L11: Link and Network layer

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

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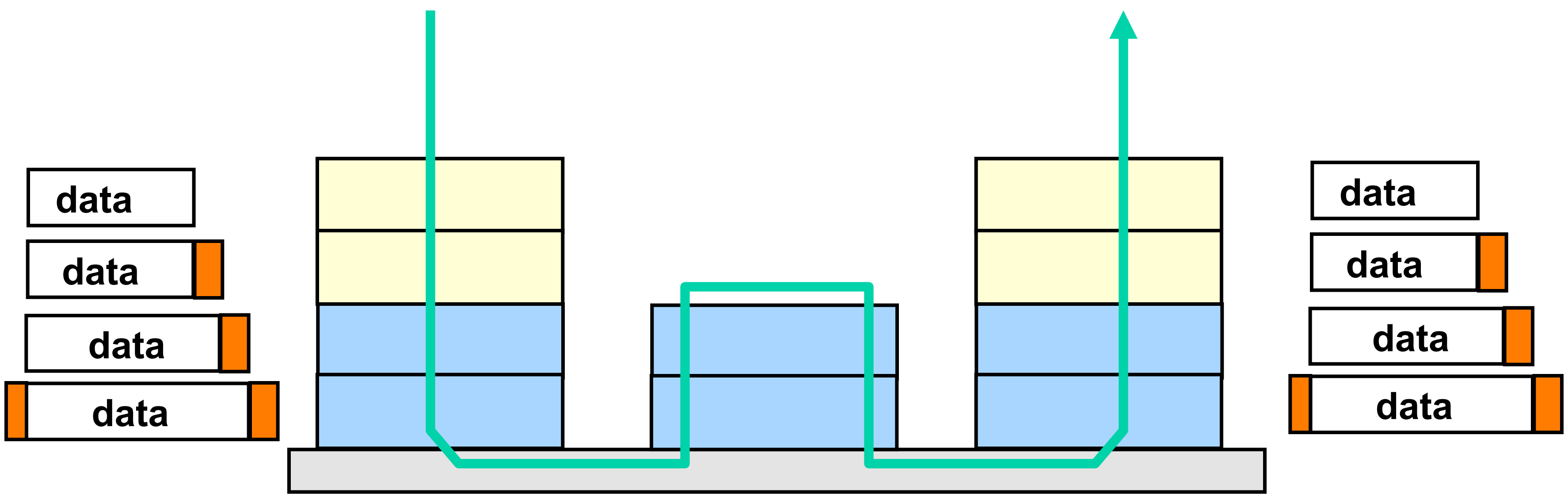
Last lecture: layering of protocols

- Each layer adds/strips off its own header
- Each layer may split up higher-level data
- Each layer multiplexes multiple higher layers
- Each layer is (mostly) transparent to higher layers



Link Layer

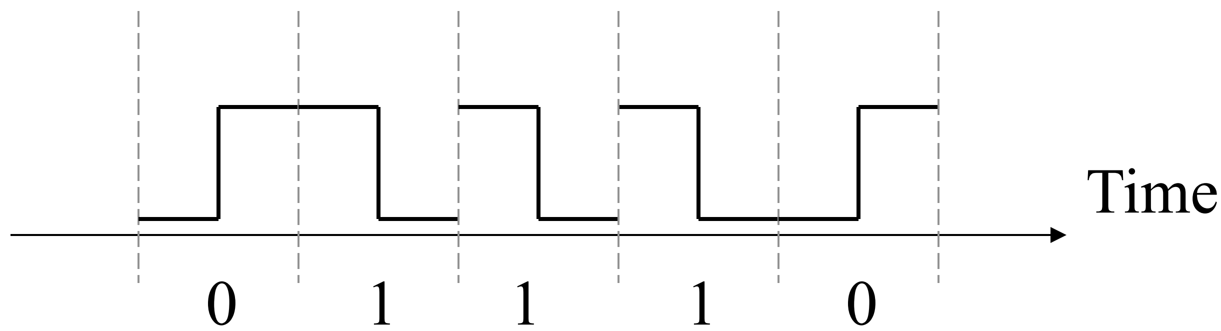
<u>Problem:</u>

Deliver data from one end of the link to the other

<u>Need to address:</u>

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

Manchester encoding



- Each bit is a transition
- Allows the receiver to sync 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

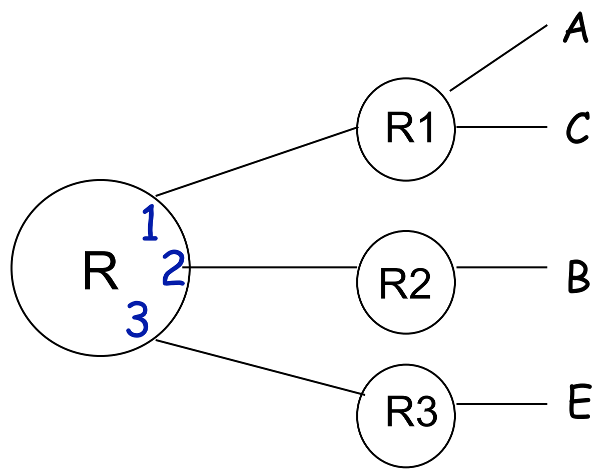
Network Layer:

