Chapter 7.C and 7.D

Link Layer & Network Layer

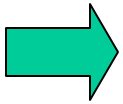
Prof. Dina Katabi

Some slides are from lectures by Nick Mckeown, Ion Stoica, Frans Kaashoek, Hari Balakrishnan, and Sam Madden

Previous Lecture

The network is organized into layers

This Lecture



- Link Layer
- Network Layer
  - Forwarding
  - Routing
  - Hierarchical Addressing and Routing

Link Layer

Problem:

Deliver data from one end of the link to the other

Need to address:

- *Bits Analog Bits*
- *Framing*
- *Errors*
- *Medium Access Control (The Ethernet Paper)*

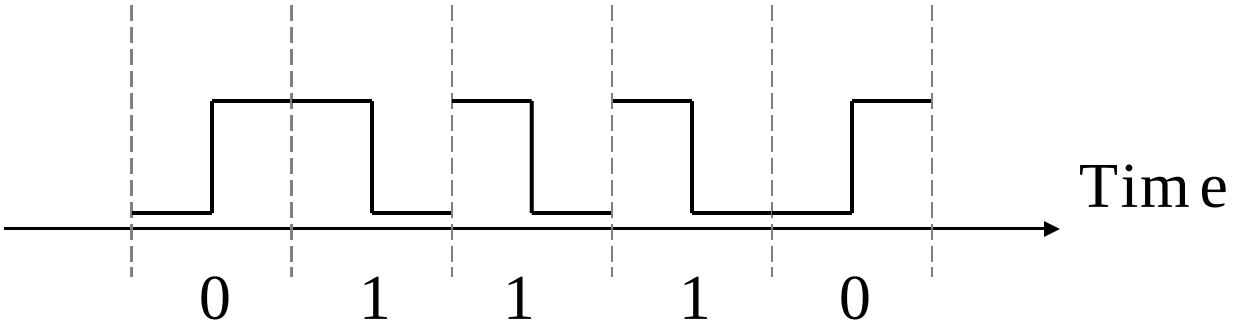
Sending bits

Bits Analog Bits

Receiver needs to detect the value of the bits

Manchester Encoding: each bit is a transition

Having a transition in each bit allows the receiver to synchronize to the sender's clock



Framing

Receiver needs to detect the beginning and the end of a frame

Use special bit-pattern to separate frames

- *E.g., pattern could be 1111111 (7 ones)*

Bit stuffing is used to ensure that a special pattern does not occur in the data

- *If pattern is 1111111 Whenever the sender sees a sequence of 6 ones in the data, it inserts a zero (reverse this operation at receiver)*

Error Handling

Detection:

Use error detection codes, which add some redundancy to allow detecting errors

When errors are detected

Correction:

- Some codes allow for correction

Retransmition:

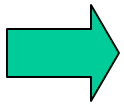
- Can have the link layer retransmit the frame (rare)

Discard:

- Most link layers just discard the frame and rely on higher layers to retransmit

