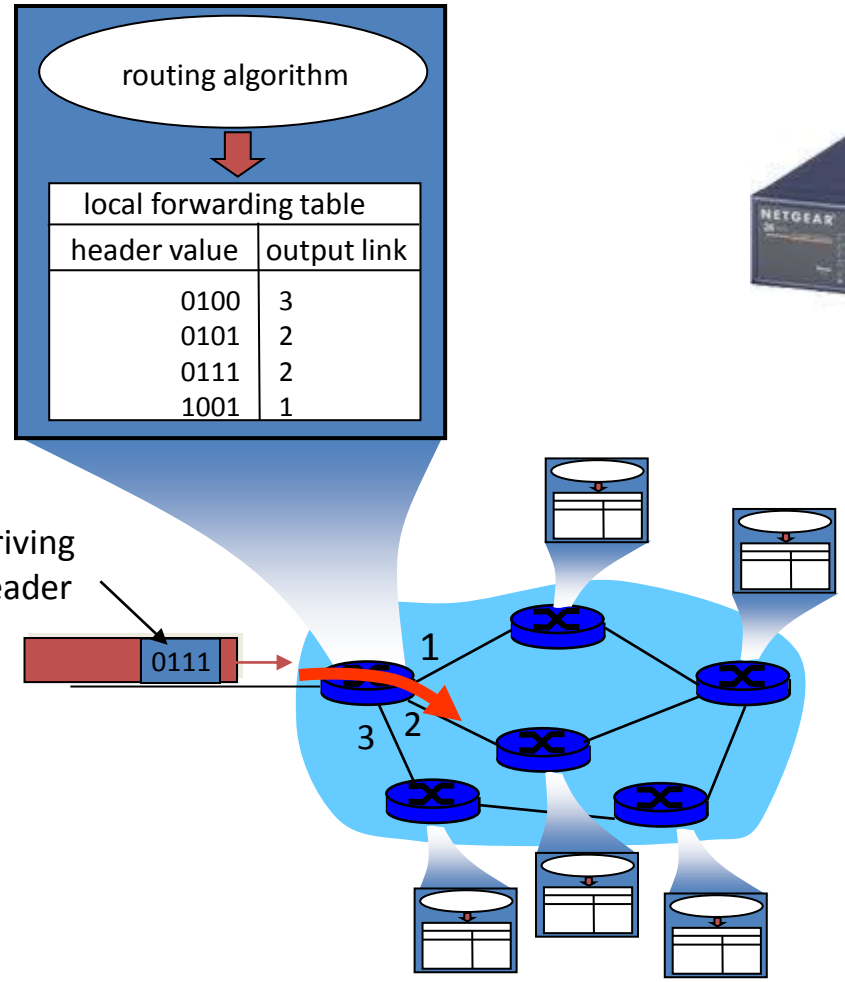
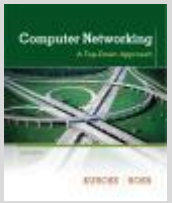
Network layer, virtual circuits



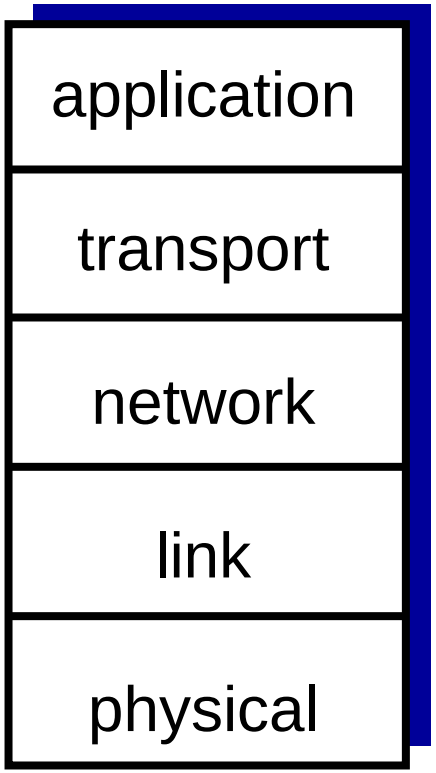
Computer Networking: A Top Down Approach
6th edition
Jim Kurose, Keith Ross
Addison-Wesley



Chapter 4: network layer

Chapter goals:

- Understand principles behind network layer:
  - Network layer service models
  - Forwarding versus routing
  - How a router works
  - Routing (path selection)
  - Broadcast, multicast
- Instantiation, implementation in the Internet



