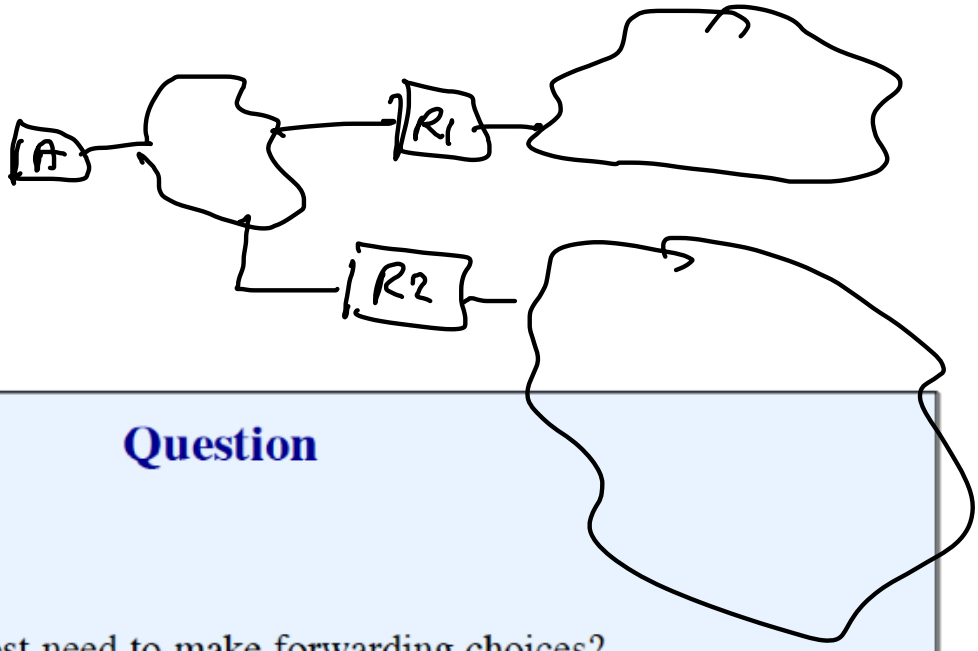
PART VII

INTERNET PROTOCOL: FORWARDING IP DATAGRAMS

Datagram Transmission

- Host delivers datagrams to directly connected machines
- Host sends datagrams that cannot be delivered directly to router
- Routers forward datagrams to other routers
- Final router delivers datagram directly



Question

Does a host need to make forwarding choices?

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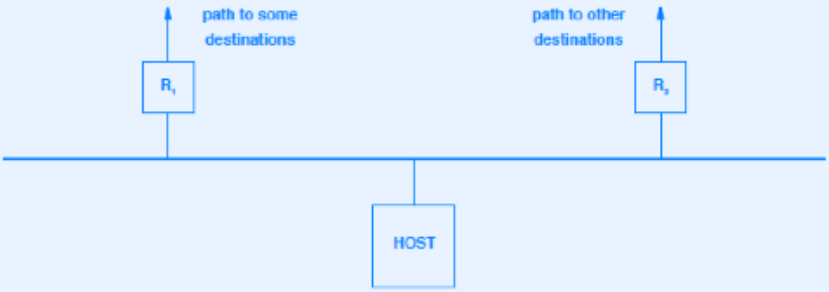
Answer: YES!

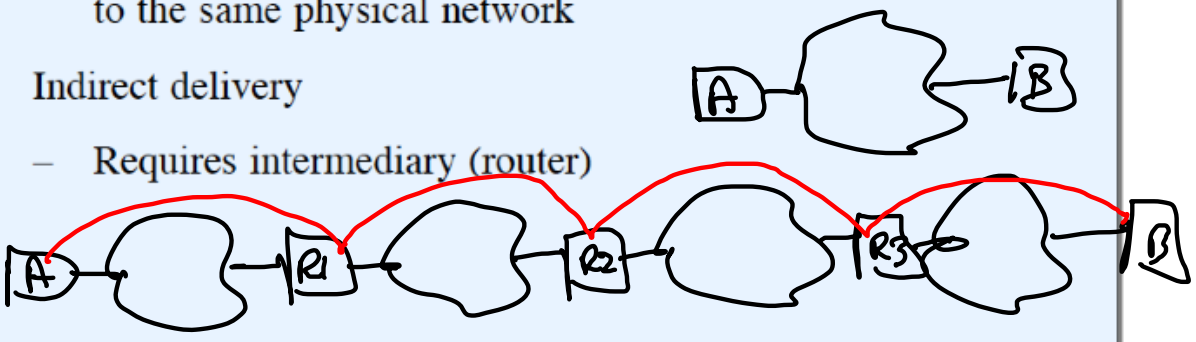
Example Host That Must Choose How To Forward Datagrams



- Note: host is singly homed!

