Chapter 8
Hardware Layers: Wireless Local Area Networks

Networking in the Internet Age
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Chapter 8. Learning Objectives

• Understand the major components of WLANs
• Understand 802.11b WLANs
• Understand 802.11a WLANs
• Understand 802.11g WLANs
• Be familiar with Bluetooth WLANs
• Understand the best practice recommendations for WLAN design
Chapter 8. Outline

• Introduction
• IEEE 802.11b
  – Topology, Media Access Control, Error Control, Message Delineation, Data Transmission in the Physical Layer
• IEEE 802.11a
  – Topology, Media Access Control, Error Control, Message Delineation, Data Transmission in the Physical Layer
• IEEE 802.11g
• Bluetooth
  – Topology, Media Access Control, Error Control, Message Delineation, Data Transmission in the Physical Layer
• The Best Practice WLAN Design
  – Effective Data Rates, Costs, Recommendations

Introduction

• Wireless LANs transmit data through the air using radio frequency transmissions.
• Several standards for WLANs have recently emerged facilitating market to take off.
• Currently the three principal WLAN technologies are: 802.11b (low speed), 802.11a (a higher speed protocol) and Bluetooth.
• An emerging WLAN standard that may prove more important in the future is 802.11g.
WLAN in the workplace

- WLANs are popular because they:
  - Eliminate cabling and make network access possible from a variety of locations
  - Facilitate computing for mobile workers at different office locations or as those workers move around the office.
  - Are increasingly used in hospitals because they enable doctors and nurses access patient records.
  - Are becoming popular in airports because they enable business travelers to access the Internet while waiting for their flights to leave.

IEEE 802.11b

- The IEEE 802.11b, also called wireless Ethernet, is now the dominant WLAN standard.
- Two version of IEEE 802.11b exist:
  - Frequency-hopping spread-spectrum (FHSS) with data rates of 1 and 2 Mbps and
  - Direct-sequence spread-spectrum (DHSS) with data rates of 1, 2, 5.5 and 11Mbps, which dominates the market due to its higher speed.
Types of Wireless Ethernet

- Two forms of the IEEE 802.11b standard currently exist:
  - **Direct Sequence Spread Spectrum (DSSS)** uses the entire
    2.4 GHz WLAN frequency band to transmit information. DSSS is capable of data rates of up to 11 Mbps with
    fallback rates of 5.5, 2 and 1 Mbps. Lower rates are used whenever interference or congestion occurs.
  - **Frequency Hopping Spread Spectrum (FHSS)** divides the
    frequency band into a series of channels and then changes
    its frequency channel about every half a second, using a
    pseudorandom sequence. FHSS is more secure, but is only
    capable of data rates of 1 or 2 Mbps, since the frequency
    band gets divided up into a number of channels.
- **IEEE 802.11a** is another Wireless LAN standard that is
  still being defined. It will operate in the 5 GHz band and be
  capable of data rates of up to 54 Mbps, but will probably
  average about 20 Mbps in practice.

IEEE 802.11b Wireless LAN Topology

- WLANs use a physical star, logical bus topology (Fig. 8-1).
- Each WLAN computer uses a wireless NIC that transmits
  radio signals to the AP.
- WLAN network access is through devices called **access points** (APs), which have a maximum transmission range of about 100–500 feet.
- AP also connect into the wired LAN. The AP acts as a
  repeater by retransmitting frames from client computers
  over the wired network.
- Multiple APs are needed to make wireless access possible in
  most areas of a building.
- IEEE 802.11 also uses 3 separate radio channels, allowing
  APs with overlapping ranges to be set up without interfering
  with each other’s signals.

Figure 8-1 A wireless Ethernet access point connected into an Ethernet Switch.
WLAN Media Access Control

- Wireless LANs use CSMA/CA where CA = collision avoidance (CA).
- With CA, a station waits until another station is finished transmitting then continues to wait an additional random period of time before sending anything, thus ensuring that the network is truly not being used.
- Two WLAN MAC techniques are now in use:
  - Distributed Coordination Function (DCF)
  - Point Coordination Function (PCF).

Distributed Coordination Function (DCF)

- With DCF, also known as physical sense carrier method, a node that wants to send first listens to make sure that the transmitting node has finished, then waits a random period of time longer.
- During transmission, each frame is sent using the Stop and Wait ARQ, so by waiting, the listening node can detect that the sending node has finished and can then begin sending its transmission.
- With Wireless LANs, ACK/NAK signals are sent a short time after a frame is received.
- Stations wishing to send a frame wait a somewhat longer time, ensuring that no collision will occur.

