CompSci 356: Computer Network Architectures

Lecture 8: Switching technologies Chapter 3.1

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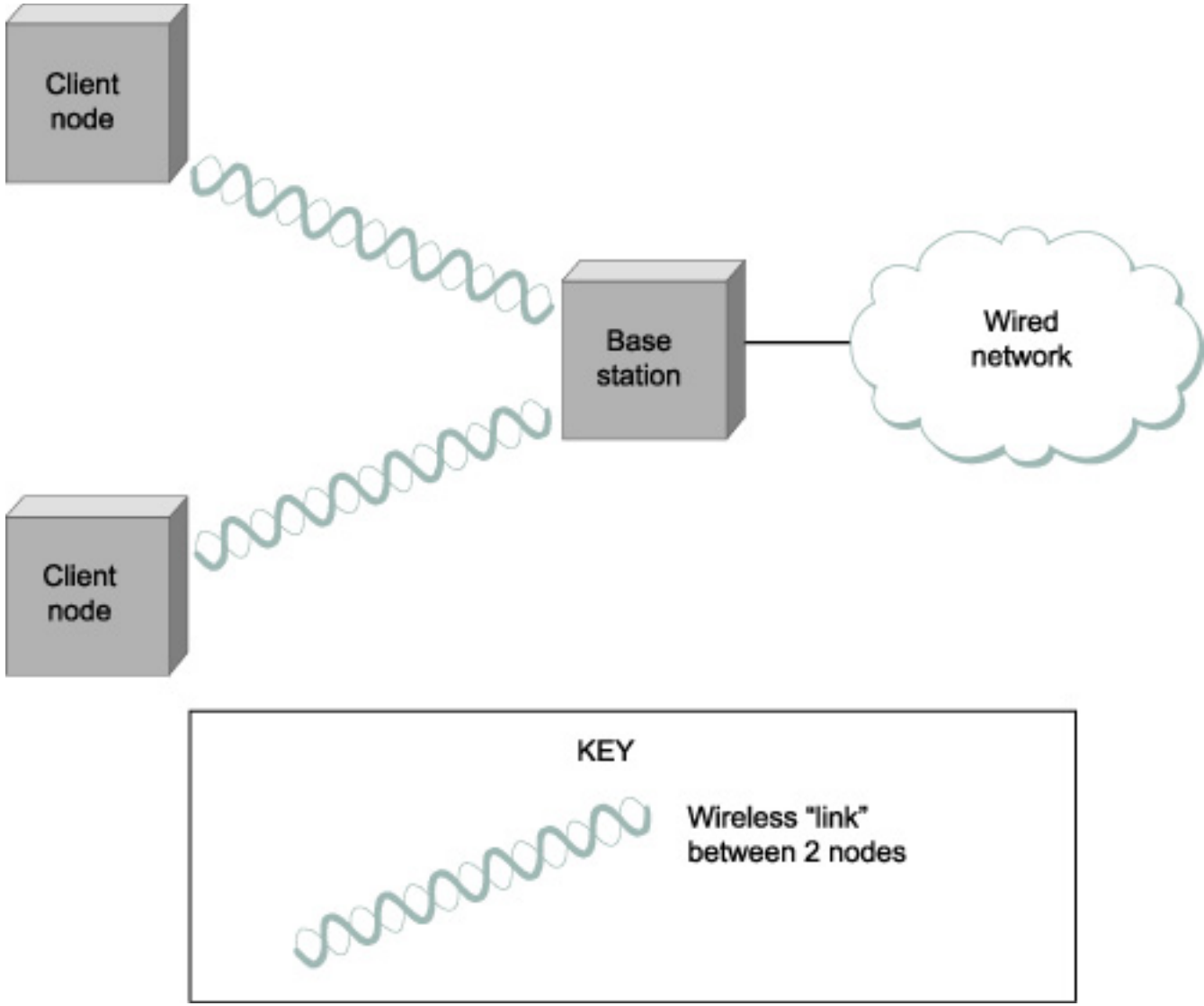
Review

