Intro to networking

- What is an IP address
  - Identifies your location in the Internet
  - Can change
  - Assigned to a specific NIC

- What is a flow
  - <Src IP, Src port, Dst IP, Dst Port, protocol>

Wireless networking

- No wires!
- Shared media
- Interference and noise
- Bandwidth and range limits
- Variable performance
- Mobility
- Implications for higher network layers

Understand your assumptions

- Disconnected operations
  - Does your app require you to be connected always?
- Delay tolerant
  - Can you handle unpredictable delays?
  - Is caching strategies useful to your app?
- Always on
  - What happens when the app is not running?

Cellular vs WiFi

Cost: Expensive licensed spectrum

Range: 1 to 20 km

Tx power: 1-10 W

Protocols: Highly coordinated

Throughputs: ~ 10 Kbps – 2 Mbps

Cost: Cheap and unlicensed use

Range: ~100 m

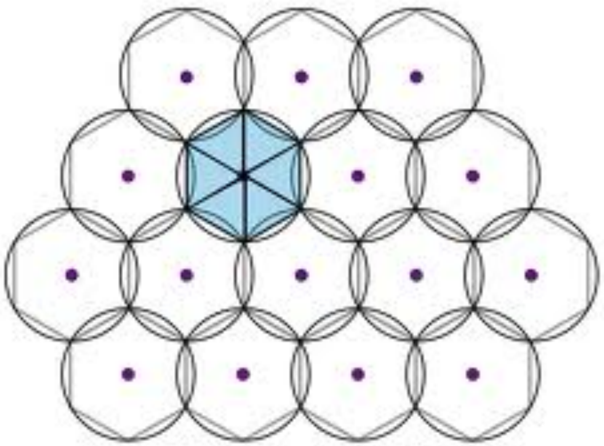
Tx power: ~0.1 W

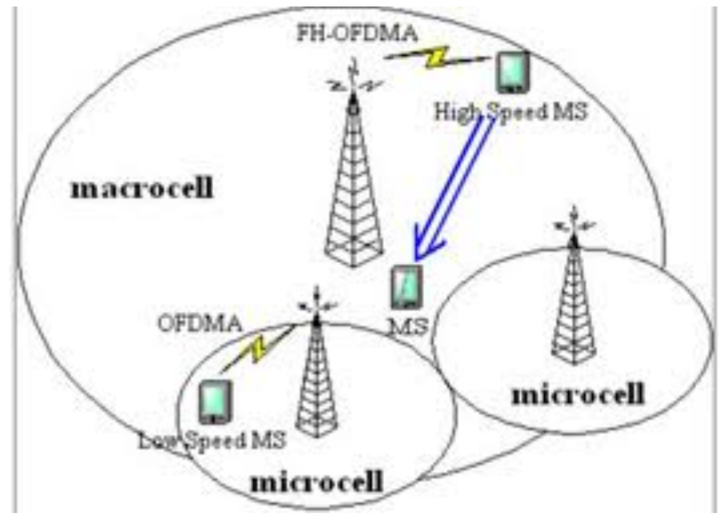
Protocols: Uncoordinated

Throughputs: ~ 1 Mbps – 100 Mbps

Cellular network planning

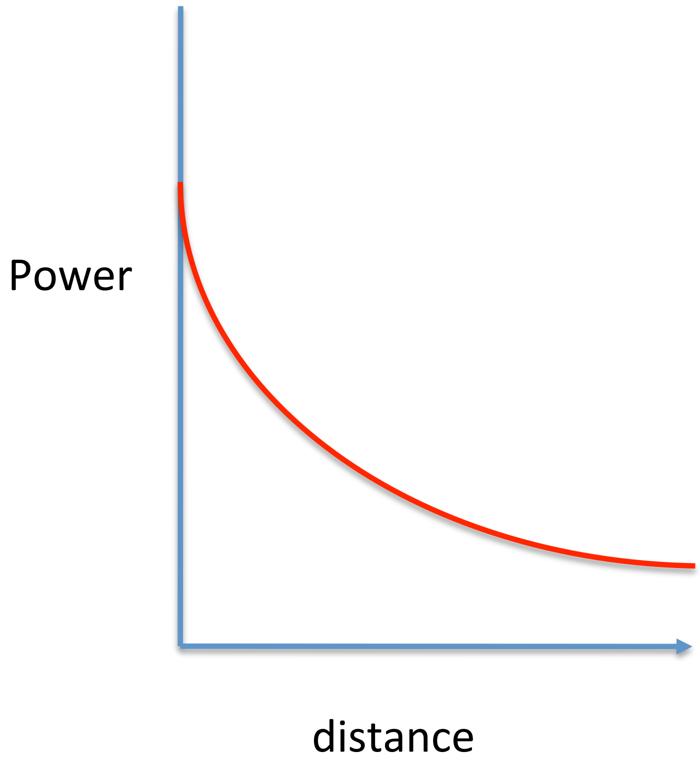
- Ideal - Hexagonal patterns

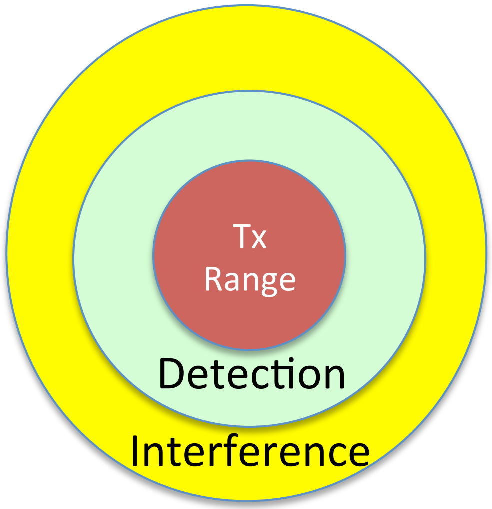




- In real life – Macro and Microcells

Signal attenuation





Signal attenuation

- Energy radiates in all directions
  - Consider a sphere (4 *pi *r ^2)

- SINR = Signal to Interference + Noise Ratio

Example 1

Consider an extremely noisy channel in which the value of the signal-to-noise ratio is almost zero. In other words, the noise is so strong that the signal is faint. For this channel the capacity C is calculated as