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

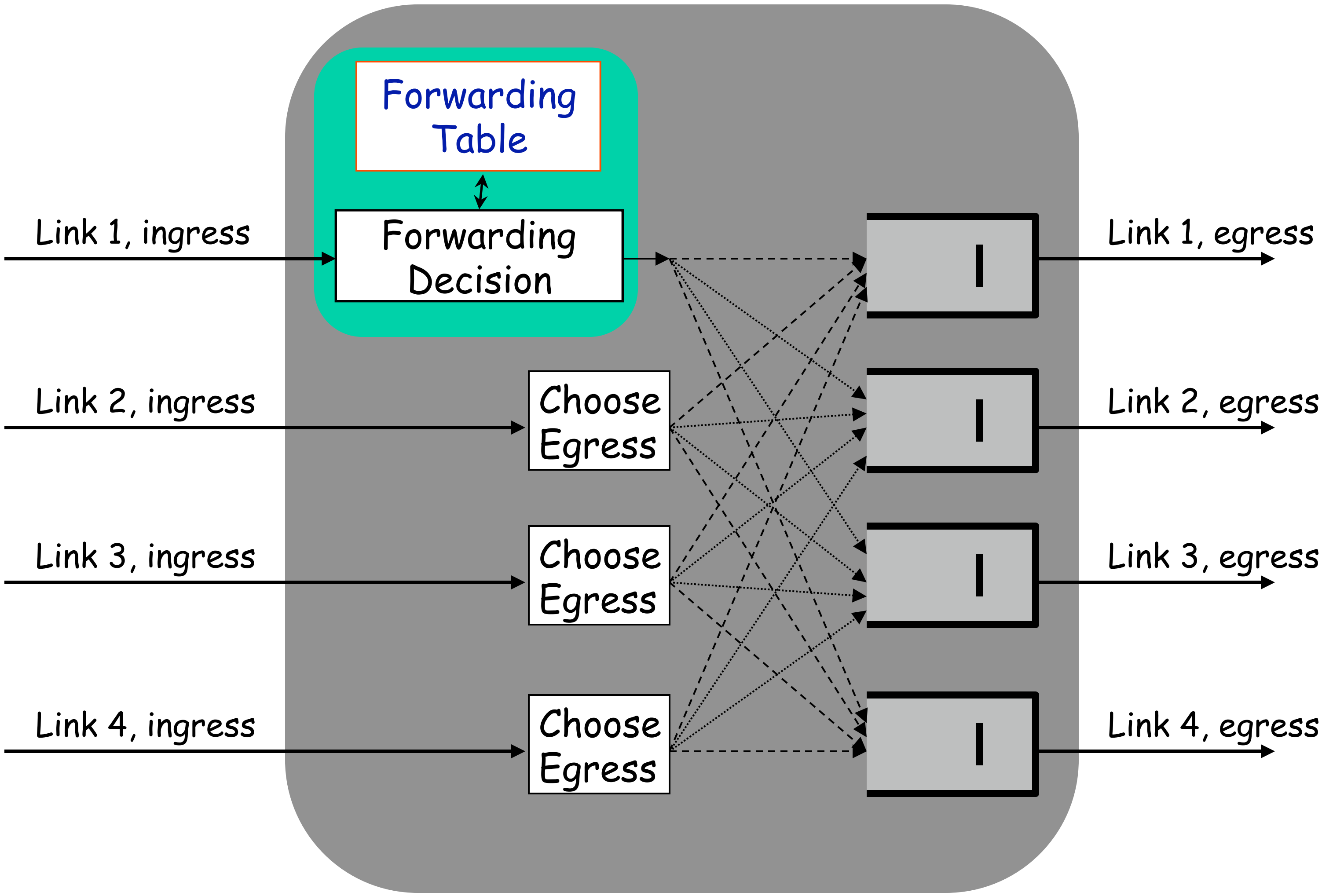
- Each router has a forwarding table
- Forwarding tables are created by a routing protocol