Chapter 4: outline

4.1 Introduction

4.2 Virtual circuit and datagram networks

4.3 What's inside a router

4.4 IP: Internet Protocol

- Datagram format
- IPv4 addressing
- ICMP
- IPv6

4.5 Routing algorithms

- Link state
- Distance vector
- Hierarchical routing

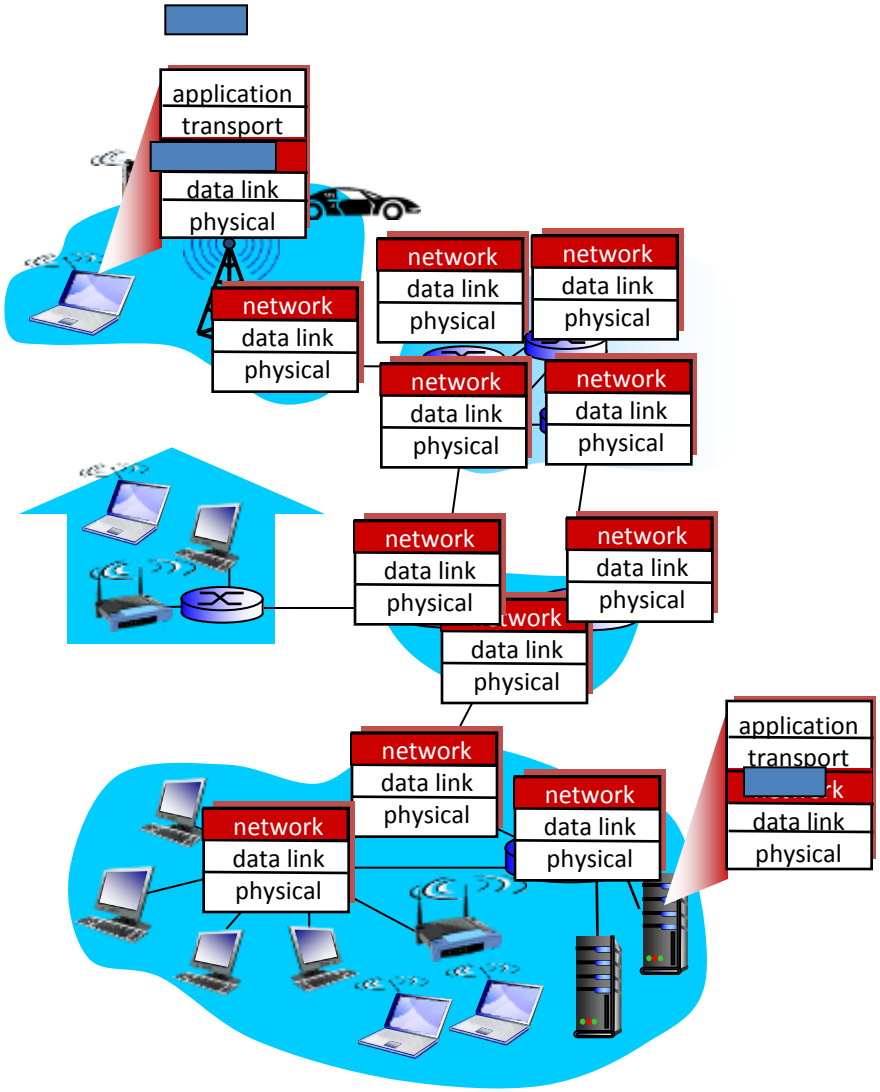
4.6 Routing in the Internet

- RIP
- OSPF
- BGP

4.7 Broadcast and multicast routing

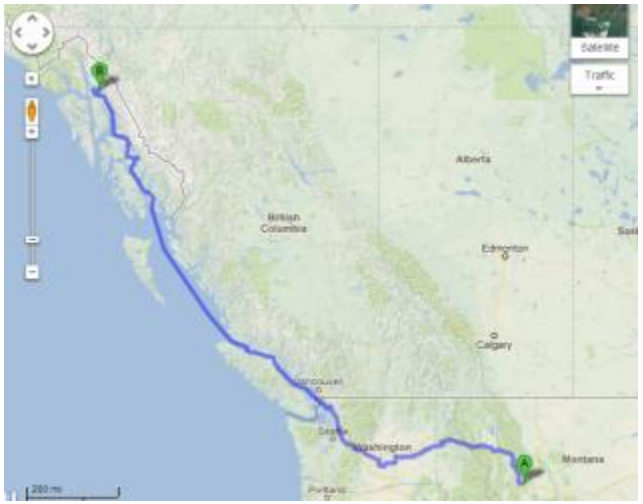
Network layer

- Transport segment from sending to receiving host
- On sending side encapsulates segments into datagrams
- On receiving side, delivers segments to transport layer
- Network layer protocols in *every* host, router
- Router examines header fields in all IP datagrams passing through it

