

Wi-Fi



- **Wireless Fidelity**
- **Spread Spectrum**
- **CSMA**
- **Ad-hoc Networks**

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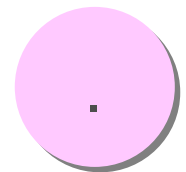
Outline for Today

- We learned how to setup a WiFi network.
- This time we will learn about the protocols that enable these networks.



‘Wifi’ – What it stands for?

“Wi-fi / Wireless-Fidelity, Otherwise known as 802.11 Wireless Network, is an open-standard, open spectrum, open-source, open-hardware, mode of wireless inter-connectivity for participating devices.”



What a wireless network is made up of:-



Wireless Network cards



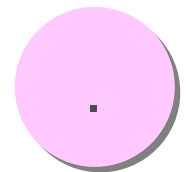
-Radios which send and receive signals from other radios or access points, usually PCMCIA* cards which fit into Laptop expansion slots, or PCI Bus in case of Desktop computers. (There are other, simpler options using USB). PDAs like PALM, and Pocket PC having a compact flash slot can also connect.

Base stations, Access points, or Gateways



-The base station sends and receives radio signals to and from the Wi-Fi radio in your laptop or PC, enabling you to share your Internet connection with other users on the network. Access points and gateways have a wide range of features and performance capabilities, but they all provide this basic network connection service.

* PCMCIA – Personal Computer Memory Card International Association.



Typical Community Wifi Constituents



High gain Parabolic grid antennas to beam the signal to over 30km from tower to tower..
Typically 5.7-5.8 GHz, 2' Diameter Parabolic Grid Antenna, 26 dBi gain, 6 degree beam width, N-Female connector



Sector antennas to beam the signal from the towers to the community users
Typically 2.4-2.5 GHz, 90 degree sector antenna, 17 dBi gain



Customer Premises equipment (CPE) to access the signal from the towers..
Typically 23dBm Radio+15dBi Antenna = 38dBm



Other components that need to be installed in order to put the above systems together



3G Evolution (source: Nokia)

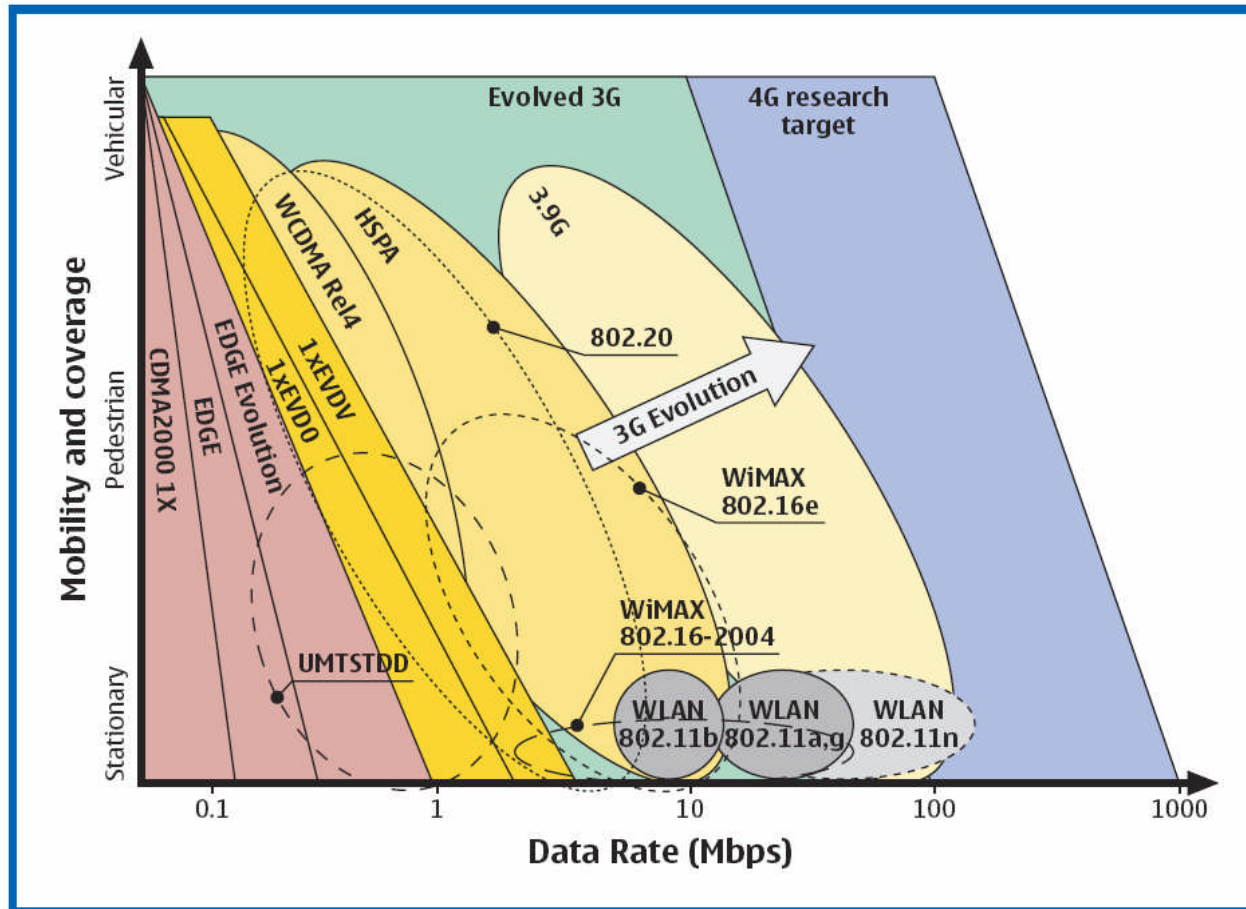


Figure 7. Mobility and coverage vs. the data rates of different radio technologies



ISM Band

ISM stands for industrial, scientific, and medical.

ISM bands are set aside for equipment that is related to industrial or scientific processes or is used by medical equipment. Perhaps the most familiar ISM-band device is the microwave oven, which operates in the 2.4-GHz ISM band. The ISM bands are license-free, provided that devices are low-power. You don't need a license to set up and operate a wireless network.