This Lecture

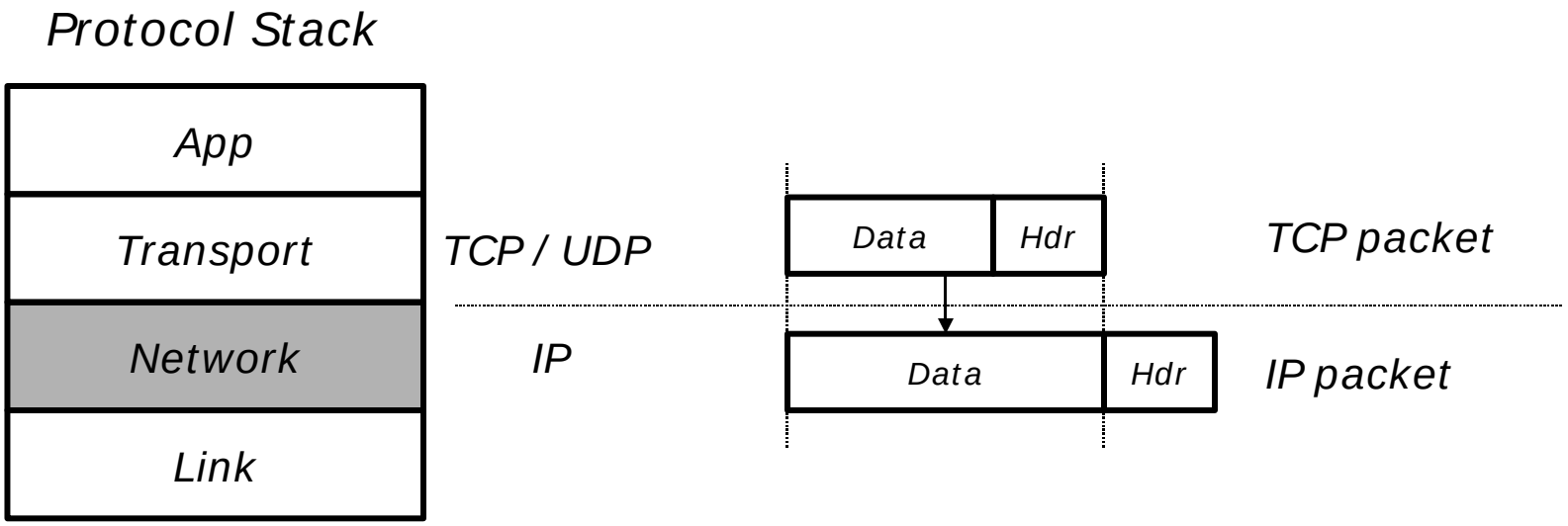
Link Layer



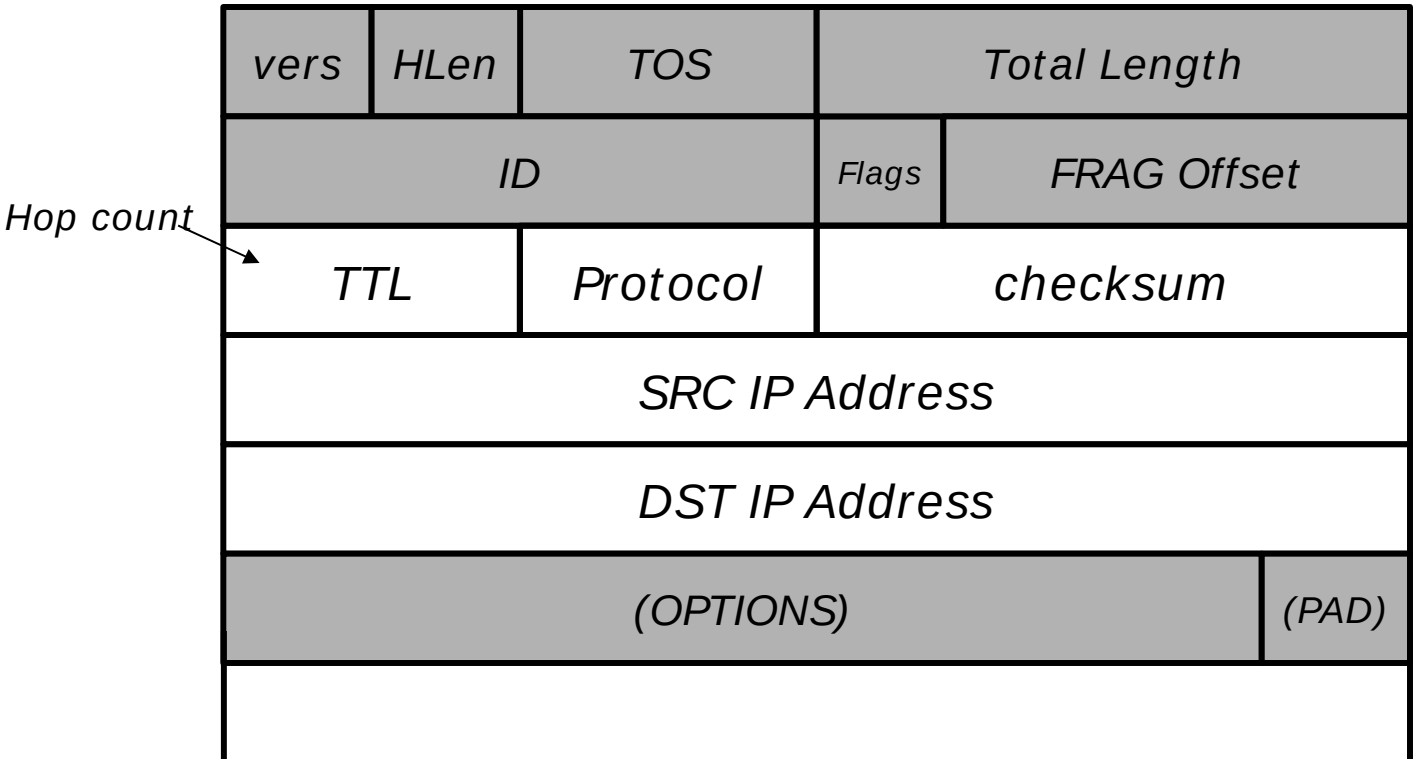
Network Layer

- *Forwarding*
- *Routing*
- *Hierarchical Addressing and Routing*

The Internet Protocol (IP)



The IP Header



Network Layer:

finds a path to the destination and forwards packets along that path

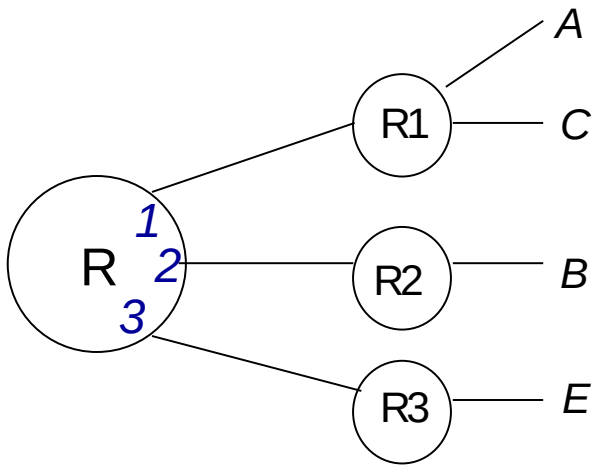
Difference between routing and forwarding

- *Routing is finding the path*
- *Forwarding is the action of sending the packet to the next-hop toward its destination*

