PART VII

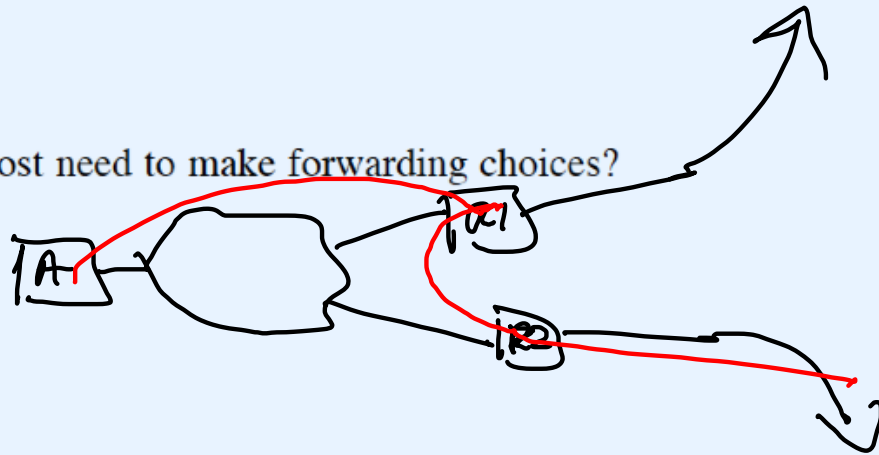# INTERNET PROTOCOL: FORWARDING IP DATAGRAMS

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

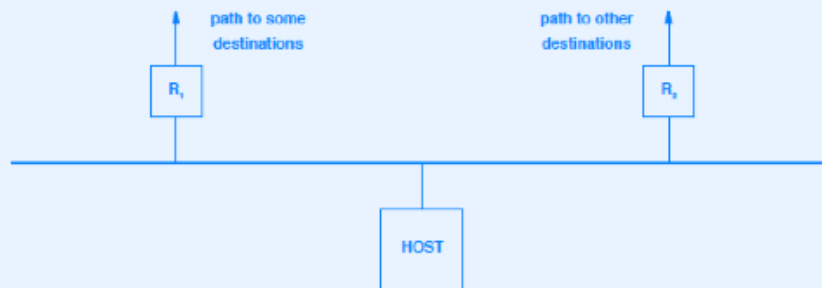Does a host need to make forwarding choices?

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.

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)

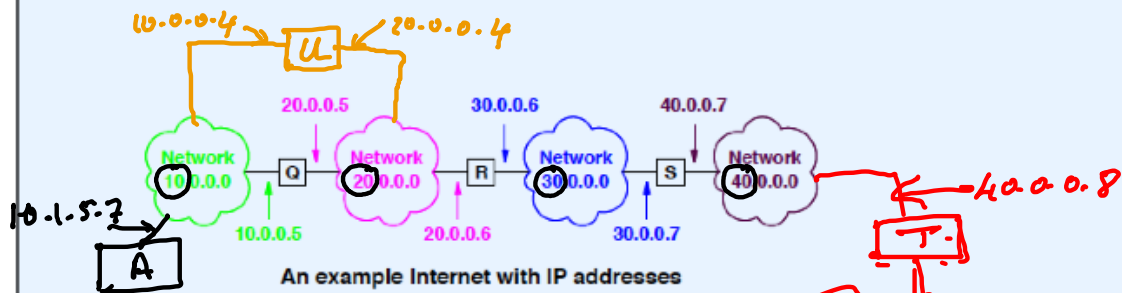- Extremely efficient

  - 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

10.0.0.4   U   20.0.0.4

20.0.0.5   30.0.0.6   40.0.0.7

Network (10) 0.0.0   Q   **Network** (20) 0.0.0   R   **Network** (30) 0.0.0   S   **Network** (40) 0.0.0

10.1.5.7

A

10.0.0.5   20.0.0.6   30.0.0.7

40.0.0.8

T.

INTERNET

An example Internet with IP addresses

10.1.5.7/32	20.0.0.4

10.1.5.7/32	20.0.0.4
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

10.0.0.0	DIRECT
20.0.0.0	DIREC
30.0.0.0	20.0.0.6
40.0.0.0	20.0.0.6
DEFAULT	20.0.0.6

The routing table for router R

DEFAULT	30.0.0.7

10.1.5.7/32	30.0.0.6
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	40.0.0.8

0.0.0.0/0 = DEFAULT

Special Cases

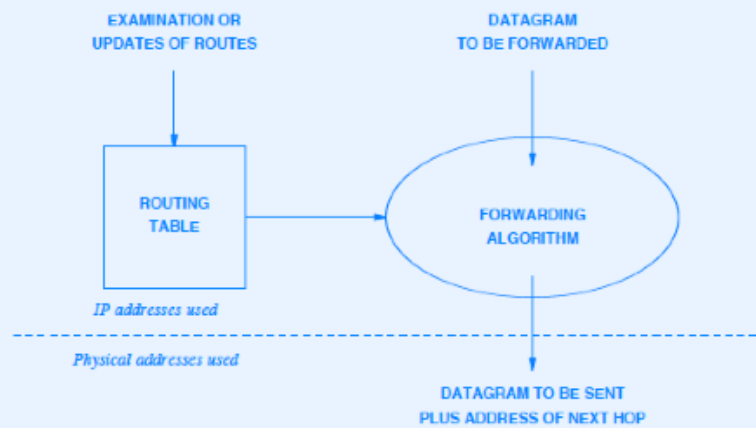- Default route

- 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

EXAMINATION OR
UPDATES OF ROUTES

DATAGRAM
TO BE FORWARDED

ROUTING
TABLE

FORWARDING
ALGORITHM

IP addresses used

Physical addresses used

DATAGRAM TO BE SENT
PLUS ADDRESS OF NEXT HOP

- Routing table uses IP addresses, not physical addresses

- 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