Basic Technology Concepts

WiFi b-a-g

IEEE Standards for Wireless LAN Spread Spectrum

Radio Technology (802.11)

- 802.11b- 2.4GHz @11mbps
- 802.11a- 5GHz @54mbps
- 802.11g- 2.4GHz @54mpbs

- 802.11e- QoS services
- 802.11i- 802.1x security



Basic Technology Concepts

WiFi b-a-g

	802.11b	802.11a	802.11g
Frequency band	2.4GHz	5GHz	2.4GHz
Max data rate	11Mbps	54Mbps	54Mbps
availability	Worldwide	US	Worldwide
Interference sources	Cordless phone Microwave oven Bluetooth	Hiperlan devices	Cordless phone Microwave oven Bluetooth

The Rules of Thumb of Radio

Higher data rates usually imply shorter transmission range

Higher power output increases range, but increases power consumption (less battery life)

The higher the frequency, the higher the data rate (but smaller range).

Basic Technology Concepts

WiFi b-a-g

	802.11b @100Mw	802.11a @40Mw	802.11g <i>estimates</i>
50 ft	11Mbps	54Mbps	54Mbps
100 ft	11Mbps	36Mbps	36Mbps
125 ft	11Mbps	12Mbps	11Mbps
150 ft	5.5Mbps	6Mbps	5.5Mbps
250 ft	2Mbps		?
350 ft	1Mbps		



Spread spectrum in 802.11

- It is a requirement imposed by the regulatory authorities for devices in ISM band in order to reduce interference.
- There is also limitations on transmitted power.
- We discuss two methods specified in 802.11, FHSS (Frequency Hopping Spread Spectrum) and DSSS (Direct Sequence Spread Spectrum)



DSSS in 802.11

- **Direct-Sequence Spread Spectrum (DSSS)**
- Used by 802.11b
- Symbol transmission rate = 1Mbps
- Multipath spread of up to $1/1 \text{ Mbps} = 1 \mu\text{s}$ does not cause ISI. For indoor applications this ensures that the system does not suffer from ISI.
- Chip rate = 11 Mcps
- Resolution is on the order of $1/11 \text{ Mcps} = 90 \text{ ns}$.

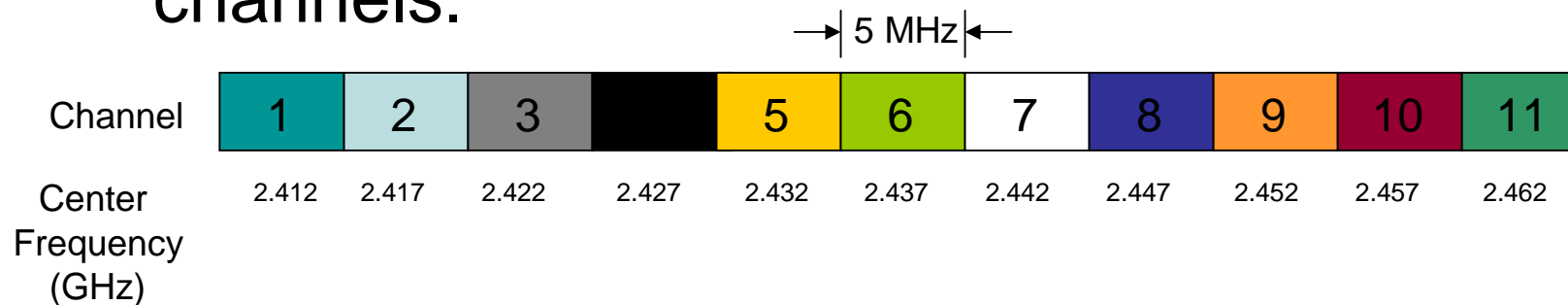


Frequency-hopping spread spectrum

- **Frequency-hopping spread spectrum (FHSS)** is a method of transmitting radio signals by rapidly switching a carrier among many frequency channels, using a pseudorandom sequence known to both transmitter and receiver.

802.11b

- The 802.11b standard defines a total of 14 frequency channels.
- FCC allows channels 1 through 11 within the U.S. Most of Europe can use channels 1 through 13. In Japan, only 1 choice: channel 14.
- Channel represents a center frequency. Only 5 MHz separation between center frequencies of channels.

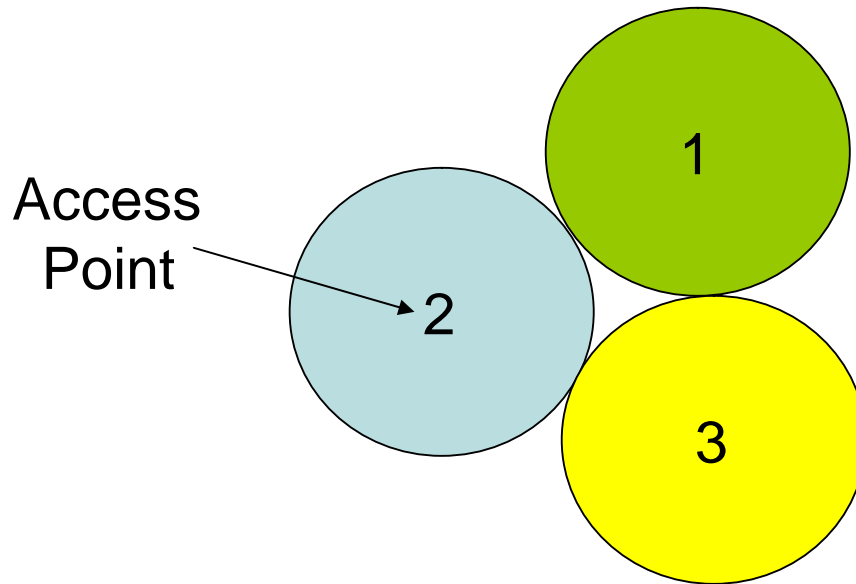



802.11b (Cont'd)

- Any 802.11b signal occupies approximately 30 MHz.
- Thus, 802.11b signal overlaps with several adjacent channel frequencies.
- Only three channels (channels 1, 6, and 11 for the U.S.) that can be used without causing interference between access points.
- Any given area can therefore support at most 3 access points (operating on different channels) at once. Equivalently, it can at most support three local ad-hoc connections.

802.11b (Cont'd)

Neighboring AP's use different channels to reduce interference. "Reuse cluster" size is equal to 3.

