Objectives:

1) basic channel models
2) factors that determines throughput/bit error rate in wireless communication

Readings:

1. Kurose & Ross, Computer Networking: A Top-Down Approach (6th Edition), Chapt 5.3

MEDIUM ACCESS

Need for Medium Access Control (MAC)

- Part of layer-2
- Addressing, and
- Channel access control mechanisms that make it possible for several terminals or network nodes to communicate within a multiple access network that incorporates a shared medium

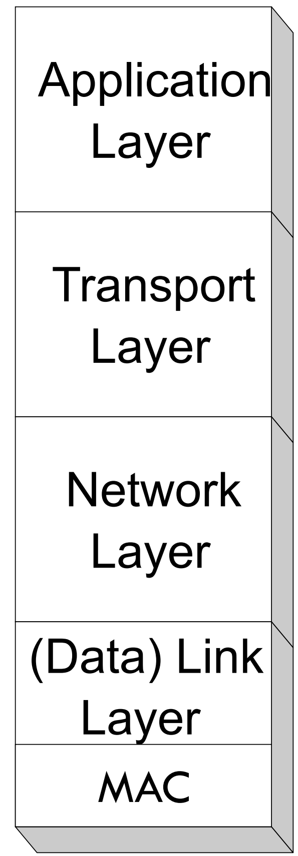
MAC in the protocol stack

- Service: Handles details of application programs.
- Functions:

- Service: Controls delivery of data between hosts.
- Functions: Connection establishment/termination, error control, flow control, congestion control, etc.

- Service: Moves packets inside the network.
- Functions: Routing, addressing, switching, etc.

- **Service: Reliable transfer of frames over a link.**
- **Functions: Synchronization, error control, flow control, link access etc.**



