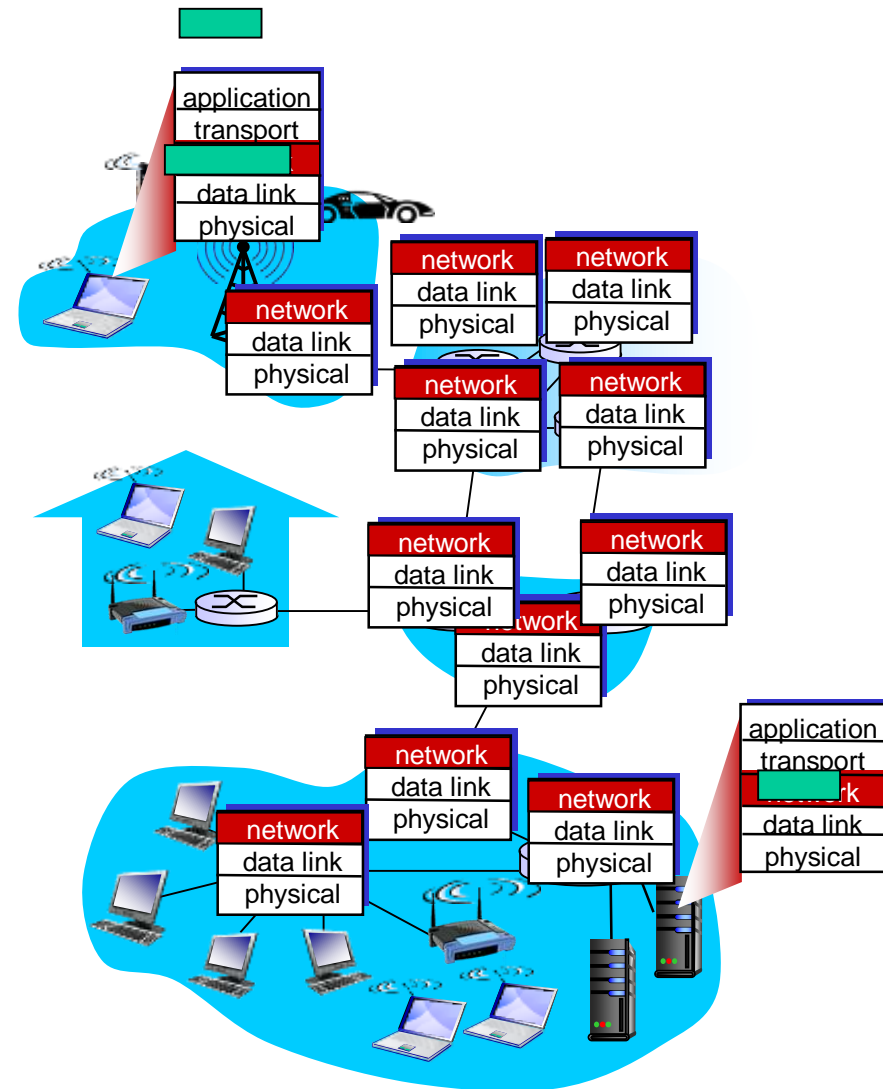
4.6 routing in the Internet

- RIP
- OSPF
- BGP

4.7 broadcast and multicast routing

Network layer

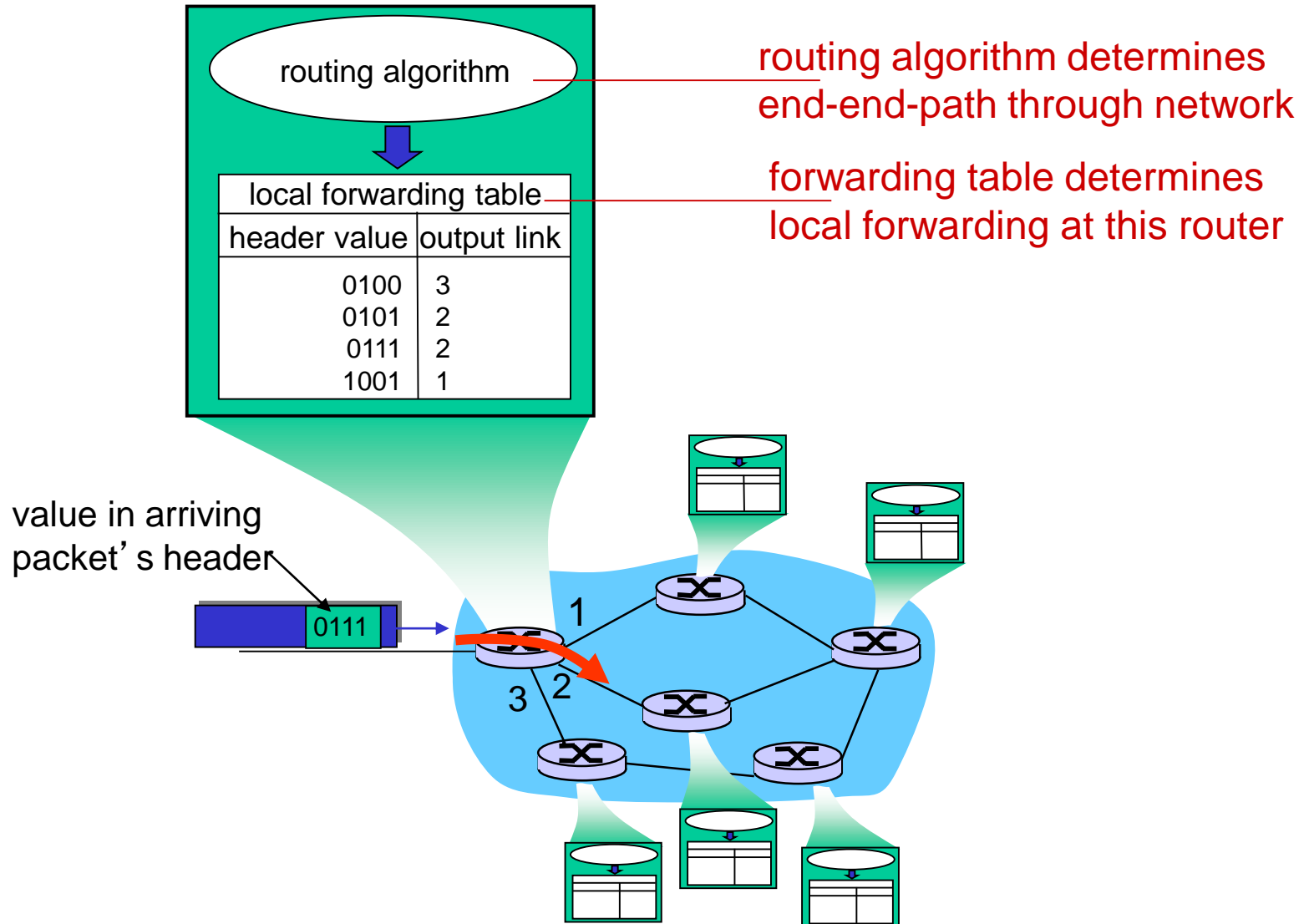
- ❖ transport segment from sending to receiving host
- ❖ on sending side encapsulates segments into datagrams
- ❖ on receiving side, delivers segments to transport layer
- ❖ network layer protocols in *every* host, router
- ❖ router examines header fields in all IP datagrams passing through it



Three key network-layer functions

- ❖ *forwarding*: move packets from router's input *link* to appropriate router output *link*
- ❖ *routing*: determine route taken by packets from source to dest.
 - The algorithms that calculate these paths
 - are referred to as **routing algorithms**
- ❖ *connection setup*

Interplay between routing and forwarding



Connection setup

- ❖ 3rd important function in *some* network architectures:
 - ATM, frame relay, X.25
- ❖ before datagram's flow, two end hosts *and* intervening routers establish virtual connection routers get involved , *this process is referred to as connection setup*
- ❖ network vs transport layer connection service:
 - *network*: between two hosts (may also involve intervening routers in case of VCs)
 - *transport*: between two processes

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Connection, connection-less service

- ❖ *datagram* network provides network-layer *connectionless* service
- ❖ *virtual-circuit* network provides network-layer *connection* service
- ❖ analogous to TCP/UDP connection-oriented / connectionless transport-layer services, but:
 - *service*: host-to-host
 - *no choice*: network provides one or the other
 - *implementation*: in network core

