Network, Transport and Application Layers

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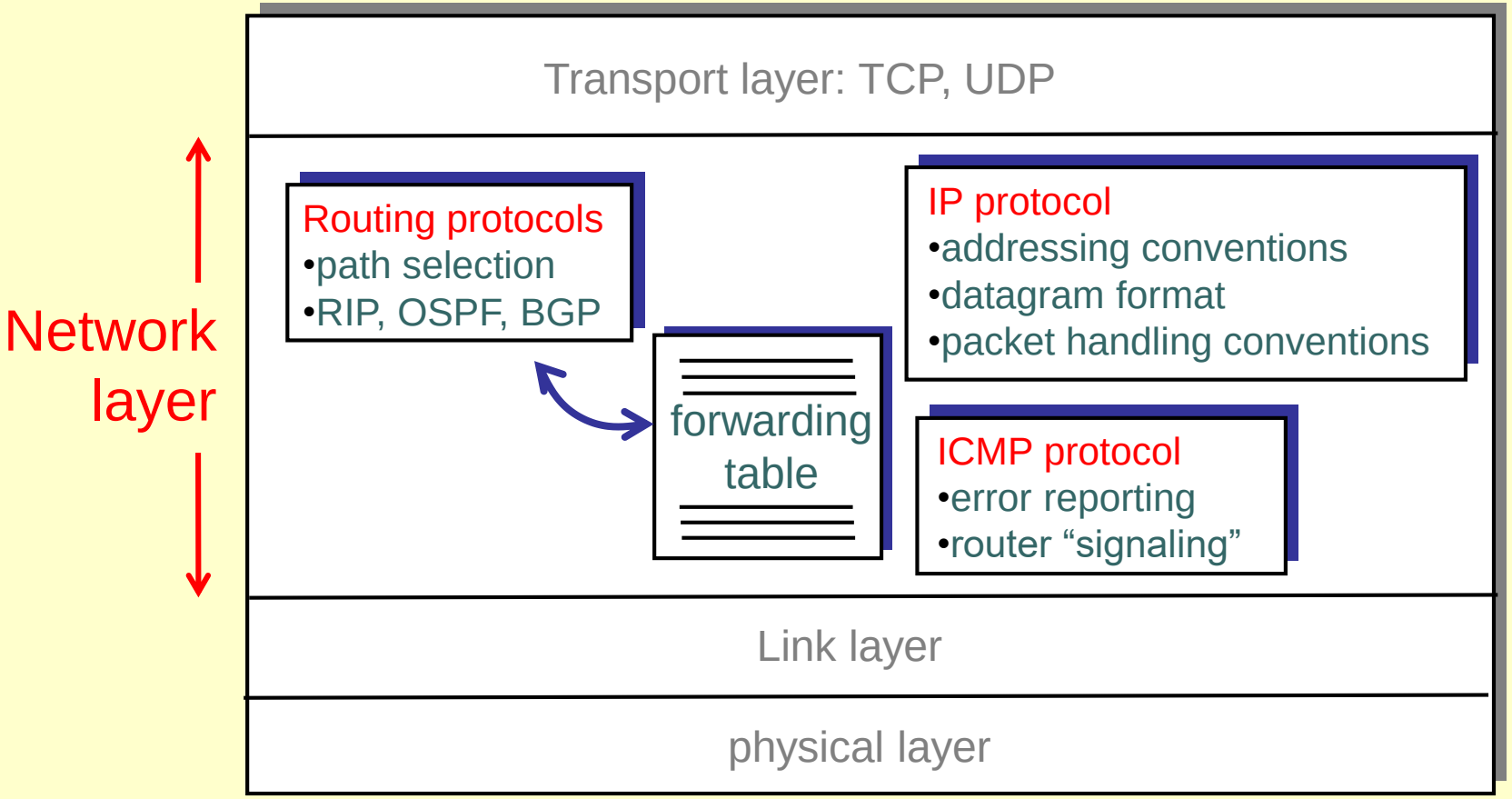
