COMPUTER NETWORKS AND INTERNET PROTOCOLS

IP Routing - I [Intra-domain routing]

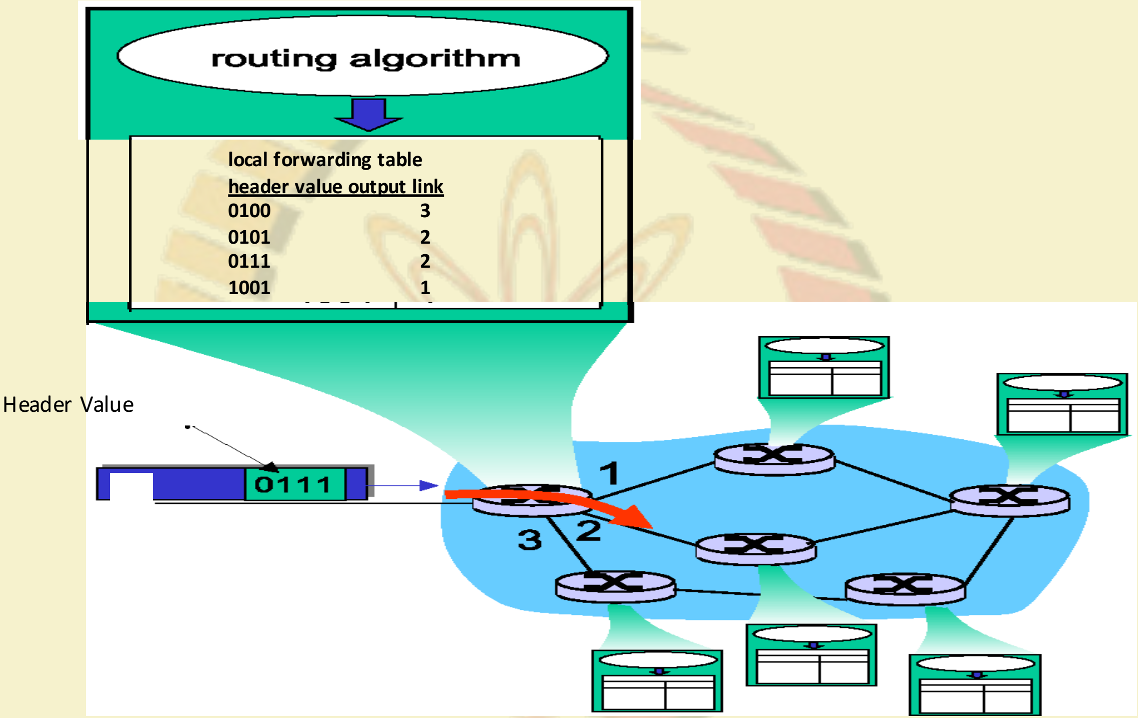
SOUMYA K GHOSH
COMPUTER SCIENCE AND ENGINEERING
IIT KHARAGPUR

SANDIP CHAKRABORTY
COMPUTER SCIENCE AND ENGINEERING
IIT KHARAGPUR

Routing ?

- Forwarding – moving packets between ports
  - Look up destination address in forwarding table
  - Find out-port or <out-port, MAC Addr> pair
- Routing is process of populating forwarding table
  - Routers exchange messages about nets they can reach
  - Goal: Find optimal route for every destination

Routing…


routing algorithm
local forwarding table
header value output link
0100 3
0101 2
0111 2
1001 1
Header Value
0111
1
2
3

Stability

- Stable routes are often preferred over rapidly changing ones
- Reason 1: management
  - Hard to debug a problem if it’s transient
- Reason 2: higher layer optimizations
  - E.g., TCP RTT estimation
  - Imagine alternating over 500ms and 50ms routes
- Choosing between optimality and stability!