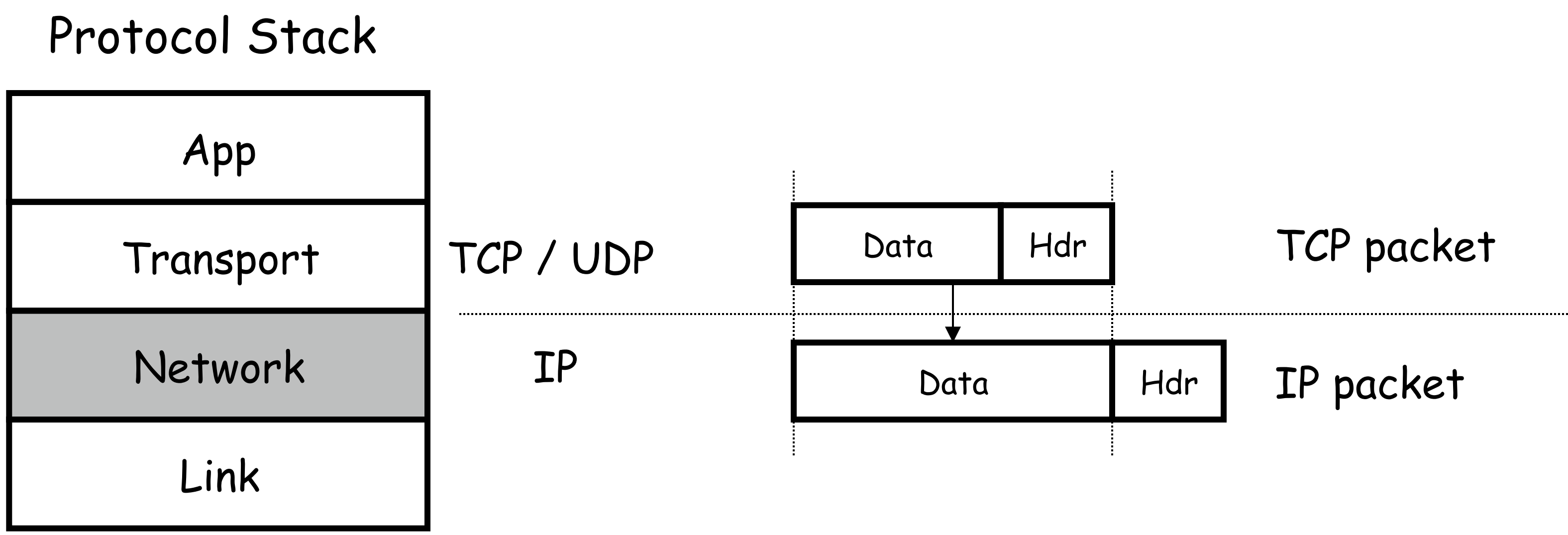
Forwarding table at R

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

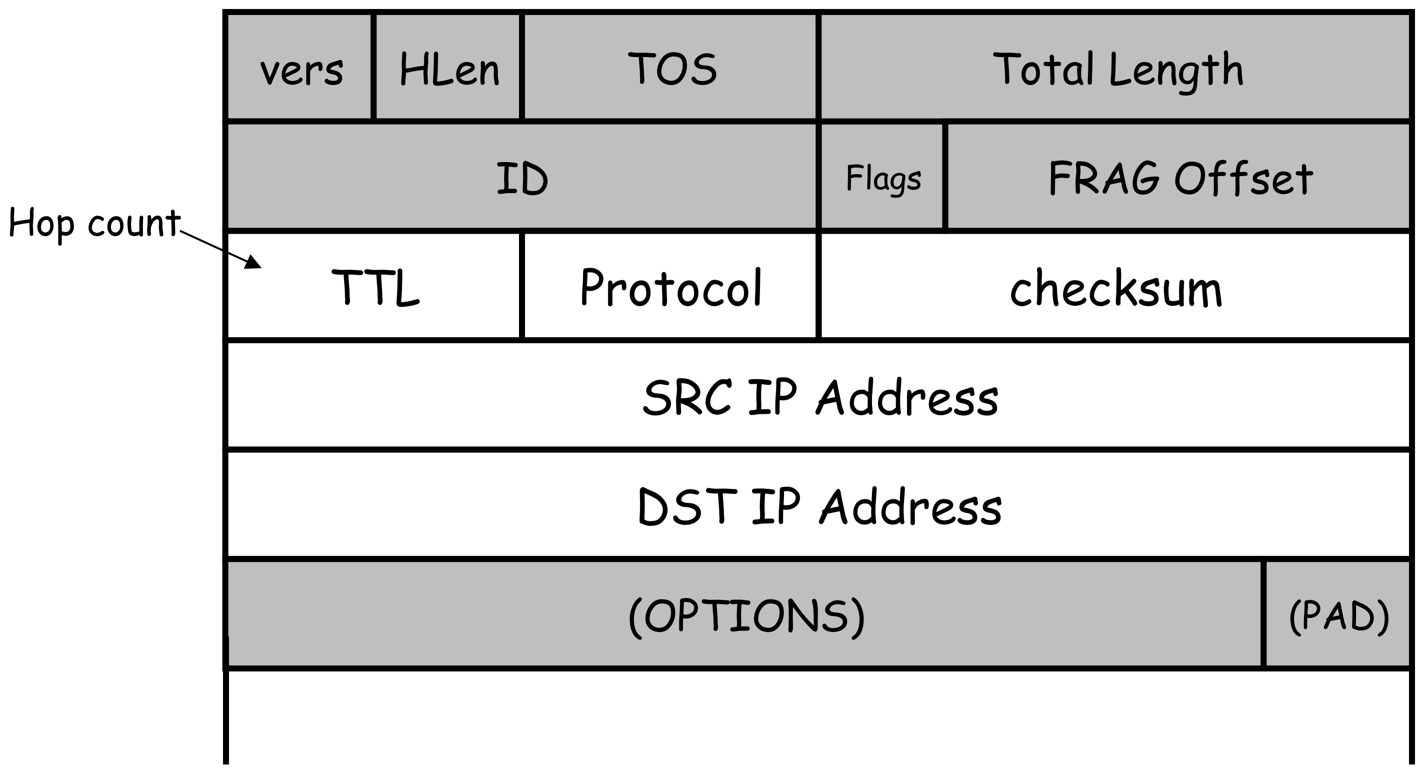
Inside a router



The Internet Protocol (IP)