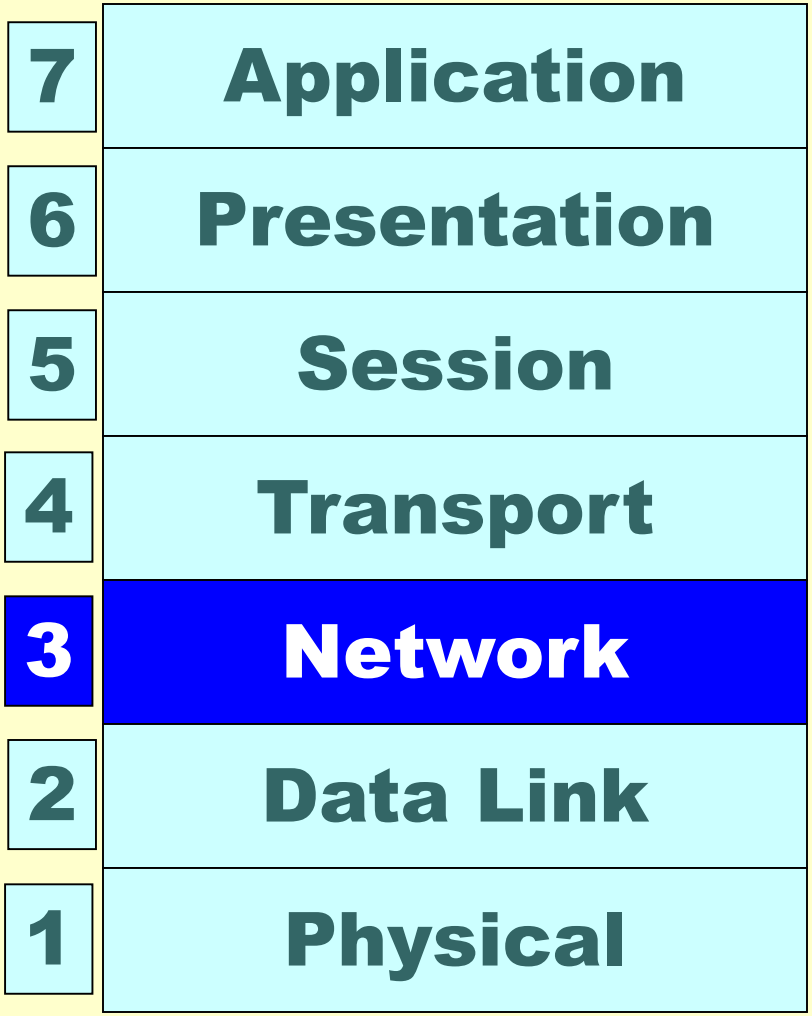
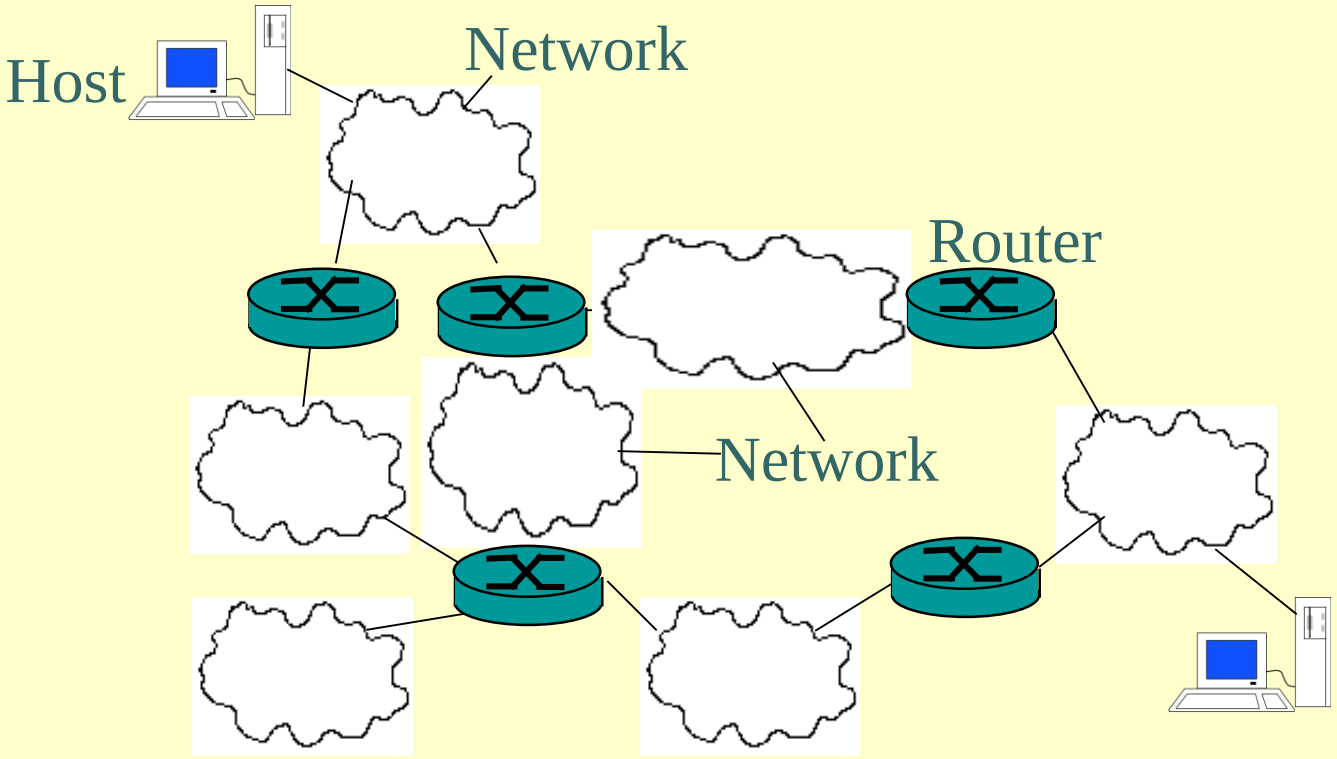
The Internet Network layer