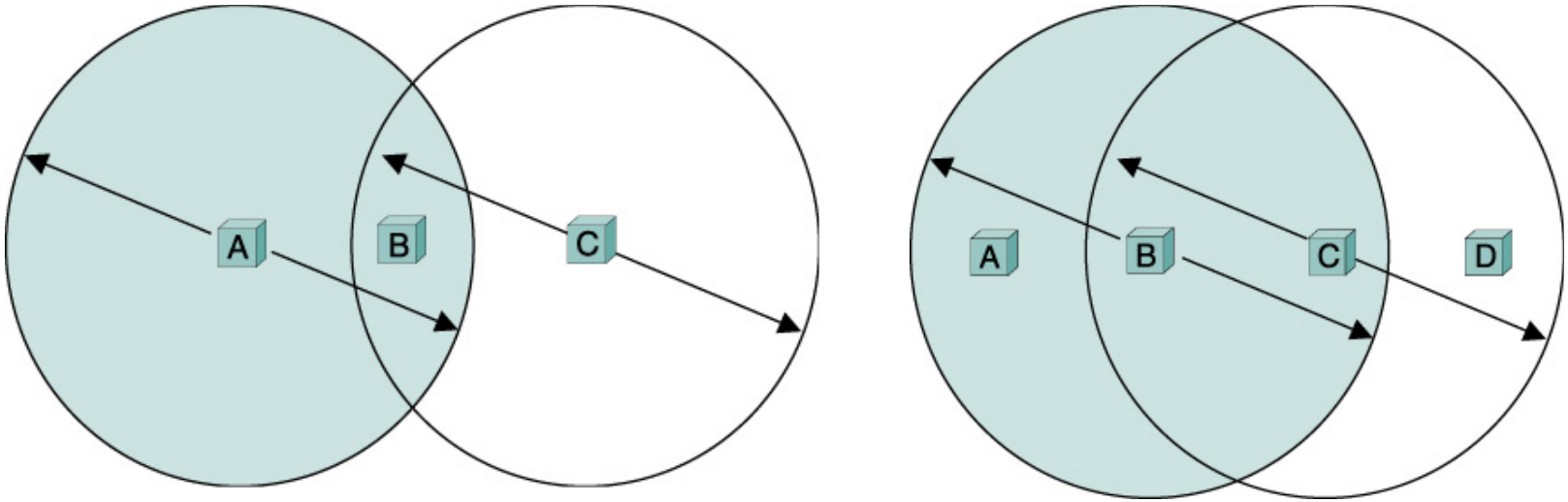
- Sliding window revisited
- End-to-end arguments
  - Reliable transmission
- Multiple access links
  - Ethernet: CSMA/CD
  - Token ring
  - Wireless
    - 802.11 (WiFi): RTS/CTS
    - Bluetooth
    - Cell phone
  - Note: understand the concepts

Wireless links



- Most common
  - Asymmetric
- Point-to-multipoint

Wireless access control



- Can't use Ethernet protocol
  - Hidden terminal
    - A and C can't hear each other's collision at B
  - Exposed terminal
    - B can send to A; C can send to D

802.11 (WiFi) Multiple access with collision avoidance (CSMA/CA)

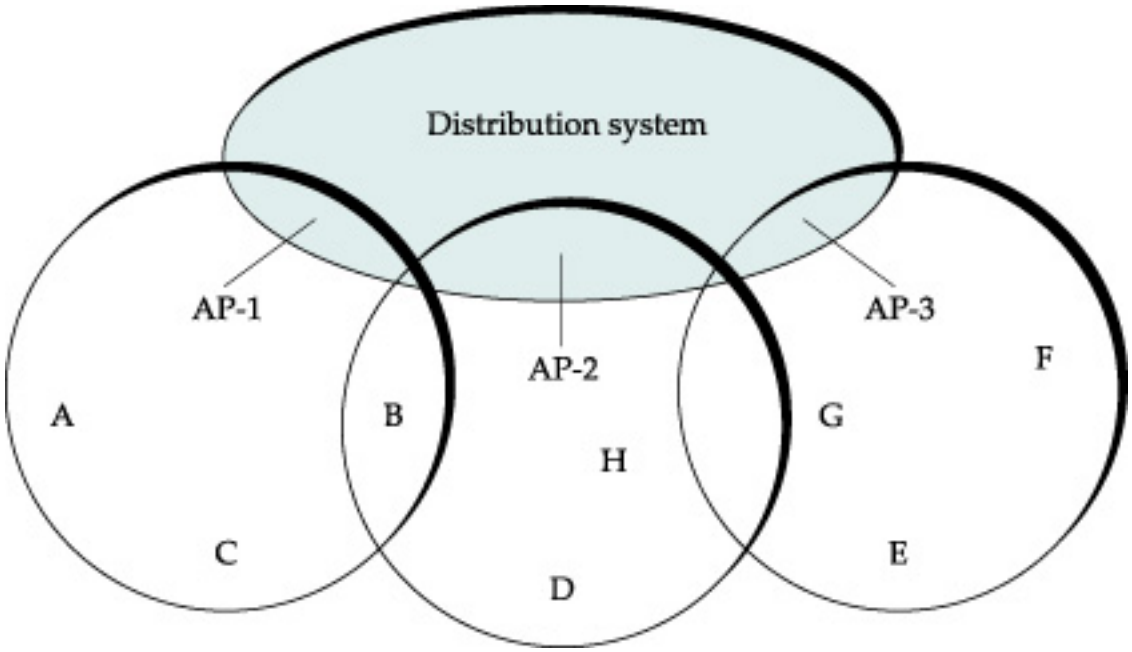
- Sender and receiver exchange control
  - Sender → receiver: Request to send (RTS)
    - Specifies the length of frame
  - Receiver → sender: Clear to send (CTS)
    - Echoes length of frame
  - Sender → receiver: frame
  - Receiver → sender: ack
  - Other nodes can send after hearing ACK

- Node sees CTS
  - Too close to receiver, can't transmit
  - Addressing hidden terminals
- Node only sees RTS
  - Okay to transmit
  - Addressing exposed terminals

How to resolve collision

- Sender cannot do collision detection
  - Single antenna can't send and receive at the same time
- If no CTS, then RTS collide
- Exponential backoff to retransmit