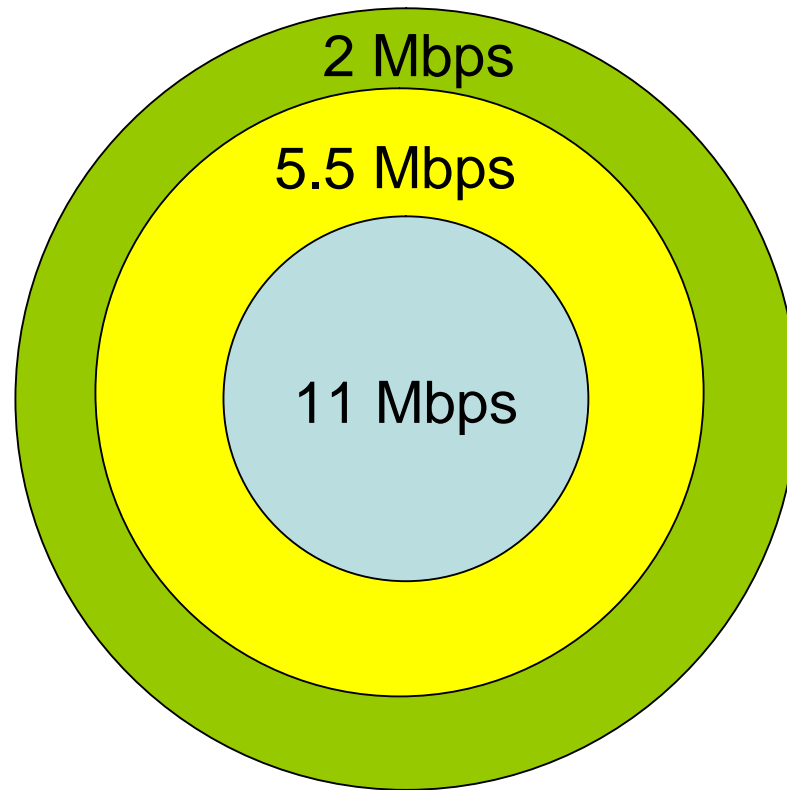




802.11b (Cont'd)

- Ideally, 802.11b supports wireless connections between an access point and a wireless device at four possible data rates: 1 Mbps, 2 Mbps, 5.5 Mbps, and 11 Mbps.
- Specifically, as terminal travels farther from its AP, the connection will remain intact but connection speed decreases (falls back).

802.11b (Cont'd)





802.11b Spread Spectrum

- When a 802.11b radio is operating at 1 Mbps and wishes to transmit a bit 1, it has to do so in 0.000001 seconds.
- The way 802.11b does is this by actually transmitting a fixed sequence of 11 shorter bits (01001000111) to represent a single bit “1”. These 11 “shorter bits” (which represent one information bit) are sent in 1/11 the time, i.e., 0.0000000909 seconds.
- These shorter bits are called “chips.”



802.11b Spread Spectrum (Cont'd)

- When the radio wishes to transmit a 0 information bit, it uses the 0.000001 seconds to transmit a different fixed sequence of chips, 01001000111.

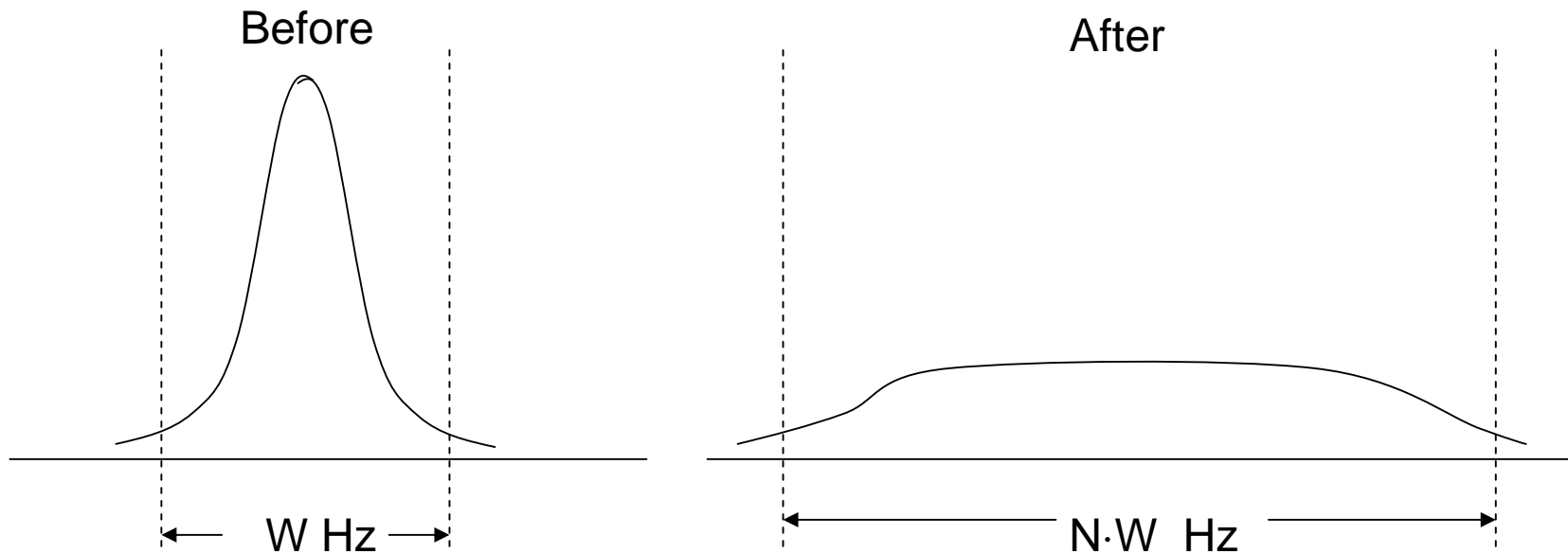
- The chip sequence used for “1” is the complement of the chip sequence used for sending a “0”.

802.11b Spread Spectrum


- Assume the original signal (the information stream of 1's and 0's) occupies a frequency bandwidth of W Hz.
- When we use N chips to transmit 1 bit, the bandwidth of the resulting signal now occupies $N \cdot W$ Hz.
- The new signal has a larger spectrum, i.e., the information signal of bandwidth W has been spread to a bandwidth of $N \cdot W$. For this reason, this process is called spread spectrum.

Spread Spectrum

Frequency representation of transmitted signal, before and after spreading.



Both signals contain the same information. The second signal uses less power/Hz (height is less). This helps meet FCC mandates in unlicensed bands.




802.11b (Cont'd)

- The above procedure is used to get 1 Mbps.
- What about the higher data rates?
- This is achieved by using more complex modulation schemes and/or changing the chip sequence.
- Recall modulation scheme is the scheme used to encode a bit stream into high-frequency sine waves, i.e., radio waves.

802.11a

- 802.11a specification operates at radio frequencies between 5.15 and 5.825 GHz, i.e. 802.11a utilizes 300 MHz bandwidth
- The FCC has divided total 300 MHz in this band into three distinct 100 MHz bands: low, middle, and high, each with different legal maximum power.