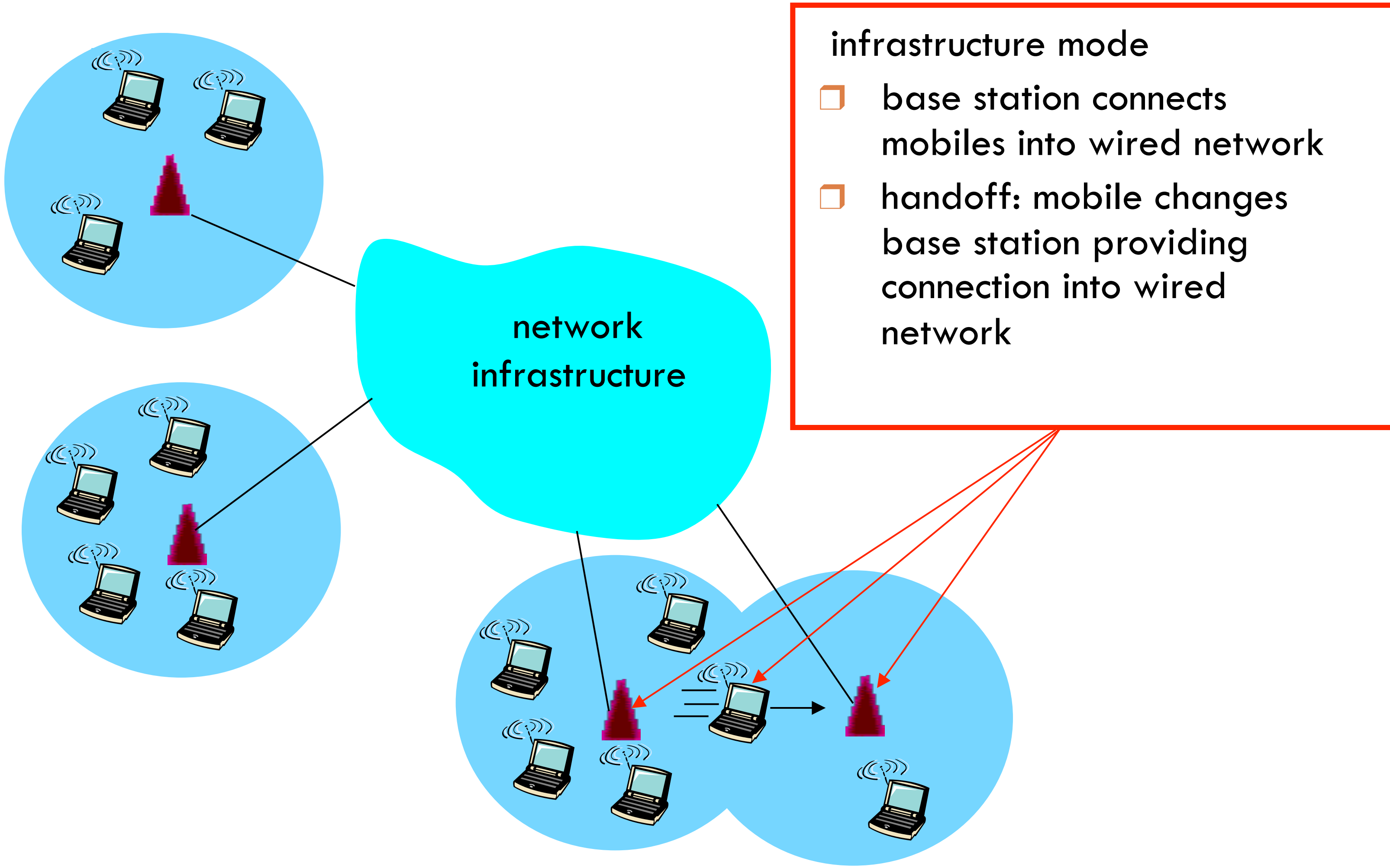
telnet, ftp, email
www, NFS

TCP, UDP

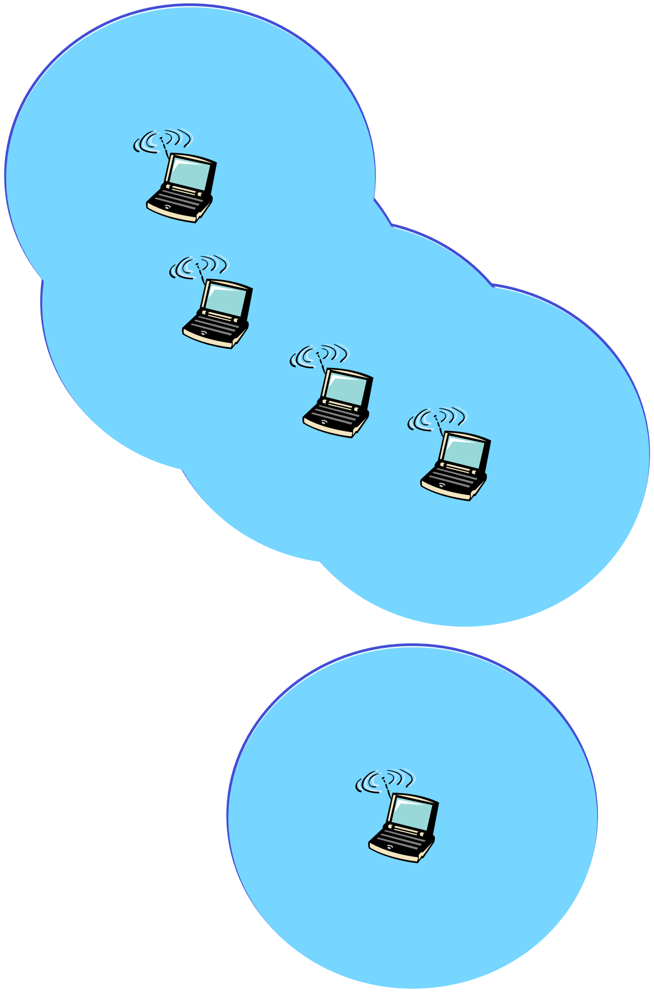
IP, ICMP, OSPF
RIP, BGP

Ethernet, WiFi
T1

Topology


network infrastructure
infrastructure mode
base station connects mobiles into wired network
handoff: mobile changes base station providing connection into wired network

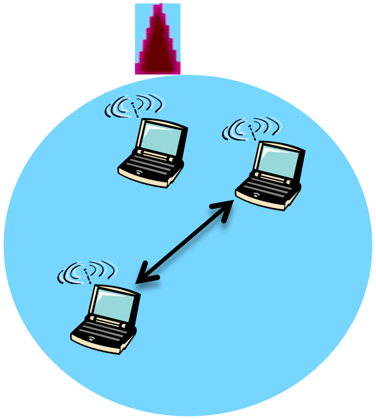
Ad hoc model



Ad hoc mode

- no base stations
- nodes can only transmit to other nodes within link coverage
- nodes organize themselves into a network: route among themselves

Peer-2-peer Model



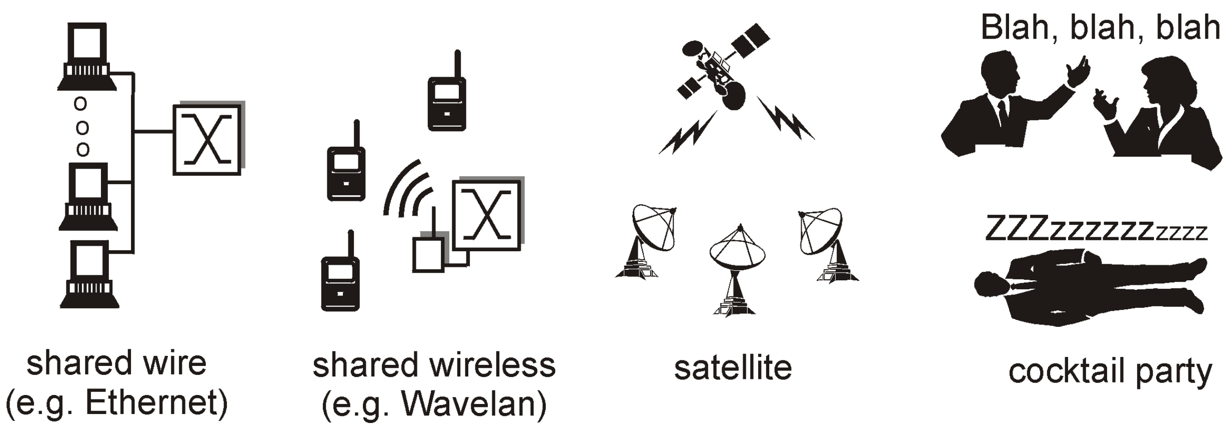
Peer-2-peer

- Group-owner/base-station coordinated
- nodes can transmit directly to other nodes within link coverage

