

CSCI 491-01

Topics: Internet Programming

Fall 2008

## Data-link Layer

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# MAC Protocols: A Taxonomy

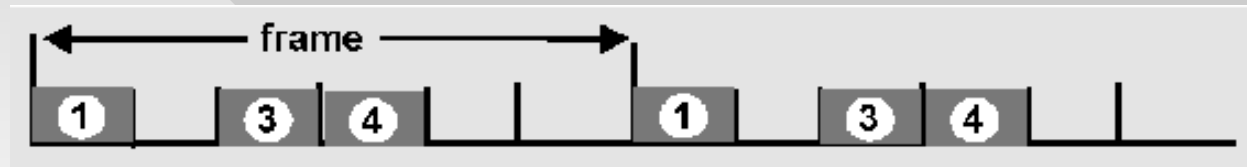
Three broad classes:

- **Channel Partitioning**
  - Divide channel into smaller “pieces” (time slots, frequency, code)
  - Allocate piece to node for exclusive use
- **Random Access**
  - Channel not divided, allow collisions
  - “Recover” from collisions
- **“Taking turns”**
  - Nodes take turns, but nodes with more to send can take longer turns

# Channel Partitioning MAC protocols: TDMA

## TDMA: time division multiple access

- Access to channel in “rounds” (time frames)
- Each station gets fixed length slot in each round (1/N of frame time to each node)
- Unused slots go idle
- Example: 6-station LAN, 1,3,4 have pkt, slots 2,5,6 idle

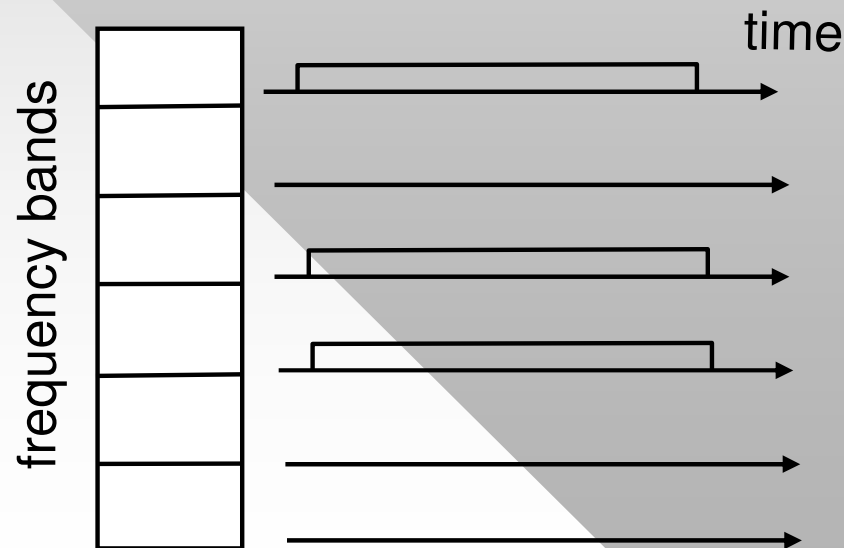


- TDM (Time Division Multiplexing): channel divided into N time slots, one per user; inefficient with low duty cycle users and at light load
- Maximum throughput for a single user is  $C/N$ , which is far from ideal!

# Channel Partitioning MAC protocols: FDMA

## FDMA: frequency division multiple access

- Channel spectrum divided into frequency bands
- Each station assigned fixed frequency band
- Unused transmission time in frequency bands go idle
- Example: 6-station LAN, 1,3,4 have pkt, frequency bands 2,5,6 idle



# Random Access Protocols

- When node has packet to send
  - Transmit at full channel data rate  $R$
  - No *a priori* coordination among nodes
- Two or more transmitting nodes cause “collision”
- **Random access MAC protocol** specifies:
  - How to detect collisions
  - How to recover from collisions (e.g., via delayed retransmissions)
- Examples of random access MAC protocols:
  - Slotted ALOHA
  - ALOHA
  - CSMA, CSMA/CD, CSMA/CA