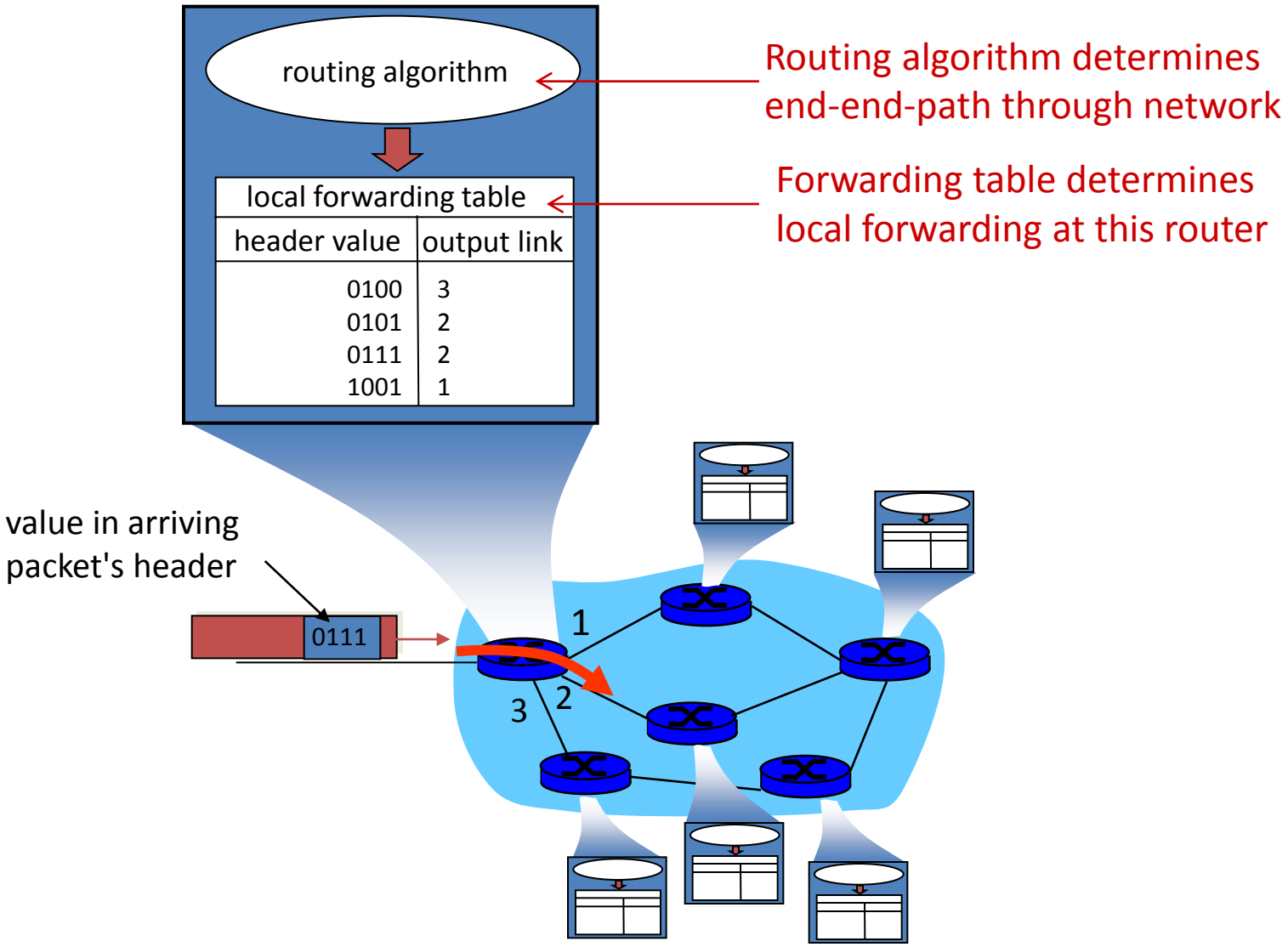


Two key network-layer functions

- *Forwarding:*
  - Move packets from router's input to appropriate output
- *Routing:*
  - Determine route taken by packets from source to destination
  - *Routing algorithms*



Interplay: routing and forwarding



Connection setup

- 3rd important function in *some* networks:
  ATM, frame relay, X.25
- Before datagrams flow
  - Two end hosts and routers get involved
  - Establish a virtual connection between two hosts
- Network vs. transport layer connections:
  - *Network:*

    Between two hosts (may also involve intervening routers in case of VCs)
  - *Transport:*

    Between two processes

Network service model

Q: What *service model* for "channel" transporting datagrams from sender to receiver?