The IP Header

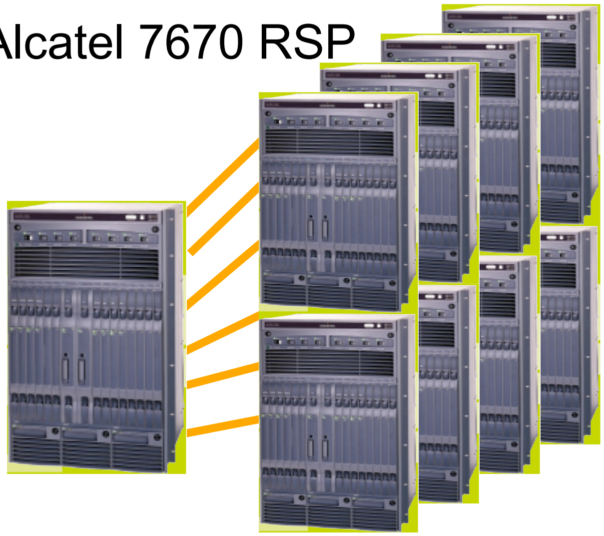


Forwarding an IP Packet

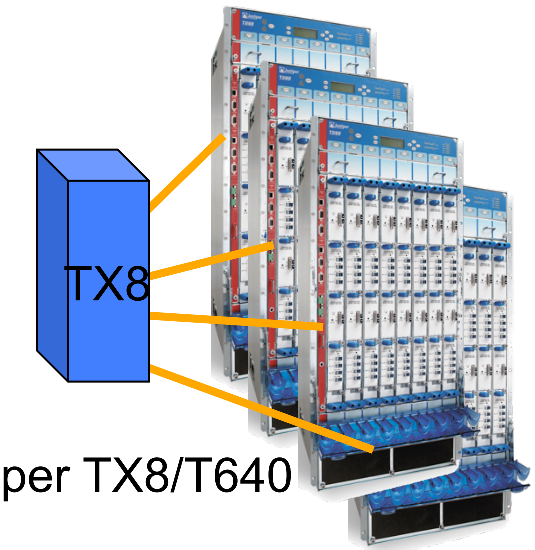
- Lookup packet's DST in forwarding table
  - If known, find the corresponding outgoing link
  - If unknown, drop packet
- Decrement TTL and drop packet if TTL is zero; update header Checksum
- Forward packet to outgoing port
- Transmit packet onto link

And switches today…

Alcatel 7670 RSP

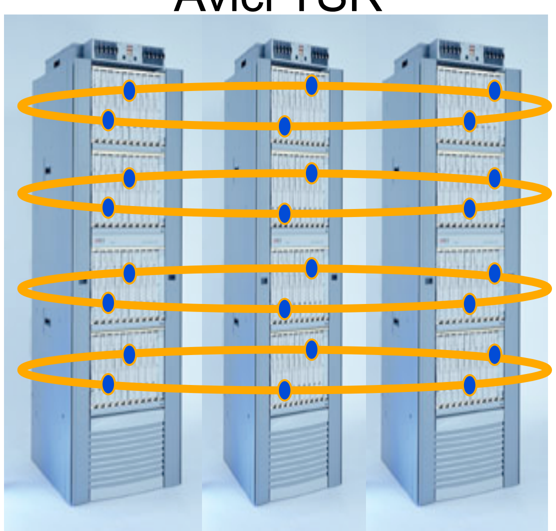


Juniper TX8/T640



Cisco GSR 12416
6ft x 2ft x 1.5ft
4.2 kW power
160 Gb/s cap.

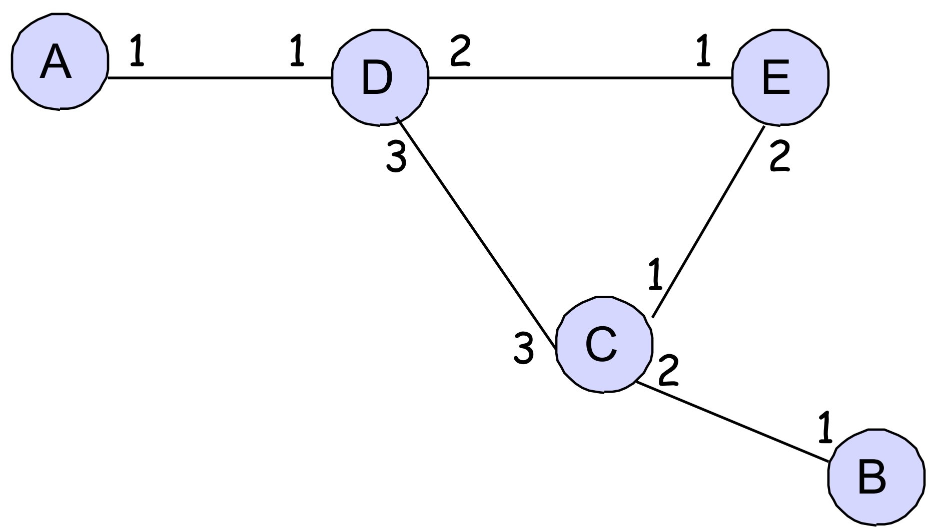
Avici TSR



Lucent 5ESS
telephone
switch

The Routing Problem:

- Generate forwarding tables



Goals: No loops, short paths, etc.