Multiple Access Links and Protocols

Two types of "links":

- point-to-point
  - PPP for dial-up access
- broadcast (shared wire or medium)
  - traditional Ethernet
  - upstream HFC
  - 802.11 wireless LAN



Multiple Access protocols

- single shared broadcast channel
- two or more simultaneous transmissions by nodes: interference
  - collision if node receives two or more signals at the same time

multiple access protocol

- distributed algorithm that determines how nodes share channel, i.e., determine when node can transmit
- communication about channel sharing must use channel itself!
  - no out-of-band channel for coordination

Ideal Mulitple Access Protocol

Broadcast channel of rate R bps

1. When one node wants to transmit, it can send at rate R.
2. When M nodes want to transmit, each can send at average rate R/M
3. Fully decentralized:
   - no special node to coordinate transmissions
   - no synchronization of clocks, slots
4. Simple

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” (not covered)
  - Nodes take turns, but nodes with more to send can take longer turns
  - Used in vehicular setting

Multiple Access

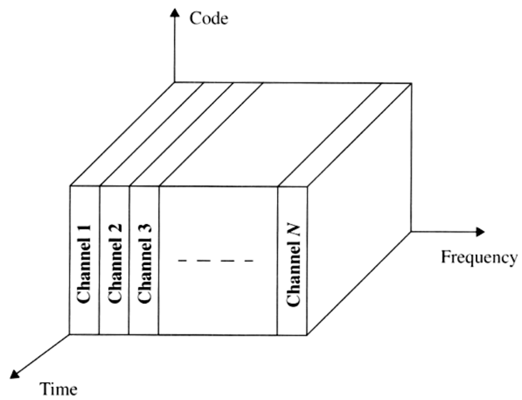


Figure 9.2 FDMA where different channels are assigned different frequency bands.

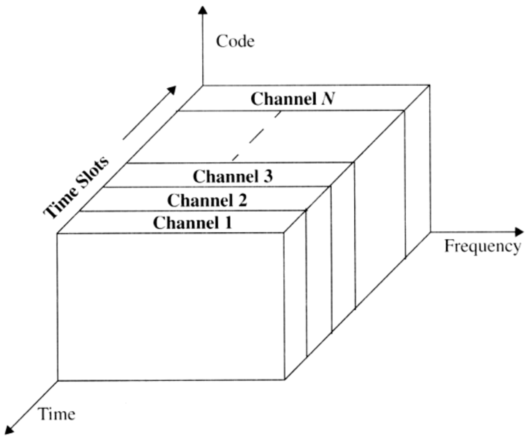


Figure 9.3 TDMA scheme where each channel occupies a cyclically repeating time slot.

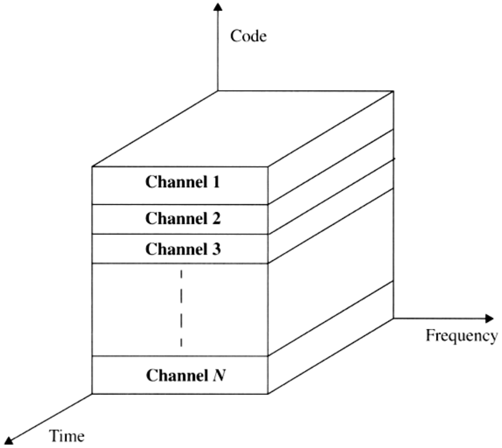


Figure 9.5 Spread spectrum multiple access in which each channel is assigned a unique PN code which is orthogonal or approximately orthogonal to PN codes used by other users.

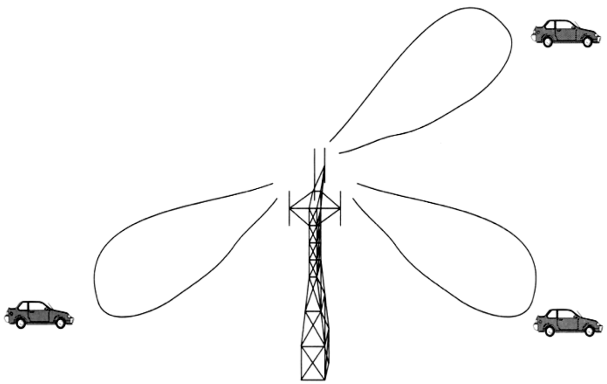
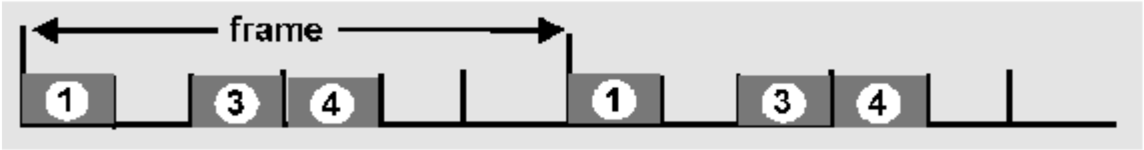


Figure 9.8 A spatially filtered base station antenna serving different users by using spot beams.