Example services for individual datagrams:

- Guaranteed delivery
- Guaranteed delivery with less than 40 ms delay

Example services for a flow of datagrams:

- In-order datagram delivery
- Guaranteed minimum bandwidth to flow
- Restrictions on changes in inter-packet spacing

Network layer server models

Network Architecture	Service Model	Guarantees ?				Congestion feedback
		Bandwidth	Loss	Order	Timing	
Internet	best effort	none	no	no	no	no (inferred via loss)
ATM	CBR	constant rate	yes	yes	yes	no congestion
ATM	VBR	guaranteed rate	yes	yes	yes	no congestion
ATM	ABR	guaranteed minimum	no	yes	no	yes
ATM	UBR	none	no	yes	no	no

Connection, connection-less service

- *Datagram* network provides network-layer *connectionless* service
- *Virtual-circuit* network provides network-layer *connection* service
- Analogous to TCP/UDP transport-layer, but:
  - *Service:* Host-to-host
  - *No choice:* Network provides one or the other
  - *Implementation:* In network core

Virtual circuits

Source-to-destination path behaves much like telephone circuit

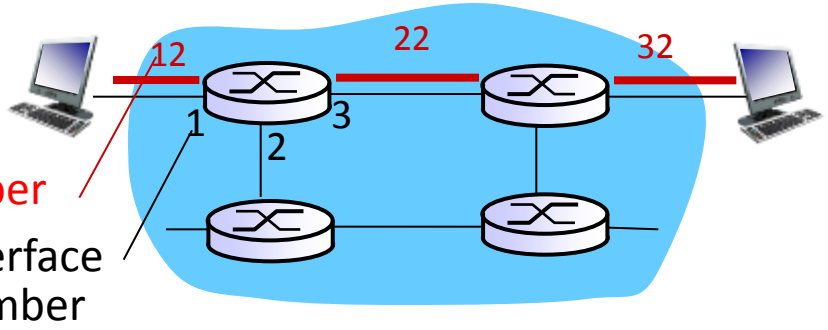
- Performance-wise
- Network actions along path

- Call setup, teardown for each call *before* data can flow
- Each packet carries VC identifier
  - Not destination host address
- *Every* router on path maintains state for each passing connection
- Link, router resources may be *allocated* to VC
  - e.g. bandwidth, buffers
  - Dedicated resources = predictable service

VC implementation

- Virtual Circuit (VC) consists of:
  1. *Path* from source to destination
  2. *VC numbers*, one number for each link along path
  3. *Entries in forwarding tables* in routers along path
- Packet belonging to a VC
  - Carries VC number (rather than dest address)
- VC number can be changed on each link
  - New VC number comes from forwarding table