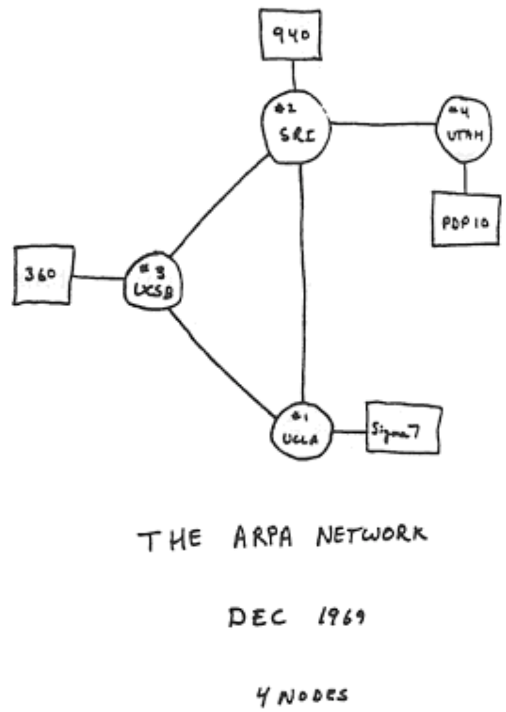
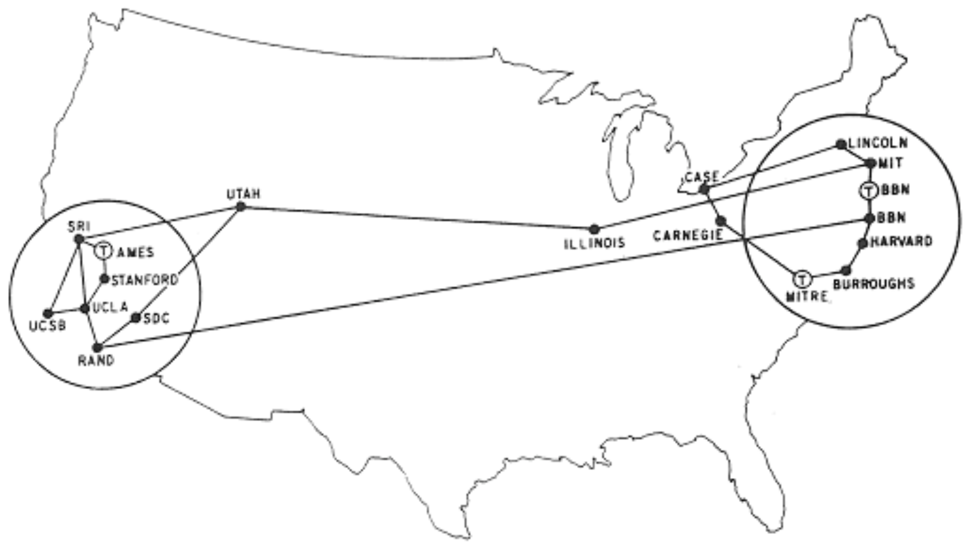
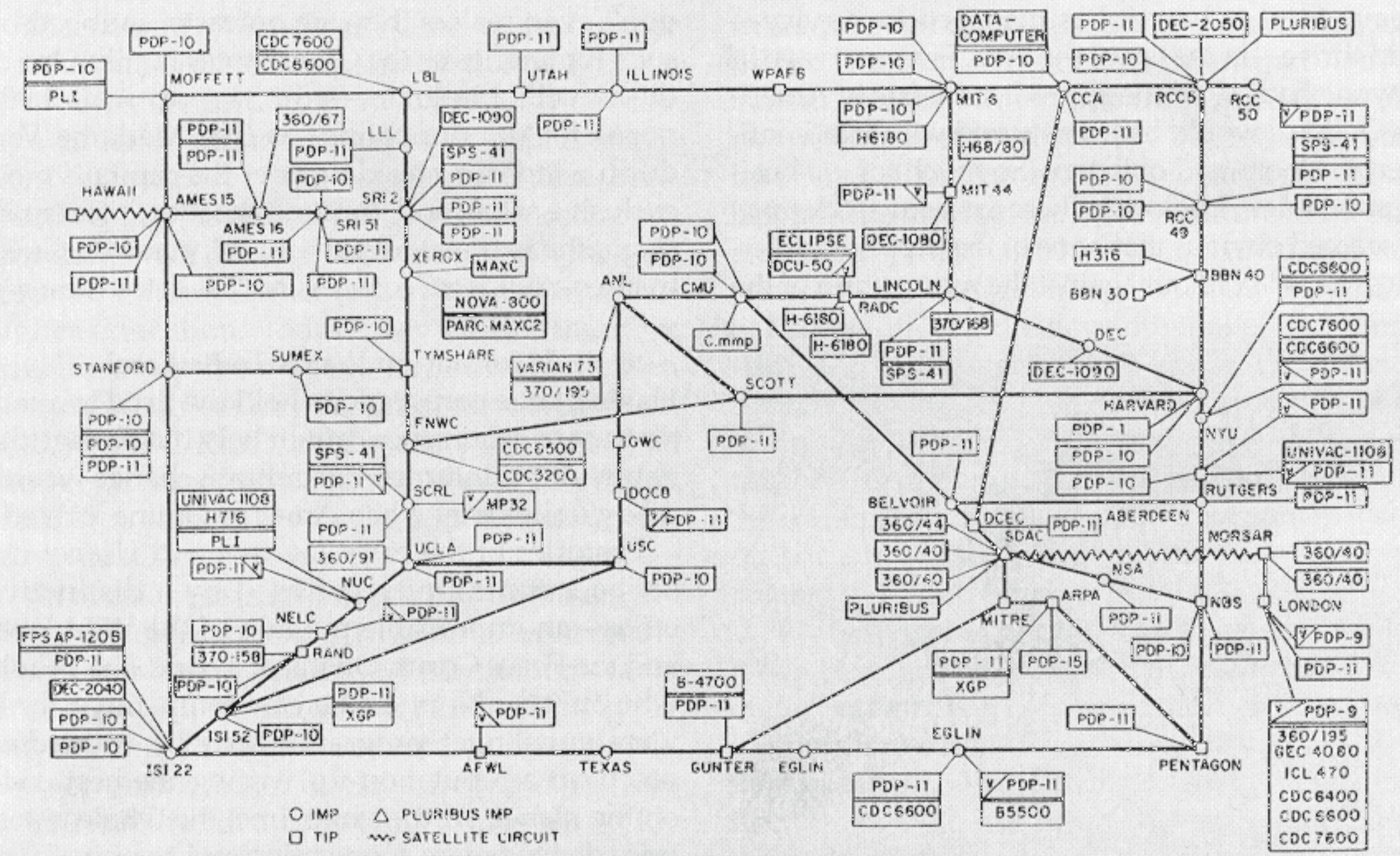