Channel Partitioning MAC protocols: TDMA

TDMA: time division multiple access

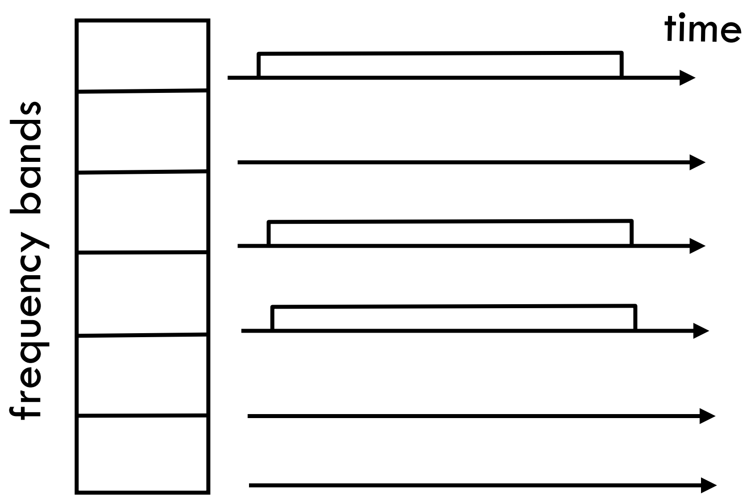
- access to channel in "rounds"
- each station gets fixed length slot (length = pkt trans time) in each round
- unused slots go idle
- example: 6-station LAN, 1,3,4 have pkt, slots 2,5,6 idle



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



Code Division Multiple Access (CDMA)

- used in several wireless broadcast channels (cellular, satellite, etc) standards
- unique "code" assigned to each user; i.e., code set partitioning
- all users share same frequency, but each user has own "chipping" sequence (i.e., code) to encode data
- *encoded signal* = (original data) X (chipping sequence)
- *decoding:* inner-product of encoded signal and chipping sequence
- allows multiple users to "coexist" and transmit simultaneously with minimal interference (if codes are "orthogonal")

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 ➜ "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

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!

CSMA collisions

collisions *can* still occur:

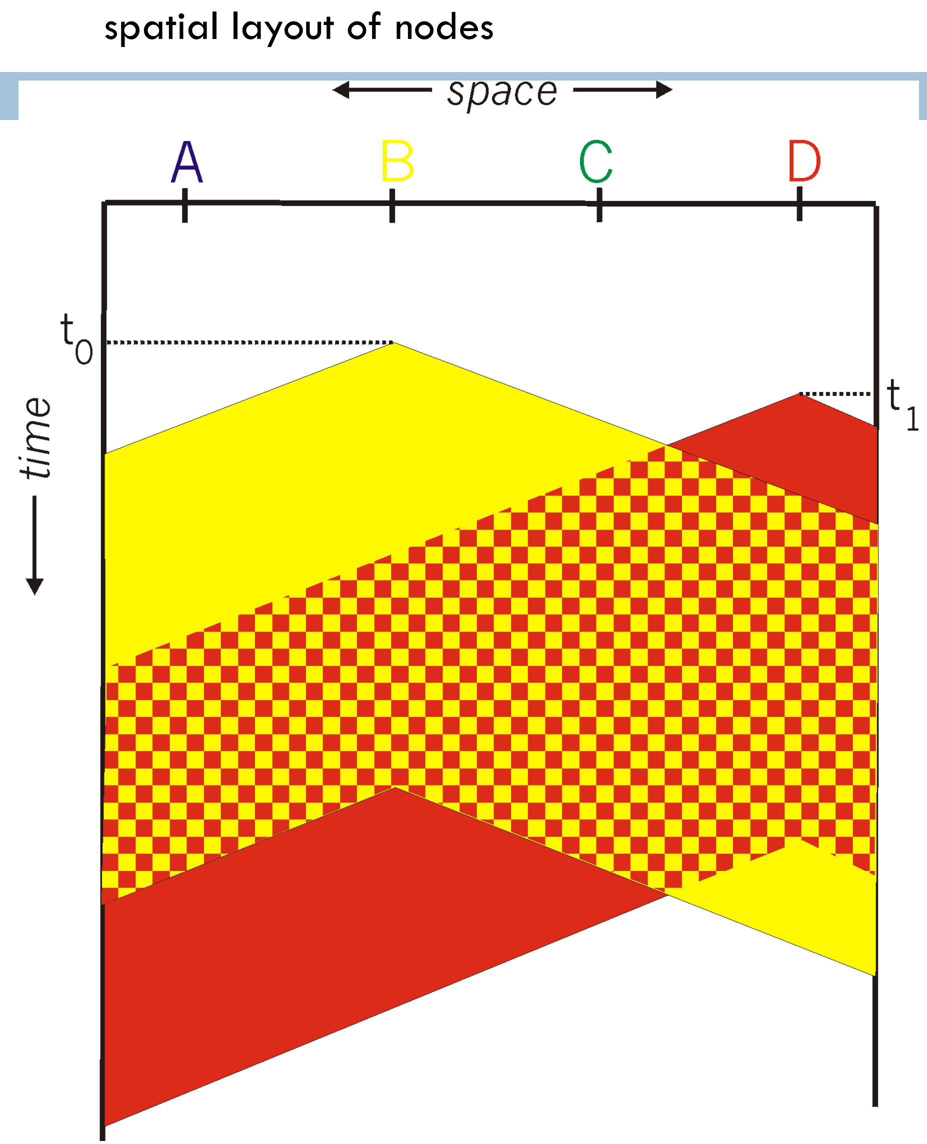
propagation delay means two nodes may not hear each other's transmission