Distribution system

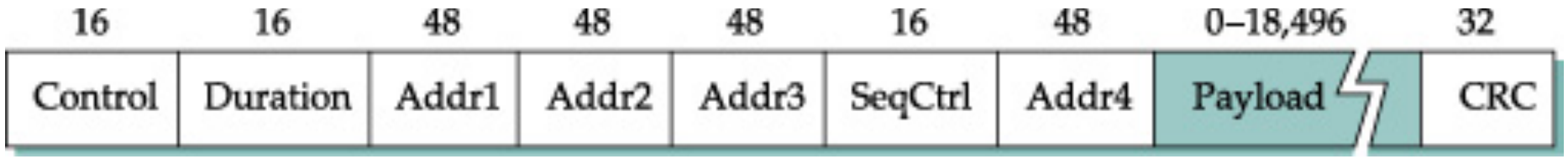


- Hosts associate with APs
- APs connect via the distribution system
  - A layer-2 system
    - Ethernet, token ring, etc.
  - Host IP addresses do not need to change

AP association

- Active scanning
  - Node: Probe
  - APs: Probe response
  - Node selects one of APs, send Association request
  - AP replies Association Response
- Passive scanning
  - AP sends Beacon to announce itself
  - Node sends Association Request

Frame format

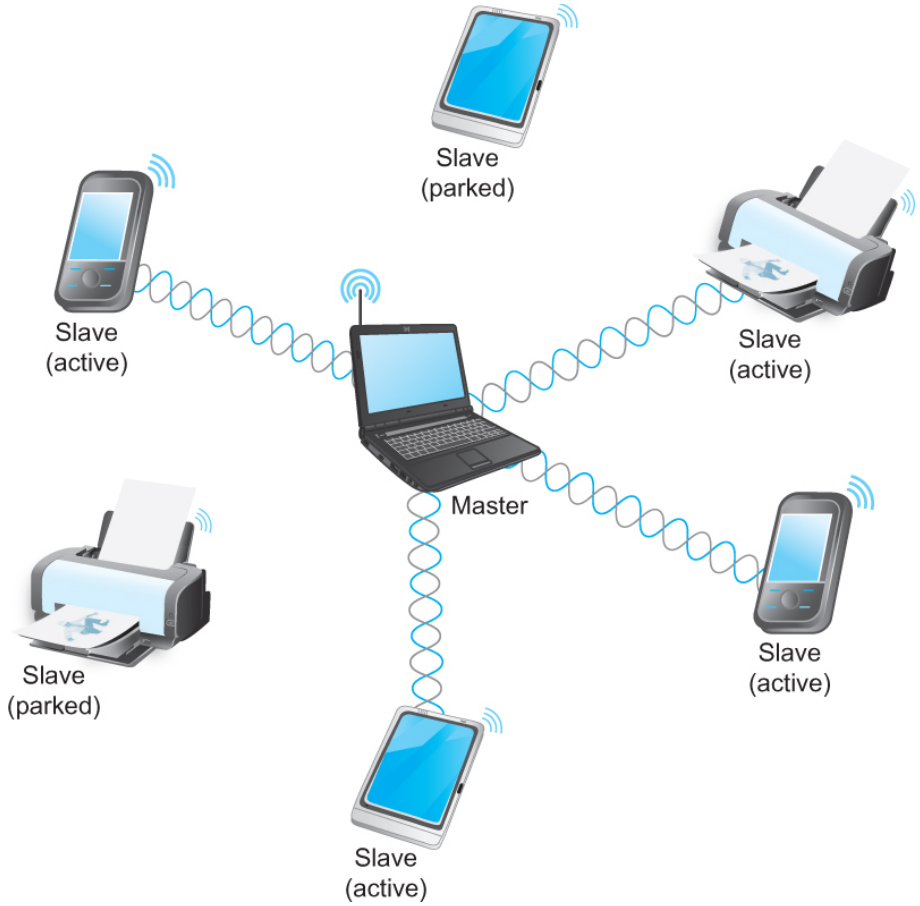


- Same AP
  - Addr1: dst
  - Addr2: src
- Different APs: Need to identify the intermediate APs
  - ToDS and FromDS in control field set
  - Add1: dst, Addr2: AP_dst
  - Addr3: AP_src, Add4: src
- Control
  - 6-bit Type
  - A pair of 1-bit field: ToDS/FromDS

Bluetooth (802.15.1)

- Connecting devices: mobile phones, headsets, keyboards
  - Very short range communication
  - Low power
- License exempt band 2.45 Ghz
- 1~3Mpbs
- Specified by Bluetooth Special Interest Group

A bluetooth piconet



- A master device and up to seven slave devices
- Communication is between the master and a slave

Cell phone technologies

- Using licensed spectrum
- Different bands using different frequencies
- Base stations form a wired network
- Geographic area served by a base station's antenna is called a cell
  - Similar to wifi
- Phone is associated with one base station
- Leaving a cell entering a cell causes a handoff

Cellular technologies

- 1G: analog
- 2G: digital and data
- 3G: higher bandwidth and simultaneous voice and data
- 4G: even higher. Top around 2.6Ghz
- 5G: 15Ghz