Forwarding

Each router has a forwarding table

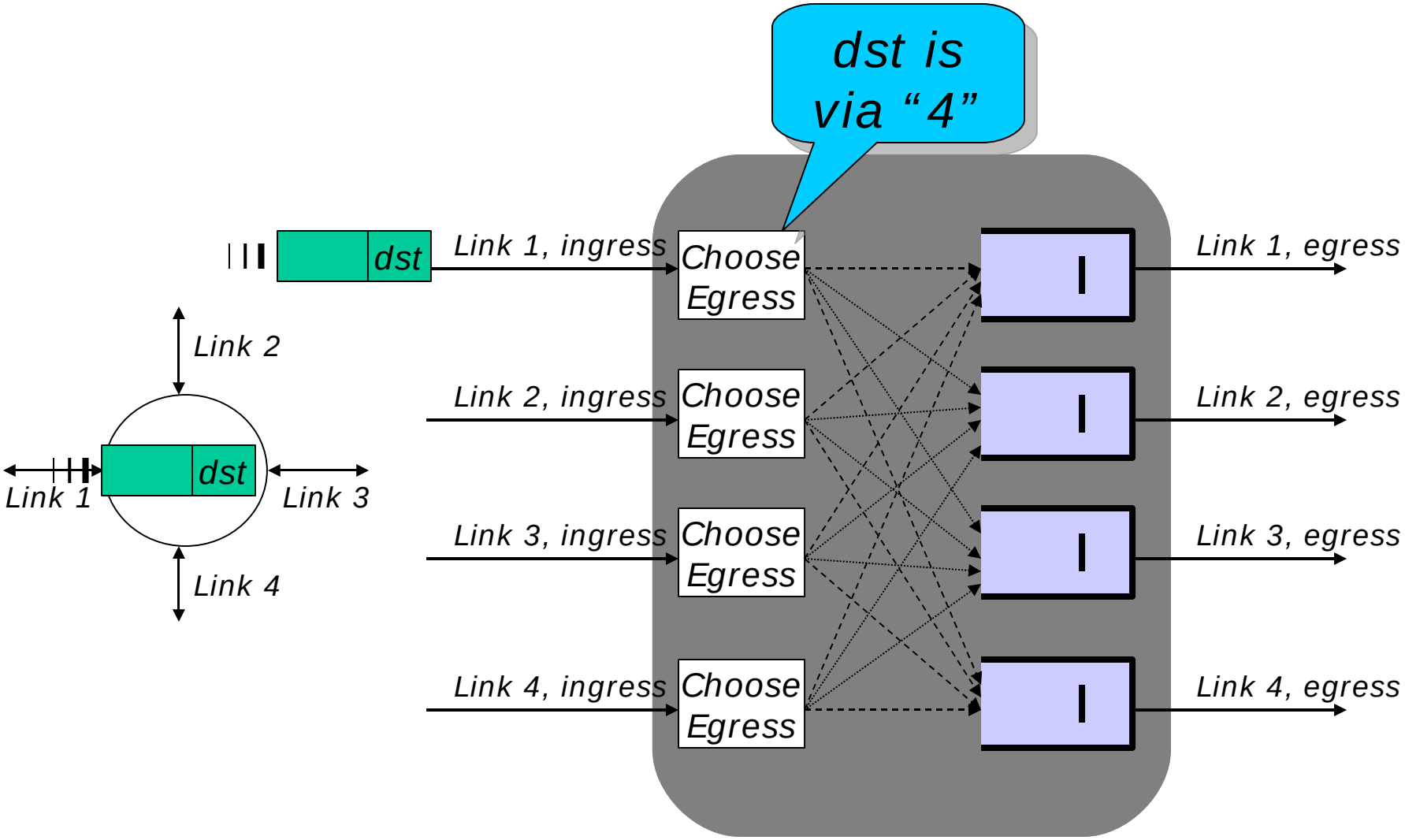
Forwarding tables are created by a routing protocol