Routing algorithms

- Global (centralized) vs. Decentralized
- Global: All routers have complete topology
- Decentralized: Only know neighbors and share information from them
- Intra-domain vs. Inter-domain routing
  - Intra : All routers under same administrative control
  - Inter : Decentralized, scale to Internet

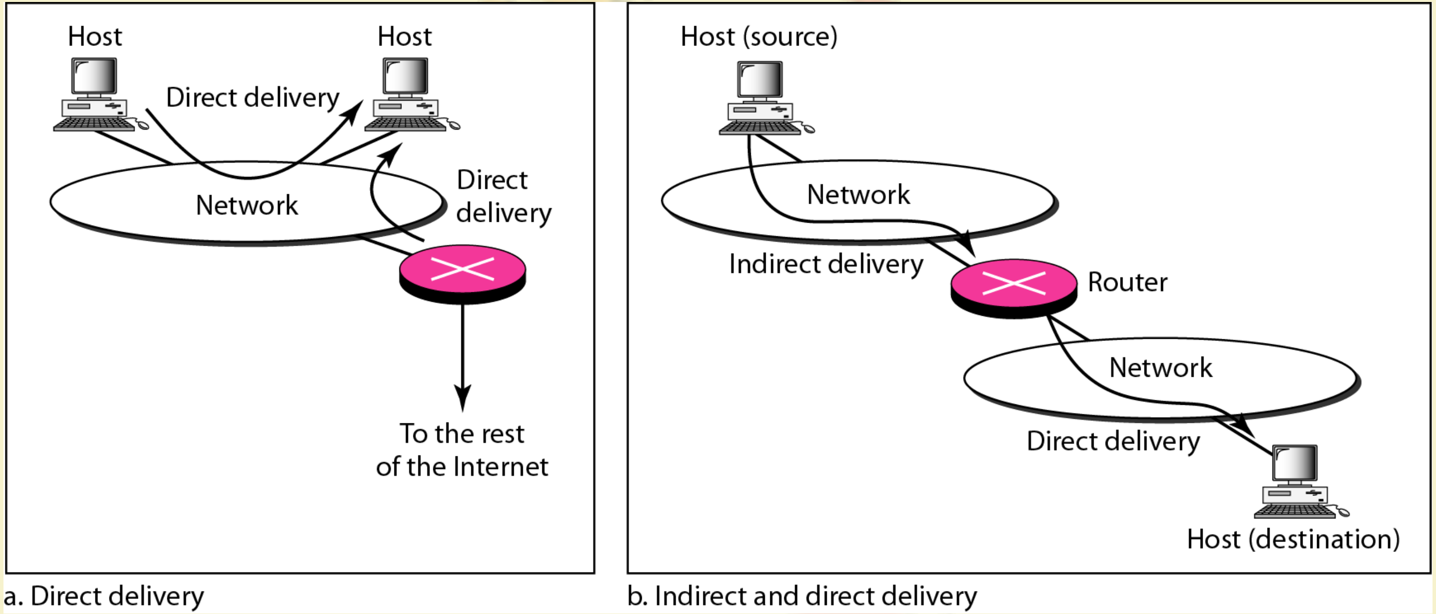
Optimality

- View network as a graph
- Assign cost to each edge
  - Can be based on latency, b/w, utilization, queue length, . . .
- Problem: Find lowest cost path between two nodes
  - Each node individually computes the cost

Scaling issues

- Every router must be able to forward based on any destination IP address
  - Given address, it needs to know ”next hop” (table)
  - Naıve: Have an entry for each address
  - There may be huge number of entries!
- Solution? - Entry covers range of addresses
  - Can’t do this if addresses are assigned randomly! (e.g., Ethernet addresses)
  - Address aggregation is important
  - Addresses allocation should be based on network structure

