ECE 356/COMPSI 356
Computer Network Architecture

Introduction to Internetworking. Switching technologies.

Wednesday September 18, 2019

Recap

- Previous lectures:
  - Ethernet, multiple access
  - Wireless communications
- Readings for this class: **PD 3.1**

Lecture Outline

- Internetworking: an introduction
- Switching
- Types of switching
  - Datagram switching
  - Virtual circuit switching
    - ATM
  - Source routing

Internetworking

- Previously we saw how to connect one node to another, or to an existing network. How do we build networks of global scale?
- How do we interconnect different types of networks to build a large global network?
- The foundation of the Internet

Next 6 Lectures: A Roadmap

1. Switching and bridging
2. Ethernet switches
3. Basic Internetworking (IP)
4. Routing – Distance Vector-based
5. Routing – Link State-based

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- Types of switching
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Why Do We Need Switches?

- Problem: single link networks have limited scale
  - Ethernet < 1024 hosts, 2500 meters
  - Wireless limited by radio ranges
  - Point-to-point links connect only two nodes

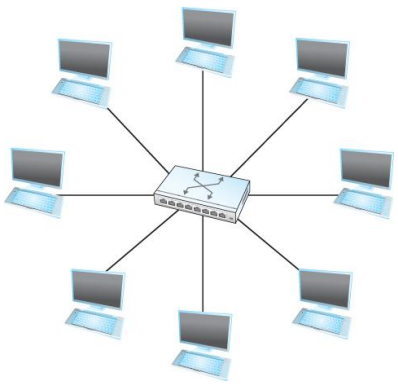
Packet Switching

- A packet switch is a device with several inputs and outputs leading to and from the nodes that the switch interconnects
  - Hosts communicate without being directly connected
- Main responsibility: receive incoming packets on one of its links and to transmit them on some other link

Difference Between a Switch and a Hub

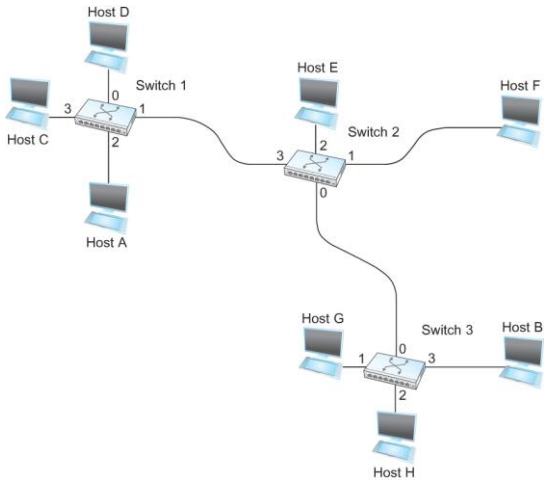
- Video posted on Piazza

A Star Topology



- A switch has a limited number of input and output ports
- Adding a new host may not reduce the performance for other hosts
  - Not true for shared media networks
  - Why?

Switches Can Be Connected to Each Other to Build Larger Networks



Switching Technologies

- Switching / forwarding: receiving incoming packets on one of switch links and transmitting them on some other link
- Problem: how does a switch decide on which output port to place each packet?
- Solution: looks at the packet header and makes a decision
  - Connectionless: datagram
  - Connection oriented: virtual circuit
  - Source routing

Challenges

- Contention
  - Input rate exceeds output rate
    - Multiple input ports may send to the same output port
  - Switches queue packets until contention disappears
- Congestion
  - When a switch runs out of buffer, it discards packets
  - Too frequent packet loss is said to be congested

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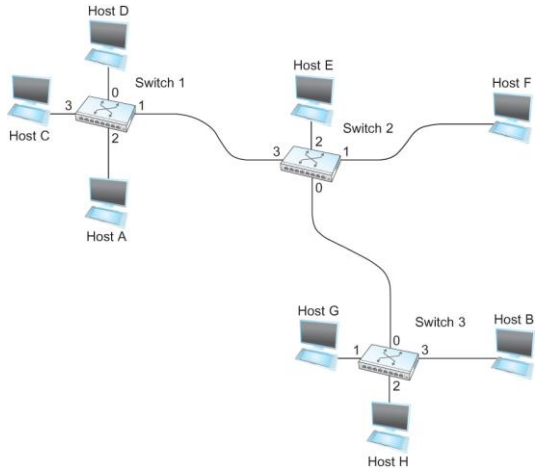
Datagram

- Every packet contains the complete destination address
  - A global unique identifier
  - Ethernet has 48-bit addresses
- A switch maintains a forwarding table that maps a packet to an output port