FIGURE 6.2 Drawing of 4 Node Network
(Courtesy of Alex McKenzie)



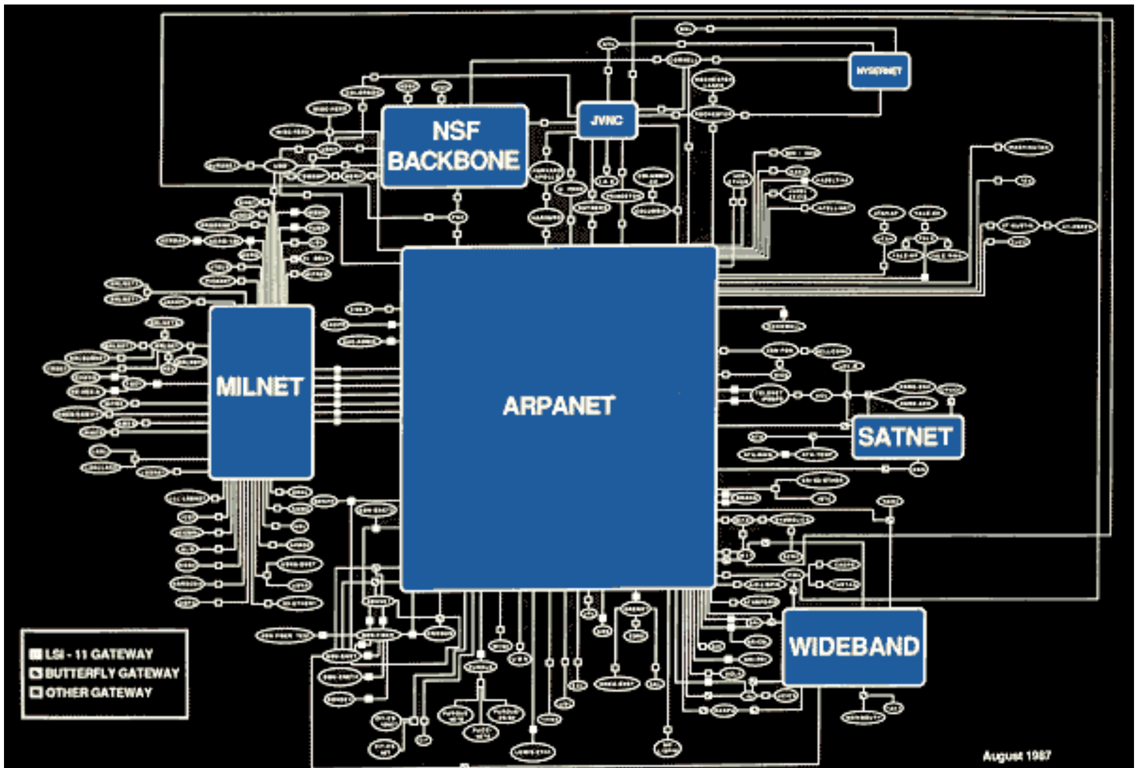
MAP 4 September 1971

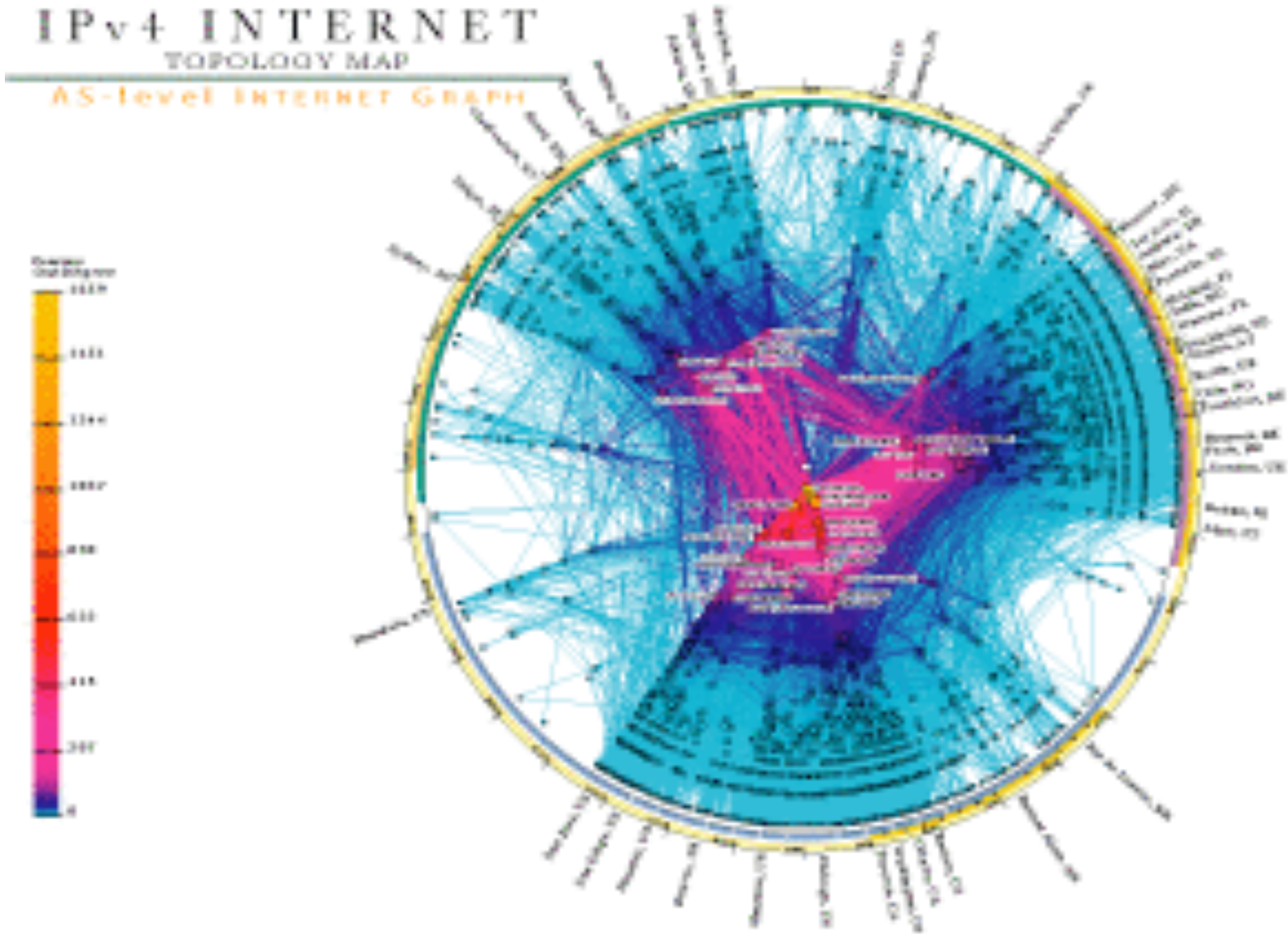
ARPANET LOGICAL MAP, MARCH 1977



(PLEASE NOTE THAT WHILE THIS MAP SHOWS THE HOST POPULATION OF THE NETWORK ACCORDING TO THE BEST INFORMATION OBTAINABLE, NO CLAIM CAN BE MADE FOR ITS ACCURACY)

