Overview

1. Code Division Multiple Access
2. IEEE 802.11 Wireless LAN PHYs
3. IEEE 802.11 MAC
4. IEEE 802.11 Architecture
5. 802.11 Frame Format and Addressing
6. 802.11 Rate Adaptation and Power Management

Note: This class lecture is based on Chapter 6 of the textbook (Kurose and Ross) and the figures provided by the authors.
Spreading factor = Code bits/data bit, 10-100 commercial (Min 10 by FCC), 10,000 for military

Signal bandwidth >10 × data bandwidth

Code sequence synchronization

Correlation between codes ⇒ Interference ⇒ Orthogonal
DS Spectrum

Time Domain | Frequency Domain

(a) Data
(b) Code

Time

Frequency
Two Sender CDMA Example

senders

data bits
\[ d_1 = -1 \]
\[ d_2 = 1 \]

code
1 1 1 1
1 1 1 1

channel, \( Z_{i,m}^* \)
2 2 2 2
2

data bits
\[ d'_1 = 1 \]
\[ d'_2 = 1 \]

code
1 1 1 1
1 1 1 1

\[ Z_{i,m}^1 = d'_i \cdot c_m^1 \]

\[ Z_{i,m}^2 = d'_i \cdot c_m^2 \]

receiver 1

\[ d_i^1 = \frac{\sum_{m=1}^{M} Z_{i,m}^* c_m^1}{M} \]
\[ d_i^1 = -1 \]
\[ d_i^1 - 1 \]
Homework 6A

- Two CDMA sender use the codes of (1, -1, 1, -1) and (-1, 1, -1, 1). First sender transmits data bit 1 while the 2nd transmits –1 at the same time. What is the combined signal waveform seen by a receiver? Draw the waveform.
Hidden Node Problem

- B and A can hear each other
  - B and C can hear each other
  - A and C cannot hear each other
    \[ \Rightarrow C \text{ is hidden for A and vice versa} \]
- C may start transmitting while A is also transmitting
  - A and C can't detect collision.
- Only the receiver can help avoid collisions
Characteristics of Selected Wireless Link Standards

- **Indoor** 10-30m
- **Outdoor** 50-200m
- **Mid-range outdoor** 200m – 4 Km
- **Long-range outdoor** 5Km – 20 Km

### Data rate (Mbps)

- **.056** IS-95, CDMA, GSM
- **.384** UMTS/WCDMA, CDMA2000
- **5-11** 802.11a, g point-to-point
- **54** 802.11a, g
- **200** 802.11n
- **802.15**
- **802.16 (WiMAX)**
- **UMTS/WCDMA-HSPDA, CDMA2000-1xEVDO**
- **UMTS/WCDMA, CDMA2000**
- **802.15**

- **3G**
- **2G**
- **data**
- **3G cellular enhanced**
IEEE 802.11 Wireless LAN PHYs

- **802.11**: 2.4 GHz, 1-2 Mbps
- **802.11b**: 2.4 GHz, 11 Mbps nominal
  - Direct sequence spread spectrum (DSSS) in physical layer
  - All hosts use the same chipping code
- **802.11a**: 5.8 GHz band, 54 Mbps nominal
- **802.11g**: 2.4 GHz band, 54 Mbps nominal
- **802.11n**: 2.4 or 5.8 GHz, Multiple antennae, up to 200 Mbps

- These are different PHY layers. All have the same MAC layer.
- All use CSMA/CA for multiple access
- All have base-station and ad-hoc network versions
- Supports multiple priorities
- Supports time-critical and data traffic
- Power management allows a node to doze off
**802.11: Passive/Active Scanning**

**Passive Scanning:**
1. Beacon frames sent from APs
2. Association Request frame sent: H1 to selected AP
3. Association Response frame sent: selected AP to H1

**Active Scanning:**
1. **Probe Request** frame broadcast from H1
2. Probes response frame sent from APs
3. Association Request frame sent: H1 to selected AP
4. Association Response frame sent: selected AP to H1
4-Way Handshake

Access Point

Mobile Node

Ready to send

Clear to send

Data

Ack
IEEE 802.11 MAC

- Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)
- Listen before you talk. If the medium is busy, the transmitter backs off for a random period.
- Avoids collision by sending a short message: Ready to send (RTS) 
  RTS contains dest. address and duration of message. Tells everyone to backoff for the duration.
- Destination sends: Clear to send (CTS)
- Can not detect collision ⇒ Each packet is acked.
- MAC level retransmission if not acked.
IEEE 802.11 Architecture

- Access Point
  - Station
  - Station
  - Basic Service Set

- Access Point
  - Station
  - 2nd BSS

- Ad-hoc Station
  - Ad-hoc Station
  - Ad-hoc network
Architecture (Cont)

- Basic Service Area (BSA) = Cell
- Each BSA may have several wireless LANs
- Extended Service Area (ESA) = Multiple BSAs interconnected via Access Points (AP)
- Basic Service Set (BSS) = Set of stations associated with an AP
- Extended Service Set (ESS) = Set of stations in an ESA
- Ad-hoc networks coexist and interoperate with infrastructure-based networks.
Transmission Example