Network Layer



Internet Networking Model



An internet consists of networks inter-connected by routers

IP Addressing: introduction

IP address: 32-bit identifier for host, router *interface*

Generally written as four decimal numbers

- Each number corresponds to eight bits (one byte)
- Dotted quad notation

Binary:
11011111000000010000011100000100

Decimal:
3741386500

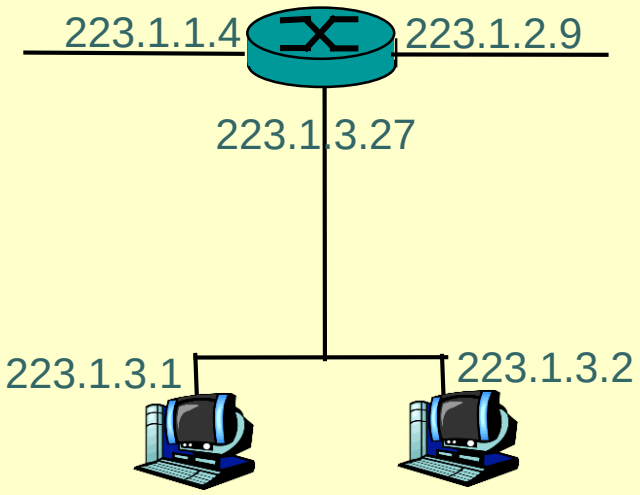
Hexadecimal:
DF010704

223.1.7.4 = 11011111 00000001 00000111 00000100

223 1 7 4

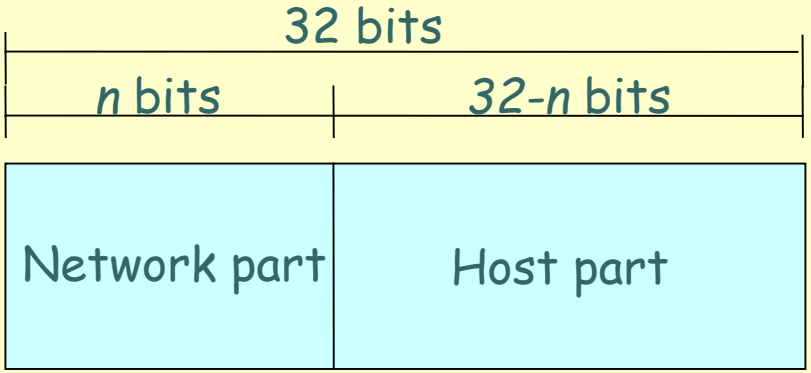
IP Addressing: introduction

- *interface:* connection between host/router and physical link
  - routers typically have multiple interfaces
  - host usually has one, but *may* have multiple interfaces
  - each interface may have an IP address
  - routers have multiple IPs



IP Addressing

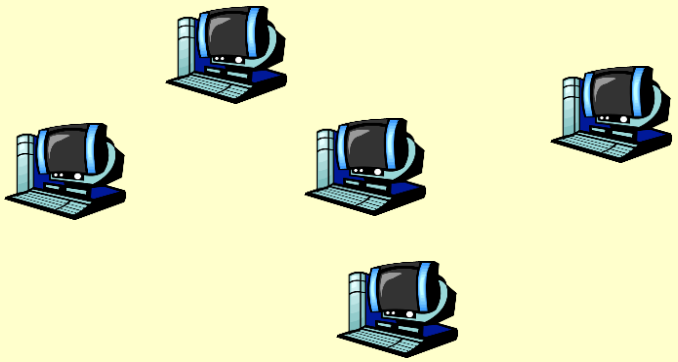
- IP address:
  - network part (high order bits)
  - host part (low order bits)
- Hosts (interfaces) with same network part of IP address are on the "same network"
  - can reach each other without going through a router