collision:

entire packet transmission time wasted

note:

role of distance & propagation delay in determining collision probability



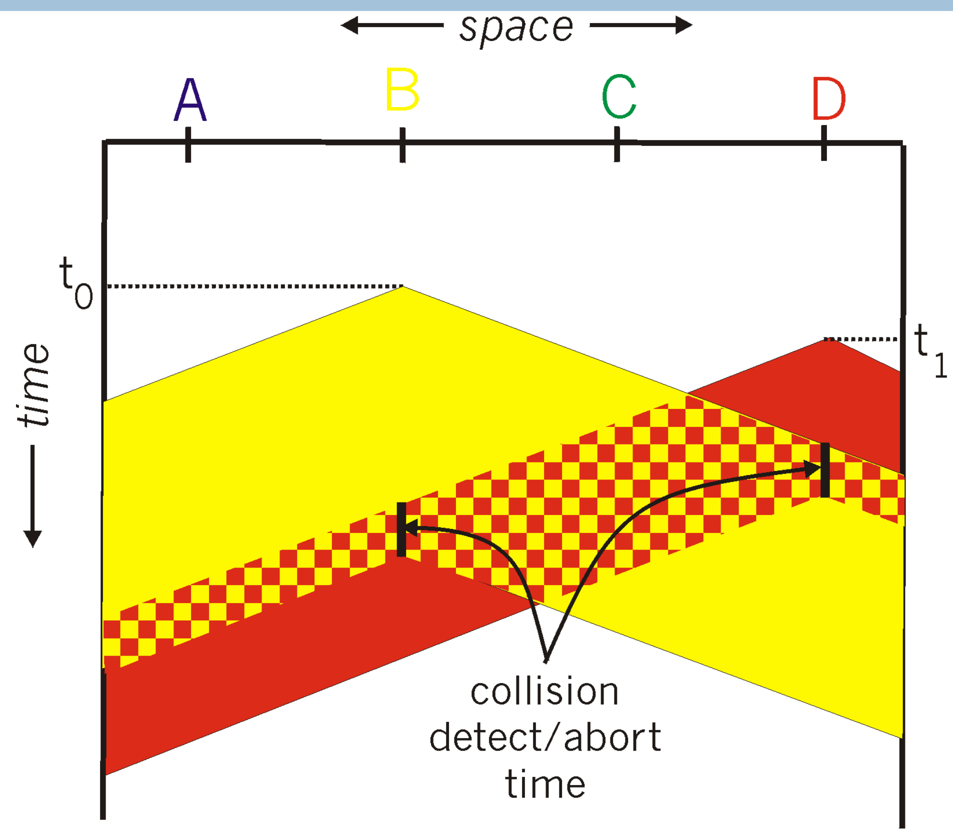
CSMA/CD (Collision Detection)

CSMA/CD: carrier sensing, deferral as in CSMA

- collisions *detected* within short time
- colliding transmissions aborted, reducing channel wastage

- collision detection:
  - easy in wired LANs: measure signal strengths, compare transmitted, received signals
  - difficult in wireless LANs: receiver shut off while transmitting
- human analogy: the polite conversationalist

