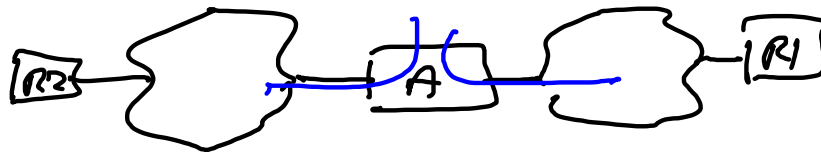


**PART VII**

**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?

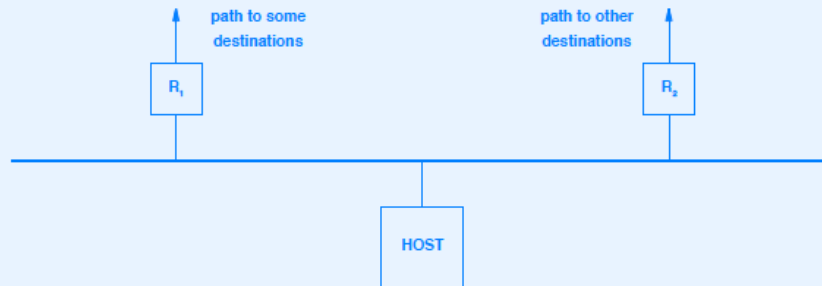
ROUTINE

## Question

Does a host need to make forwarding choices?

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.*

ROUTER = GATEWAY  
FORWARDING = ROUTING

## 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

128.10.50.22  
128.10.0.0  
9.32.126.15  
9.0.0.0

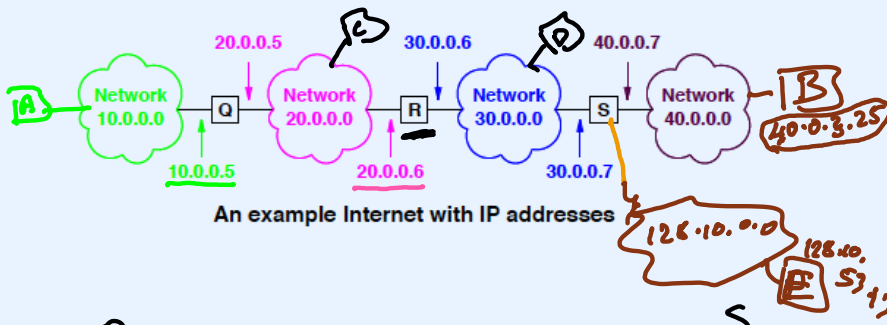
## Important Idea

- 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*

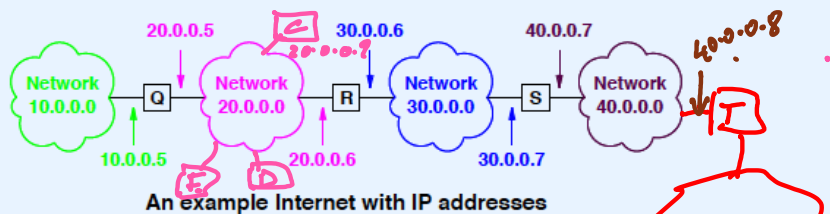
## Conceptual Contents Of Routing Table Found In An IP Router



	TO REACH NETWORK	ROUTE TO THIS ADDRESS
Q	10.0.0.0	DIRECT
	20.0.0.0	DIRECT
	30.0.0.0	20.0.0.6
	40.0.0.0	30.0.0.6
	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
	128.10.0.0/16	30.0.0.7
S	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
	128.10.0.0/16	DIRECT

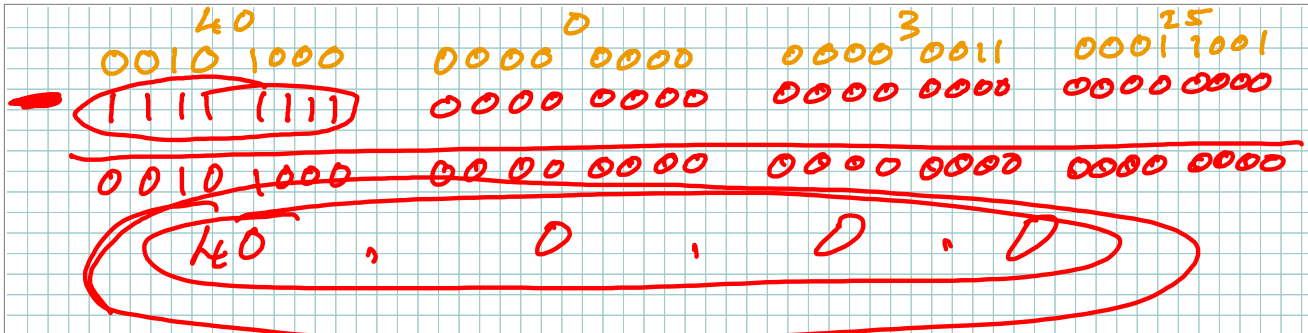
The routing table for router R

## Conceptual Contents Of Routing Table Found In An IP Router



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
<b>DEFAULT</b>	<b>30.0.0.7</b>
The routing table for router R	
20.0.0.0/32	20.0.0.5

DEFAULT	40.0.0.8



a	b	a <b>nb</b>
0	0	0
0	1	0
1	0	0
1	1	1

128. 10. 52. 13

128. 0. 0. 0 18  
 128. 10. 0. 0 116



## Special Cases

Default route

- Host-specific route

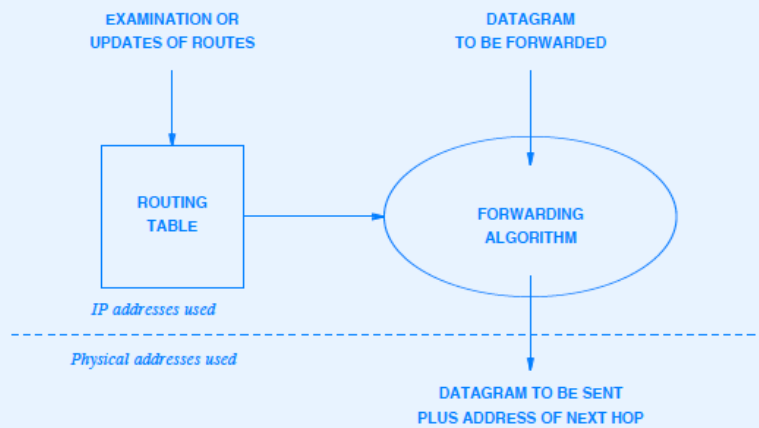
## **Default Route**

- 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