	Band	Channel	Max Power
High band	5.725-5.825 GHz	9-12	1000 mW
Middle band	5.25-5.35 GHz	5-8	250 mW
Low band	5.15-5.25 GHz	1-4	50 mW




802.11a (Cont'd)

- Because of high power output, high band used for building-to-building products. Lower two bands suitable for in-building wireless products.
- In 802.11a, radio signals are generated using a method called Orthogonal Frequency Division Multiplexing (OFDM).
- OFDM is defined over the lower two bands (low and middle).

802.11a (Cont'd)

- The low and middle bands have a total of 200 MHz of frequency.
- This 200 MHz supports 8 non-overlapping channels.
- Each channel is split in 52 bands, each approximately 300 kHz wide.
- Each of these smaller bands is called a sub carrier in OFDM terminology.
- In OFDM, a transmitter can select some number of sub carriers to transmit a signal over.

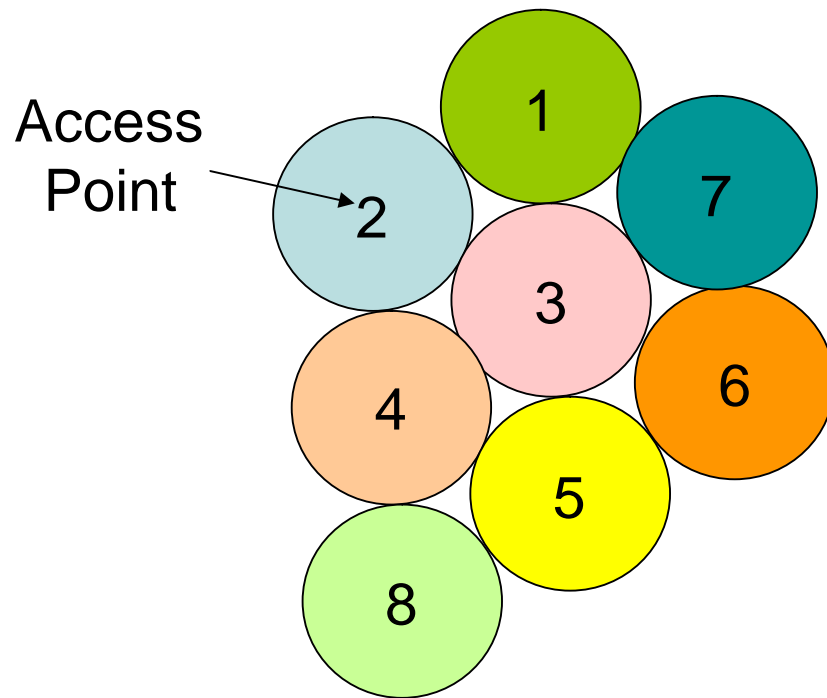


802.11a (Cont'd)

- Depending on the number of sub carriers chosen, the transmitter can achieve transmission rates of 6, 9, 12, 18, 24, 36, 48, or 54 Mbps.
- Since there are eight non-overlapping channels, 802.11a can support 8 different access-point to wireless device links in a given location. Or equivalently, it can support at most 8 ad hoc connections simultaneously.
- This is an improvement over 802.11b, where only 3 could be supported.

802.11a (Cont'd)

Neighboring AP's use different channels to reduce interference. "Reuse cluster" size is equal to 8.

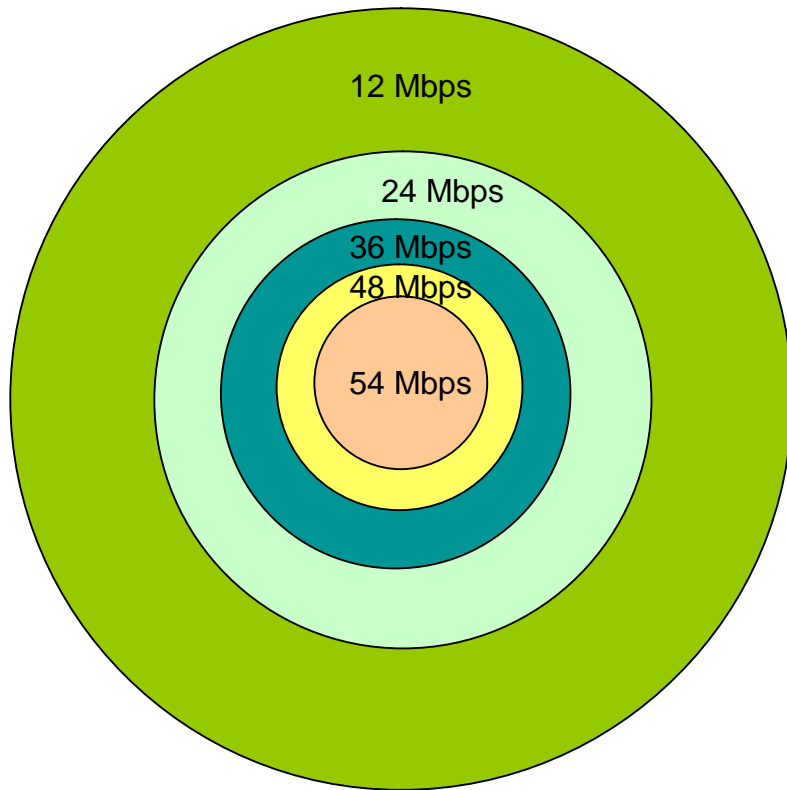


802.11a (Cont'd)