List of mobile phone generations		
0G (radio telephones)	MTS · MTA - MTB - MTC - MTD · IMTS · AMTS · OLT · Autoradiopuhelin · B-Netz · Altai · AMR	
1G (1985)	**AMPS family**	AMPS (TIA/EIA/IS-3, ANSI/TIA/EIA-553) · N-AMPS (TIA/EIA/IS-91) · TACS · ETACS
	Other	NMT · C-450 · Hicap · Mobitex · DataTAC
2G (1992)	**GSM/3GPP family**	GSM · CSD · HSCSD
	3GPP2 family	cdmaOne (TIA/EIA/IS-95 and ANSI-J-STD 008)
	AMPS family	D-AMPS (IS-54 and IS-136)
	Other	CDPD · iDEN · PDC · PHS
2G transitional (2.5G, 2.75G)	**GSM/3GPP family**	GPRS · EDGE/EGPRS (UWC-136/136HS/TDMA-EDGE)
	3GPP2 family	CDMA2000 1X (TIA/EIA/IS-2000) · CDMA2000 1X Advanced
	Other	WiDEN · DECT
3G (2003)	**3GPP family**	UMTS (UTRA-FDD / W-CDMA · UTRA-TDD LCR / TD-SCDMA · UTRA-TDD HCR / TD-CDMA)
	3GPP2 family	CDMA2000 1xEV-DO Release 0 (TIA/IS-856)
3G transitional (3.5G, 3.75G, 3.9G)	**3GPP family**	HSPA (HSDPA · HSUPA) · HSPA+ · LTE (E-UTRA)
	3GPP2 family	CDMA2000 1xEV-DO Revision A (TIA/EIA/IS-856-A) · EV-DO Revision B (TIA/EIA/IS-856-B) · EV-DO Revision C
	IEEE family	Mobile WiMAX (IEEE 802.16e) · Flash-OFDM · iBurst (IEEE 802.20)
4G (2013) (IMT Advanced)	**3GPP family**	LTE Advanced (E-UTRA) · LTE Advanced Pro (4.5G Pro/pre-5G/4.9G)
	IEEE family	WiMAX (IEEE 802.16m) (WiMax 2.1 (LTE-TDD))
5G (2020) (IMT-2020) (Under development)	**LTE**	
	5G-NR	

Today

- Types of switching
  - Datagram
  - Virtual circuit
  - Source routing

Packet switching

- 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

- 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

A star topology

- A switch has a limited number of input and output ports
- Switches can be connected to each other to build larger networks
- Adding a new host may not reduce the performance for other hosts
  - Not true for shared media networks
  - Why?

Switching technologies

- Switching / forwarding: to receive incoming packets on one of its links and to transmit 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

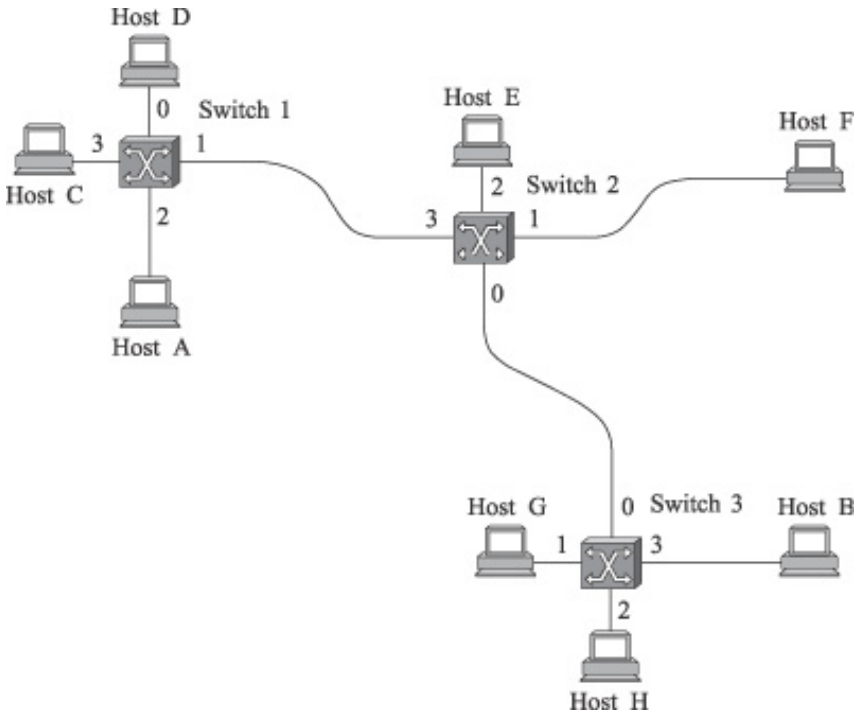
Challenges

- 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

Datagram

- Every packet contains the 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

Switch 2's forwarding table



A	3
B	0
C	3
D	
E	
F	
G	
H	

Q: how does a switch compute the table?