Network Bits	Host Bits	Host addr
10	22	4M
20	12	4096
24	8	256
28	4	16
30	2	4

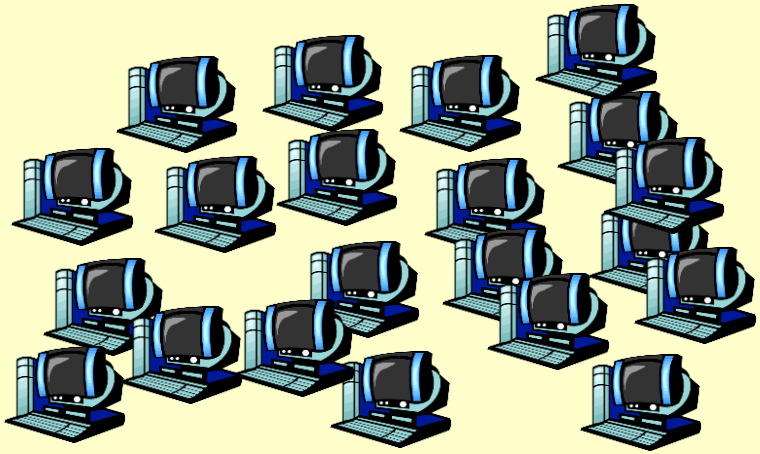
IP Addresses

- Small network has less bits for host part
  - More bits for network part



29 bits	3bits

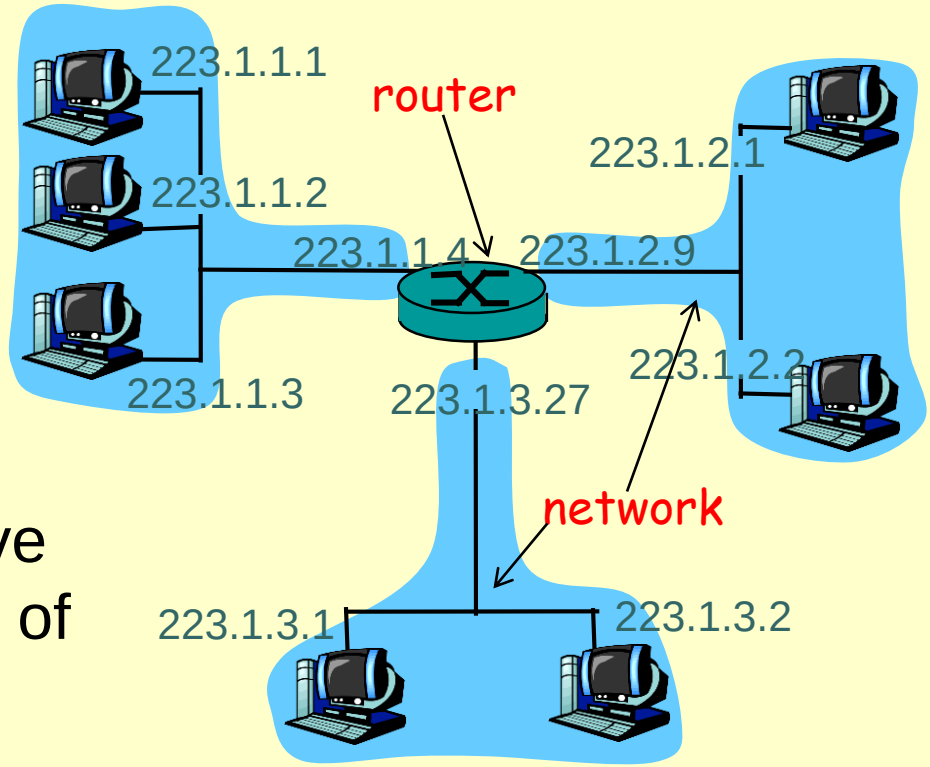
- Large network has more bits for host part
  - Less bits for network part



27 bits	5 bits

Network

- Three networks connected by a router
  - 223.1.1.xx
  - 223.1.2.xx
  - 223.1.3.xx
- All hosts on a network have same network part (24 bits) of IP address
- Router has three interfaces, each with an IP address

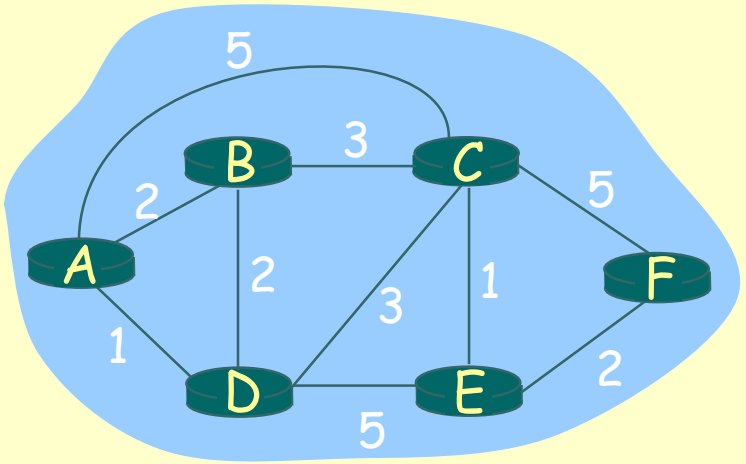


network consisting of 3 IP networks

Routing

Routing protocol

Goal: determine "good" path (sequence of routers) thru network from source to dest.