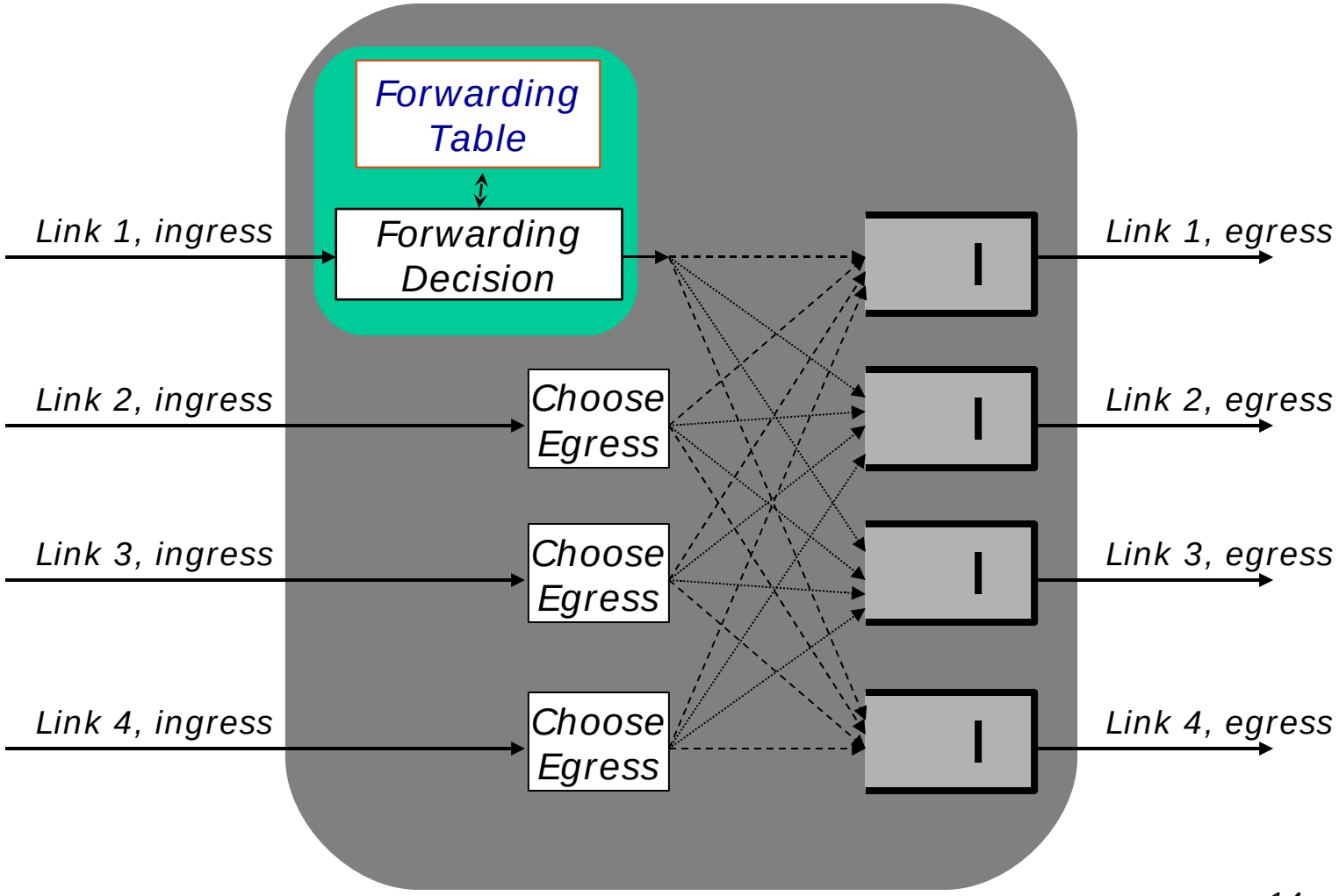
Forwarding table at R

Dst. Addr	Link
A	1
B	2
C	1
E	3

Forwarding In a Router



Inside a router



Forwarding an IP Packet

- *Lookup packet's DST in forwarding table*
  - *If known, find the corresponding outgoing link*
  - *If unknown, drop packet*
- *Decrement TTL and drop packet if TTL is zero; update header Checksum*
- *Forward packet to outgoing port*
- *Transmit packet onto link*