Features of datagram switching

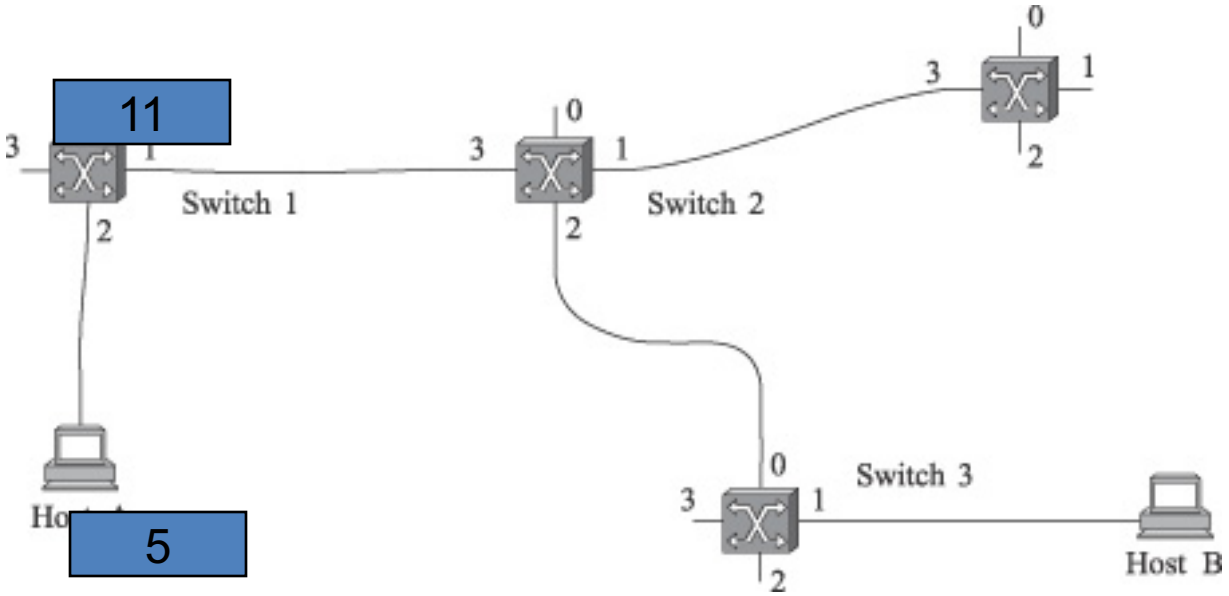
- Connectionless
- Unknown network state
- Independent forwarding
- Robust to failures
  - Switches can re-compute forwarding tables

Virtual circuit switching

- Connection oriented
  - Set up a virtual circuit
  - Data transfer

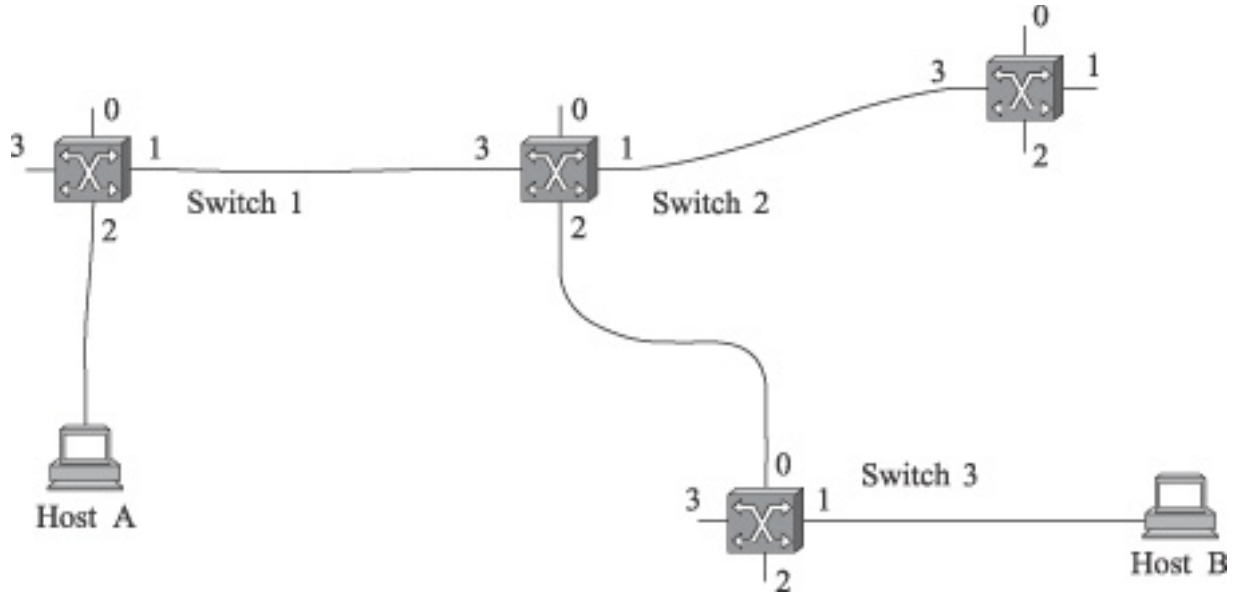
- Connection setup phase
  - Set up connection state
  - A virtual circuit identifier, an incoming interface, an outgoing interface, and an outgoing virtual circuit identifier

Virtual circuit table (switch1)