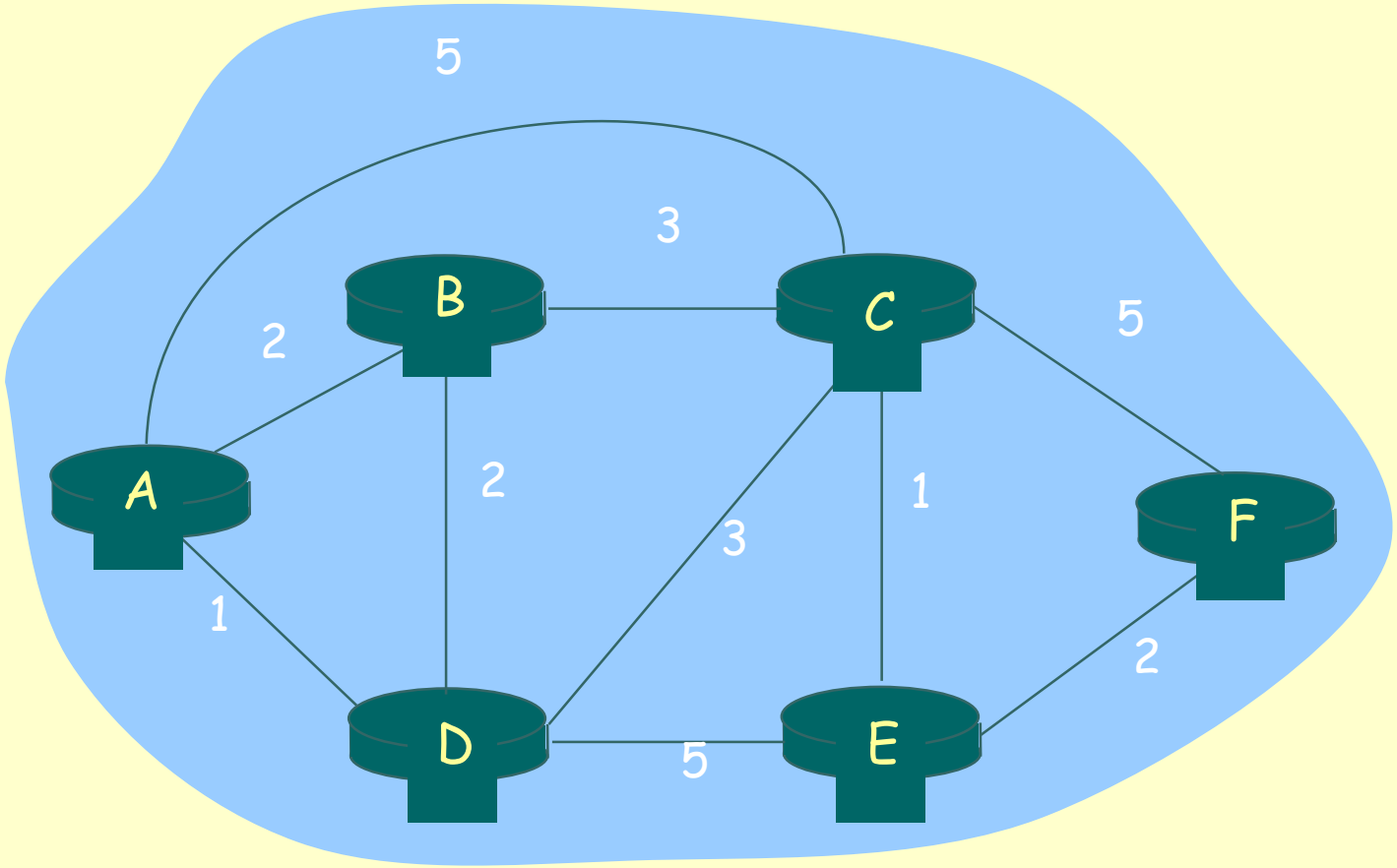


Graph abstraction for routing algorithms:

- graph nodes are routers
- graph edges are physical links
  - link cost: delay, $ cost, or congestion level

- "good" path:
  - typically means minimum cost path
  - other def's possible

What is the “shortest” path from A to F?



Routing Algorithm classification

Global or Local routing?

Global:

- router has complete topology, link cost info
- e.g.: Airline

Local:

- router knows physically-connected neighbors, link costs to neighbors
- iterative process of computation, exchange of info with neighbors

Static or dynamic?

Static:

- routes change slowly over time

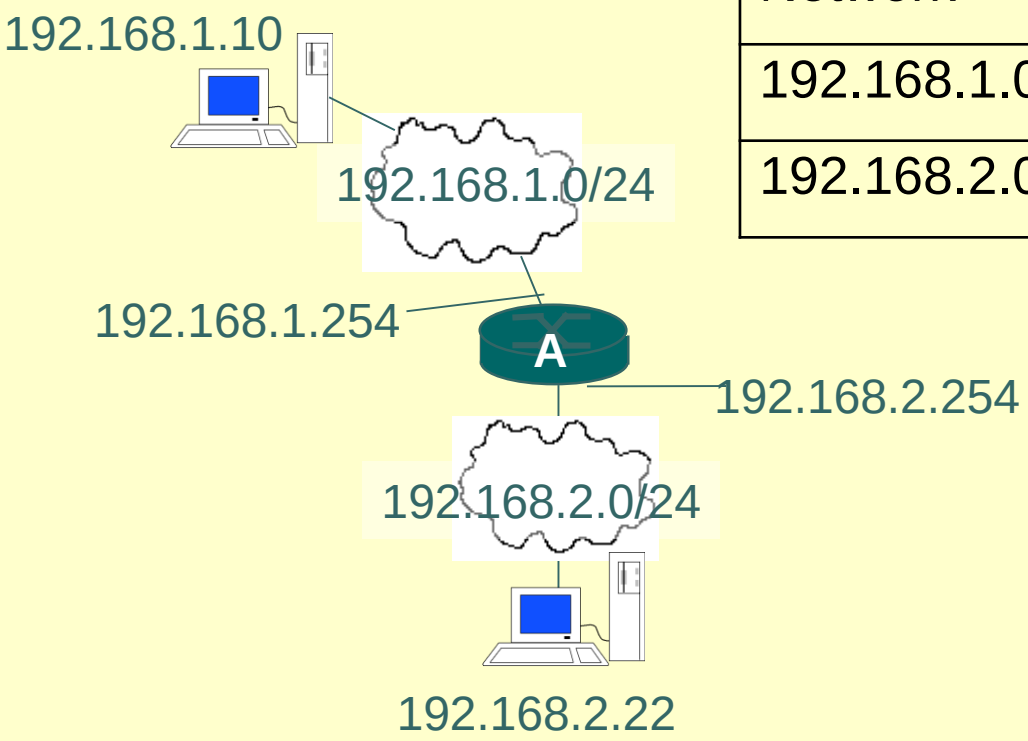
Dynamic:

- routes change more quickly
- periodic update
- in response to link cost changes

Source

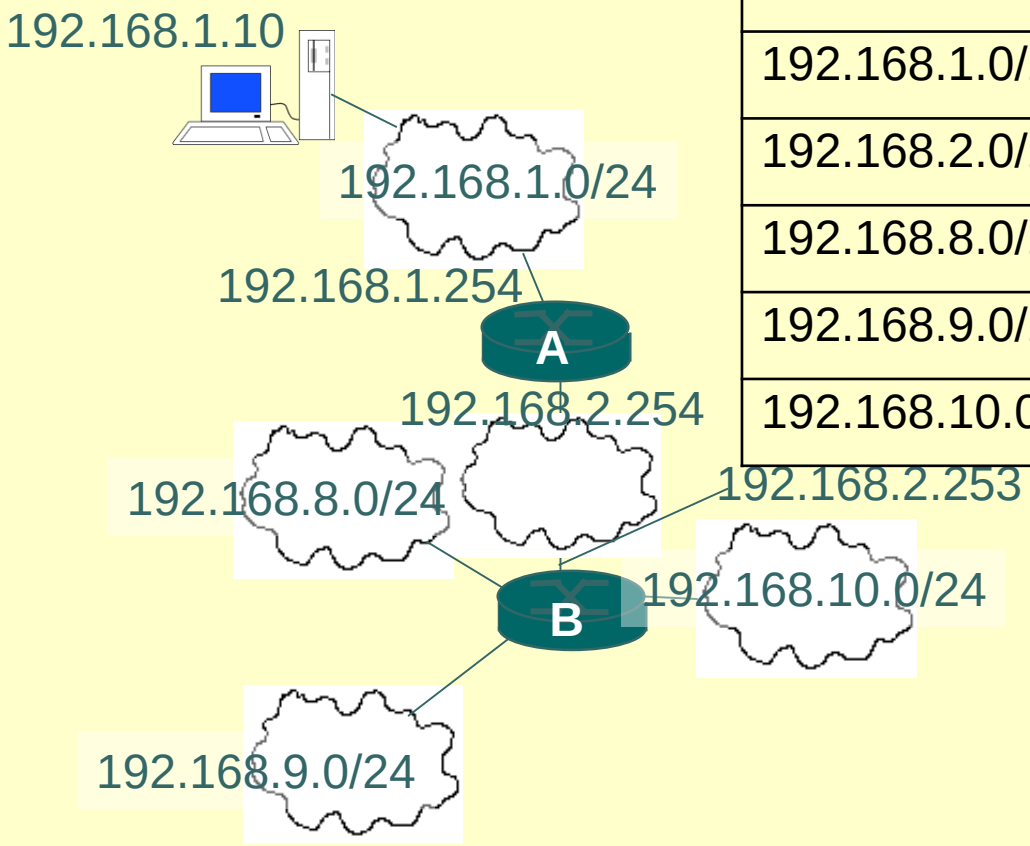
- Route pre-defined by the sender

Static Routing



Network	Next Hop
192.168.1.0/24	Direct (1)
192.168.2.0/24	Direct (2)

Static Routing (2)



Network	Next Hop
192.168.1.0/24	Direct (1)
192.168.2.0/24	Direct (2)
192.168.8.0/24	192.168.2.253
192.168.9.0/24	192.168.2.253
192.168.10.0/24	192.168.2.253

Dynamic (adaptive) Routing

- Intermediate Stations exchange routing information periodically
- Each station computes best path to each destination
- Based on
- link speed - delay
- congestion - error rate
- cost - policy

Distance

In routing, distance may be defined by

- no. of hops
- physical distance
- delay
- bandwidth (inverse)
- communication cost
- etc.

Routing Mechanisms

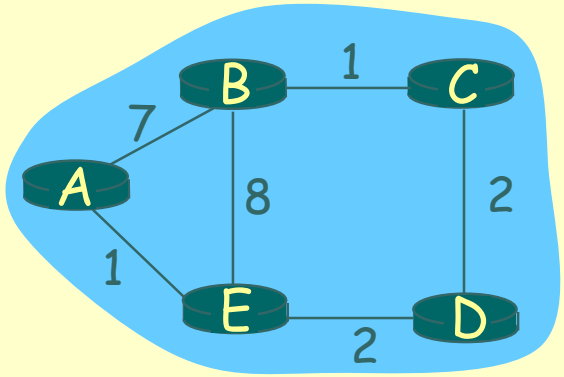
- Shortest Path Routing
  - calculates the shortest path between pairs of nodes
- Flooding
  - packets are sent on all unused links
- Distance Vector Routing
  - each router has table of distances to each destination

Routing Mechanisms (cont.)