Virtual circuits

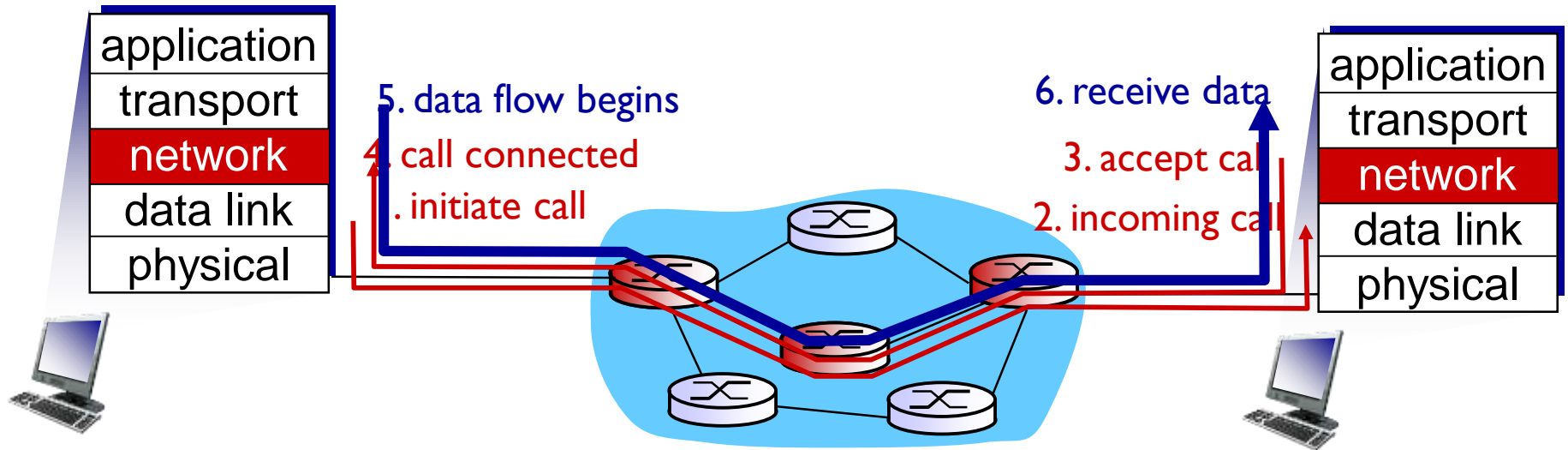
“source-to-dest path behaves much like telephone circuit”

- performance-wise
- network actions along source-to-dest path

- ❖ call setup, for each call *before* data can flow
- ❖ each packet carries VC identifier (not destination host address)
- ❖ every router on source-dest path maintains “state” for each passing connection
- ❖ link, router resources (bandwidth, buffers) may be *allocated* to VC (dedicated resources = predictable service)