# Slotted ALOHA

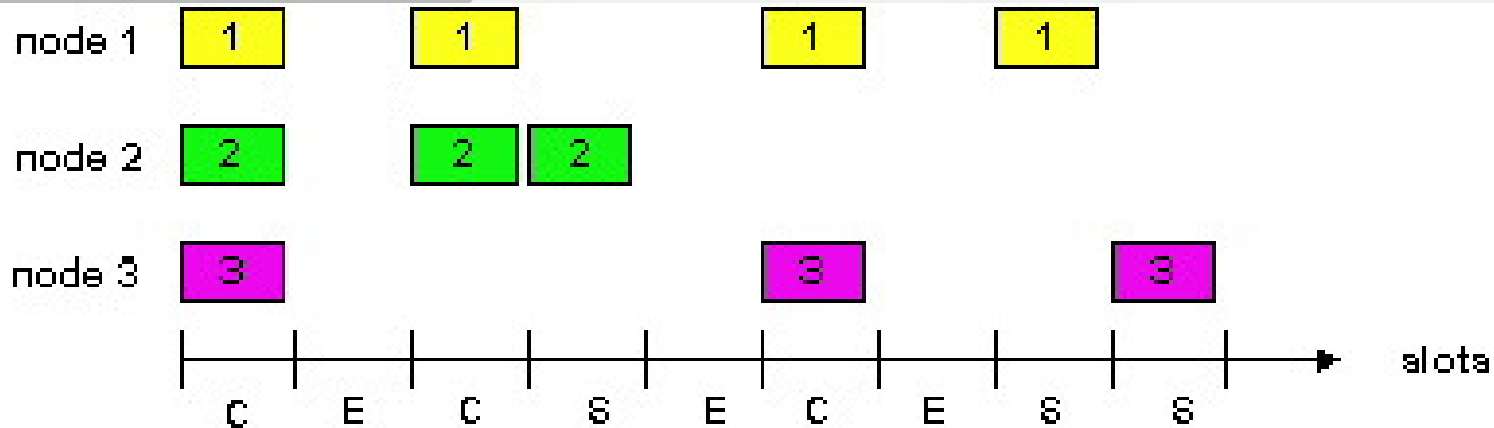
## Assumptions

- All frames same size
- Time is divided into equal size slots, time to transmit 1 frame
- Nodes start to transmit frames only at beginning of slots
- Nodes are synchronized
- If 2 or more nodes transmit in slot, all nodes detect collision

## Operation

- When node obtains fresh frame, it transmits in the next time slot
- No collision, node can send new frame in next slot
- If collision, node retransmits frame in each subsequent slot with probability  $p$  until success

# Slotted ALOHA



## Pros

- Single active node can continuously transmit at full rate of channel
- Highly decentralized: only slots in nodes need to be in sync
- Simple

## Cons

- Collisions, wasting slots
- Idle slots
- Nodes may be able to detect collision in less than time to transmit packet
- Clock synchronization

# Slotted Aloha efficiency

**Efficiency** is the long-run fraction of successful slots when there are many nodes, each with many frames to send

- Assume  $N$  nodes with many frames to send, each transmits in every slot with probability  $p$
- Prob that node 1 has success in a slot =  $p(1-p)^{N-1}$
- Prob that any node has a success =  $Np(1-p)^{N-1}$

- For max efficiency with  $N$  nodes, find  $p$  that maximizes  $Np(1-p)^{N-1}$
- Optimal  $p_0 = 1/N$
- For many nodes, take limit of  $Np_0(1-p_0)^{N-1}$  as  $N$  goes to infinity, which gives  $1/e = 0.37$