- Link State Routing
- keeps track of the state of each link
- Broadcast Routing
- sends packet to all nodes in a network

Autonomous Routers

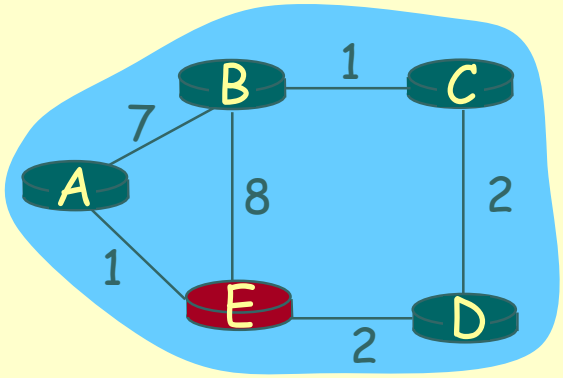
- Q: How can a router, which is directly connected to only a few other routers on a network, find the paths to all other routers?
- It can exchange information with its neighbors, who exchange info with *their* neighbors, etc…



Distance Vector Routing

- Each node keeps a list of the “shortest distance” to every other node, and the best way to reach it

Distance Table: example



Node E

cost to destination via

$D^E()$	A	B	D
A	1	14	5
B	7	8	5
C	6	9	4
D	4	11	2

destination

Distance table gives routing table

cost to destination via

$D^E()$

destination	A	B	D
A	1	14	5
B	7	8	5
C	6	9	4
D	4	11	2

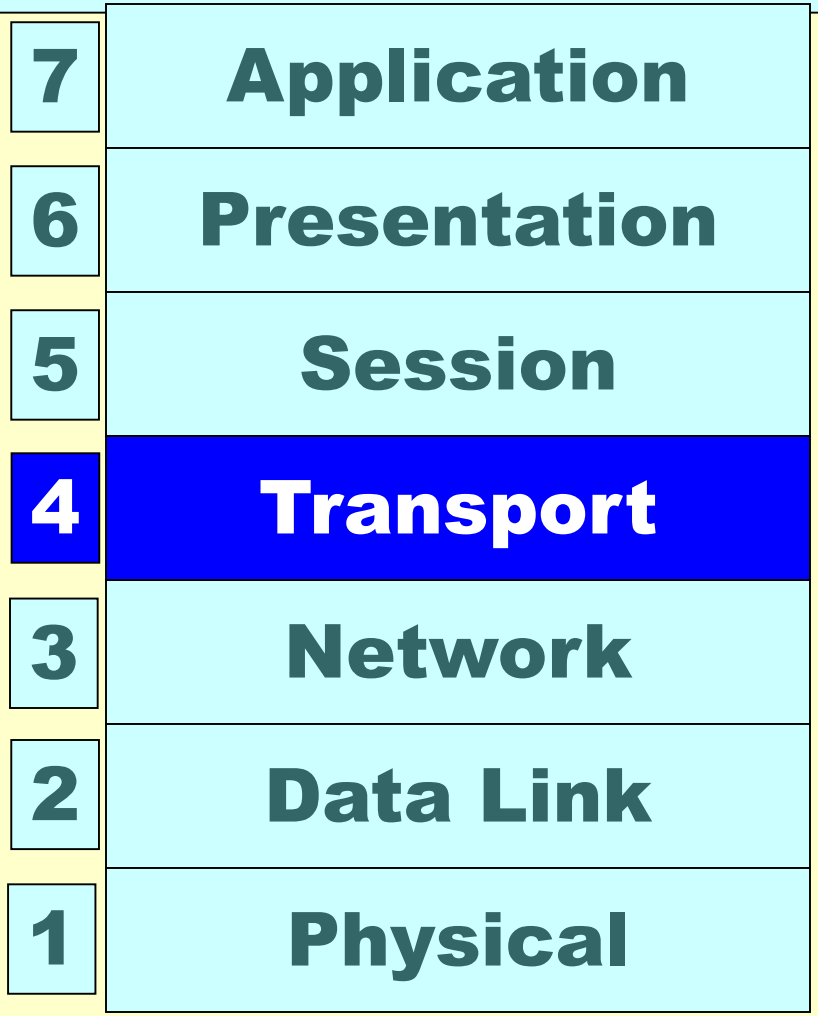
Distance table → Routing table

destination	Outgoing link to use, cost
A	A,1
B	D,5
C	D,4
D	D,2

Link-State Routing

- Each router finds out information about directly connected links
- Sends this information to neighbours
- Eventually each node knows about all the links
- Each node computes best path to get to each other node, based on its knowledge about links
- If information is consistent, then network will route packets correctly

Transport Layer



Objectives of the transport layer

to provide end-to-end delivery of data

to provide an

efficient

reliable and

cost-effective service

to shield upper layers from the peculiarities of the network

Transport and network layers

Transport layer operates in the end stations

Network layer operates mostly inside the network (in routers)

Transport layer can improve the service provided by the network layer

transport service can be more reliable than the network service

Functions of Transport Layer

Ensure data is delivered to the other end

Deal with peculiarities of the NW layer

fragmentation

multiplexing

inverse multiplexing

Type of service

Transport Layer functions (cont.)