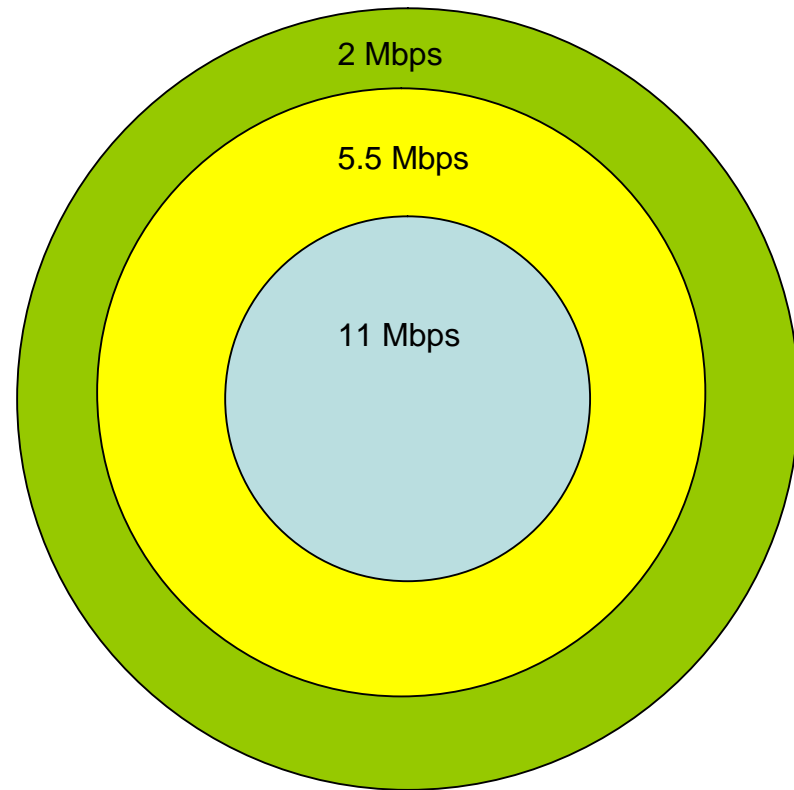
- The various data rates are supported in 802.11a by varying the number of subcarriers, the modulation scheme, etc.
- 802.11a (like 11b) has a rate fall back mechanism, i.e., as the distance between the transmitter and receiver increases, the supported data rate decreases.


802.11a (Cont'd)

802.11a




802.11b






802.11g

- 802.11g offers throughput of 802.11a with backward compatibility of 802.11b.
- 802.11g operates over 3 non-overlapping channels.
- 802.11g operates in 2.4 GHz band but it delivers data rates from 6 Mbps to 54 Mbps.
- 802.11g also uses OFDM but supports spread-spectrum capabilities if any one component of the system has older equipment, i.e., 802.11b equipment.



802.11g

- Once again, 802.11g's "backward compatibility" with 802.11b means that when a mobile 802.11b device joins an 802.11g access point, all connections on that access point slow down to 802.11b speeds.
- So both 11a and 11g offer the same data rates. Which is better?



Comparing 11a and 11g

- 802.11a operates in underused 5 GHz band;
802.11g operates in heavily used 2.4 GHz band.
- 11g systems experience interference from other 2.4 GHz devices such as cordless phones, microwave ovens, satellites, etc.
- Both 802.11a and 802.11g offers up to 54Mbps speeds in the lab.



Comparing 11a and 11g (Cont'd)

- In the field, 802.11a delivers about 20Mbps.
- 802.11b's 11Mbps theoretical speed is more often 4Mbps in practice.
- The realistic data rates quoted for 802.11g thus far range from 6 Mbps to 20 Mbps.
- 11g has to contend with more interference in the 2.4 GHz range as compared to 11a in the 5 GHz band.



Comparing 11a and 11g (Cont'd)

- Higher number of channels in 11a allows more flexibility in avoiding interference.
- Range will depend on antenna gain, transmit power applied to the antenna, the receive sensitivity of the radio card and the obstacles between path ends.
- 802.11a has range 150-300 ft in practical scenarios. 11g has range comparable to 11b (approximately 1000 ft).
- 11a range is smaller than 11b and 11g. This is because 11a operates at a much higher frequency band.



Comparing 11a and 11g (Cont'd)

- Generally, 802.11a is the most expensive of the three options.
- 802.11b is the cheapest and most popular WLAN option.
- 802.11g is more expensive than 11b but cheaper than 11a.
- Because of its smaller range, 11a requires more Access Points to a region, thereby increasing cost.

What does a typical 802.11 Packet look like?

- Typical 802.11 packet:



- Preamble is used to synchronize the receiver, so it can tell when the packet starts. It contains 96 bits.
- PLCP (Physical Layer Convergence Procedure) indicates how many bytes in data portion, what is the data rate of the transmission, etc. This portion contains about 192 bits.

802.11 Packet (Cont'd)

- Data is the actual data transmitted by the source. This contains source/destination addresses, the information conveyed between the two, whether WEP is on or not, etc. The amount of data bits can vary. ~200 bits to ~18000 bits.
- CRC is the cyclic redundancy check, which is way of checking if there was an error in the received sequence of bits. This is usually 32 bits long.





How are Multiple Transmitters Supported?


- Recall the method for supporting multiple transmitter is called the multiple access method.
- In 802.11 systems, only one user is allowed to communicate with a receiver at a time (cannot use another frequency channel support a second or third additional user).
- The way the one user is selected depends on the carrier sense multiple access with collision avoidance (CSMA/CA) random access method.

CSMA

- To help illustrate the operation of CSMA, we will use an analogy of a dinner table conversation.

- Let's represent our wireless medium as a dinner table, and let several people engaged in polite conversation at the table represent the wireless nodes.





CSMA (Cont'd)

- The term **multiple access** covers what we already discussed above: When one wireless device transmits, all other devices using the wireless medium hear the transmission, just as when one person at the table talks, everyone present is able to hear him or her.
- Now let's imagine that you are at the table and you have something you would like to say.
- At the moment, however, I am talking.



CSMA (Cont'd)

- Since this is a polite conversation, rather than immediately speak up and interrupt, you would wait until I finished talking before making your statement.
- This is the same concept described in the CSMA protocol as **carrier sense**.
- Before a station transmits, it "listens" to the medium to determine if another station is transmitting. If the medium is quiet, the station recognizes that this is an appropriate time to transmit.

CSMA/CA

- Carrier-sense multiple access gives us a good start in regulating our conversation, but there is one scenario we still need to address.
- Let's go back to our dinner table analogy and imagine that there is a momentary silence in the conversation.
- You and I both have something we would like to add, and we both "sense the carrier" based on the silence, so we begin speaking at approximately the same time. In 802.11 terminology, a **collision** occurs when we both spoke at once.

CSMA/CA (Cont'd)

- The collision will result in an unexplained message to the intended receivers (listeners).
- What we need is a polite contention method to get access to the medium; this is the collision avoidance part of CSMA/CA.
- 802.11 has come up with two ways to deal with this kind of collision.
 - One uses a two-way handshake when initiating a transmission.
 - The other uses a four-way handshake.



2 Way Handshake

- Node with packet to send monitors channel.
- If channel idle for specified time interval called DIFS, then node transmits.
- If channel busy, then
 - node continues to monitor until channel idle for DIFS.
 - At this point, terminal backs-off for random time (collision avoidance) and attempts transmitting after waiting this random amount of time.



