Long Distance Wireless Communication

Principally satellite communication:

- LOS (line of sight) communication
  → satellite base station is relay
- Effective for broadcast
- Limited bandwidth for multi-access
  → not scalable
Multi-access protocols:

- FDM + TDMA: dominant
  -→ broadband
  -→ GSM cellular

- CDMA: e.g., GPS and defense related systems
  -→ CDMA cellular (Qualcomm)

- CSMA/CA: impractical due to large RTT
  -→ low utilization/throughput

Long-distance wireless communication: effective when broadcasting

-→ special applications
-→ e.g., TV, GPS, digital radio, atomic clock
Short Distance Wireless Communication

- very short: wireless PAN
- short: wireless LAN
- medium: wireless MAN

→ TDMA, FDMA, CDMA, polling
→ contention-based multiple access w/o priority
Cellular telephony: frequency & time division

Ex.: GSM (U.S. IS-136) with 25 MHz frequency band

- uplink: 890–915 MHz
- downlink: 935–960 MHz
- 125 channels 200 kHz wide each ($= 25000 \div 200$)
  → separation needed due to cross-carrier interference
  → FDM portion
- 8 time slots within each channel
  → TDM portion
- total of 1000 possible user channels
  → $125 \times 8$ ($124 \times 8$ realized)
- codec/vocoder: 13.4 kb/s
- compare with T1 standard
  → 24 users at 64 kb/s data rate each
Dedicated channels workable because data traffic is speech:

- Low bit rate & approximately CBR (constant bit rate)
  \[ \rightarrow \text{flat} \]
  \[ \rightarrow \text{good/bad?} \]

- Not so for:
  \[ \rightarrow \text{different for compressed video (e.g., MPEG, H.261)} \]
  \[ \rightarrow \text{cf. Terminator video} \]
  \[ \rightarrow \text{VBR (variable bit rate)} \]
  \[ \rightarrow \text{data files?} \]
Cellular telephony: code division multiplexing

→ same frequency band; different codes

Ex.: IS-95 CDMA with 25 MHz frequency band
- uplink: 824–849 MHz; downlink: 869–894 MHz
  → downlink: prepared; uplink: physical diversity
  → capture effect: closer station has advantage
- codec: 9.6 kb/s
Packet radio: ALOHA

→ downlink broadcast channel $F1$

→ shared uplink channel $F1'$

→ both baseband

Ex.: ALOHANET

• data network over radio

• Univ. of Hawaii, 1970; 4 islands, 7 campuses
• Norm Abramson
  → precursor to Ethernet (Bob Metcalfe)
  → pioneering Internet technology
  → parallel to packet switching technology
• FM radio carrier frequency
  → uplink: 407.35 MHz; downlink: 413.475 MHz
• bit rate: 9.6 kb/s
• contention-based multiple access: MA
  → plain and simple
  → needs explicit ACK frames
  → ALOHA
ALOHA protocol:

- send frame (no carrier sense)
- wait for ACK
  - collision detection through explicit ACK
- if timeout, retry with probability $p$

  → looks familiar...

  → pure vs. slotted ALOHA
Wireless LAN (WLAN): infrastructure mode

-→ shared uplink & downlink channel $F_1$
-→ single baseband channel

- 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
→ share forwarding responsibility

• 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: wireline or wireless
  → common: Ethernet switch
• How do APs and Ethernet switches know where to forward frames?
  → bridge: link layer forwarding device
  → i.e., switch using MAC address relay
  → learning bridge: source address discovery
  → spanning tree: IEEE 802.1 (Perlman’s algorithm)
  → distributed ST & leader election
Additional headache: mobility

→ how to perform handoff
→ mobility management at MAC
→ mobility management at IP (Mobile IP)

Mobility between BSSes in an ESS

• association
  → registration process
  → mobile station (MS) associates with one AP

• disassociation
  → upon permanent departure: notification

• reassociation
  → movement of MS from one AP to another
  → inform new AP of old AP
  → forwarding of buffered frames
Association, disassociation, reassociation provides necessary information for distribution service within ESS

\[ \rightarrow \text{distribution service implemented in AP} \]

Compatibility with non-802.11 devices in ESS:

\[ \rightarrow \text{integration service: portal abstraction} \]
\[ \rightarrow \text{translation service} \]

Complicated 802.11 frame format

\[ \rightarrow \text{30-byte MAC header} \]
\[ \rightarrow \text{four 48-bit address fields} \]
\[ \rightarrow \text{16-bit frame control field: 11 fields} \]
\[ \rightarrow \text{e.g., version, type, subtype, to DS, from DS, \ldots} \]
\[ \rightarrow \text{type (2-bit): mgt (00), control (01), data (10)} \]
\[ \rightarrow \text{subtype (4-bit): association (mgt), ACK (ctl)} \]
\[ \rightarrow \text{payload: 0–2313 bytes} \]
WLAN spectrum 2.4–2.4835 GHz:

\[ \rightarrow \quad 11 \text{ channels (U.S.)} \]

\[ \rightarrow \quad 2.412 \text{ GHz}, 2.417 \text{ GHz}, \ldots, 2.462 \text{ GHz} \]

Non-interference specification:

- each channel has 22 MHz bandwidth
- require 25 MHz channel separation

\[ \rightarrow \quad \text{thus, only 3 concurrent channels possible} \]

\[ \rightarrow \quad \text{e.g., channels 1, 6 and 11} \]

\[ \rightarrow \quad \text{3-coloring} \ldots \]
Examples:

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

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

Seattle, SF, San Diego, Boston, etc.: WiFi communities
  → free Internet access
  → roof-top mesh networks
  → cable & DSL companies don’t like it
Graffiti: warcycling

\[ \rightarrow \text{some cities} \]
\[ \rightarrow \text{benevolent kids with lots of free time} \]

Soon: integrated WLAN + cellular phones

\[ \rightarrow \text{use VoIP when near WLAN network} \]
\[ \rightarrow \text{use cellular when outside WLAN coverage} \]
\[ \rightarrow \text{automatic switch-over} \]