VC forwarding table



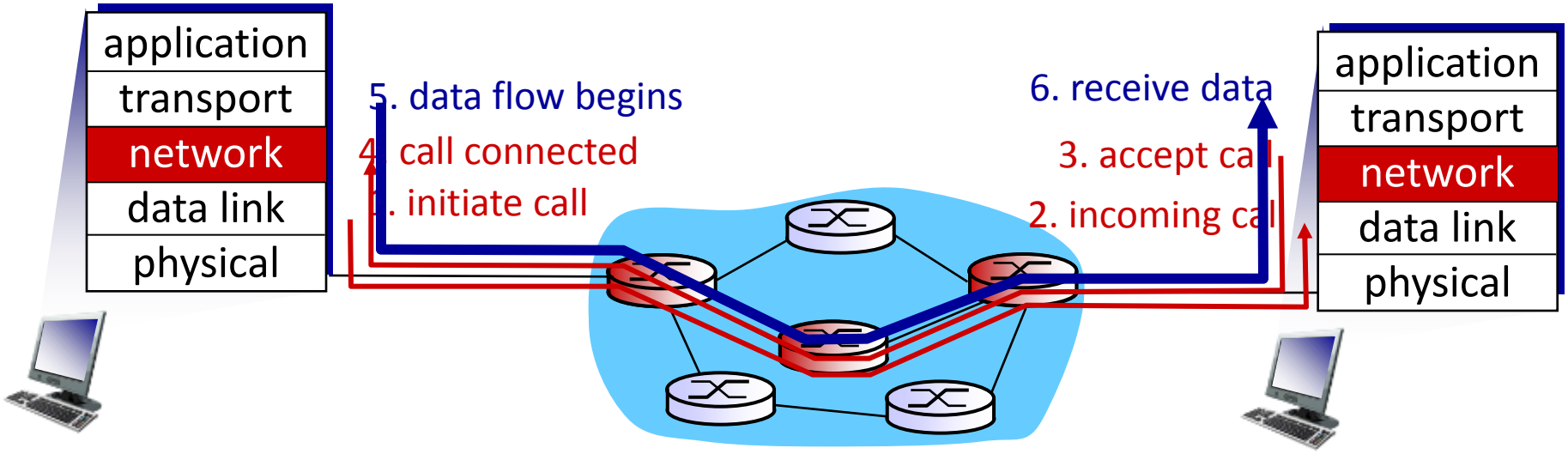
Forwarding table in northwest router:

Incoming interface	Incoming VC #	Outgoing interface	Outgoing VC #
1	12	3	22
2	63	1	18
3	7	2	17
1	97	3	87
…	…	…	…

VC routers maintain connection state information!

Virtual circuits: signaling protocols

- Used to setup, maintain, teardown VC
- Used in ATM, frame-relay, X.25
- Not used in today's Internet

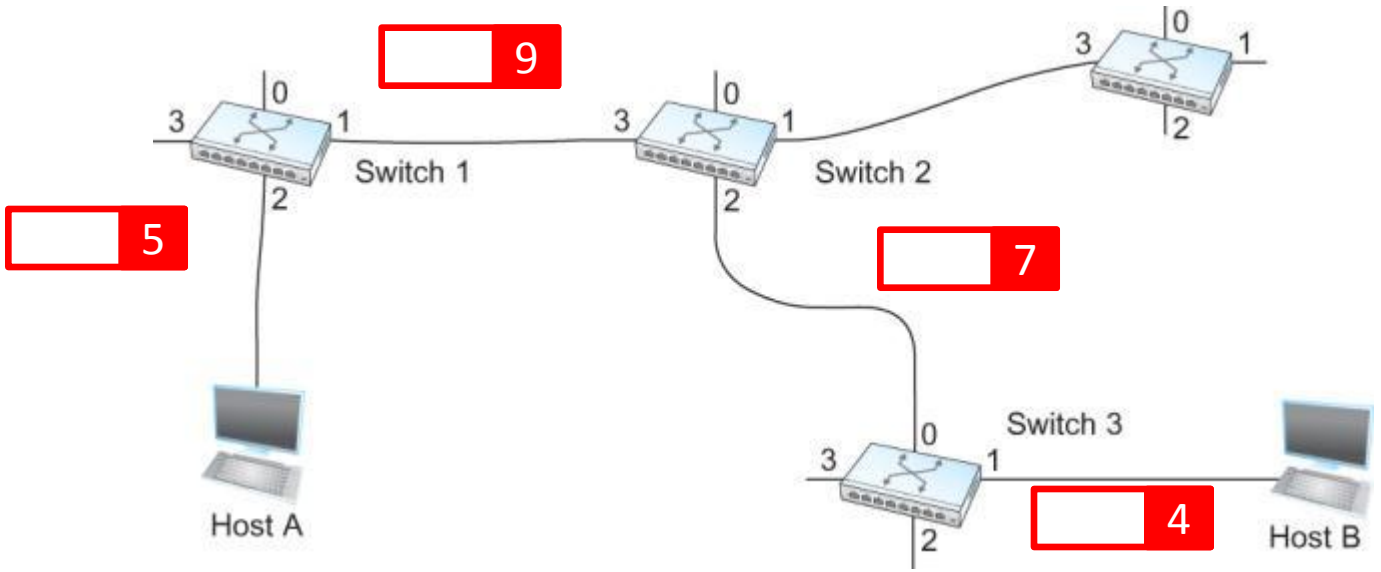


Establishing a connection

- Network admin based
  - Virtual circuit is permanent
  - Setup by admin and long-lived
- Host setup
  - Host sends messages into network (signaling)
  - Avoids the need for admin involvement