2 Way Handshake

- If the node does not back-off the random time, then it will definitely collide with another node that has something to send.
- Reason for **random** back-off time is that if I choose a random time and you choose a random time, the probability that we choose the same random time is slim.
- This way we both back-off transmitting and will therefore probably not interfere with each other when we are ready to transmit.



2 Way Handshake (Cont'd)

- First way of the 2 way handshake was for the transmitter to send its information packet to the destination node, after following the collision avoidance method described above.
- If the packet reaches the destination without problems, the destination sends a short packet over the wireless medium acknowledging the correct reception.
- This packet is typically called an ACK packet. ACK is the second way of the 2 way handshake.



4 Way Handshake

- “Listen before you talk”
- If medium is busy, node backs-off for a random amount of time after waiting DIFS, just as before.
- But now, instead of packet, sends a short message: Ready to Send (RTS). This message is basically attempting to inform others that “I have something to send.”



4 Way Handshake (Cont'd)

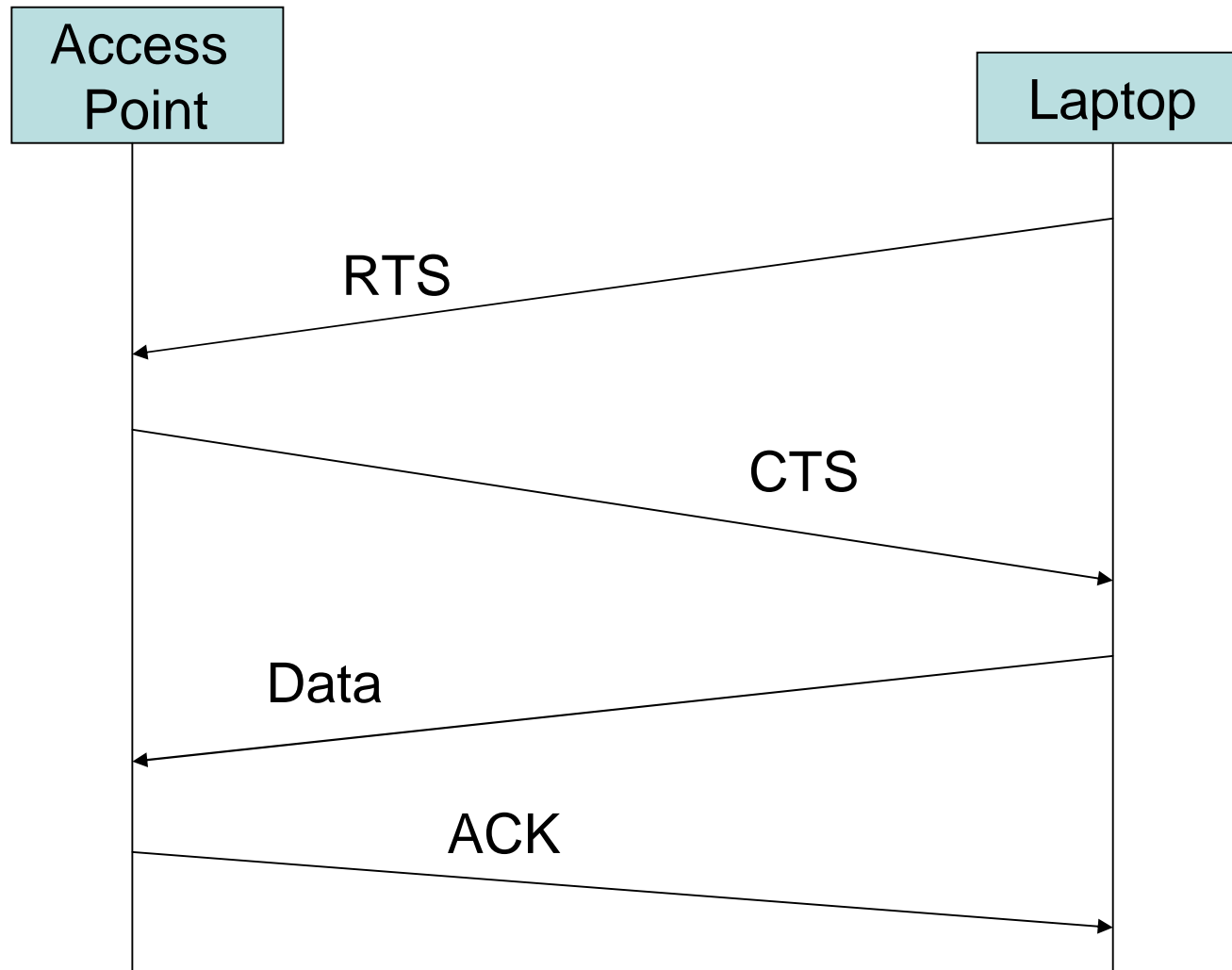
- RTS contains destination address and duration of message.
- RTS tells everyone else to back-off for the duration.
- If RTS reaches the destination okay (no one else collides with this message), the destination sends a Clear to Send (CTS) message after waiting a prescribed amount of time, called SIFS.



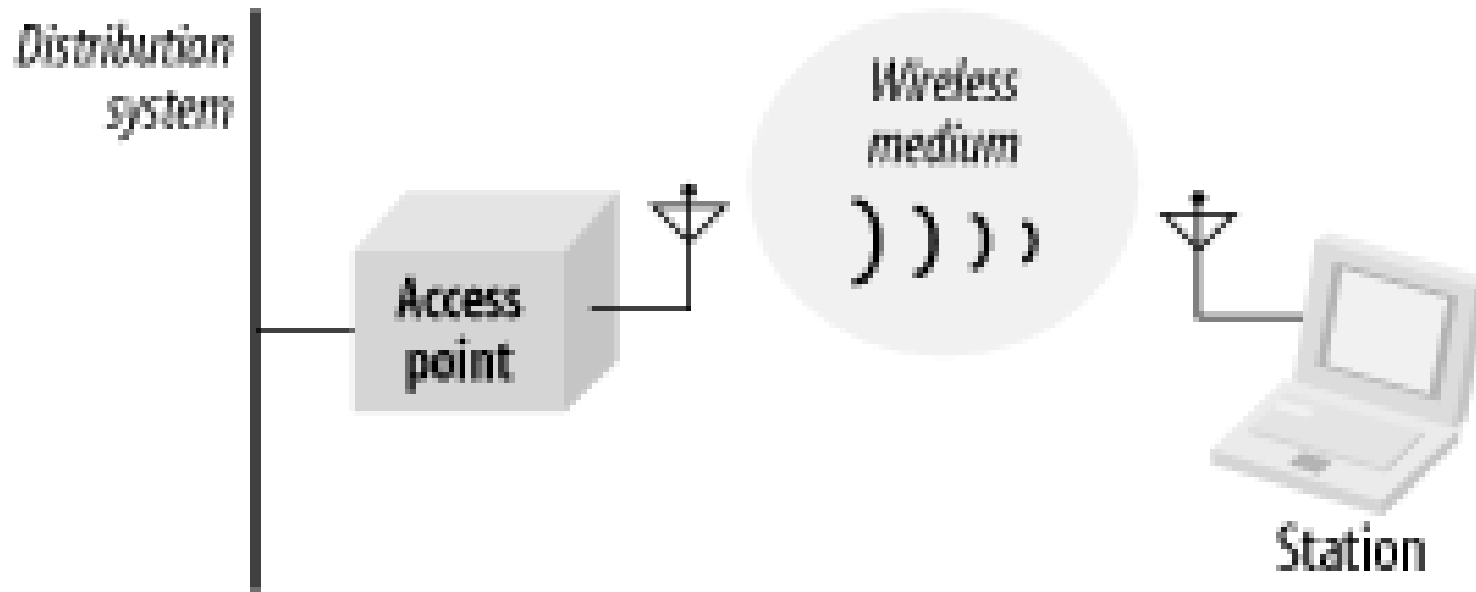
4 Way Handshake (Cont'd)