Point Coordination Function (PCF)

- When a computer on a Wireless LAN is near the transmission limits of the AP at one end and another computer is near the transmission limits at the other end of the AP’s range, both computers may be able to transmit to the AP, but cannot detect each other’s signals.
- This is known as the hidden node problem. When it occurs, the physical carrier sense method will not work.
- The virtual carrier sense method solves this problem by having a transmitting station first send a request to send (RTS) signal to the AP. If the AP responds with a clear to send (CTS) signal, the computer wishing to send a frame can then begin transmitting.
IEEE 802.11b Message Delineation

• IEEE 802.11b frames (Figure 8-3) have 5 sections:
  • preamble, which contains a preamble used to mark the start of the frame.
  • physical layer convergence protocol (PLCP) header, enables the NIC and AP to determine the best data rate to use. The length field also gives the length of the payload portion of the frame.
  • payload header contains frame control, source and dest. addresses, & sequence ctr’l information.
  • LLC PDU is the data field.
  • payload trailer, contains the CRC-32 error detection value.

Figure 8-3 Ethernet 802.11b DSSS frame layout

802.11b DSSS Data Transmission

• 802.11b transmits data using radio waves, a form of analog transmission.
  • The direct sequence spread spectrum (DSSS) form of 802.11b divides the bandwidth into three 22 MHz channels, each separated by a 3 MHz guardband at: 2.412, 2.437 and 2.642 GHz.
  • In all cases, an 11 Mbps symbol rate is used, but since each symbol the number of bits per symbol is usually higher, the actual data rates are lower.
  • For example, 1 Mbps version of 802.11b transmits 11 bits for each data bit.
Barker Codes and DPSK (Figure 8-4)

- The 1 Mbps version of DSSS first converts each bit into an 11-bit Barker sequence, used to minimize signal interference.
- A 1011101000 sequence is used for a 0 and its inverse, 0100010111 for a 1.
- The bits in the Barker sequence are sent using differential binary phase shift keying (DBPSK) in which a 0 is sent as a 0° phase shift and a 1 is sent as a 180° phase shift.
- The 2 Mbps version of DSSS uses differential quadrature phase shift keying (DQPSK) in which four phase shifts are used (0°, 90°, 180° and 270°) to encode 2 bits per phase shift.

5.5 Mbps 802.11b using CCK

- The 5.5 Mbps version of DSSS uses complementary code keying (CCK).
- With CCK, data is broken up into groups of four bits (see Figure 8-5).
- The second two bits are used to select an 8-bit CCK code word, again designed to minimize signal interference.
- The first two data bits are used to select one of four phase shifts that will be used for transmitting the data using DQPSK.
IEEE 802.11b

IEEE 802.11a WLAN Topology

- 802.11a uses the same topology as 802.11b, transmitting data rates of up to 54 Mbps using frequencies in the 5 GHz range, with a total available bandwidth of 300 MHz.
- The signal range for 802.11a is also reduced to only 50m, for 12-24 Mbps and to only 15m for 54 Mbps.
- This means that more APs are needed to cover the same area as for 802.11b (see Figure 8-6).
- 802.11a uses 12 channels instead of the 3 802.11b uses, making AP co-location possible. Higher data rates are then possible by having multiple APs co-located and assigning each to a different frequency.
IEEE 802.11a: MAC, Error Control and Message Delineation

- Media access control and error control: same as with IEEE 802.11b
- IEEE 802.11a frames: very similar structure to 802.11b frames (Figure 8-7).

Figure 8-7 Ethernet 802.11a frame layout
Data Transmission using OFDM and BPSK

- 802.11a uses a technique called orthogonal frequency division multiplexing (OFDM) to transmit data.
- With OFDM, the 20 MHz channels are broken up into 48 352 kHz channel (see Figure 8-8).
- Transmissions are made up of 48 bit OFDM symbols.
- In the case of 6 Mbps 802.11a, each group of 24 bits of data is converted into a 48-bit OFDM symbol.
- Data is sent through each channel using BPSK.