Routing/Forwarding Packets in the Internet



Ref: Data Communication and Networking by B.A. Forouzan

Route method vs. Next-hop method

a. Routing tables based on route

b. Routing tables based on next hop

Routing table for host A

Destination	Route
Host B	R1, R2, host B

Destination	Next hop
Host B	R1

Routing table for R1

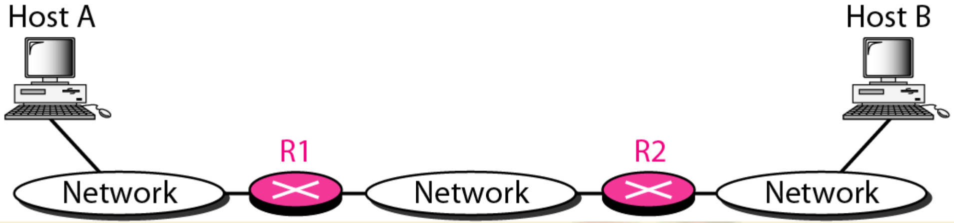
Destination	Route
Host B	R2, host B

Destination	Next hop
Host B	R2

Routing table for R2

Destination	Route
Host B	Host B

Destination	Next hop
Host B	---



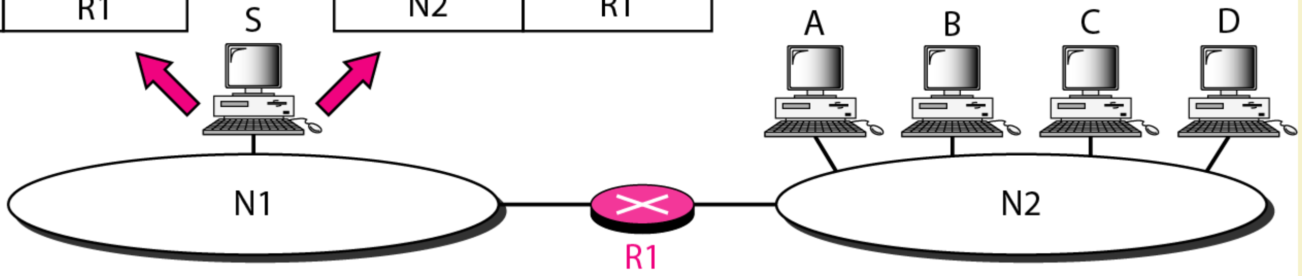
Host-specific vs. Network-specific method