This Lecture

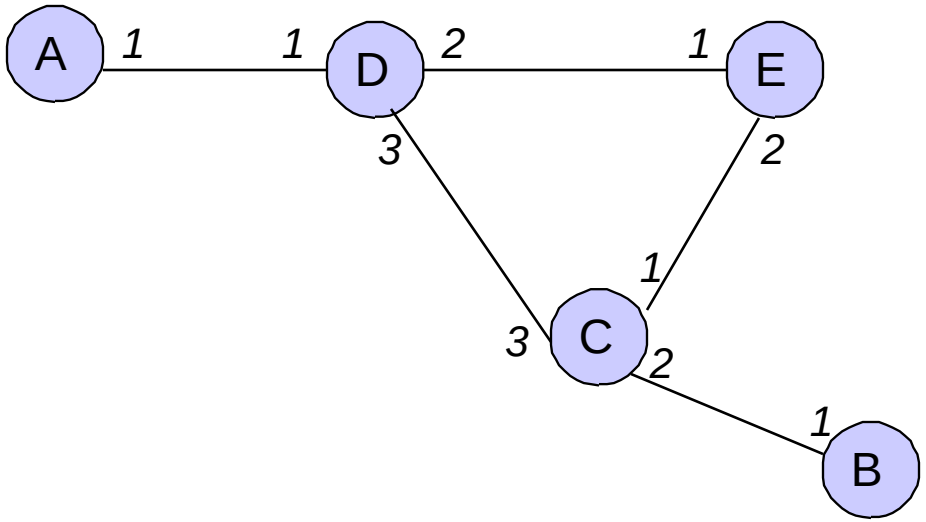
Link Layer

Network Layer

- *Forwarding*
- *Routing*
- *Hierarchical Addressing & Routing*

The Routing Problem:

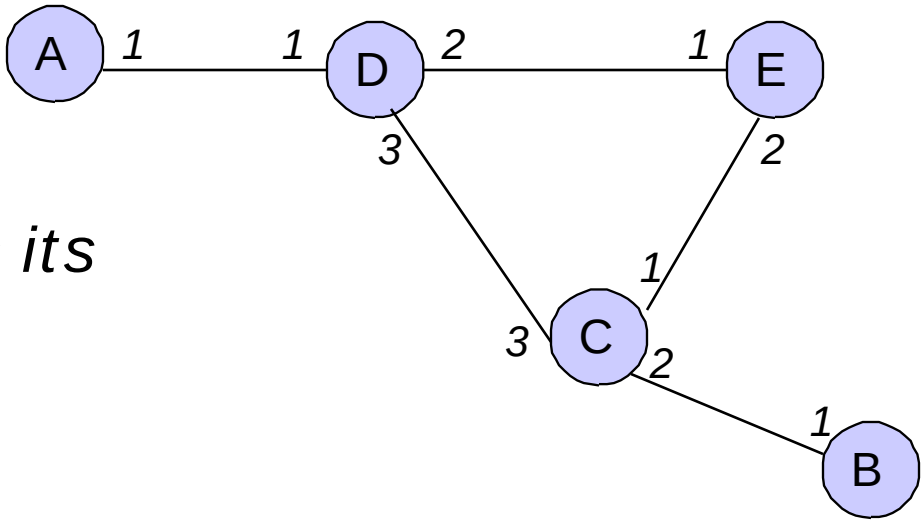
Generate forwarding tables



Path Vector Routing Protocol

Initialization

Each node knows the path to itself



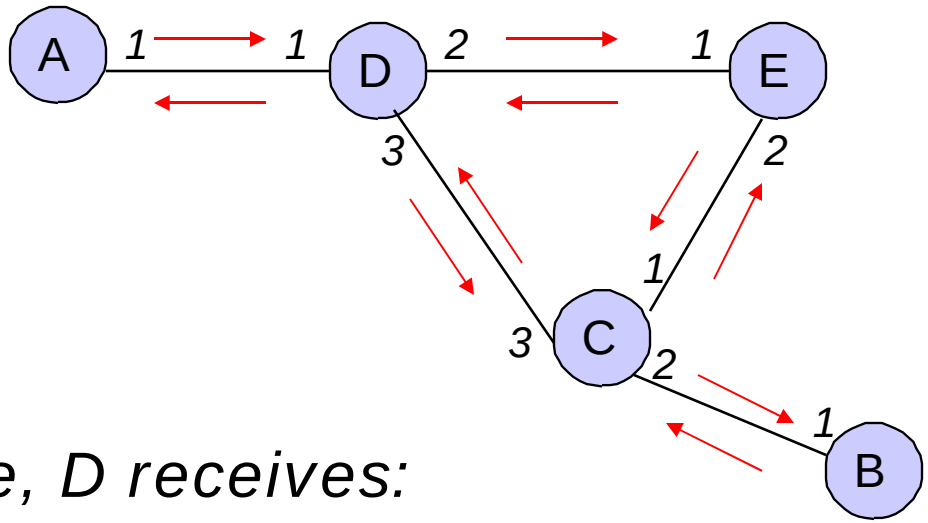
For example, D initializes its paths

DST	Link	Path
D	End layer	null

Path Vector

Step 1: Advertisement

Each node tells its neighbors its path to each node in the graph



For example, D receives:

From A:

To	Path
A	null

From C:

To	Path
C	null

From E:

To	Path
E	null

Path Vector

Step 2: Update Route Info

Each node use the advertisements to update its paths

D received: From A:

To	Path
A	null

From C:

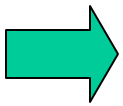
To	Path
C	null

From E:

To	Path
E	null

D updates its paths:

DST	Link	Path
D	End layer	null



DST	Link	Path
D	End layer	null
A	1	< A>
C	3	< C>
E	2	< E>

Note: At the end of first round, each node has learned all one-hop paths

Path Vector

Periodically repeat Steps 1 & 2

In round 2, D receives:

From A:

To	Path
A	null
D	< D>

From C:

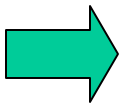
To	Path
C	null
D	< D>
E	< E>
B	< B>

From E:

To	Path
E	null
D	< D>
C	< C>

D updates its paths:

DST	Link	Path
D	End layer	null
A	1	< A>
C	3	< C>
E	2	< E>



DST	Link	Path
D	End layer	null
A	1	< A>
C	3	< C>
E	2	< E>
B	3	< C, B>

Note: At the end of round 2, each node has learned all two-hop paths

Questions About Path Vector

How do we ensure no loops?

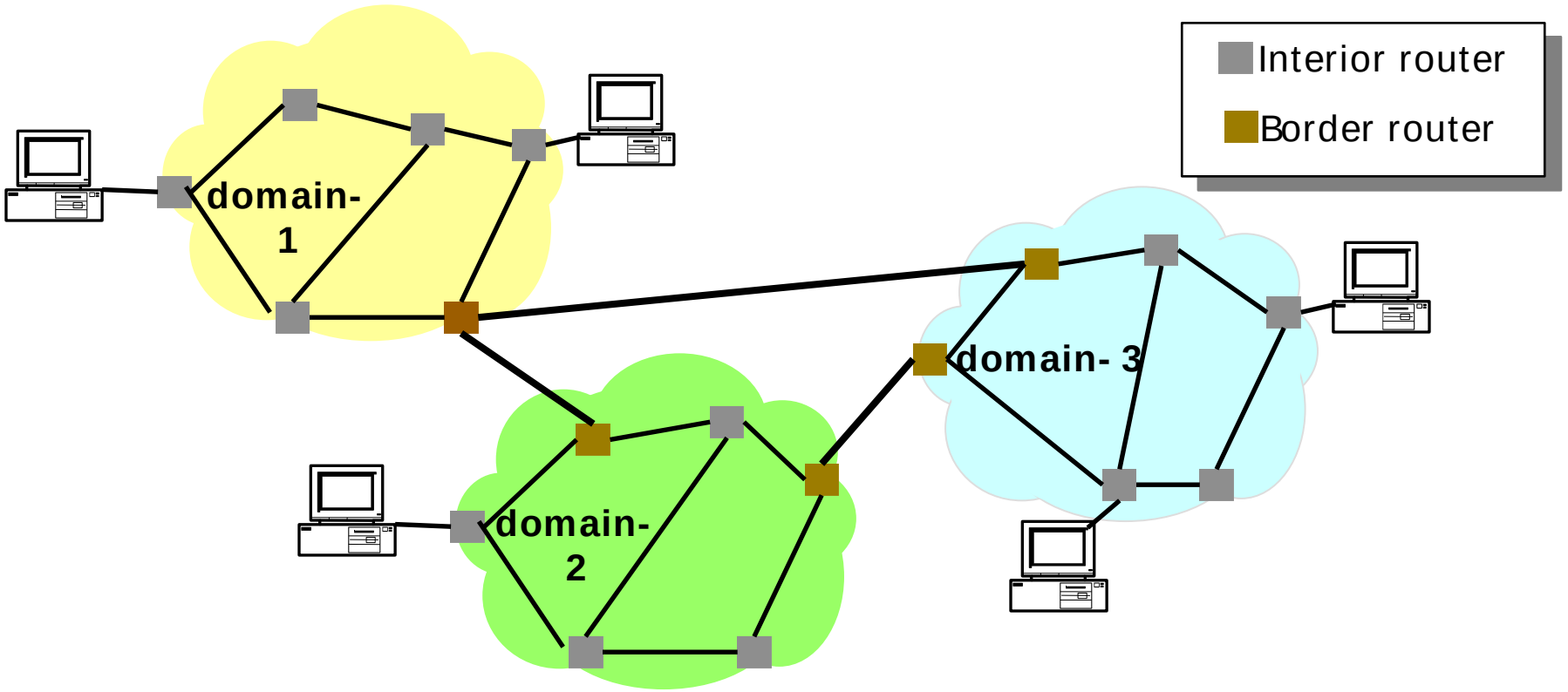
What happens when a node hears multiple paths to the same destination?