Sender

DIFS

RTS

CTS

SIFS

data

SIFS

ACK

Receiver

SIFS

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802.11 Frame Format

- Frame control
- Duration of reserved transmission time (RTS/CTS)
- Frame sequence # (for RDT)
- Address 1
- Address 2
- Address 3
- Address 4
- Seq. Control
- Protocol version
- Frame type (RTS, CTS, ACK, data)
- Type
- Subtype
- To AP
- From AP
- More frag
- Retry
- Power mgt
- More data
- WEP
- Rsvd
- Payload
- CRC

<table>
<thead>
<tr>
<th>Protocol version</th>
<th>Type</th>
<th>Subtype</th>
<th>To AP</th>
<th>From AP</th>
<th>More frag</th>
<th>Retry</th>
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### 802.11 Frame Addressing

<table>
<thead>
<tr>
<th>Field</th>
<th>Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>Frame Control</td>
<td>2</td>
<td>Contains information about the frame, such as type and duration.</td>
</tr>
<tr>
<td>Duration</td>
<td>2</td>
<td>Indicates the time duration of the transmission.</td>
</tr>
<tr>
<td>Address 1</td>
<td>6</td>
<td>MAC address of the wireless host or AP receiving the frame.</td>
</tr>
<tr>
<td>Address 2</td>
<td>6</td>
<td>MAC address of the wireless host or AP transmitting the frame.</td>
</tr>
<tr>
<td>Address 3</td>
<td>6</td>
<td>MAC address of the router interface to which the AP is attached.</td>
</tr>
<tr>
<td>Address 4</td>
<td>6</td>
<td>Used only in ad hoc mode.</td>
</tr>
<tr>
<td>Seq. Control</td>
<td>2</td>
<td>Contains sequence control information.</td>
</tr>
<tr>
<td>Address 4</td>
<td>6</td>
<td>MAC address of the router interface to which the AP is attached.</td>
</tr>
<tr>
<td>Payload</td>
<td>0-2312</td>
<td>The data payload of the frame.</td>
</tr>
<tr>
<td>CRC</td>
<td>4</td>
<td>Cyclic redundancy check to verify the integrity of the data.</td>
</tr>
</tbody>
</table>

- **Address 1**: MAC address of the wireless host or AP receiving this frame.
- **Address 2**: MAC address of the wireless host or AP transmitting this frame.
- **Address 3**: MAC address of the router interface to which the AP is attached.
- **Address 4**: Used only in ad hoc mode.
802.11 Frame Addressing (Cont)

- **802.3 frame**
  - R1 MAC addr
  - H1 MAC addr
  - dest. address
  - source address

- **802.11 frame**
  - AP MAC addr
  - H1 MAC addr
  - R1 MAC addr
  - address 1
  - address 2
  - address 3

Diagram shows a network with an AP (Access Point) connecting devices H1 and R1, with R1 also connected to the Internet via a router. The MAC addresses are shown for each device and the network layer addresses for both 802.3 and 802.11 frames.
802.11 Rate Adaptation

- Base station and mobile dynamically change transmission rate (physical layer modulation technique) as mobile moves, SNR varies.
- SNR decreases $\Rightarrow$ BER increase as node moves away from base station.
- When BER becomes too high, switch to lower transmission rate but with lower BER.
Power Management

- A station can be in one of three states:
  - Transmitter on
  - Receiver only on
  - Dozing: Both transmitter and receivers off.
- Access point (AP) buffers traffic for dozing stations.
- AP announces which stations have frames buffered. Traffic indication map included in each beacon. All multicasts/broadcasts are buffered.
- Dozing stations wake up to listen to the beacon. If there is data waiting for it, the station sends a poll frame to get the data.
1. Code Division Multiple Access uses multiple chips to encode each bit
2. IEEE 802.11 PHYs: 11, 11b, 11g, 11a, 11n, …
3. IEEE 802.11 MAC uses CSMA/CA with a 4-way handshake: RTS, CTS, data, and ack
4. IEEE 802.11 network consists of extended service set consisting of multiple basic service sets each with an AP.
5. 802.11 Frame Format has 4 addresses and includes final destination’s MAC which may not be wireless
6. 802.11 has automatic rate adaptation based on error rate. Power management allows stations to sleep.
Review Exercises

- Try in a group. Do not submit.
- Review questions: R1-R8, R9-R11
- Problems: P1, P2, P3, P4, P5 (Skip P6, P7, P8)

- Read Pages 523 through 554 (Section 6-1 through 6.3.5)
Homework 6B

- Submit answer to following (modified problem P7)
- Suppose an 802.11b station is configured to always reserve the channel with the RTS/CTS sequence. Suppose this station suddenly wants to transmit 1,000 bytes of data, and all other stations are idle at this time. Using SIFS of 10us and DIFS of 50us, and ignoring propagation delay and assuming no bit errors, calculate the time required to transmit the frame and receive the acknowledgment. Assume a frame without data (RTS/CTS/Ack) is 32 bytes long and the transmission rate is 11 Mbps.