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

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

How to setup connection state

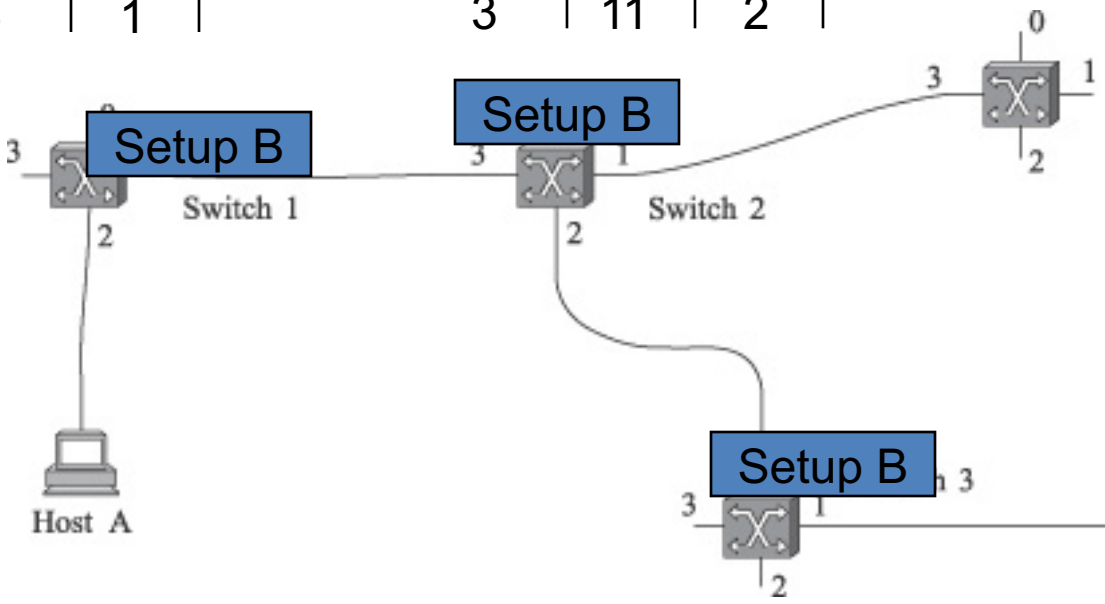
- Administrator configured
  - Permanent virtual circuit (PVC)
  - Admin manually sets up VC tables
  - Does not suit large networks
- Signaling
  - A host sends messages to dynamically setup or tear down a VC

VC setup protocol

- A host A sends a setup message to first hop switch, including the final destination address
  - Similar to a datagram packet
- The switch picks an unused VCI to identify the incoming connection, and fills part of the VC table
  - *Why not let the host pick it?*
- 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