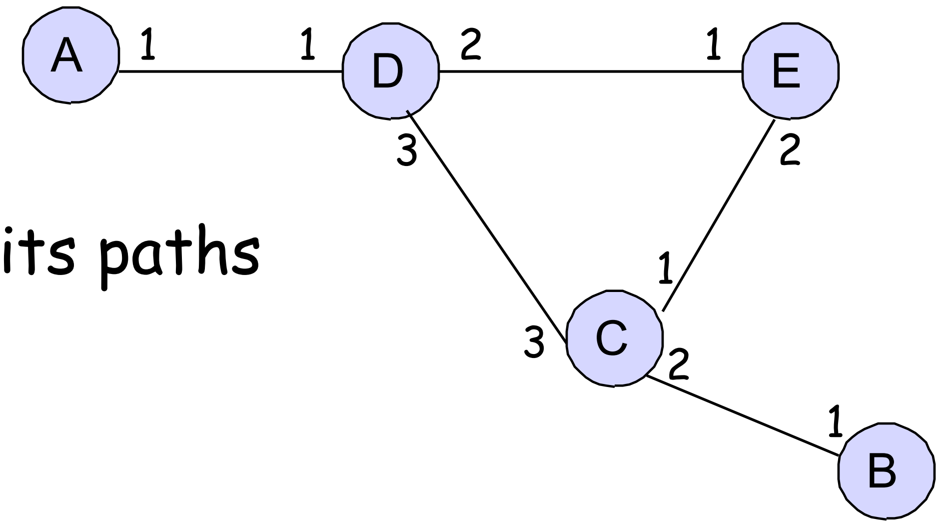
NAMES SHOWN ARE IMP NAMES, NOT (NECESSARILY) HOST NAMES


NSF
BACKBONE
JVNC
NYSERNET
MILNET
ARPANET
SATNET
WIDEBAND
LSI - 11 GATEWAY
BUTTERFLY GATEWAY
OTHER GATEWAY
August 1987


IPv4 INTERNET
TOPOLOGY MAP
AS-level INTERNET GRAPH

Path Vector Routing Protocol

- Initialization
  - Each node knows the path to itself

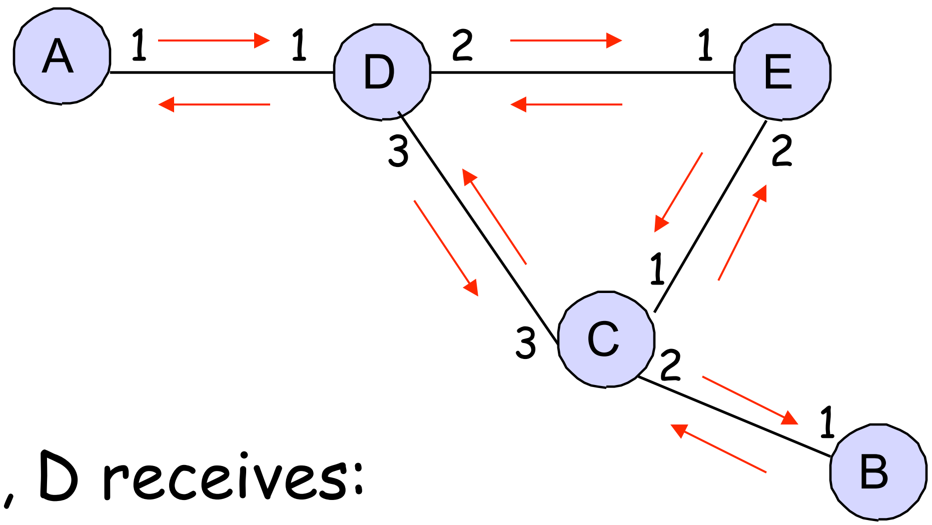


For example, D initializes its paths

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

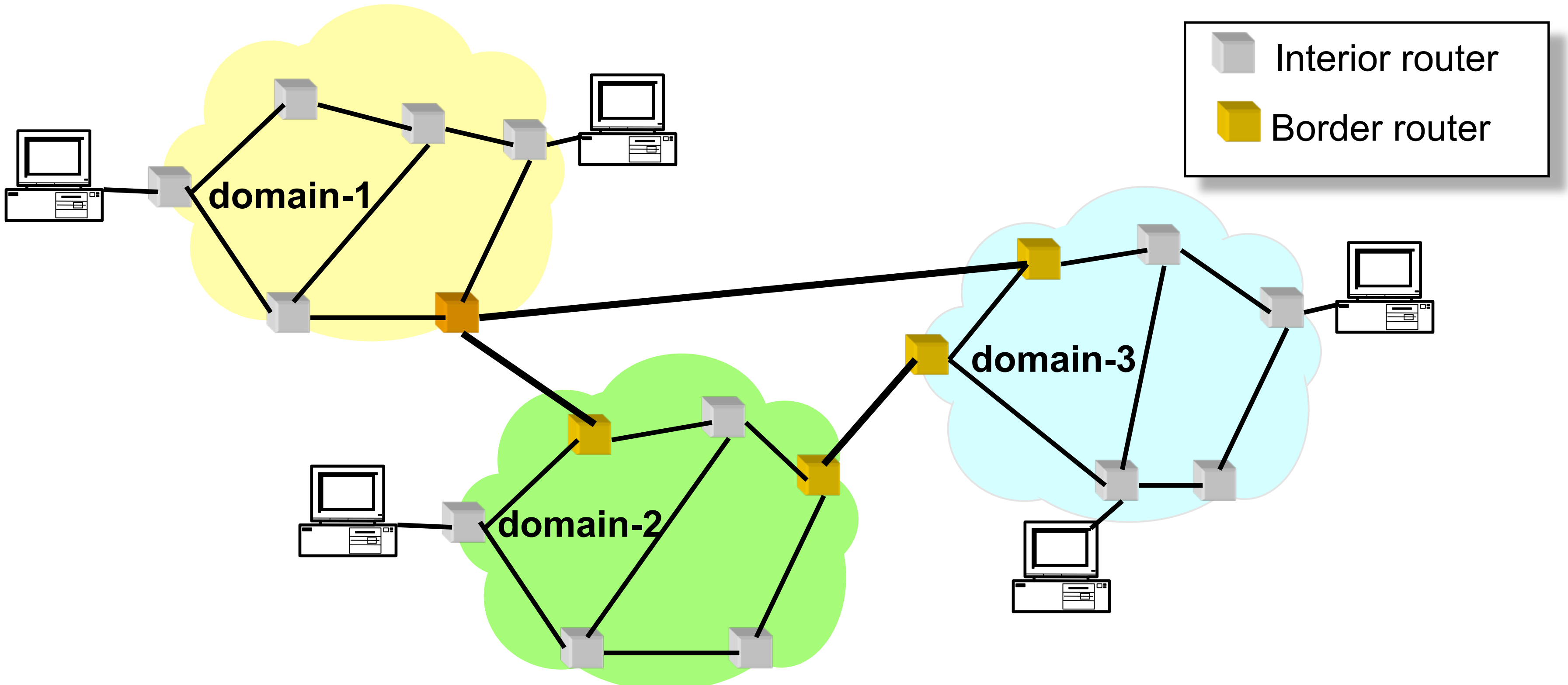
Questions About Path Vector

- How do we avoid permanent loops?
- What happens when a node hears multiple paths to the same destination?
