Multiple Access in Cellular and 802.11 Systems

1

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)

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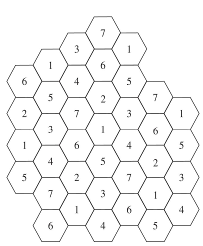
Frequency Reuse



Frequency reuse is poor in narrowband systems because of lack of interference averaging.

3

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 accomodated depends on the interference tolerable.

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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
    - Not for multiple access, but for frequency diversity
  - widely deployed, using base stations
- 802.11a
  - 5-6 GHz range
  - up to 54 Mbps
  - OFDM PHY layer
- 802.11g
  - 2.4-5 GHz range
  - up to 54 Mbps
- All use CSMA/CA for multiple access
- All have base-station and ad-hoc network versions

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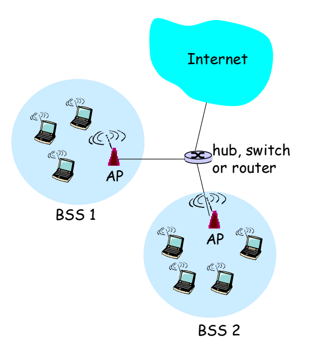
802.11 LAN architecture



- 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

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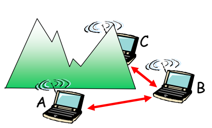
802.11: Channels, association

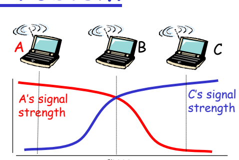
- 802.11b: 2.4GHz-2.485GHz spectrum divided into 11 channels at different frequencies
  - AP admin chooses frequency for AP
  - interference possible: channel can be same as that chosen by neighboring AP!
- host: must *associate* with an AP
  - scans channels, listening for *beacon frames* containing AP's name (SSID) and MAC address
  - selects AP to associate with
  - will typically run DHCP to get IP address in AP's subnet

IEEE 802.11: random multiple access

- avoid collisions: 2^+ 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.

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.

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 MAC Protocol: CSMA/CA

Sender

1 if sense channel idle then
    transmit entire frame (no CD)

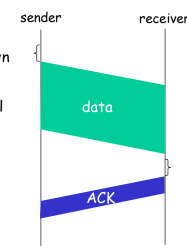
2 if sense channel busy then
    Choose a random backoff time and count down whenever the channel is sensed idle.
    When the counter is zero, then transmit.
    Question: Why not transmit once the channel is sensed idle?

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)



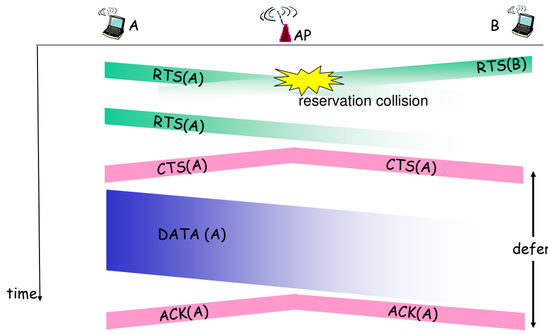
Avoiding collisions (more)

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!

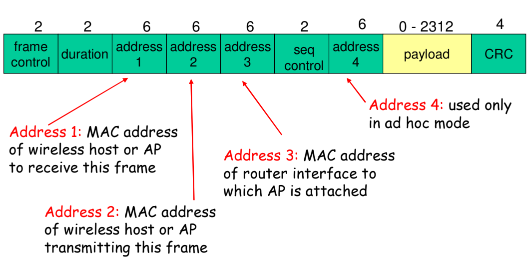
Collision Avoidance: RTS-CTS exchange



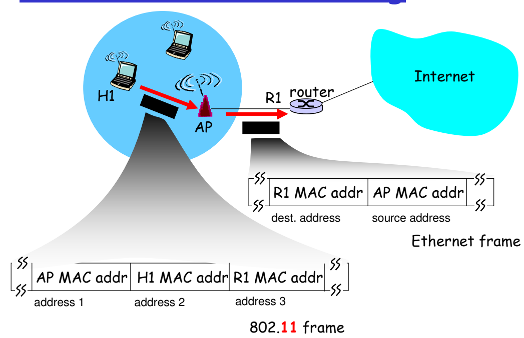
Channel Partitioning, Random Access and Scheduling

- Channel partitioning is inflexible in accomdating 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.

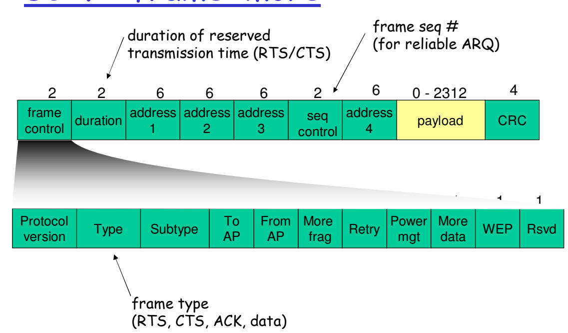
802.11 frame: addressing



802.11 frame: 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