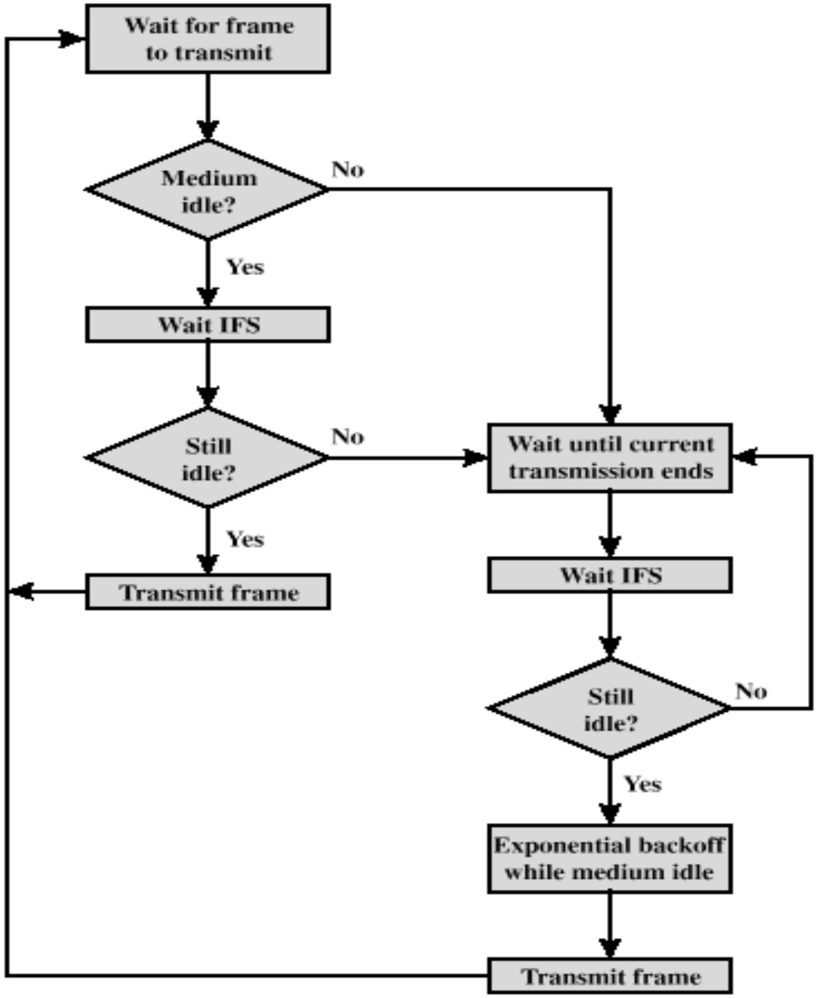
CSMA/CD collision detection



Medium Access in WLAN

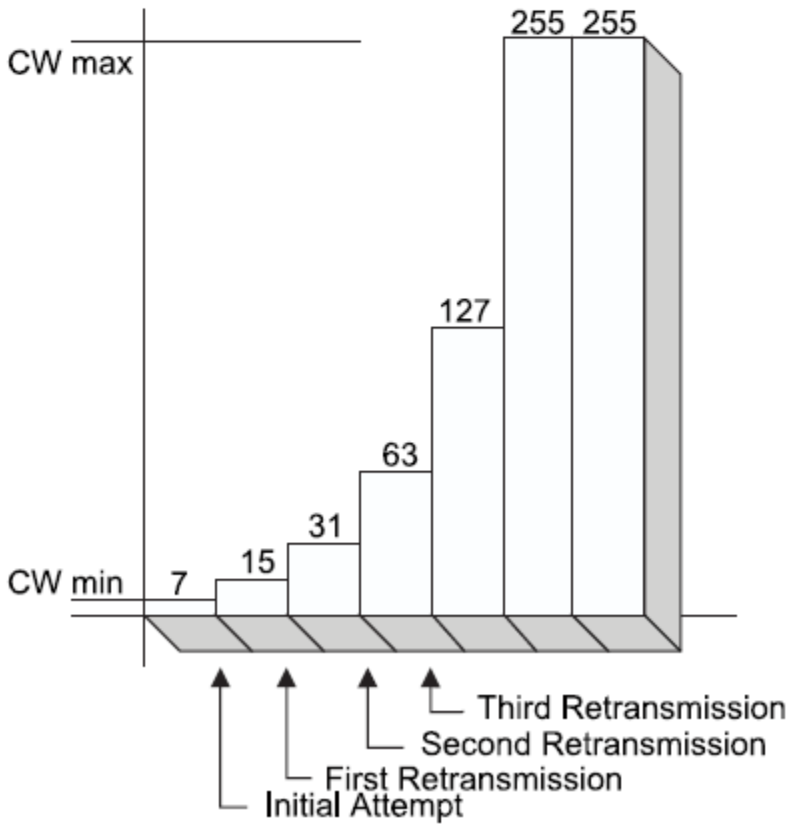
- Like Ethernet, uses CSMA:
  - random access
  - carrier sense: don't collide with ongoing transmission
- Unlike Ethernet:
  - no collision detection – transmit all frames to completion
  - acknowledgment – because without collision detection, you don't know if your transmission collided or not
- Why no collision detection?
  - difficult to receive (sense collisions) when transmitting due to weak received signals (fading)
  - can't sense all collisions in any case: hidden terminal, fading
- Goal: *avoid collisions:* CSMA/C(ollision)A(voidance)