- What happens if the graph changes?

Questions About Path Vector

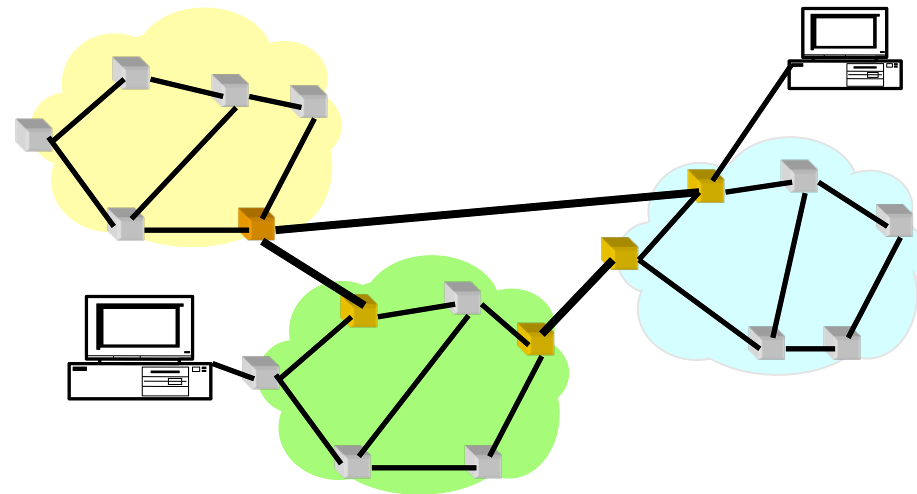
- How do we ensure no loops?
  - When a node updates its paths, it never accepts a path that has itself
- What happens when a node hears multiple paths to the same destination?
  - It picks the better path (e.g., the shorter number of hops)
- What happens if the graph changes?
  - Algorithm deals well 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 consists 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.

Routing: many open issues

- Flat addresses and scalable?
- Routing in multihop WiFi networks?
- Routing in peer-to-peer networks?
- Misconfigurations between domains?