Admin setup example

- Admin finds path A → B, sets up tables in switch 1-3



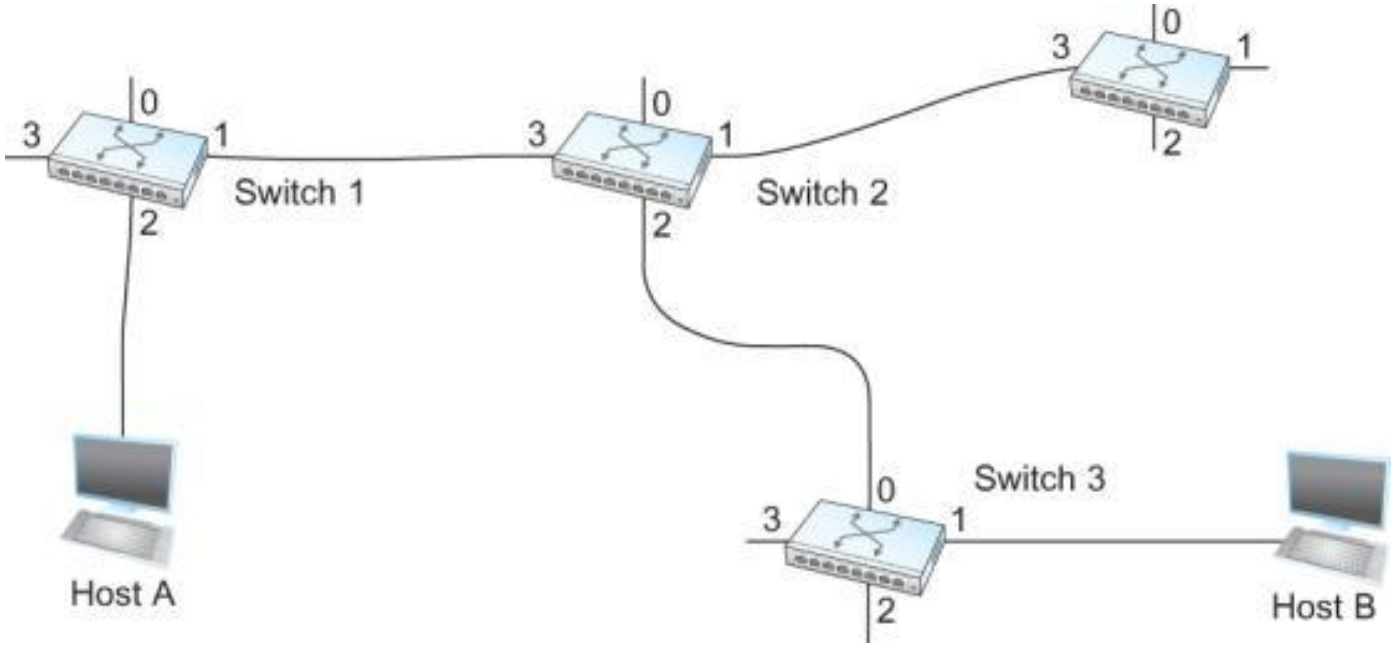
Switch	Incoming Interface	Incoming VC	Outgoing Interface	Outgoing VC
1	2	5	1	9
2	3	9	2	7
3	0	7	1	4

Signaling

- Signaling
  - Real networks too large for manual setup
  - "Permanent" VCs established by admin using signaling
  - Temporary VCs established by one of the hosts

Signaling

- Signaling process
  - Assume switches know network topology
  - A sends message to switch 1 with address B
  - Each switch on path to B adds VC table entry
  - Signaling back from B to A sets up reverse path
  - Connection terminated via teardown message



Connection-oriented

- Advantages:
  - Before data flows, A knows B is alive and well
  - Resources can be preallocated for the circuit
  - VC identifiers small compared to 48-bit MAC
  - Could provide different quality of service (QoS)
- Disadvantages:
  - One RTT to establish connection
  - Link or switch failure breaks connection

Summary

- Network layer
  - Provides host-to-host connectivity
  - Runs on all hosts and routers on the Internet
  - Forwarding vs. routing
- Virtual circuits
  - Connection-oriented network
  - Pre-allocate resources along path from source to dest
  - Not used extensively in modern networks
- Datagram networks
  - Conectionless network
  - More next time…