Medium Access Control Logic

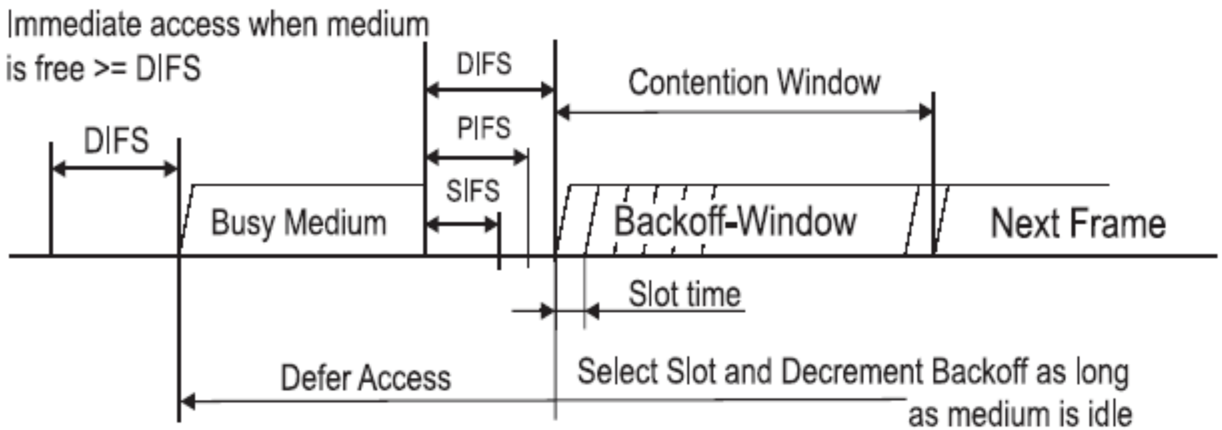


More on Medium Access Control Logic

- Slot time = 50us
- Contention window
  - Each station maintains a contention window (CW) set to CW_{min} initially
  - Upon collision, CW' = (CW +1)*2 –1 (exponentially backoff) till it reaches CW_{max}.
  - CW is reset to CW_{min} upon successful delivery



Interframe Space (IFS)

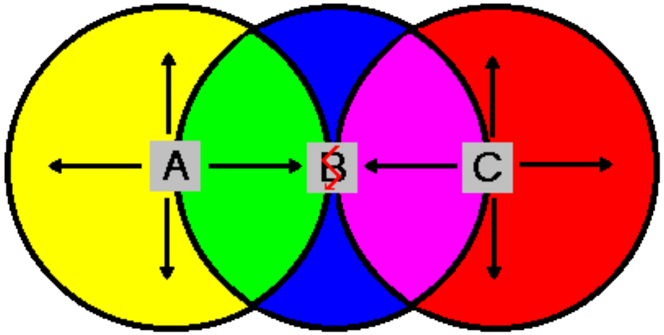


- Short IFS (SIFS)
  - Shortest IFS (used for ACK, CTS, poll response)
  - Used for immediate response actions
- Distributed coordination function IFS (DIFS)
  - Longest IFS (data, RTS)
  - Used as minimum delay of asynchronous frames contending for access