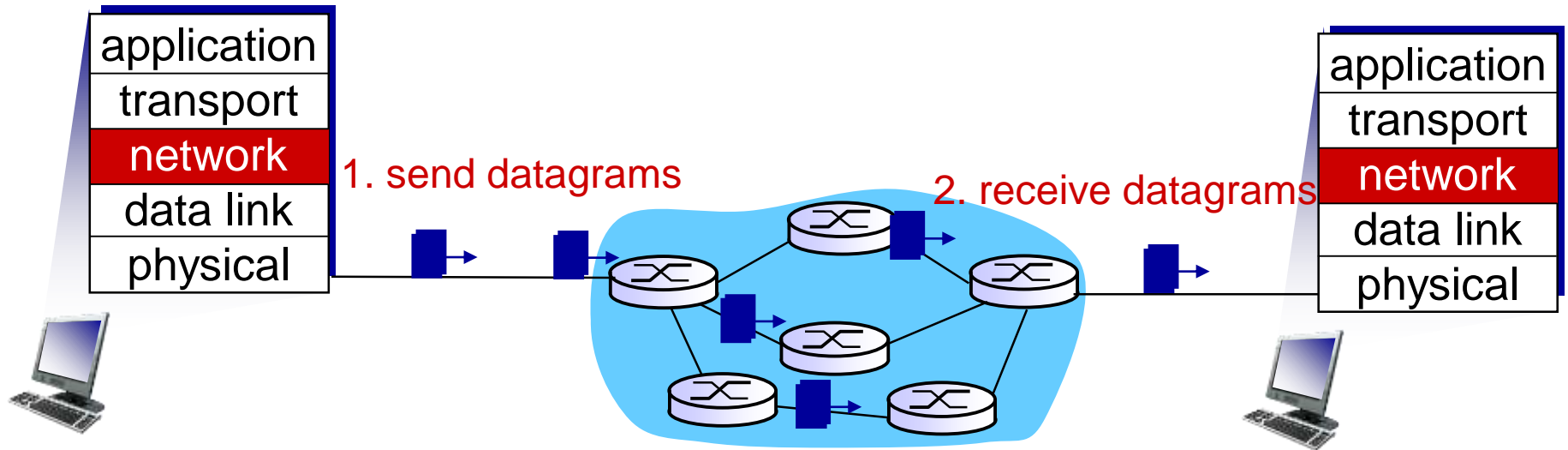
Virtual circuits: signaling protocols

- ❖ used in ATM, frame-relay, X.25
- ❖ not used in today's Internet

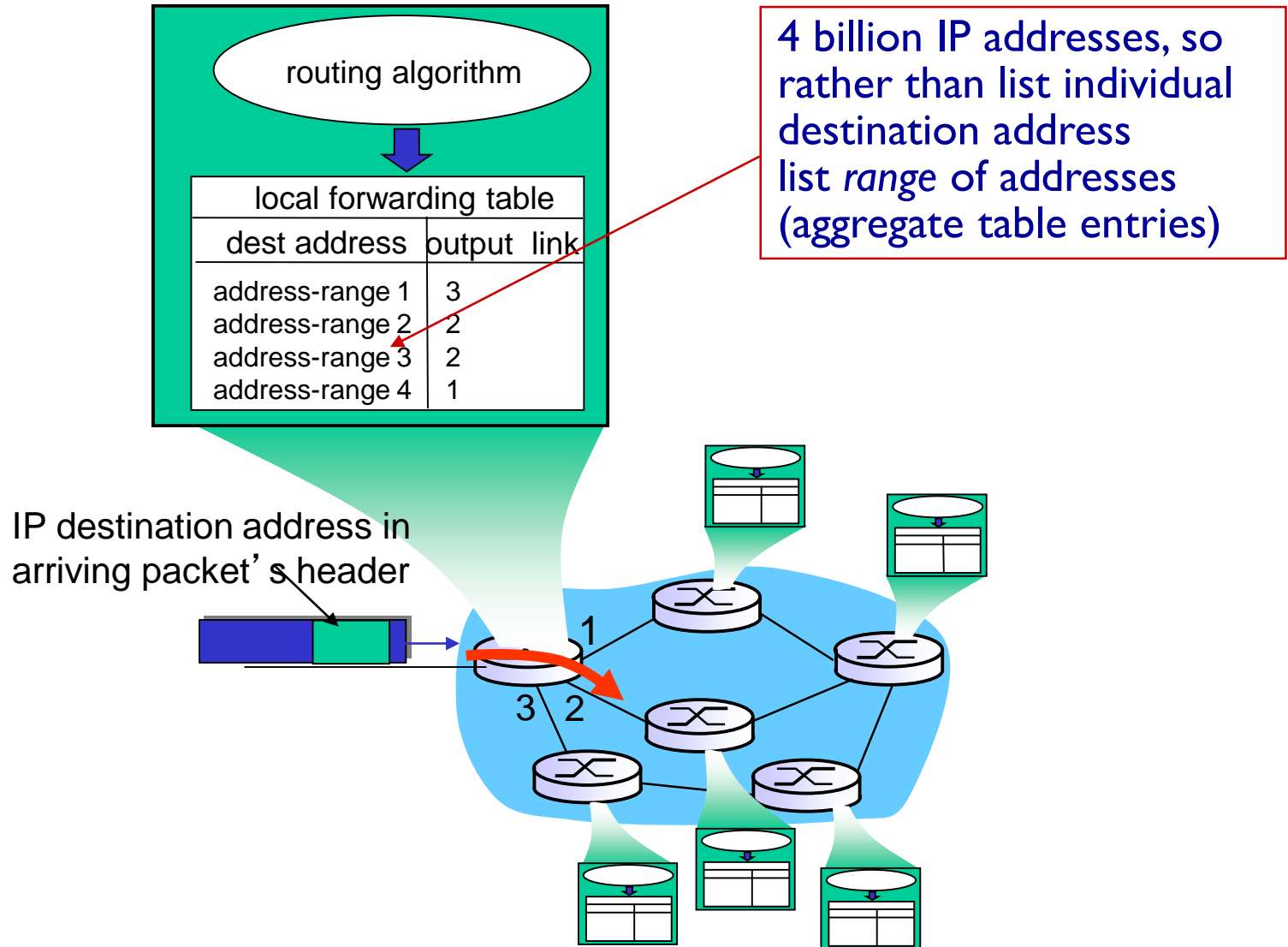


Datagram networks

- ❖ no call setup at network layer
- ❖ routers: no state about end-to-end connections
- ❖ packets forwarded using destination host address



Datagram forwarding table



Datagram or VC network: why?

Internet (datagram)