Two Broad Cases

- Direct delivery
  - Ultimate destination can be reached over one network
  - The ‘‘last hop’’ along a path
  - Also occurs when two communicating hosts both attach to the same physical network
- Indirect delivery
  - Requires intermediary (router)



Important Design Decision

Transmission of an IP datagram between two machines on a single physical network does not involve routers. The sender encapsulates the datagram in a physical frame, binds the destination IP address to a physical hardware address, and sends the resulting frame directly to the destination.

Testing Whether A Destination Lies On The Same Physical Network As The Sender

Because the Internet addresses of all machines on a single network include a common network prefix and extracting that prefix requires only a few machine instructions, testing whether a machine can be reached directly is extremely efficient.

Datagram Forwarding

- General paradigm
  - Source host sends to first router
  - Each router passes datagram to next router
  - Last router along path delivers datagram to destination host
- Only works if routers cooperate

General Concept

Routers in a TCP/IP Internet form a cooperative, interconnected structure. Datagrams pass from router to router until they reach a router that can deliver the datagram directly.

Efficient Forwarding

- Decisions based on table lookup
- Routing tables keep only network portion of addresses (size proportional to number of networks, not number of hosts)
- Extremely efficient
  - Lookup
  - Route update

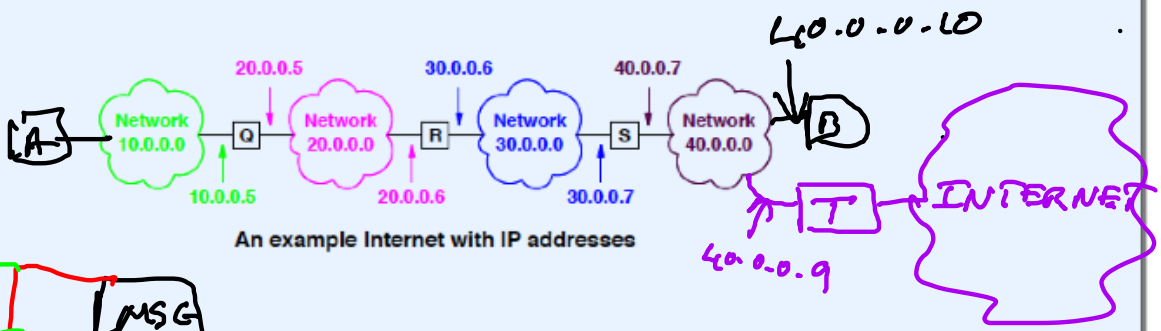
Important Idea

- Table used to decide how to send datagram known as *routing table* (also called a *forwarding table*)
- Routing table only stores address of next router along the path
- Scheme is known as *next-hop forwarding* or *next-hop routing*

Terminology

- Originally
  - *Routing* used to refer to passing datagram from router to router
- More recently
  - Purists decided to use *forwarding* to refer to the process of looking up a route and sending a datagram
- But...
  - Table is usually called a *routing table*