Example: Switch 2 Forwarding Table



A	3
B	0
C	3
D	
E	
F	
G	
H	

Routing is the process of creating forwarding tables

Features of Datagram Switching (1/2)

- Connectionless
  - Hosts can send anytime. No need to wait for connection to set up
- Unknown network state
  - Not sure whether a packet can reach the destination
- Independent forwarding
  - Packets can take different paths

Features of Datagram Switching (2/2)

- Robust to failures
  - A failure of a switch may not disrupt communications
  - Switches can re-compute forwarding tables
- Commonly deployed

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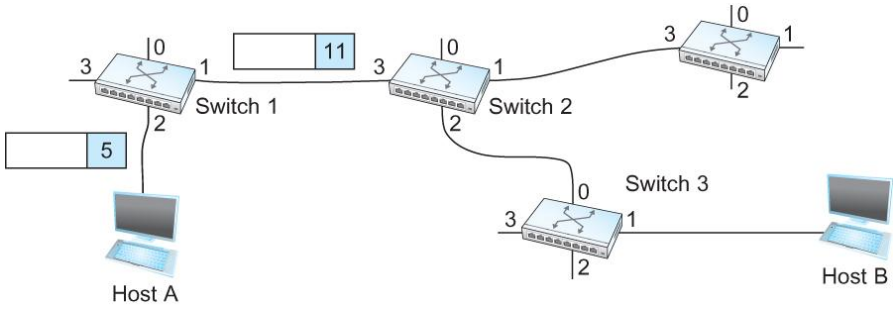
Virtual Circuit Switching

- *Connection-oriented* model
- Two steps:
  - Set up a virtual circuit
  - Data transfer

Virtual Circuit Switching: Connection Setup Phase

- Set up *connection state* in each of the switches between the source and the destination
- **VC table** entry in each switch, for each VC:
  - A virtual circuit identifier (VCI)
  - An incoming interface
  - An outgoing interface
  - An outgoing VCI

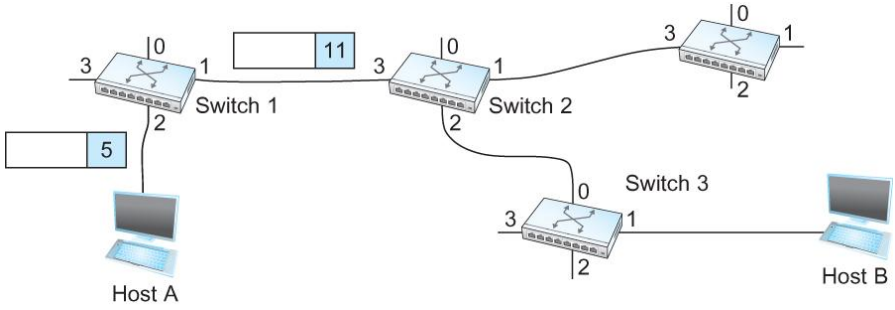
Virtual Circuit Switching: Algorithm



- If a packet arrives on the matching incoming port with the matching incoming VCI, it will be sent to the corresponding outgoing port with the corresponding VCI
- VCIs are link-local → VCI IDs can be kept short

Example: Virtual Circuit Table, Switch 1

Incoming interface	Incoming VCI	Outgoing interface	Outgoing VCI
2	5	1	11



How to Establish Connection State

- Administrator-configured
  - **Permanent virtual circuit** (PVC)
  - Administrators manually sets up VC tables
  - Does not suit large networks
- Signaling to establish state
  - **Switched virtual circuit** (SVC)
  - A host sends messages to dynamically setup or tear down a VC

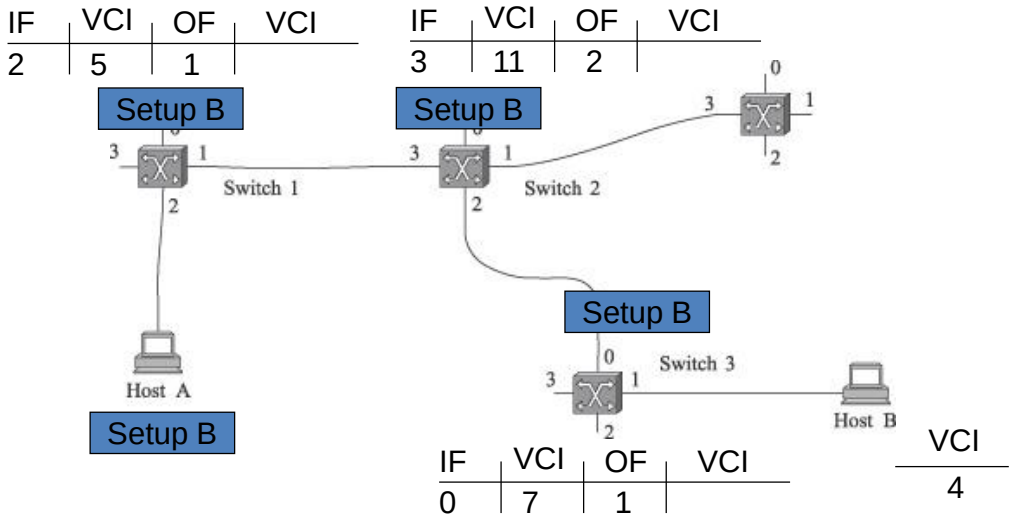
VC Setup Protocol: Host A to Destination B (1/2)