Routing table for host S based on host-specific method

Destination	Next hop
A	R1
B	R1
C	R1
D	R1

Routing table for host S based on network-specific method

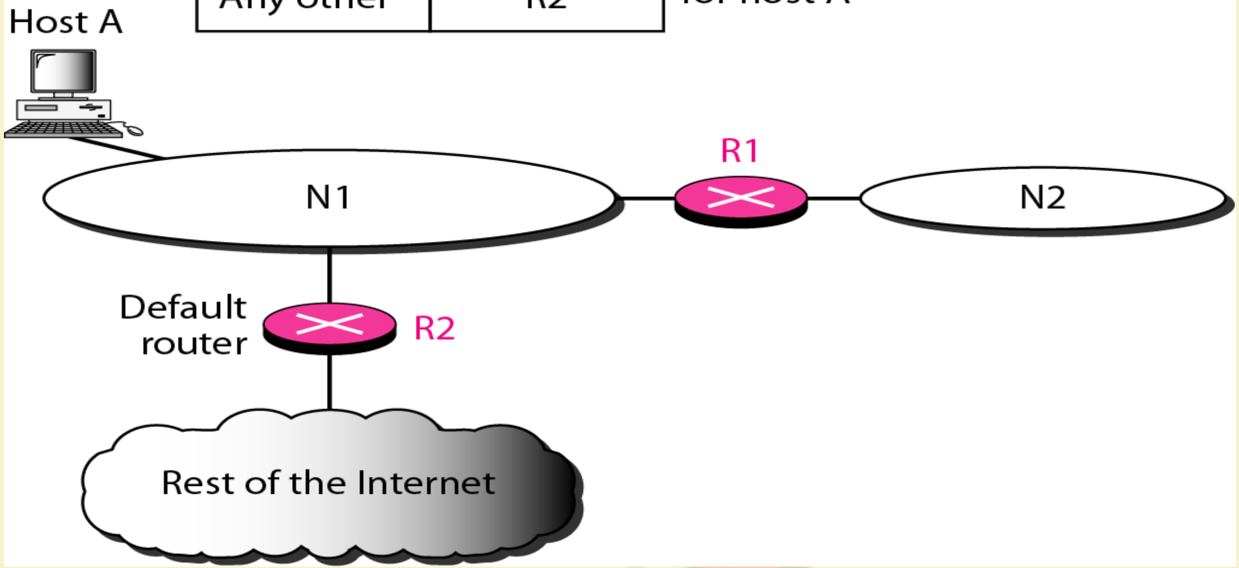
Destination	Next hop
N2	R1



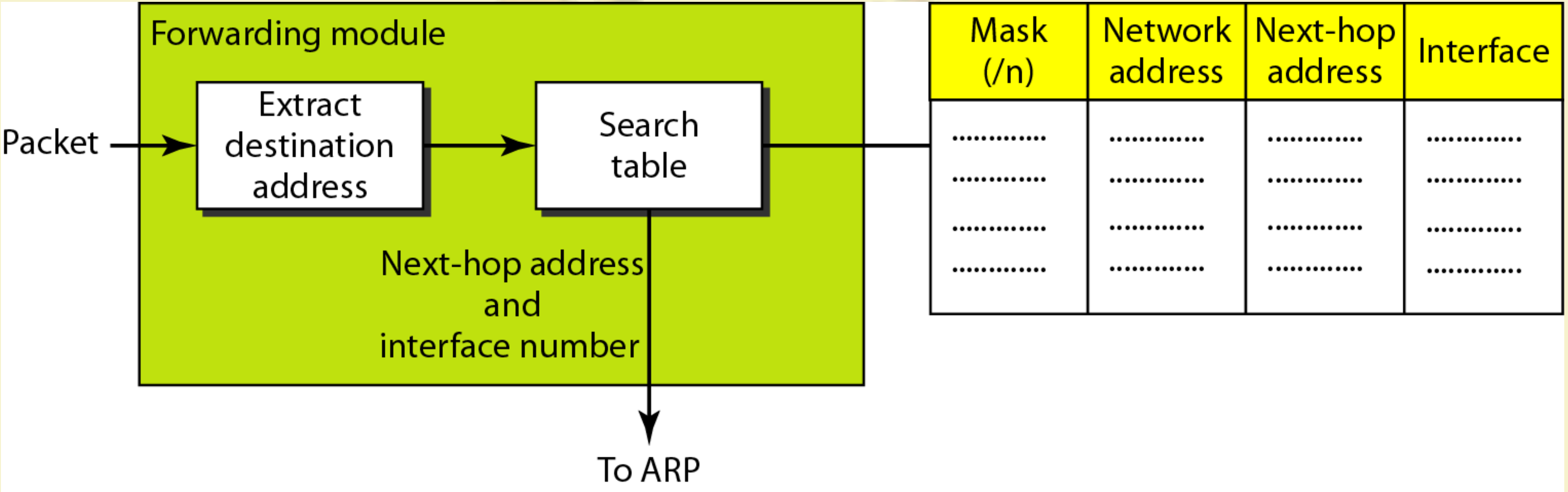
Default Route

Destination	Next hop
N2	R1
Any other	R2

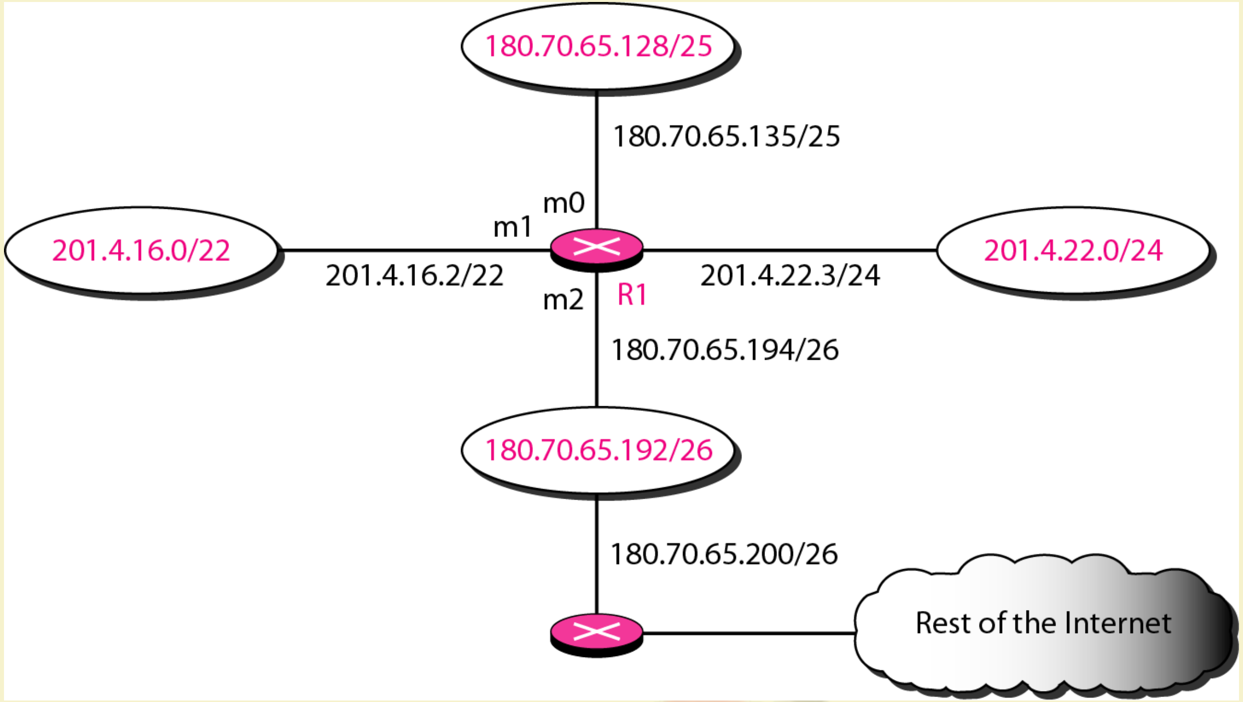
Routing table for host A



Basic Routing module in classless address



Example Routing Configuration



Routing table for router R1

Mask	*Network Address*	*Next Hop*	*Interface*
/26	180.70.65.192	—	m2
/25	180.70.65.128	—	m0
/24	201.4.22.0	—	m3