***At best:*** channel used for useful transmissions 37% of time!

# CSMA (Carrier Sense Multiple Access)

**CSMA**: listen before transmit:

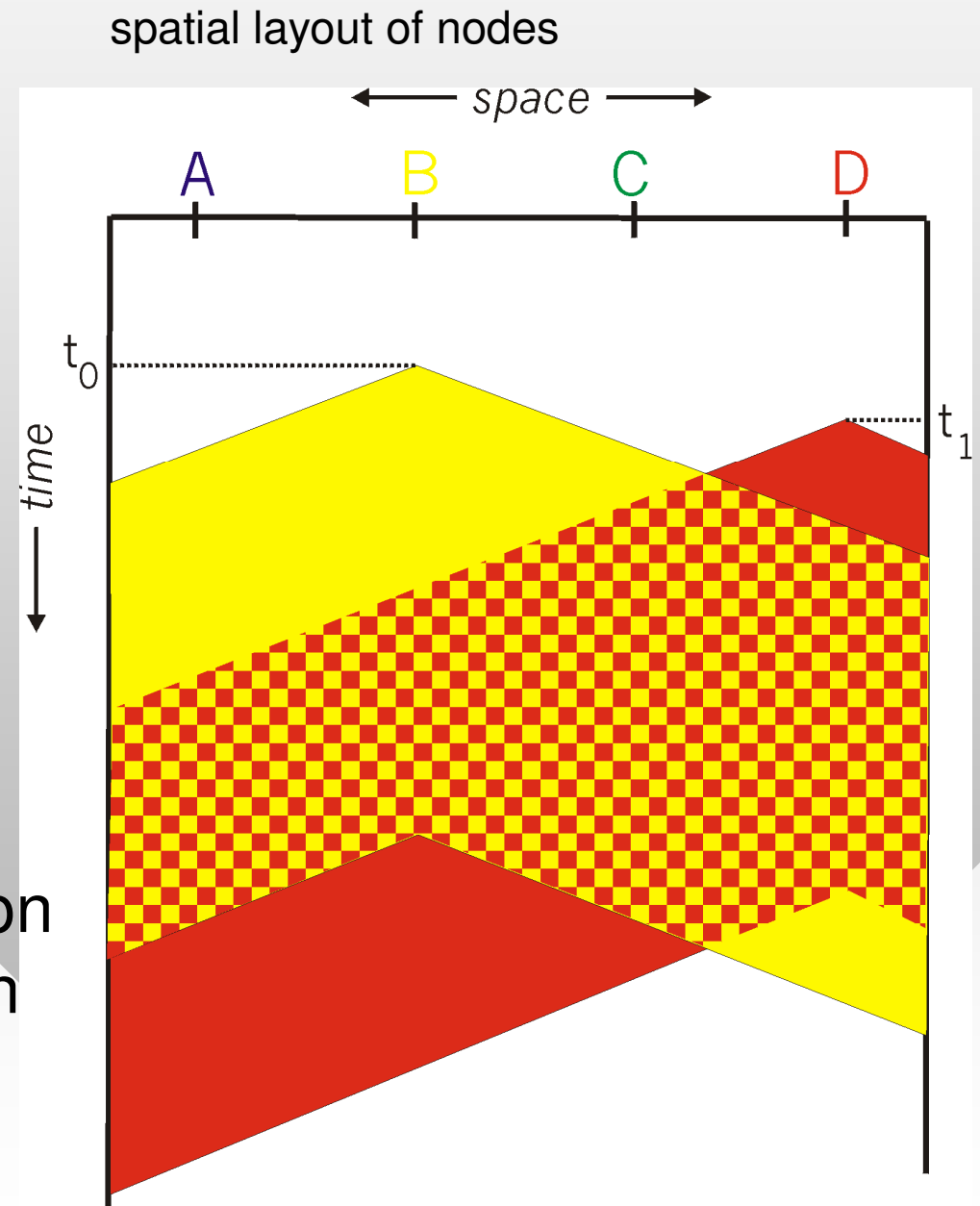
- If channel sensed idle, transmit entire frame
- If channel sensed busy, defer transmission
  - Human analogy: don't interrupt others!
- If collision is detected at **the end of transfer**, wait a random period of time, then retransmit
  - Human analogy: talk until you're done, then repeat if someone else happened to start at the same time