- A host A sends a setup message to first hop switch, including the final destination address
  - Similar to a datagram packet
  - Message to get all the way to B
    - Assume switches know how to do it
- The switch picks an unused VCI to identify the incoming connection, and fills part of the VC table
  - *Why not let the host pick the VCI value?*

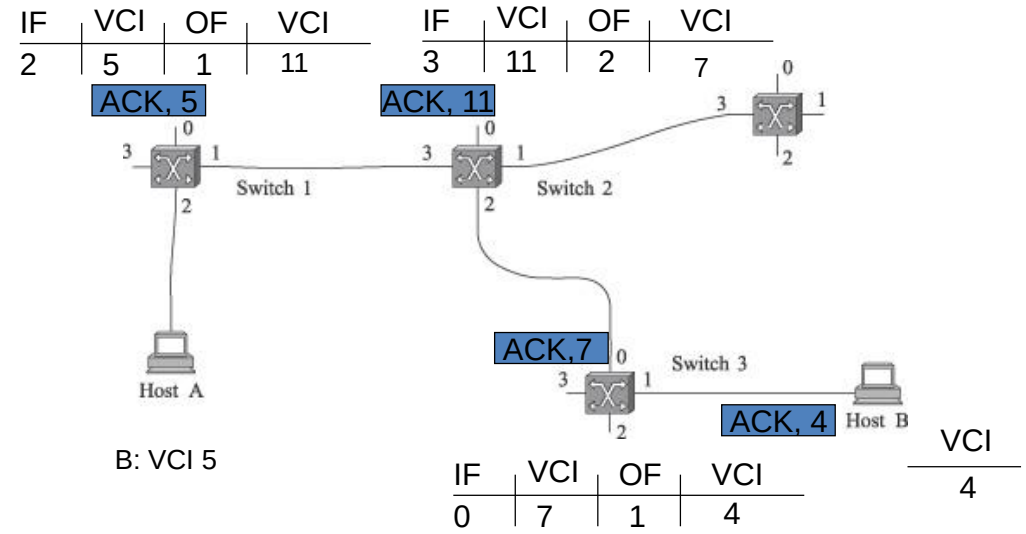
VC Setup Protocol: Host A to Destination B (2/2)

- Every switch repeats the process until the packet reaches the destination B
- The destination B sends an ACK to inform its upstream switch the VCI for the connection

VC Setup: An Example (1/2)



VC Setup: An Example (2/2)



After VC Setup is Complete

- Data transmission can begin
- Unused connections need to be torn down

Characteristics of VC Switching

- Pros:
  - Data packets contain a small VCI, not the full destination addresses
- Cons:
  - Connection setup wait
  - One switch failure tears down the entire connection
  - Connection sets up require routing algorithms
    - Setup packet is forwarded using a datagram algorithm

VC Allows Resource Reservation

- Pro: buffers can be allocated during the setup phase to avoid congestion
- An example (X.25)
  - Buffers allocated during connection setup
  - Sliding window is run between pairs of nodes: *hop-by-hop flow control*
  - Circuit is rejected if no more buffer

Quality of Service (QoS)

- Connectionless network is difficult to allocate resources
  - Switches send packets independently
  - How to associate one packet with other packets?
- Virtual circuit can be used to provide different QoS
  - Allocate a fraction of link bandwidth to each circuit
- Examine QoS in detail in the second half of the course

Technologies That Use VC

- A number have been popular over the years
  - X.25 – financial transaction systems (ATMs, point-of-sale terminals, credit card payments), aviation
  - Frame Relay
  - Asynchronous Transfer Mode (ATM)

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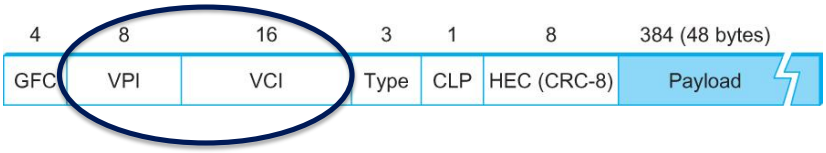
Asynchronous Transfer Mode

- *ATM Cells*: fixed-size packets
  - 5 bytes header
  - 48 bytes payload
- If payload smaller than 48B, uses padding
- If greater than 48B, breaks it

Why Small, Fixed-Length Packets?