/22	201.4.16.0	....	m1
Any	Any	180.70.65.200	m2

Example: forwarding process if a packet arrives at R1 in with the destination address 180.70.65.140.

Router performs the following steps:

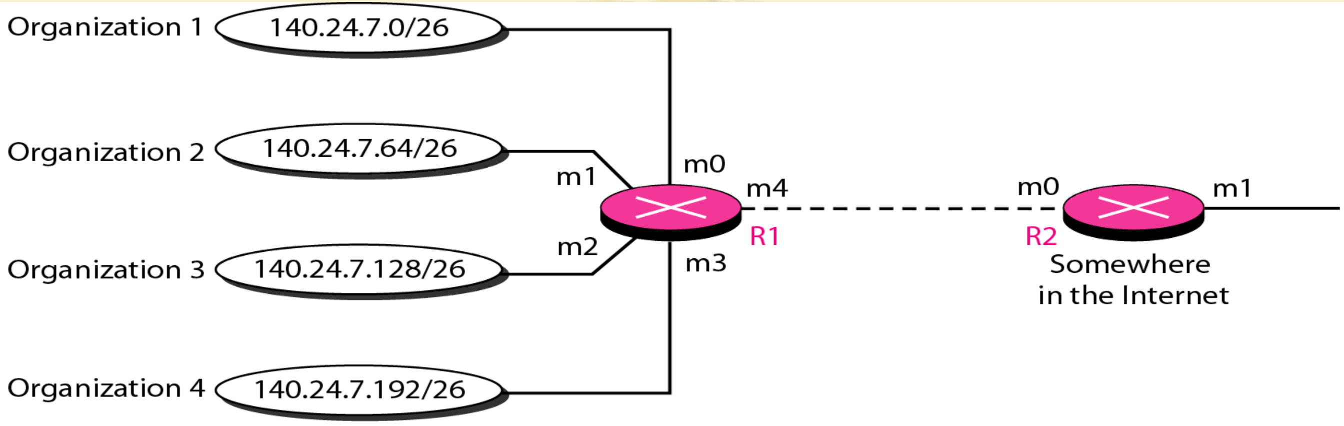
1. The first mask (/26) is applied to the destination address. The result is 180.70.65.128, which does not match the corresponding network address.
2. The second mask (/25) is applied to the destination address. The result is 180.70.65.128, which matches the corresponding network address. The next-hop address and the interface number m0 are passed to ARP for further processing.