# CSMA Collisions

Collisions *can* still occur:  
propagation delay means  
two nodes may not hear  
each other's transmission

Collision:  
entire packet transmission  
time wasted

Note:  
role of distance & propagation  
delay in determining collision  
probability

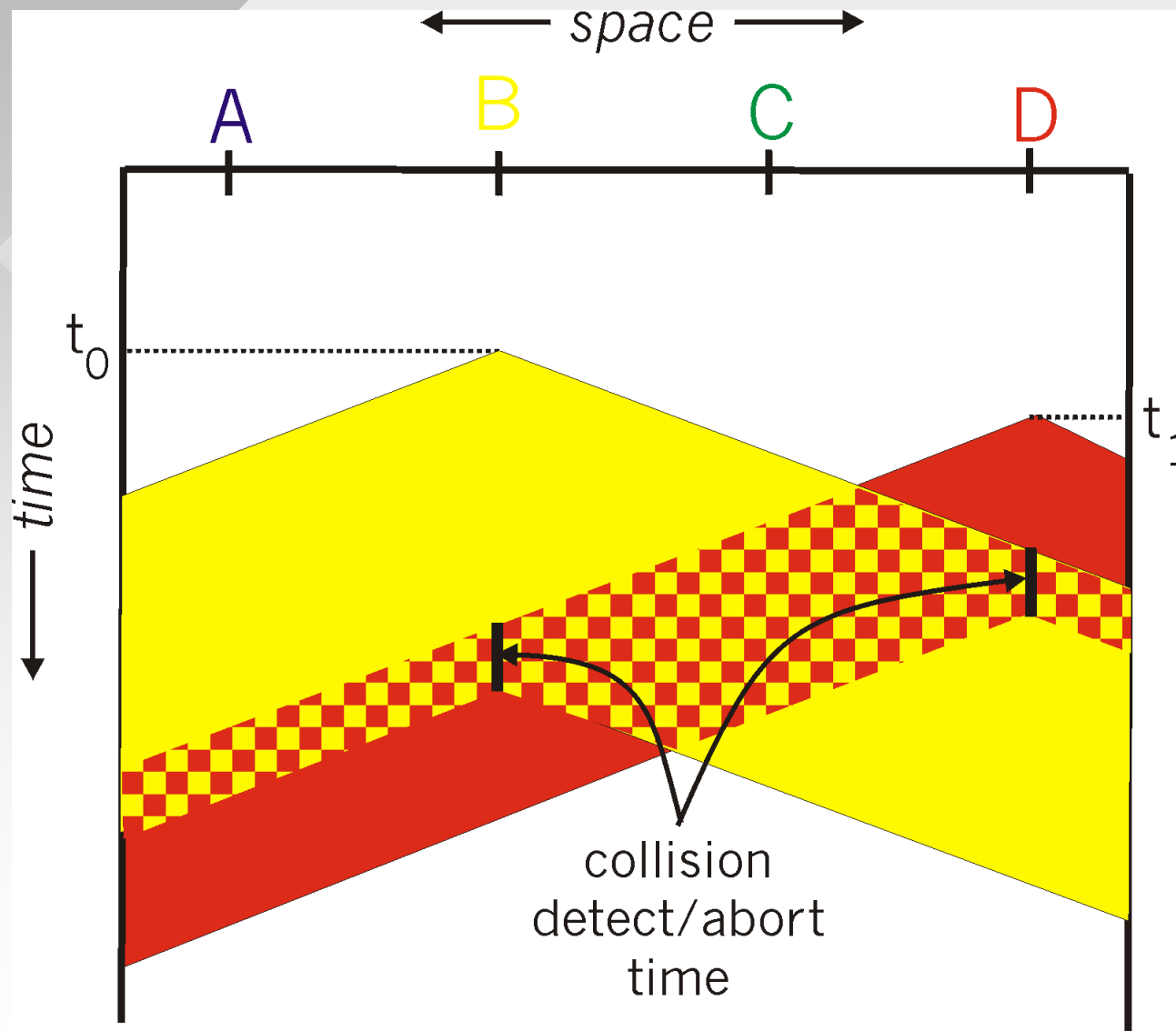


# CSMA/CD (Collision Detection)

**CSMA/CD:** carrier sensing, deferral as in CSMA

- Collisions *detected* within short time
- Colliding transmissions aborted, reducing channel waste
- Human analogy: the polite conversationalist
- Collision detection:
  - Easy in wired LANs: measure signal strengths, compare transmitted, received signals
  - Difficult in wireless LANs: receiver shut off while transmitting

# CSMA/CD Collision Detection



# Features

## TDMA/FDMA:

- Share channel efficiently and fairly at high load
- Inefficient at low load: delay in channel access,  $1/N$  bandwidth allocated even if only 1 active node!

## Random access:

- Efficient at low load: single node can fully utilize channel