SIFS < DIFS

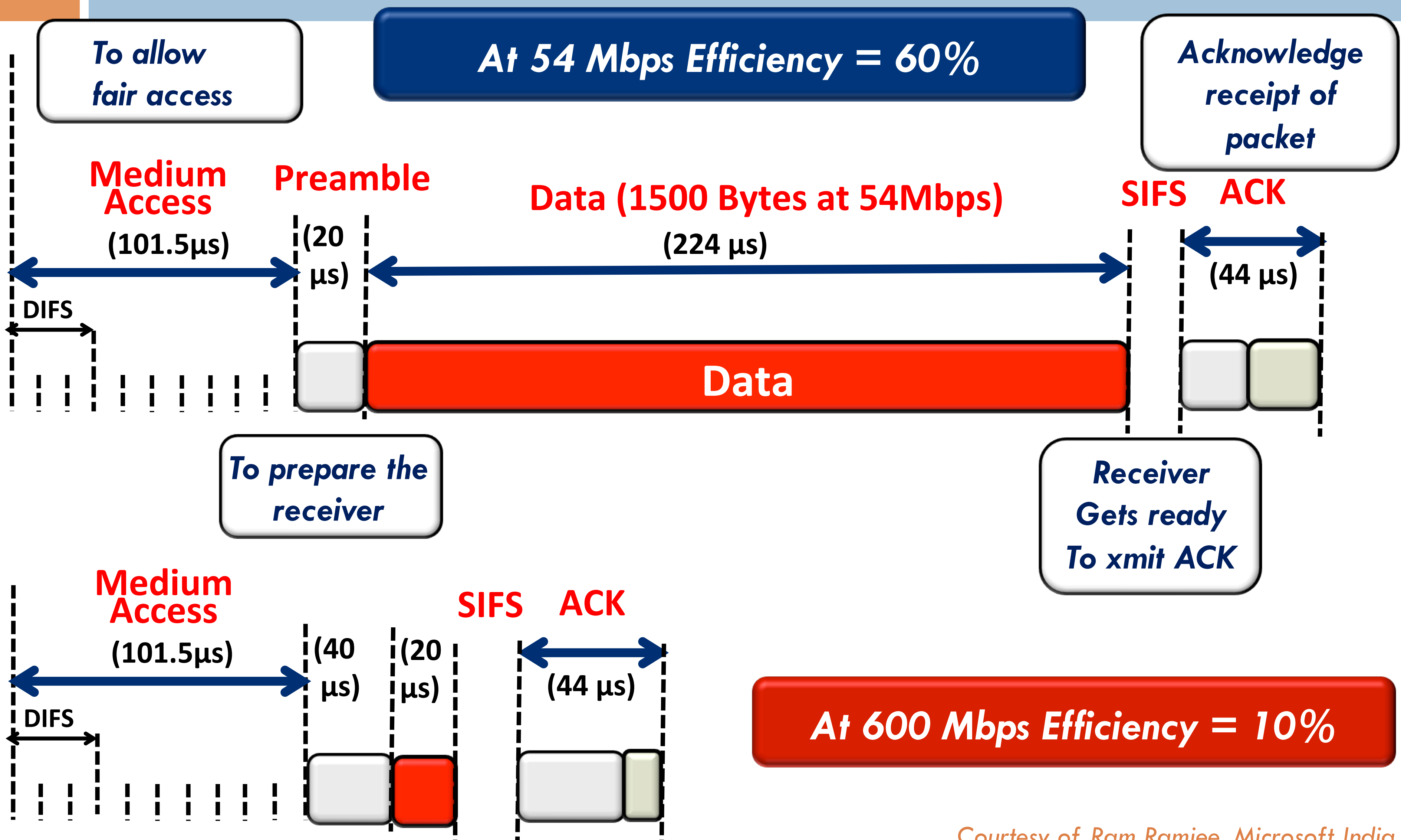
Some Issues in CSMA/CA

- Hidden terminal



A, C's transmissions would collide at B!!

High Protocol Overhead



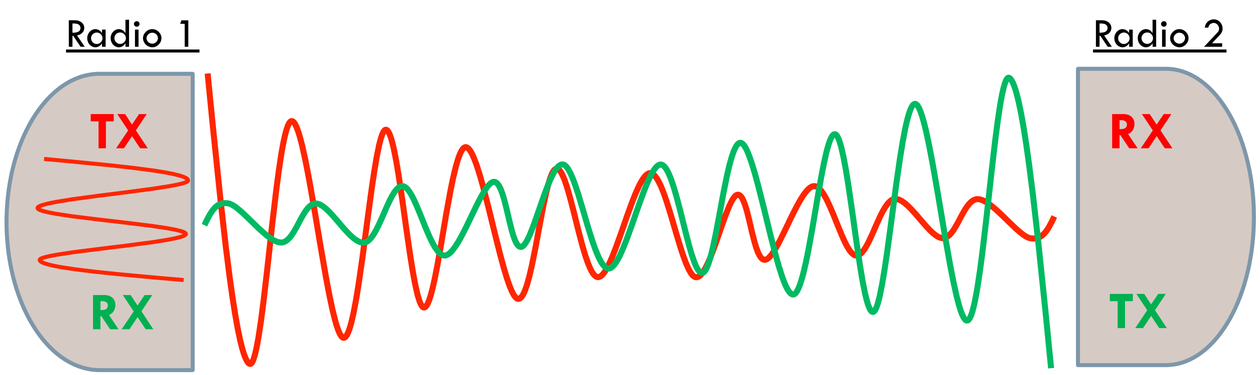
Courtesy of Ram Ramjee, Microsoft India

Inefficiency of Half-duplex Radio

"It is generally not possible for radios to receive and transmit on the same frequency band because of the interference that results."

- *Andrea Goldsmith, "Wireless Communications," Cambridge Press, 2005.*

Why are radios half duplex?



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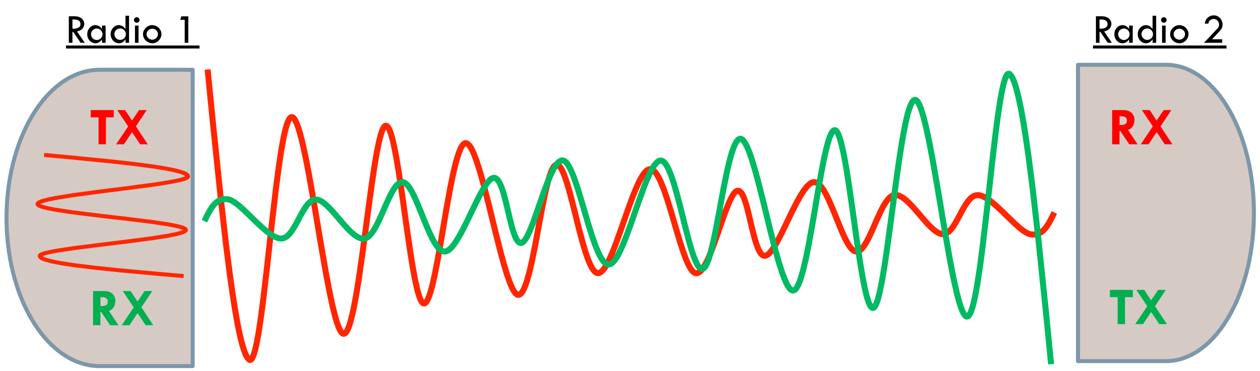

Self-Interference is a hundred billion times (110dB+) stronger than the received signal

Courtesy of Dinesh Bharadia, Stanford