Example: Show the forwarding process if a packet arrives at R1 with the destination address 201.4.22.35.

The router performs the following steps:

1. The first mask (/26) is applied to the destination address. The result is 201.4.22.0, which does not match the corresponding network address.
2. The second mask (/25) is applied to the destination address. The result is 201.4.22.0, which does not match the corresponding network address (row 2).
3. The third mask (/24) is applied to the destination address. The result is 201.4.22.0, which matches the corresponding network address. The destination address of the packet and the interface number m3 are passed to ARP.

Address aggregation



Mask	Network address	Next-hop address	Interface
/26	140.24.7.0	----------	m0
/26	140.24.7.64	----------	m1
/26	140.24.7.128	----------	m2
/26	140.24.7.192	----------	m3
/0	0.0.0.0	Default	m4

Routing table for R1

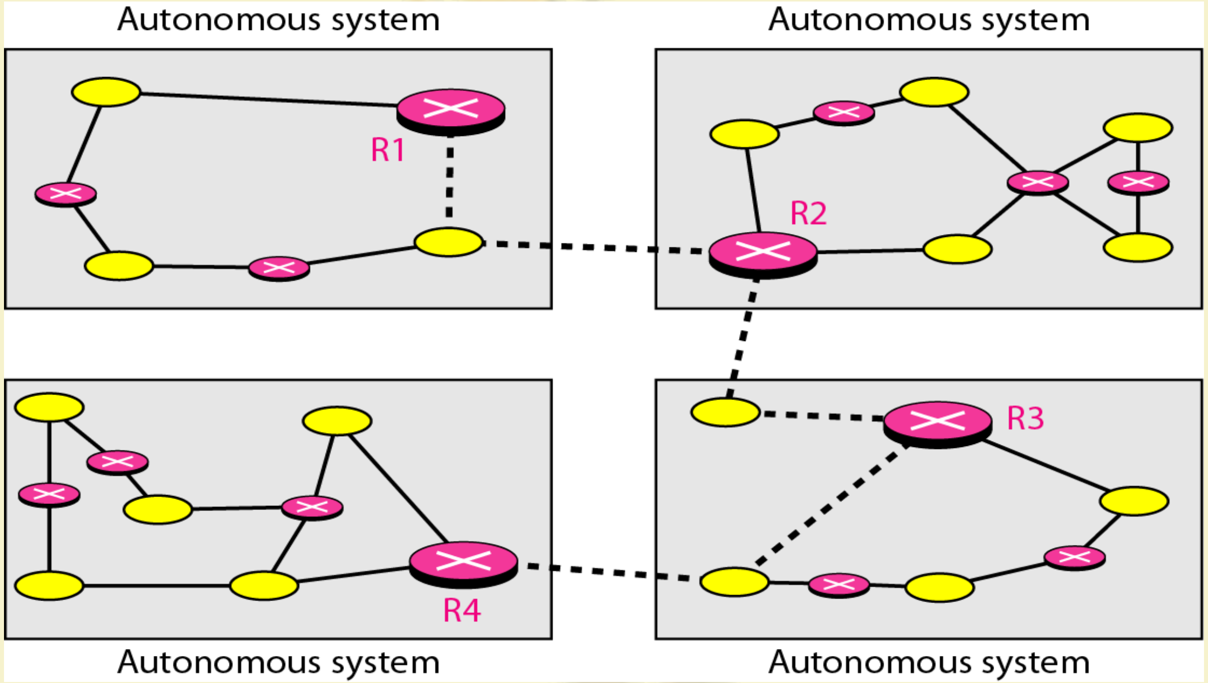
Mask	Network address	Next-hop address	Interface
/24	140.24.7.0	----------	m0
/0	0.0.0.0	Default	m1