- High load: potentially huge collision overhead

## “Taking turns” protocols:

- Look for best of both worlds!

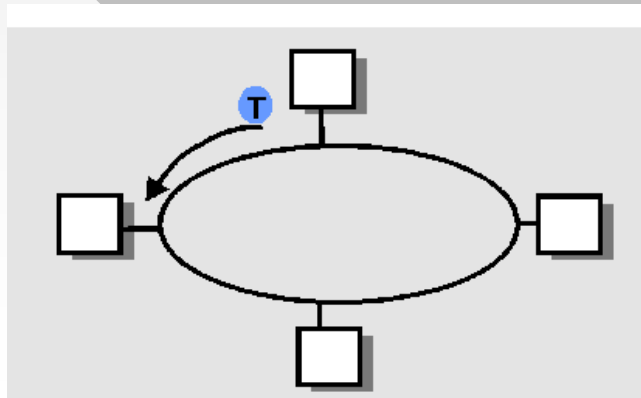
# “Taking Turns” MAC Protocols

## A) Polling:

- Master node “invites” slave nodes to transmit in turn
- Concerns:
  - Polling overhead
  - Latency
  - Single point of failure (master)

## B) Token passing:

- Control **token** passed from one node to next sequentially
- Token message
- Concerns:
  - Token overhead
  - Latency
  - Single point of failure (token)



# Summary of MAC Protocols

- What do you do with a shared media?
  - Channel Partitioning, by time, frequency or code
    - Time Division, Frequency Division
  - Random partitioning (dynamic),
    - ALOHA, S-ALOHA, CSMA, CSMA/CD
    - carrier sensing: easy in some technologies (wire), hard in others (wireless)
    - CSMA/CD used in Ethernet
    - CSMA/CA used in 802.11
  - Taking Turns
    - Polling from a central site, token passing