- ❖ data exchange among computers
 - “elastic” service, no strict timing req.
- ❖ “smart” end systems (computers)
 - can adapt, perform control, error recovery
 - ***simple inside network, complexity at “edge”***

ATM (VC)

- ❖ evolved from telephony
- ❖ human conversation:
 - strict timing, reliability requirements
 - need for guaranteed service
- ❖ “dumb” end systems
 - telephones
 - ***complexity inside network***

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Router architecture overview

two key router functions:

- ❖ run routing algorithms/protocol (RIP, OSPF, BGP)
- ❖ *forwarding* datagrams from incoming to outgoing link

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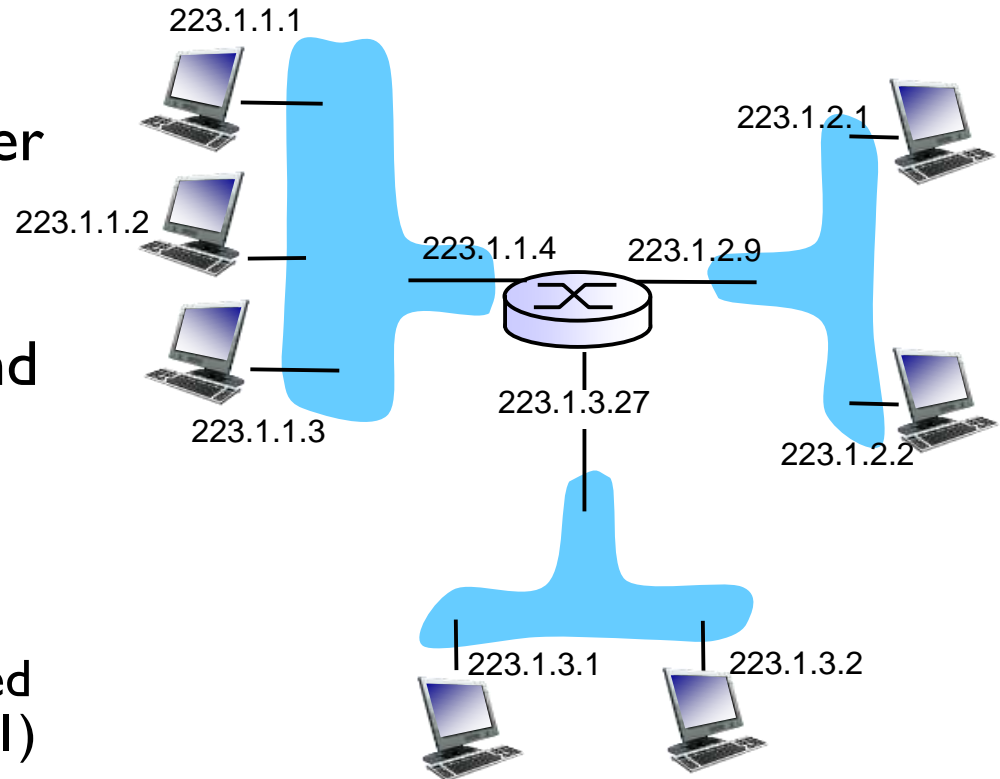
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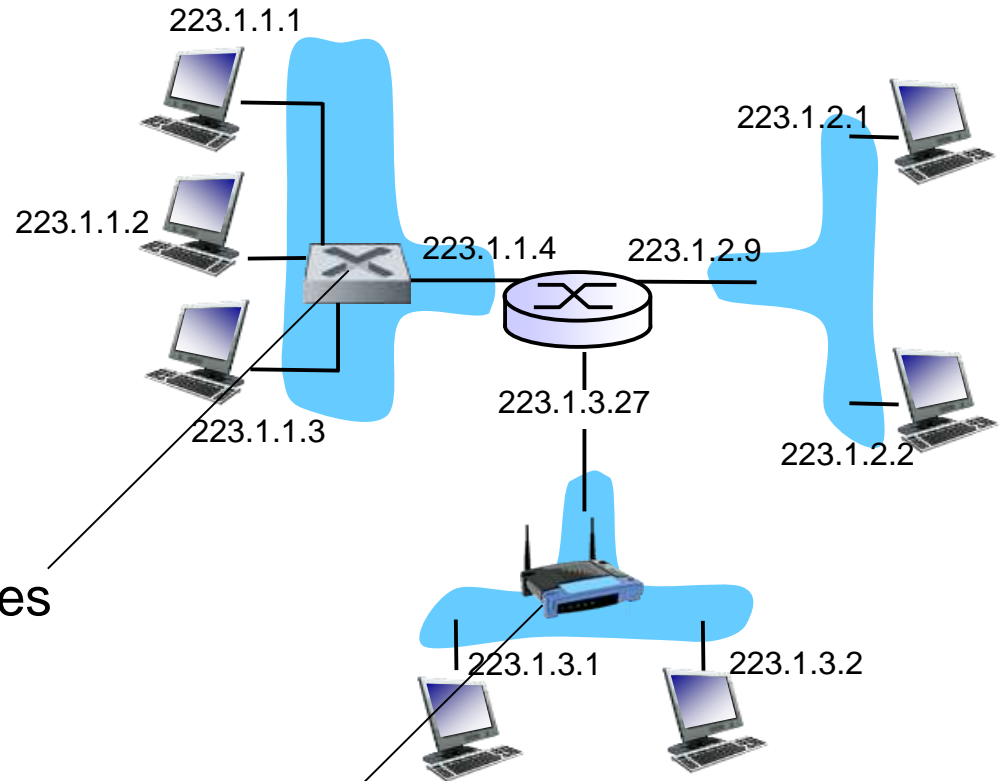
IP addressing: introduction

