Multiple Access in Cellular and 802.11 Systems

GSM
- The total bandwidth is divided into many narrowband channels. (200 kHz in GSM)
- Users are given time slots in a narrowband channel (8 users)
- A channel partitioning protocol!
- Co-channel interference between users in different cells is minimized by reusing the same channel only in cells far apart (low frequency reuse)

CDMA (IS-95, CDMA 2000, UMTS)
- Universal frequency reuse: all the users in all cells share the same bandwidth (1.25 MHz in IS-95)
- Each user spreads its signal across the whole bandwidth and appears as noise to each other.
- The data of each user is extracted by its unique code and complex signal processing
- Interference averaging across cells: each interferer only contributes a small fraction of the interference.
- Power control and soft handoff.
- Maximum number of users that can be accommodated depends on the interference tolerable.

IEEE 802.11 Wireless LAN
- 802.11b
  - 2.4-5 GHz unlicensed radio spectrum
  - up to 11 Mbps
  - direct sequence spread spectrum (DSSS) in physical layer
- 802.11g
  - 2.4-5 GHz range
  - up to 54 Mbps
  - OFDM PHY layer
- 802.11a
  - 5-6 GHz range
  - up to 54 Mbps
  - OFDMA PHY layer
- All use CSMA/CA for multiple access
- All have base-station and ad-hoc network versions

802.11 LAN architecture
- wireless host communicates with base station
- base station = access point (AP)
- Basic Service Set (BSS) (aka “cell”) in infrastructure mode contains:
  - wireless hosts
  - access point (AP): base station

Frequency Reuse
Frequency reuse is poor in narrowband systems because of lack of interference averaging.
**802.11: Channels, association**
- 802.11b: 2.4GHz-2.485GHz spectrum divided into 11 channels at different frequencies
- AP admin chooses frequency for AP
- interference possible: channel can be same as that chosen by neighboring AP
- host: must **associate** with an AP
  - scans channels, listening for *beacon frames* containing AP’s name (SSID) and MAC address
  - selects AP to associate with
  - will typically run DHCP to get IP address in AP’s subnet

**Collision Detection**
- In Ethernet, collision detection ends useless transmission quickly
- 802.11: **no** collision detection!
  - difficult to receive (sense collisions) when transmitting due to weak received signals (many dBs lower)
  - can’t sense all collisions in any case: hidden terminal problem
  - goal: **avoid** collisions: CSMA/C(ollision)A(voidance)

**IEEE 802.11: random multiple access**
- avoid collisions: $2^n$ nodes transmitting at same time
- 802.11: CSMA - sense before transmitting
  - don’t collide with ongoing transmission by other nodes
  - In Ethernet, sensing is limited by propagation delay.
  - In 802.11, sensing is limited by the hidden terminal problem.

**IEEE 802.11 MAC Protocol: CSMA/CA**

Sender:
1. If sense channel idle then transmit entire frame (no CD)
2. If sense channel busy then Choose a random backoff time and count down whenever the channel is sensed idle. When the counter is zero, then transmit.

Question: Why not transmit once the channel is sensed idle?

Receiver:
- If CRC checks for frame, return ACK

Sender:
- If no ACK, choose a backoff time from a larger interval and try again (retransmission for link layer reliability)

**Hidden Terminal Problem**
- B, A hear each other
- B, C hear each other
- A, C can not hear each other
- means A, C unaware of each other’s transmissions.

**Avoiding collisions (more)**

*idea:* allow sender to “reserve” channel rather than random access of data frames: avoid collisions of long data frames
- sender first transmits small *request-to-send* (RTS) packets to BS using CSMA
- RTSs may still collide with each other (but they’re short)
- BS broadcasts *clear-to-send* CTS in response to RTS
- RTS heard by all nodes
  - sender transmits data frame
  - other stations defer transmissions

*Avoid data frame collisions completely using small reservation packets!*
Collision Avoidance: RTS-CTS exchange

Channel Partitioning, Random Access and Scheduling
- Channel partitioning is inflexible in accommodating bursty traffic.
- Random access allows “on-demand” allocation, but has significant overhead due to collision or RTS/CTS.
- 4th generation cellular systems are shifting to explicit centralized scheduling of resources by the BS.

802.11 frame: addressing

802.11 frame: more

802.11: mobility within same subnet
- H1 remains in same IP subnet: IP address can remain same
- switch: which AP is associated with H1?
  - self-learning (Ch. 5): switch will see frame from H1 and “remember” which switch port can be used to reach H1