Manage multiple connections on the same hosts

Establishing and deleting connections

naming

Flow control

Types of Transport service

Connection-oriented

Connectionless

Reliable

Not reliable

Multicast

Internet Transport Protocols

TCP (Transmission Control Protocol)

connection-oriented

reliable

unicast

UDP (Unreliable Datagram Protocol)

connectionless

unacknowledged (at the TP layer)

Unicast / Multicast

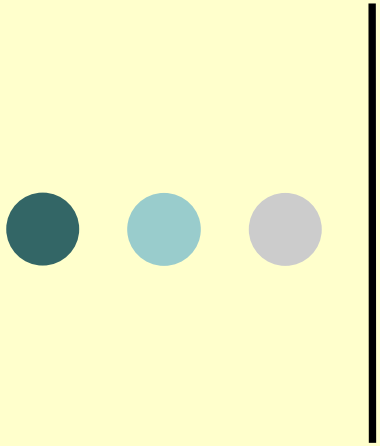
Why is there a UDP?

no connection establishment (which can add delay)

simple: no connection state at sender, receiver

small segment header

no congestion control: UDP can blast away as fast as desired



Network Applications

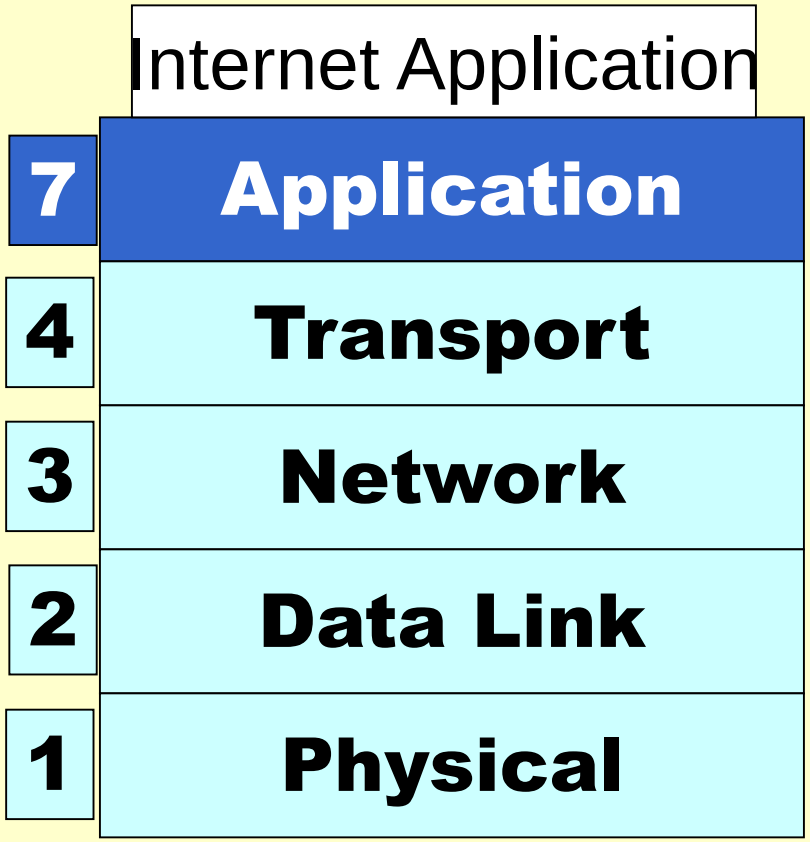
Network Applications

- World-Wide Web
- Facebook
- Googledocs
- YouTube
- Games
- Skype, videoconferencing
- BitTorrent
- Remote Files
- Remote Desktop

Why Internet Applications?

- Without applications, Internet (or any other network) would be useless

App. Layer in Internet Stack



Internet Applications Layer Model

- Application talks directly to the transport layer (TCP or UDP)
- Application Layer defined as a protocol

–both sides must implement the protocol

- APIs usually not defined by IETF
- Third-party APIs available

–C, Java, VB, XML, etc.

- Generally use the *client-server* model

Client-server operation (cont.)

- Servers should be always on

–generally sit in a data centre

–or on the “cloud”

- Clients are often user machines

–PCs, phones, mobile devices,

–sometimes other servers

Common Internet App. Protocols

- E-mail
  - Simple Mail Transfer Protocol SMTP
  - Post Office Protocol (V3) POP
  - Interactive Mail Access Protocol IMAP
- File Transfer
  - File Transfer Protocol FTP
  - BitTorrent
- Domain Name Service DNS

Common Protocols (cont.)

- Web
  - HyperText Transfer Protocol HTTP
- Remote Login
  - Telnet
  - rlogin
  - Secure Shell SSH

Common Protocols (Cont.)

- Remote graphics
  - –X Window System
  - –Microsoft Remote Desktop
  - –VNC
- Remote File Systems
  - –Sun Network File System NFS
  - –SMB / CIFS
- Network Management
  - –Simple Network Management Protocol

Common Protocols (cont.)

- Voice and Teleconferencing
  - –Session Initiation Protocol SIP
  - –H.323

many others...

Protocol Format

Many protocols have a similar format

- Client - Server
- Command / Response

–text commands

–numeric responses

- Half duplex data exchange

–why?

Protocol Format (cont.)

- ASCII text commands and responses

>> MAIL From:<gihan@mail.mrt.ac.lk> SIZE=54

<< 250 2.1.0 <gihan@mail.mrt.ac.lk>... Sender ok

>> RCPT To:<gihan@cse.mrt.ac.lk>

<< 250 2.1.5 <gihan@cse.mrt.ac.lk>... Recipient ok

–why?

Summary

- Internetworking
- IP addressing
- Routing principles
- Transport Layer
- Applications Layer