What happens if the graph changes?

Questions About Path Vector

- How do we ensure no loops?
  - When a node updates its paths, it never accepts a path that has itself
- What happens when a node hears multiple paths to the same destination?
  - It picks the better path (e.g., the shorter number of hops)
- What happens if the graph changes?
  - Algorithm deals well with new links
  - To deal with links that go down, each router should discard any path that a neighbor stops advertising

Hierarchical Routing



Internet: collection of domains/networks

Inside a domain: Route over a graph of routers

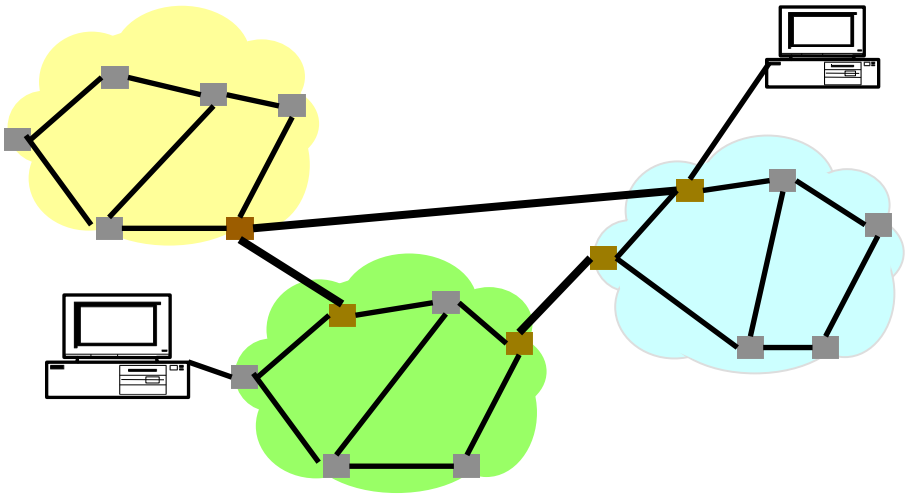
Between domains: Route over a graph of domains

Address: concatenation of "Domain Id", "Node Id"

Hierarchical Routing

Advantage

- scalable
  - Smaller tables
  - Smaller messages
- Delegation
  - Each domain can run its own routing protocol



Disadvantage

- Mobility is difficult
  - Address depends on geographic location
- Sup-optimal paths
  - E.g., in the figure, the shortest path between the two machines should traverse the yellow domain. But hierarchical routing goes directly between the green and blue domains, then finds the local destination path traverses more routers.