$$C = B \log_2 (1 + \text{SNR}) = B \log_2 (1 + 0) = B \log_2 1 = B \times 0 = 0$$

This means that the capacity of this channel is zero regardless of the bandwidth. In other words, we cannot receive any data through this channel.

Example 2

We can calculate the theoretical highest bit rate of a regular telephone line. A telephone line normally has a bandwidth of 3000 Hz. The signal-to-noise ratio is usually 3162. For this channel the capacity is calculated as

$$C = B \log_2 (1 + \text{SNR}) = 3000 \log_2 (1 + 3162) = 3000 \log_2 3163$$
$$= 3000 \times 11.62 = 34{,}860 \text{ bps}$$

This means that the highest bit rate for a telephone line is 34.860 kbps. If we want to send data faster than this, we can either increase the bandwidth of the line or improve the signal-to-noise ratio.

Example 3

The signal-to-noise ratio is often given in decibels. Assume that SNR_{dB} = 36 and the channel bandwidth is 2 MHz. The theoretical channel capacity can be calculated as

$$SNR_{dB} = 10 \log_{10} SNR \rightarrow SNR = 10^{SNR_{dB}/10} \rightarrow SNR = 10^{3.6} = 3981$$

$$C = B \log_2 (1 + SNR) = 2 \times 10^6 \times \log_2 3982 = 24 \text{ Mbps}$$

Example 4

For practical purposes, when the SNR is very high, we can assume that SNR + 1 is almost the same as SNR. In these cases, the theoretical channel capacity can be simplified to

$$C = B \times \frac{\text{SNR}_{\text{dB}}}{3}$$

For example, we can calculate the theoretical capacity of the previous example as

$$C = 2\ \text{MHz} \times \frac{36}{3} = 24\ \text{Mbps}$$

Example 5

We have a channel with a 1-MHz bandwidth. The SNR for this channel is 63. What is the appropriate bit rate?