Conceptual Contents Of Routing Table Found In An IP Router



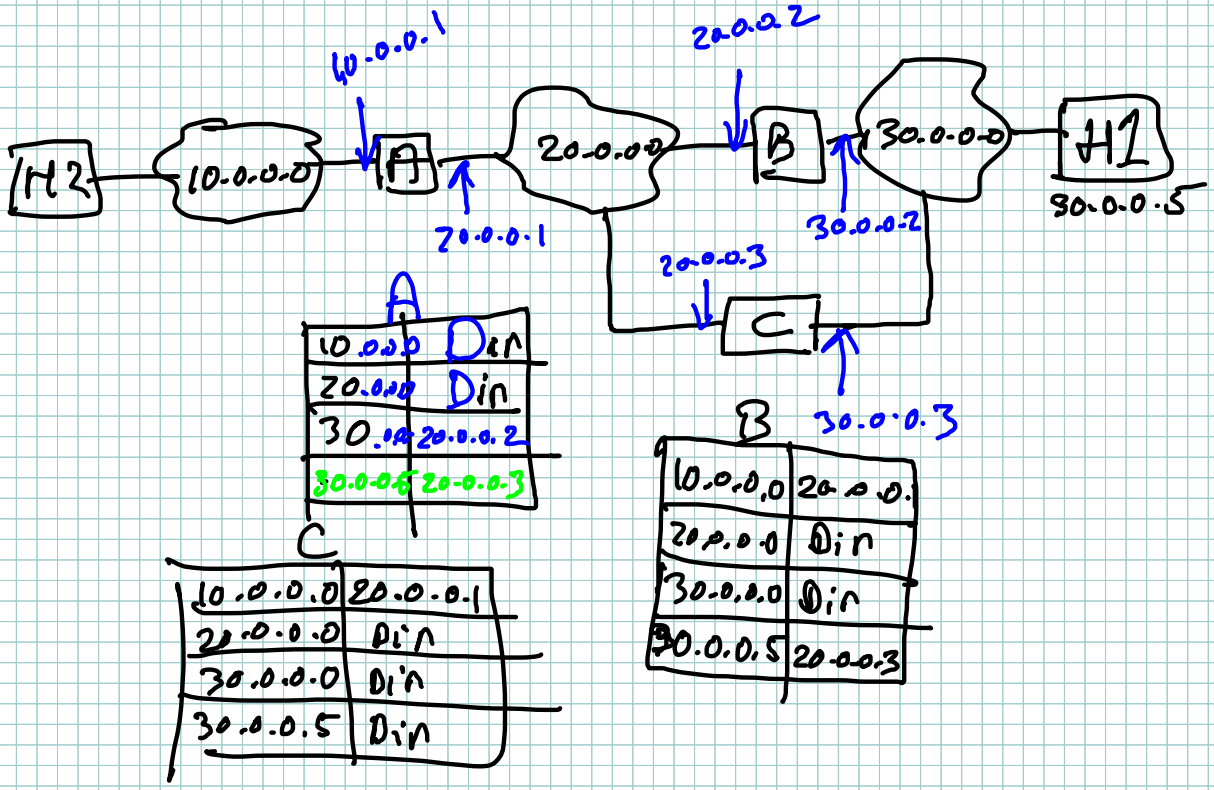
An example Internet with IP addresses

TO REACH NETWORK	ROUTE TO THIS ADDRESS
20.0.0.0/8	DELIVER DIRECT
30.0.0.0/8	DELIVER DIRECT
10.0.0.0/8	20.0.0.5
40.0.0.0/8	30.0.0.7
DEFAULT	30.0.0.7

The routing table for router R

10.0.0.0	DIRECT
20.0.0.0	DIRECT
30.0.0.0	20.0.0.6
40.0.0.0	10.0.0.6
DEFAULT	20.0.0.5

10.0.0.0	30.0.0.6
20.0.0.0	30.0.0.6
30.0.0.0	DIRECT
40.0.0.0	DIRECT
DEFAULT	40.0.0.9


H2
10.0.0.0
40.0.0.1
A
20.0.0.1
20.0.0.0
20.0.0.2
B
30.0.0.0
H1
30.0.0.5
30.0.0.2
20.0.0.3
C
30.0.0.3
A
10.0.0.0 Dir
20.0.0.0 Din
30.0.0.0 20.0.0.2
30.0.0.5 20.0.0.3
B
10.0.0.0 20.0.0.
20.0.0.0 Din
30.0.0.0 Din
30.0.0.5 20.0.0.3
C
10.0.0.0 20.0.0.1
20.0.0.0 Din
30.0.0.0 Din
30.0.0.5 Din

Special Cases

- Default route
- Host-specific route

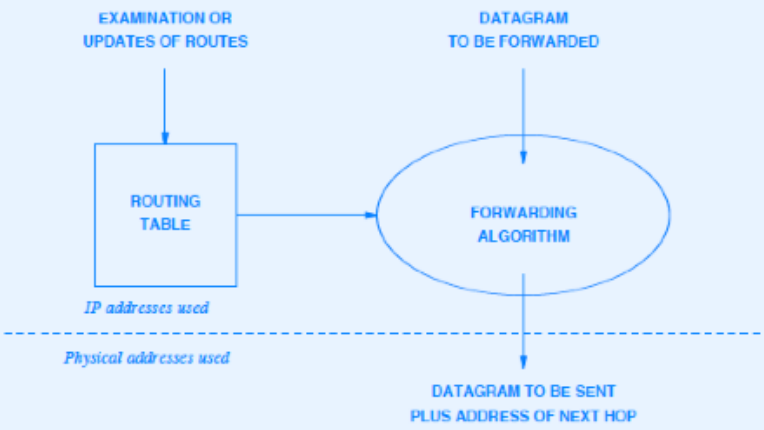
Default Route

- Special entry in IP routing table
- Matches ‘‘any’’ destination address
- Only one default permitted
- Only selected if no other match in table

Host-Specific Route

- Entry in routing table
- Matches entire 32-bit value
- Can be used to send traffic for a specific host along a specific path (i.e., can differ from the network route)
- More later in the course

Level Of Forwarding Algorithm



- Routing table uses IP addresses, not physical addresses

Summary

- IP uses routing table to forward datagrams
- Routing table
  - Stores pairs of network prefix and next hop
  - Can contain host-specific routes and a default route