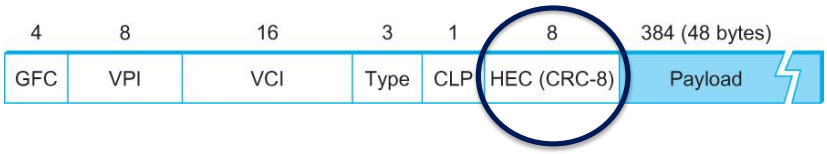
- Cons: maximum efficiency 48/53=90.6%
- Pros:
  - Suitable for efficient high-speed hardware implementation
  - Many switching elements doing the same thing in parallel

ATM: Virtual Paths



- 24-bit circuit identifiers
- Two-levels of hierarchy
  - 8-bit Virtual Path Identifier (VPI), 16-bit VCI
  - Virtual paths shared by multiple connections
    - Circuits with the same VPI could be switched together

ATM: Header Error Check



- 8-bit CRC specifically for the header
  - Error causes an ATM cell to be mis-delivered

History of ATM: Why 48 Bytes?

- It's from the telephone technology
- Thought data would be mostly voice
- A compromise
  - US wanted 64 bytes for efficiency
  - Europe wanted 32 bytes for simplifying echo cancellation
  - (64+32) / 2 = 48 bytes

History of ATM: Where Is It Now?

- Popular in the late 80s and early 90s due to its high speed
  - Major telecommunication companies supported it
- Popularity faded. IP/Ethernet ruled
  - IP over ATM
  - DSL over ATM: DSL modem takes Ethernet frames and chop them into cells

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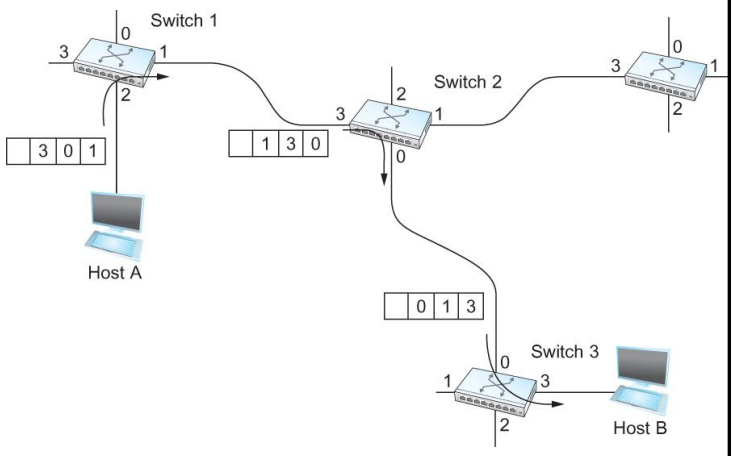
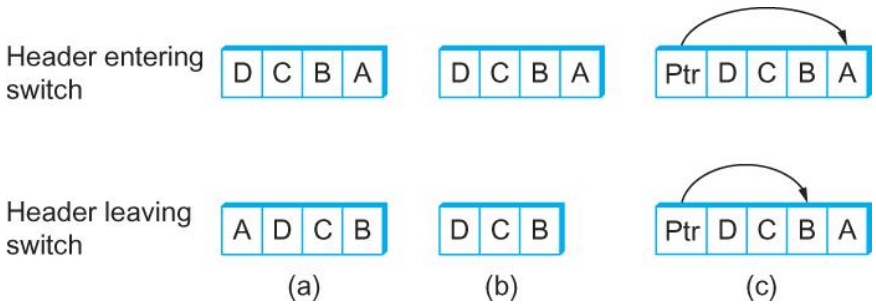
Source Routing

- Source host provides all the information for packets to travel across the network
  - ➢ Packets carry output port numbers
  - ➢ Packets carry switch addresses
  - ➢ Variable header length



Handling Source Routing Headers



a. Rotation
b. Stripping
   - No return path!
c. Pointer

Loose or Strict Source Routing

- Strict
  - Must visit every node on the path
- Loose
  - Waypoints rather than the complete route
  - Impractical to expect to be able to construct the entire route in a large network

Summary

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Next Lecture

- Switches that are used to forward packets between local area networks
  - LAN switches
  - Bridges