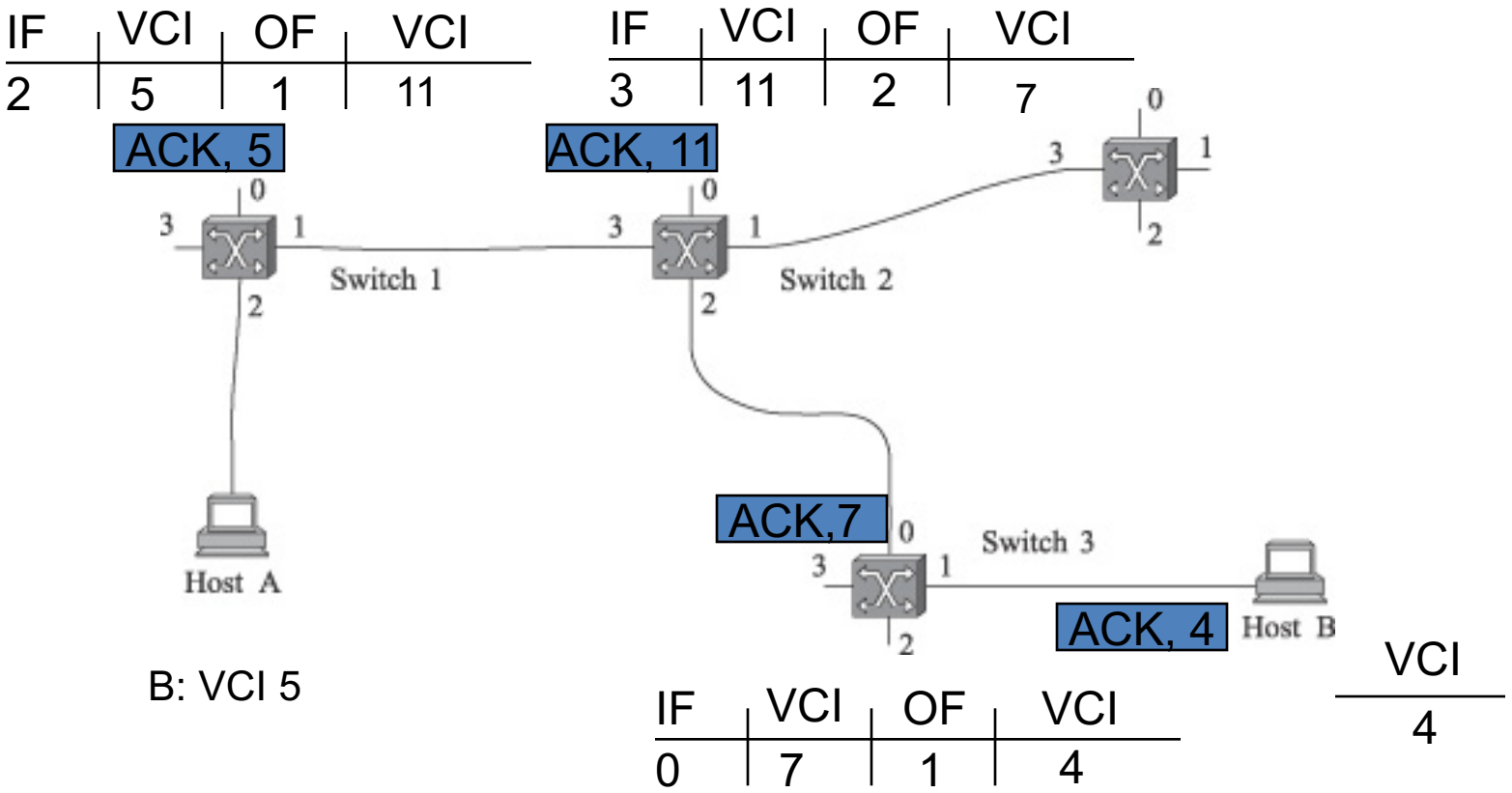
IF	VCI	OF	VCI
2	5	1	

IF	VCI	OF	VCI
3	11	2	



IF	VCI	OF	VCI
0	7	1	

VCI
4



- After setup, A sends to B
- A tears down after done

Characteristics of VC switching

- - Connection setup wait
- + Data packets contain a small VCI, not the full destination addresses
- - 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

- + 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

Link layer technologies that use VC

- X.25
- Frame relay
- Asynchronous Transfer Mode (ATM)

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

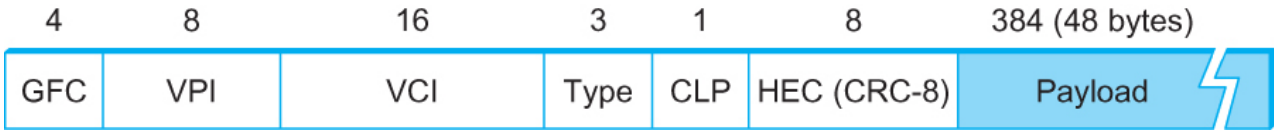
Why small, fixed-length packets?

- Cons: maximum efficiency 48/53=90.6%

- Pros:
  - Suitable for high-speed hardware implementation
  - Many switching elements doing the same thing in parallel
  - Reducing priority packet latency
    - Good for QoS
  - Reducing transmission latency

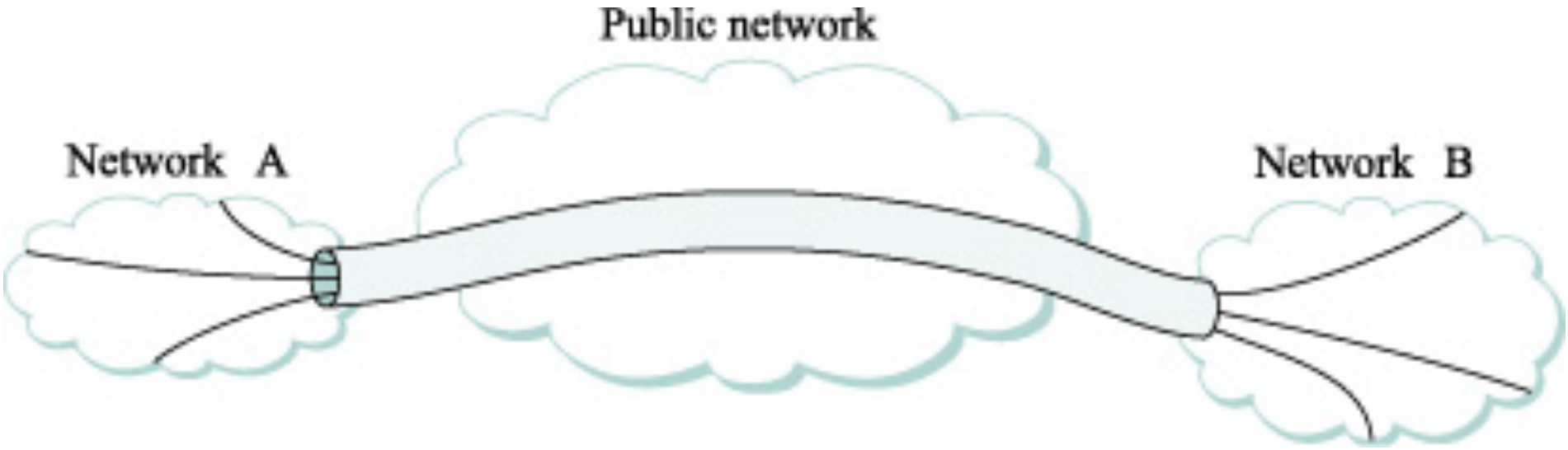
Switching and Forwarding

- ATM
  - User-Network Interface (UNI)
    - Host-to-switch format
    - GFC: Generic Flow Control
    - VCI: Virtual Circuit Identifier
    - Type: management, congestion control
    - CLP: Cell Loss Priority
    - HEC: Header Error Check (CRC-8)