Routing table for R2

Autonomous Systems (AS)

- Correspond to an administrative domain
  - Internet is not a single network
  - ASes reflect organization of the Internet
  - e.g., Stanford, large company, etc.
- Goals:
  - ASes want to choose their own local routing algorithm
  - ASes want to set policies about non-local routing
  - Each AS assigned unique 16-bit number

Autonomous systems



AS Traffic

- Local traffic – packets with src or dst in local AS
- Transit traffic – passes through an AS
- Stub AS -Connects to only a single other AS
- Multihomed AS
  - Connects to multiple ASes
  - Carries no transit traffic
- Transit AS - Connects to multiple ASes and carries transit traffic

Intra-domain Routing

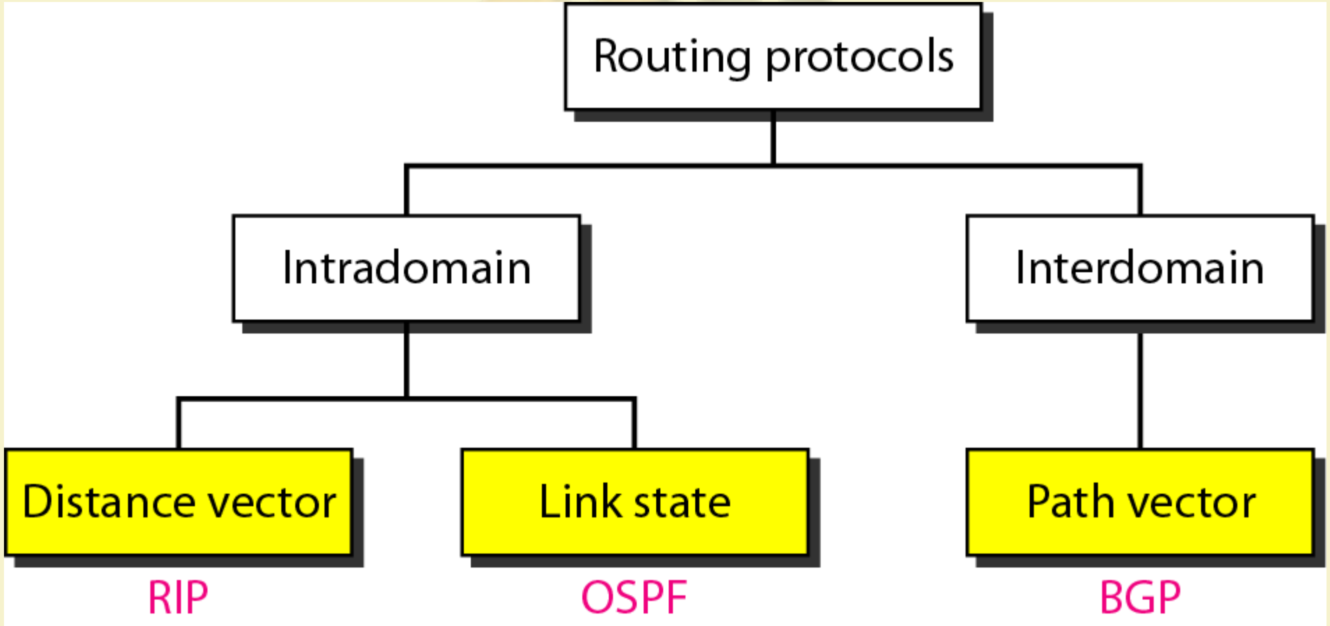
- Intra-domain routing: within an AS
- Single administrative control: *optimality* is important
  - Contrast with inter-AS routing, where policy dominates
  - Next lecture will cover inter-domain routing (BGP)

Intra-domain Routing Algorithms

- Distance vector
  - Require only local state (less overhead, smaller footprint)
  - Harder to debug
  - Can suffer from loops