- ❖ **IP address:** 32-bit identifier for host, router interface
- ❖ **interface:** connection between host/router and physical link
 - router's typically have multiple interfaces
 - host typically has one or two interfaces (e.g., wired Ethernet, wireless 802.11)
- ❖ **IP addresses associated with each interface**



$$223.1.1.1 = \underbrace{11011111}_{223} \underbrace{00000001}_1 \underbrace{00000001}_1 \underbrace{00000001}_1$$

IP addressing: introduction



A: wired Ethernet interfaces connected by Ethernet switches

b: wireless WiFi interfaces connected by WiFi base station

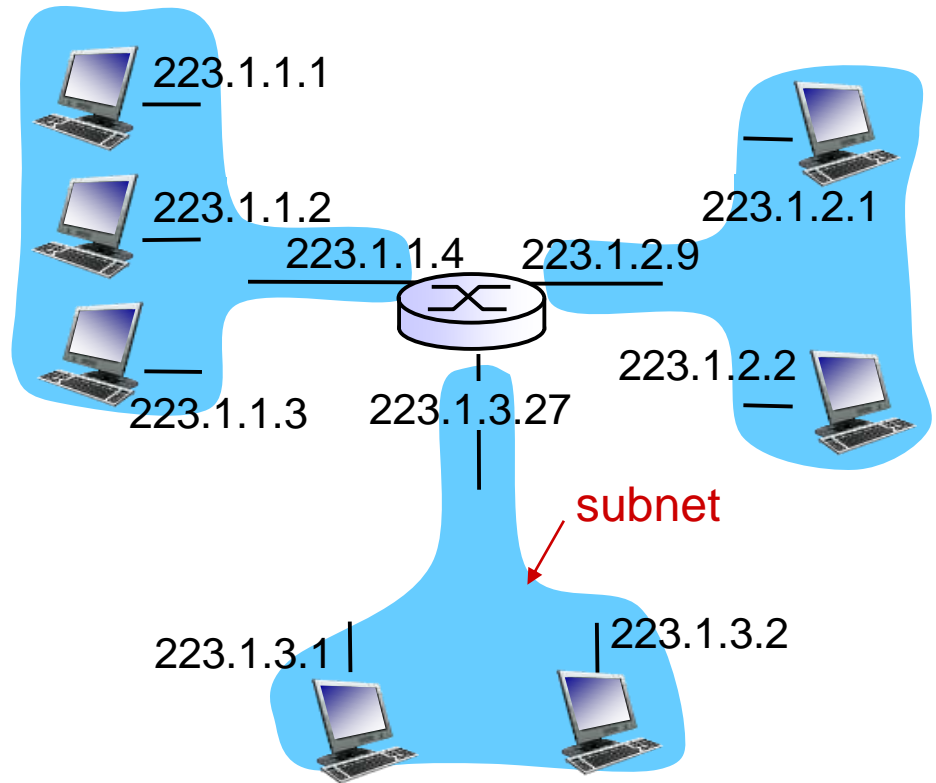
Subnets

❖ IP address:

- subnet part - high order bits
- host part - low order bits

❖ *what's a subnet?*

- device interfaces with same subnet part of IP address

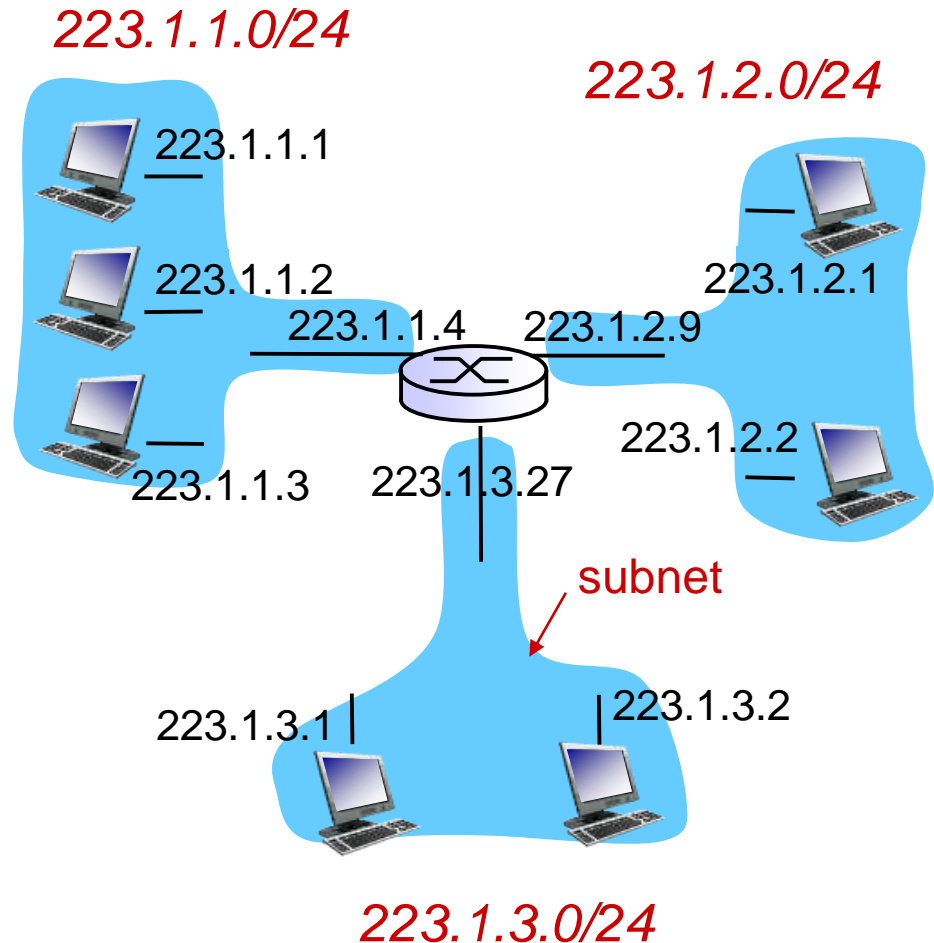


network consisting of 3 subnets

Subnets

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*



subnet mask: /24

Subnets

how many?