# Link Layer

5.1 Introduction and services

5.2 Error detection and correction

5.3 Multiple access protocols

5.4 Link-Layer Addressing

5.5 Ethernet

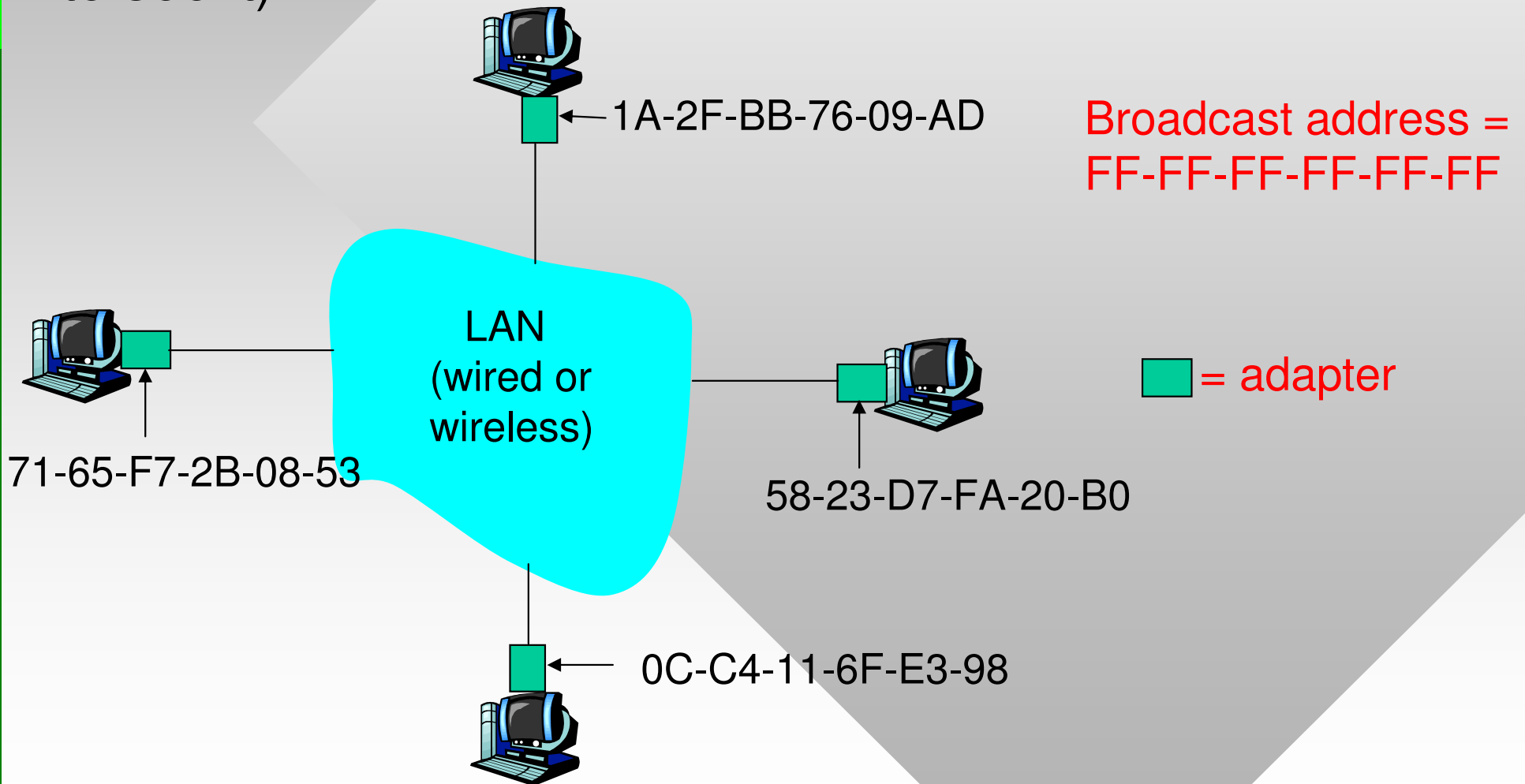
5.6 Hubs and switches

# MAC Addresses and ARP

- Recall that 32-bit IP addresses:
  - Belong to the **network** layer
  - Are used to get datagram to destination IP subnet
- MAC (or LAN, or physical, or Ethernet) address:
  - Used to get datagram from one interface to another physically-connected interface (same network)
  - 48 bit MAC address (for most LANs) burned in the adapter ROM

# LAN Addresses and ARP

Each adapter on LAN has unique LAN address (ipconfig /all to see it)



## LAN Address (More)

- MAC address allocation administered by IEEE
- Manufacturer buys portion of MAC address space (to assure uniqueness)
- Analogy:
  - (a) MAC address: like Social Security Number
  - (b) IP address: like postal address
- MAC flat address → portability
  - Can move LAN card from one LAN to another
- IP hierarchical address NOT portable
  - Depends on IP subnet to which node is attached