- Link state
  - Have a global view of the network
  - Simpler to debug
  - Require global state

Popular routing protocols



Distance vector routing

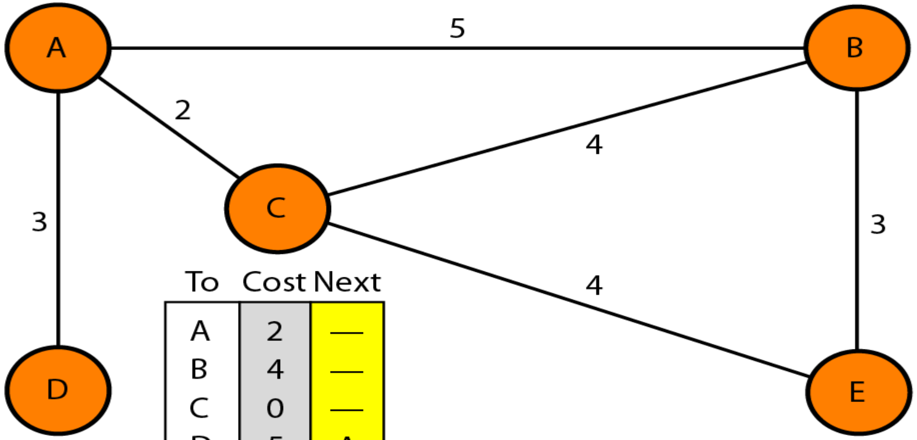
In distance vector routing, each node shares its routing table with its immediate neighbors periodically and when there is a change.

To	Cost	Next
A	0	—
B	5	—
C	2	—
D	3	—
E	6	C

A's table

To	Cost	Next
A	5	—
B	0	—
C	4	—
D	8	A
E	3	—

B's table



To	Cost	Next
A	3	—
B	8	A
C	5	A
D	0	—
E	9	A

D's table

To	Cost	Next
A	2	—
B	4	—
C	0	—
D	5	A
E	4	—

C's table

To	Cost	Next
A	6	C
B	3	—
C	4	—
D	9	C
E	0	—

E's table

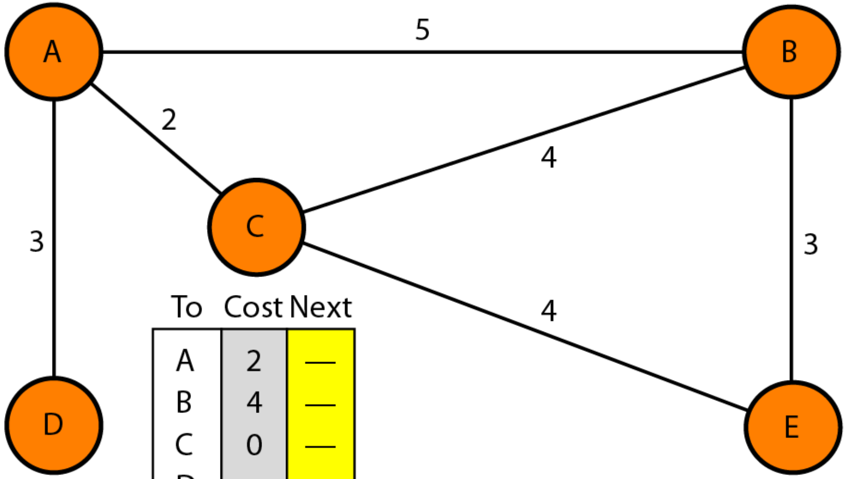
Distance Vector routing: Initialization of tables

To	Cost	Next
A	0	—
B	5	—
C	2	—
D	3	—
E	∞	

A's table

To	Cost	Next
A	5	—
B	0	—
C	4	—
D	∞	
E	3	—

B's table



To	Cost	Next
A	3	—
B	∞	
C	∞	
D	0	—
E	∞	

D's table

To	Cost	Next
A	2	—
B	4	—
C	0	—
D	∞	
E	4	—

C's table

To	Cost	Next
A	∞	
B	3	B
C	4	C
D	∞	
E	0	D

E's table

thank you!