![Fig. 8-8 How 6 Mbps 802.11a uses OFDM and BPSK to transmit data](image)

Data Transmission using OFDM at other data rates

- Data sent at high data rates works in a similar way to the previous example, but the details may vary according to:
  - How much data is used to create the 48 bit OFDM symbols
  - How many OFDM symbols are created
  - The modulation technique (BPSK, QPSK, QAM)
- For example, to send data at 24 Mbps, 96 bits are converted into 4 OFDM symbols. Data is sent using 16-QAM, i.e., four bits per channel (see Figure 8-9).
IEEE 802.11g

- 802.11g is a new WLAN standard being developed but not yet finalized.
- The initial proposal provides a 22 Mbps data rate. 54 Mbps is also possible over shorter distances.
- Like 802.11b, 802.11g will transmit using the 2.4 GHz frequency band (like 802.11b) operate over distances of up 100-150m.
- 802.11g will also use the OFDM transmission approach similar to 802.11a.
- Some experts are critical of the new protocol since they believe that it may end up undermining the markets for both 802.11b and 802.11a.
Bluetooth

- Bluetooth, standardized as IEEE 802.15, provides networking for small personal networks.
- Bluetooth’s basic data rate is 1 Mbps.
- Devices are small and cheap and have been designed to eliminate cabling between keyboards, mice, telephone handsets and PDAs.
- Bluetooth is not compatible with the other IEEE 802.11 WLAN standards.

Bluetooth Media Access Control

- Bluetooth network is called a piconet.
- All communications is between the master devices and the slave devices. Slaves do not communicate directly.
- Bluetooth uses a controlled MAC technique and frequency-hopping spread spectrum (FHSS) using 79 channels.
- During communications the signal makes about 1,600 channel changes per second (called hops).
- Data is encoded using 2-level frequency modulation, with one frequency encoding a binary 0 and another for binary 1.
Bluetooth Message Delineation

- A typical Bluetooth frame (see Figure 8-10 for details) has five sections:
  - **access code**, which contains a preamble and special sync bytes based on the sender’s address.
  - **header**, which contains the frame address and error control information (i.e., ACK/NAK, sequence number).
  - **payload header**, which contains the channel number and payload length.
  - **payload**, which is the data field.
  - **payload trailer**, contains the CRC-16 error detection value.

![Fig. 8-10 Bluetooth frame layout](image)

The Best Practice WLAN Design
Media Access Control Protocol Efficiency

- Unlike CSMA/CD, Wireless Ethernet’s PCF controlled-access technique imposes time delays, even when traffic is low (see Figure 8-11).
- Response time delays increase only slowly with increased traffic up to about 85-90 percent of nominal capacity.
- At traffic levels of about 85-90 percent of nominal capacity performance begins to fall dramatically, though it remains better than with a comparable wired network.

![Figure 8-11 Performance of wireless versus wired Ethernet LANs](image)

Effective Data Rates for WLANs

- Figure 8-12 presents effective data rates of 802.11b and 802.11a protocols under a range of conditions.
- At close range, 802.11a clearly provides superior performance to 802.11b.
- If range is a factor, however, 802.11a performs only modestly better than 802.11b.
- To achieve higher performance, many companies are now installing overlay networks, i.e., combined networks where the wireless portions extend the reach of the wired network into areas not normally wired.
<table>
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<th>Technology</th>
<th>Network Traffic Conditions</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
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<tr>
<td>802.11b perfect conditions (11 Mbps)</td>
<td></td>
<td>4.8 Mbps</td>
<td>1.9 Mbps</td>
<td>960 kbps</td>
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<tr>
<td>802.11b normal conditions (5.5 Mbps)</td>
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<td>2.4 Mbps</td>
<td>1 Mbps</td>
<td>480 kbps</td>
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<td>802.11a perfect conditions (54 Mbps)</td>
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<td>17.2 Mbps</td>
<td>6.9 Mbps</td>
<td>3.4 Mbps</td>
</tr>
<tr>
<td>802.11a long range (12 Mbps)</td>
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<td>3.8 Mbps</td>
<td>1.5 Mbps</td>
<td>760 kbps</td>
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<tr>
<td>802.11b perfect conditions w/ 4 APs (54 Mbps)</td>
<td></td>
<td>34.4 Mbps</td>
<td>27.5 Mbps</td>
<td>13.7 Mbps</td>
</tr>
</tbody>
</table>

Assumed: 1500 byte frames, no transmission errors
(No. of active users: Low traffic = 2, moderate = 5, high = 10)

**Figure 8-12 Effective data rate estimates for Wireless Ethernet**

**Recommendations**

- For new construction, WLANs are only modestly more expensive than wired LANs.
- WLANs have the advantage of mobility, linking indoor to outdoor areas as well as areas without wired access.
- Given its lower price, longer track record and ability to operate over greater distances 802.11b is the more attractive of the two WLAN protocols,
- If high capacity is critical, then 802.11a becomes more attractive.
- Over time, as 802.11a technology should drop in price. As experience with the technology increases, its popularity should increase as well.

**End of Chapter 8**