- After getting the CTS, the original transmitter sends the information packet to its destination.
- In these systems, the transmitter cannot detect collisions. The receiver uses the CRC to determine if the packet reached correctly. If it does then, it sends out an ACK packet.
- If the information packet not ACKed, then the source starts again and tries to retransmit the packet.

4 Way Handshake (Cont'd)

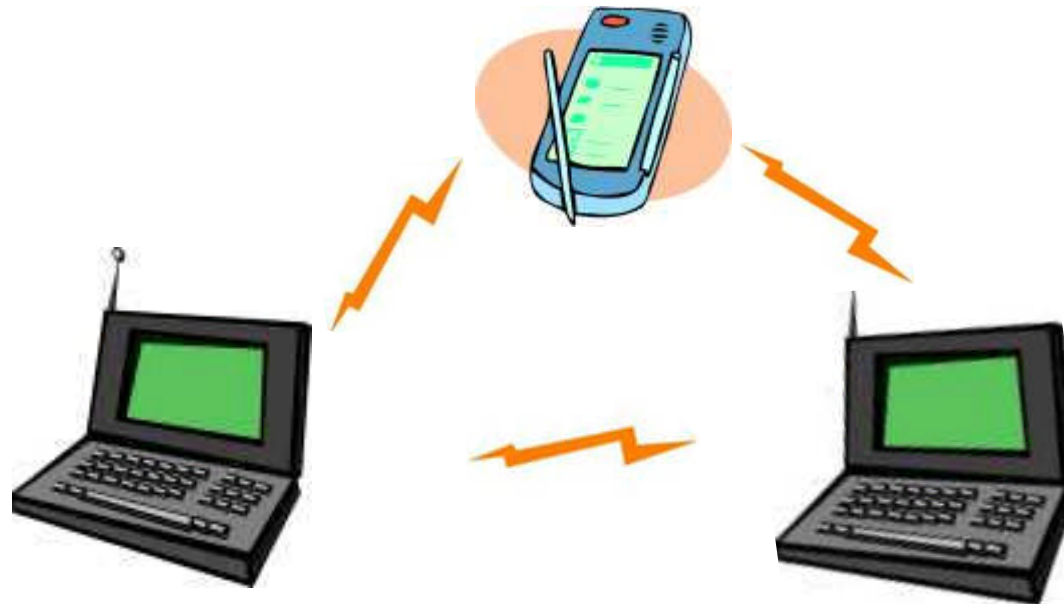


Wireless LAN Networks



WLAN Architecture—Ad Hoc Mode

- **Ad-Hoc mode:** Peer-to-peer setup where clients can connect to each other directly. Generally not used for business networks.





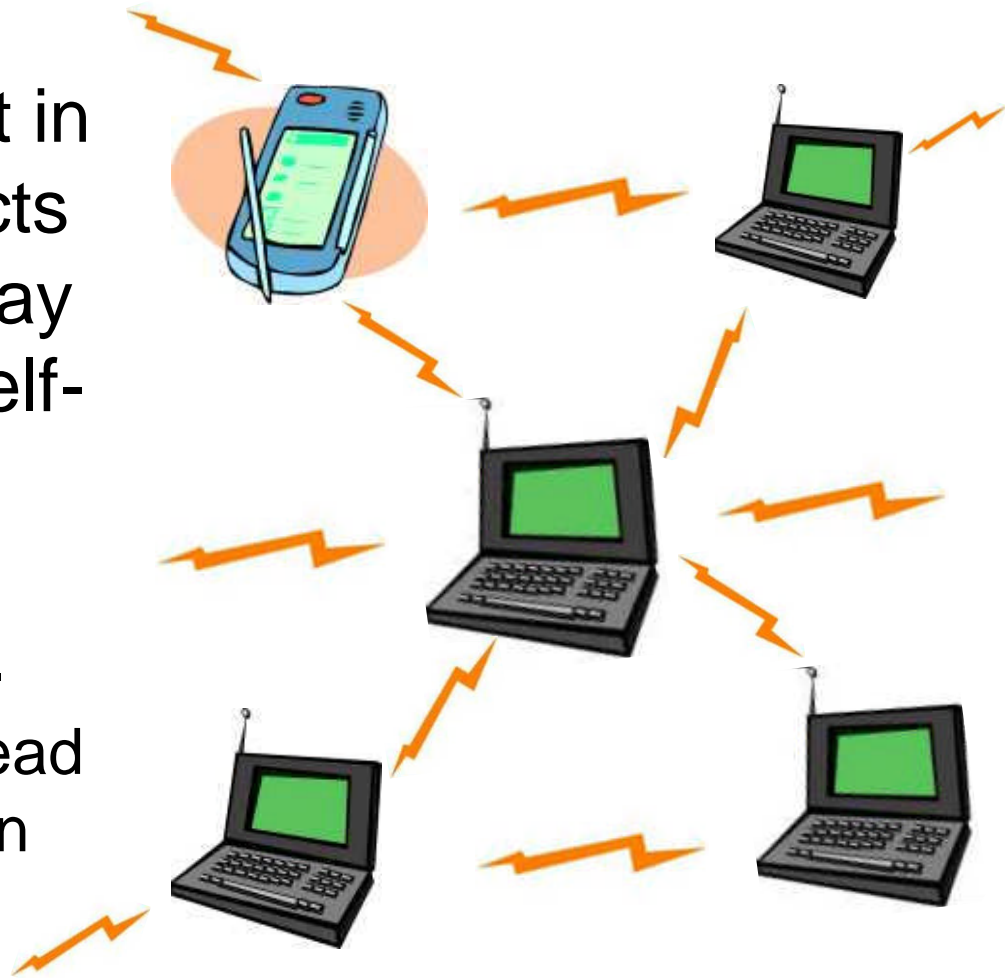
Ad Hoc Structure

- Mobile stations communicate to each other directly.
- It's set up for a special purpose and for a short period of time. For example, the participants of a meeting in a conference room may create an ad hoc network at the beginning of the meeting and dissolve it when the meeting ends.