  - Network-Network Interface (NNI)
    - Switch-to-switch format
    - GFC becomes part of VPI field

Virtual paths



- 24-bit virtual circuit identifiers (VCIs)
- Two-levels of hierarchy
  - 8-bit virtual path, 16-bit VCI
  - Virtual paths shared by multiple connections

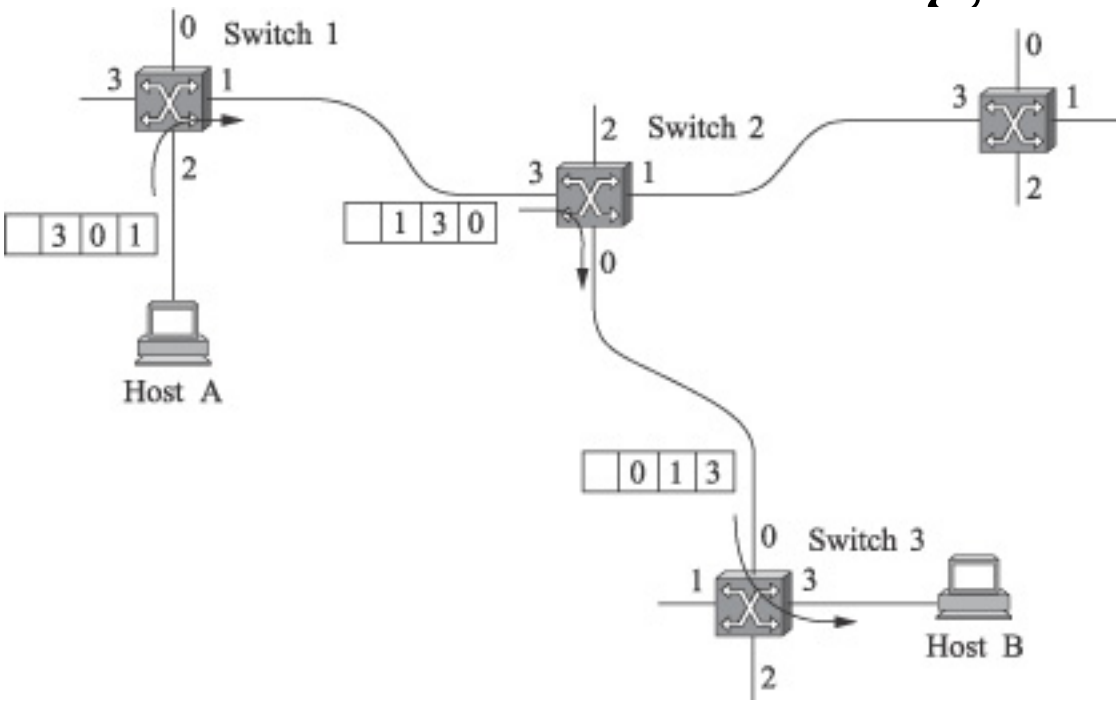
History of ATM

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

Switching technologies

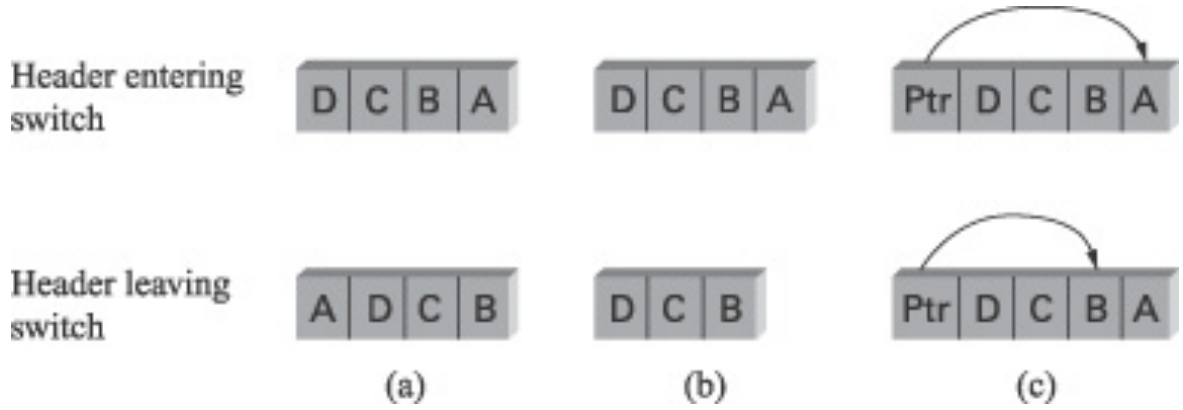
- Connectionless: datagram
- Connection oriented: virtual circuit
  - An example of VC switching: ATM
- Source routing

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

Summary

- Wireless links
- Types of switching
  - Datagram
  - Virtual circuit
  - Source routing
- Next: Bridges and LAN switches