Long Distance Wireless Communication

Principally satellite communication:

- LOS relay
- Effective for broadcast
- Limited bandwidth for multi-access

→ not scalable for multi-access
Multi-access protocols:

- FDMA + TDMA: dominant
  \[\rightarrow\] broadband
  \[\rightarrow\] GSM cellular

- CDMA: e.g., GPS and defense related systems
  \[\rightarrow\] CDMA cellular (Qualcomm)

- CSMA/CA: impractical due to large RTT
  \[\rightarrow\] low utilization/throughput

Long-distance wireless communication: effective when broadcasting
  \[\rightarrow\] special applications, e.g., TV, GPS
Short Distance Wireless Communication

Basic communication problem

→ shared frequency spectrum (e.g., 2.4–2.4835 GHz)

- TDMA
- FDMA
- CDMA
- multiple access
- polling
Cellular telephony: frequency & time division

Ex.: GSM (U.S. IS-136)

- uplink: 890–915 MHz
- downlink: 935–960 MHz
  → 25 MHz frequency band
- 125 channels 200 kHz wide each \(= 25000 \div 200\)
  → FDM portion
• 8 time slots within each channel
  → TDM portion
• total of 1000 possible user channels (= 125 × 8)
  → 124 × 8 realized
• codec: 13.4 kb/s

Dedicated channels workable because traffic is speech:
• Low bit rate & approximately CBR (constant bit rate)
• Not so for:
  → VBR (variable bit rate), e.g., MPEG video
  → data files (why?)
Cellular telephony: code division

→ same frequency band; different codes

Ex.: IS-95 CDMA

• uplink: 824–849 MHz
• downlink: 869–894 MHz
  → 25 MHz frequency band
• codec: 9.6 kb/s
Packet radio: ALOHA

Ex.: ALOHANET

- data network
- Univ. of Hawaii, 1970; 4 islands, 7 campuses
• Norm Abramson (precursor to Ethernet; Bob Metcalfe)

• FM radio carrier frequency
  → uplink: 407.35 MHz; downlink: 413.475 MHz

• bit rate: 9.6 kb/s

• Multiple access method: MA
  → plain and simple
ALOHA protocol:

• send frame (no carrier sense)

• wait for ACK

→ “collision detection” through explicit ACK

→ different from Ethernet CSMA/CD

• if timeout, reattempt with probability $p$

→ looks familiar...
Wireless LAN (WLAN): infrastructure mode

→ shared uplink & downlink channel $F1$
→ bus!

• technically called basic service set (BSS)
• base station: access point (AP)
• mobile stations must communicate through AP
WLAN: ad hoc mode

→ homogeneous: no base station
→ everyone is the same (kind of like KaZaA)

• independent basic service set (IBSS)
• mobile stations communicate peer-to-peer
  → also called peer-to-peer mode
WLAN: internetworking

--- internetworking between BSS’s through APs
--- mobility and handoff

- extended service set (ESS)
- APs are connected by distribution system (DS)
• DS: wireless or wireline
  → most common: Ethernet switch

• how do APs and Ethernet switches know where to forward frames?
  → learning bridge: source address discovery
  → spanning tree: IEEE 802.1 (Perlman’s algorithm)

Additional headache: mobility
  → how to perform handoff
  → mobility management at MAC
  → mobility management at IP (Mobile IP)
Examples:

Purdue Univ.: IEEE 802.11b (11 Mbps) WLAN network
   $\rightarrow$ PAL (Purdue Air Link)
   $\rightarrow$ partial mobility: MAC roaming
   $\rightarrow$ no mobile IP
   $\rightarrow$ but football scores at Ross-Ade through PDAs

Dartmouth College: IEEE 802.11b WLAN (500+ APs)
   $\rightarrow$ full VoIP
   $\rightarrow$ free long distance

Seattle, SF, San Diego, Boston, etc.: Wi-Fi communities
   $\rightarrow$ free Internet access
   $\rightarrow$ roof-top mesh networks
   $\rightarrow$ cable & DSL companies don’t like it
Graffiti: warchalking

→ some cities

→ benevolent kids with lots of free time

Soon: integrated WLAN + cellular phones

→ use VoIP when near WLAN network

→ use cellular when outside WLAN coverage

→ automatic switch-over
WLAN spectrum 2.4–2.4835 GHz:

→ 11 channels (U.S.)