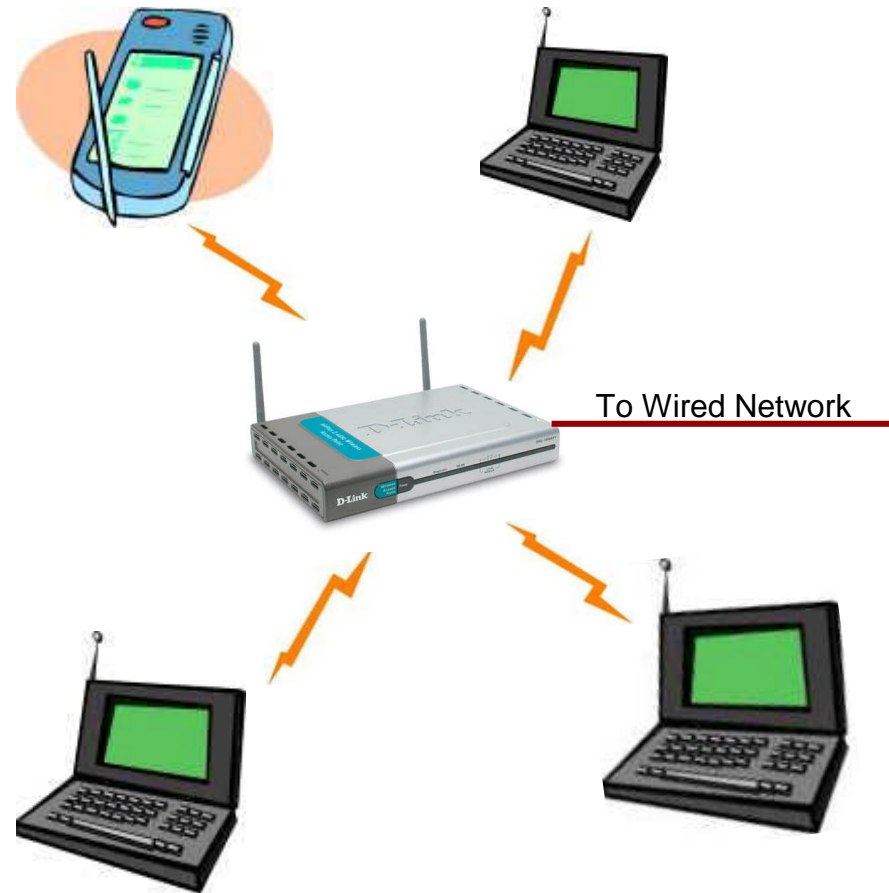
WLAN Architecture--Mesh

Mesh: Every client in the network also acts as an access or relay point, creating a “self-healing” and (in theory) infinitely extensible network.

- Not yet in widespread use, unlikely to be in homes.



WLAN Architecture—Infrastructure Mode

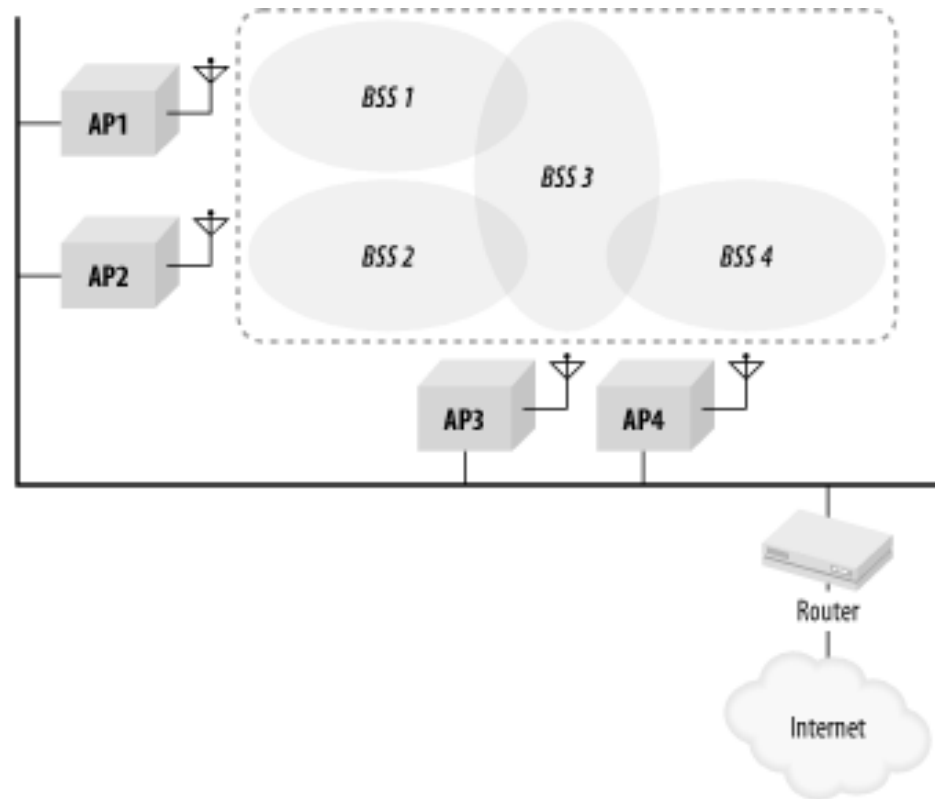




Infrastructure network

- There is an Access Point (AP), which becomes the hub of a “star topology.”
- Any communication has to go through AP. If a Mobile Station (MS), like a computer, a PDA, or a phone, wants to communicate with another MS, it needs to send the information to AP first, then AP sends it to the destination MS
- Multiple APs can be connected together and handle a large number of clients.
- Used by the majority of WLANs in homes and businesses.

Extended Service Area



Q & A