→ 2.412 GHz, 2.417 GHz, . . . , 2.462 GHz

Non-interference specification:

• each channel has 22 MHz bandwidth

• require 25 MHz channel separation

→ thus, only 3 concurrent channels possible

→ e.g., channels 1, 6 and 11

→ 3-coloring. . .
IEEE 802.11 MAC

→ CSMA/CA with exponential backoff
→ almost like CSMA/CD
→ instead of CD, use CA (collision avoidance)
→ CA is optional (CD is not)

Two modes for MAC operation:

• Distributed coordination function (DCF)
  → multiple access

• Point coordination function (PCF)
  → polling-based priority scheme
CSMA with exponential backoff operation:

Sender:

- MAC (firmware in NIC) receives frame from upper layer
- Check if channel is idle (CS)
  - If busy, goto Backoff procedure
  - If idle, wait for DIFS duration, then goto Backoff
- Transmit frame
- Wait for ACK
- If timeout, goto Backoff procedure

Receiver:

- Check if received frame is ok
- Wait for SIFS
- Transmit ACK
Timeline without collision:

Time units:

- SIFS (short interframe space): 10 $\mu$s
- Slot Time: 20 $\mu$s
- DIFS (distributed interframe space): 50 $\mu$s
  $\rightarrow$ DIFS = SIFS + 2 $\times$ slot time
- BO: variable back-off (within one CW)
Backoff:

- If due to timeout, double contention window ($CW$)
- If due to CS, wait until channel is idle plus an additional DIFS
- Choose random waiting time between $[1, CW]$
  \[ \rightarrow CW \text{ is in units of slot time} \]
- Decrement $CW$ when channel is idle
- Transmit when $CW = 0$
Time snapshot with Mira-come-lately:

→ Sue sends to Arnold

Mira wants to send a frame

Wait
CS = BUSY

DIFS

DATA

SIFS

ACK

Slot Time

DIFS

DATA

BO

Contention Window CW
Time snapshot with collision (Sue & Mira):

Sue wants to send a frame

Mira wants to send a frame
Throughput and collision:

Throughput:
- MAC System Throughput (Mb/s)

Collision Probability:
- Collision Probability (%)
Additional issues with multiple access in wireless media:

Hidden station problem:

(1) $A$ transmits to $B$

(2) $C$ does not sense $A$; transmits to $B$

(3) interference occurs at $B$: i.e., collision
Exposed station problem:

(1) \( B \) transmits to \( A \)

(2) \( C \) wants to transmit to \( D \) but senses \( B \)
    \[ \rightarrow C \text{ refrains from transmitting to } D \]
    \[ \rightarrow \text{omni-directional antenna} \]
Solution: CA (congestion avoidance)

→ RTS/CTS reservation handshake

- Before data transmit, perform RTS/CTS handshake
- RTS: request to send
- CTS: clear to send
Hidden station problem: RTS/CTS handshake “clears” hidden area

RTS/CTS Handshake

RTS/CTS perform only if data > RTS threshold

→ why not for small data?
Additional optimization: virtual carrier sense

- transmit connection duration information
- stations maintain NAV (network allocation vector)
  → decremented by clock
- if NAV > 0, then do not access even if physical CS says channel is idle
PCF (point coordination function):

→ support for real-time traffic

- Periodically inject contention free period (CFP)
  → after BEACON
- Under the control of point coordinator: AP
  → polling

PIFS (priority IFS):

→ SIFS < Slot Time < PIFS < DIFS
Properties of PCF:

- **BEACON** period is not precise
  - → has priority (PIFS $<$ DIFS) but cannot preempt DCF

- During CFP services stations on polling list
  - → delivery of frames
  - → polling: reception of frames
  - → must maintain polling list: group membership

- Uses NAV to maintain CFP

- **BEACON**: separate control frame used to coordinate BSS
  - → time stamp, SSID, etc.
IEEE 802.11 wireless LAN standard:

- ratified in 1997: 1 or 2 Mbps using either DSSS or FHSS
- 11 bit chip sequence
- uses IEEE 802 address format along with LLC
- uses 2.4–2.4835 GHz ISM band in radio spectrum
- IEEE 802.11b (High Rate) ratified: 5.5 or 11 Mbps using DSSS only
- others: e.g., IEEE 802.11a at 54 Mbps
  $\rightarrow$ 5.725–5.85 GHz band

Bluetooth, 802.16, ...