Solution

We use the Shannon formula to find the upper limit.

$$C = B \log_2 (1 + \text{SNR}) = 10^6 \log_2 (1 + 63) = 10^6 \log_2 64 = 6 \text{ Mbps}$$

dB

- dB = deciBels

- dBm = 10 log10 (power in mW)

- dBW = 10 log10 (power in W)

- Express 1 W in dBW and dBm
- Express 1 mW in dBW and dBm
- Expres 10 mW in dBW and dBm

Channel capacity

- Shannon' law
  - C = B log (1 + SINR)

- Spectral efficiency: units of b/s/Hz

- Check http://en.wikipedia.org/wiki/Spectral_efficiency for some example spectral efficiencies

Spatial re-use

- Macrocell vs Microcell vs Pico/Femtocells

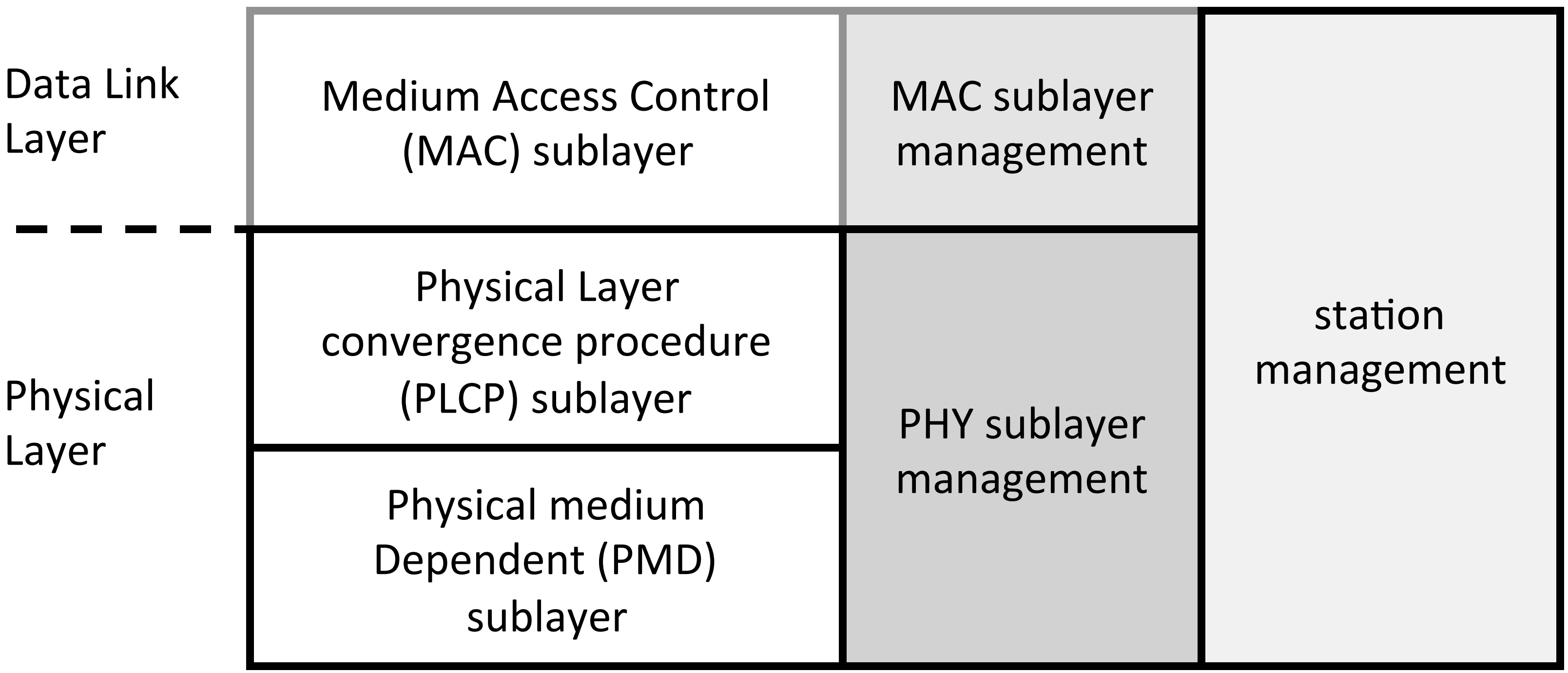
IEEE 802.11

- Characteristics
- Modes of operation
- Association, authentication and privacy

IEEE 802.11 Standard

- Final draft approved in 1997
- Operates in the 2.4 GHz industrial, scientific and medical (ISM) band
- Standard defines the physical (PHY) and medium access control (MAC) layers
  - Note that the 802.11 MAC layer also performs functions that we usually associated with higher layers (e.g., fragmentation, error recovery, mobility management)
- Initially defined for operation at 1 and 2 Mbps
  - DSSS, FHSS or infrared
  - Extensions (IEEE 802.11b, IEEE 802.11a, etc.) allow for operation at higher data rates and (in the case of 802.11a) different frequency bands

Reference Model (1)



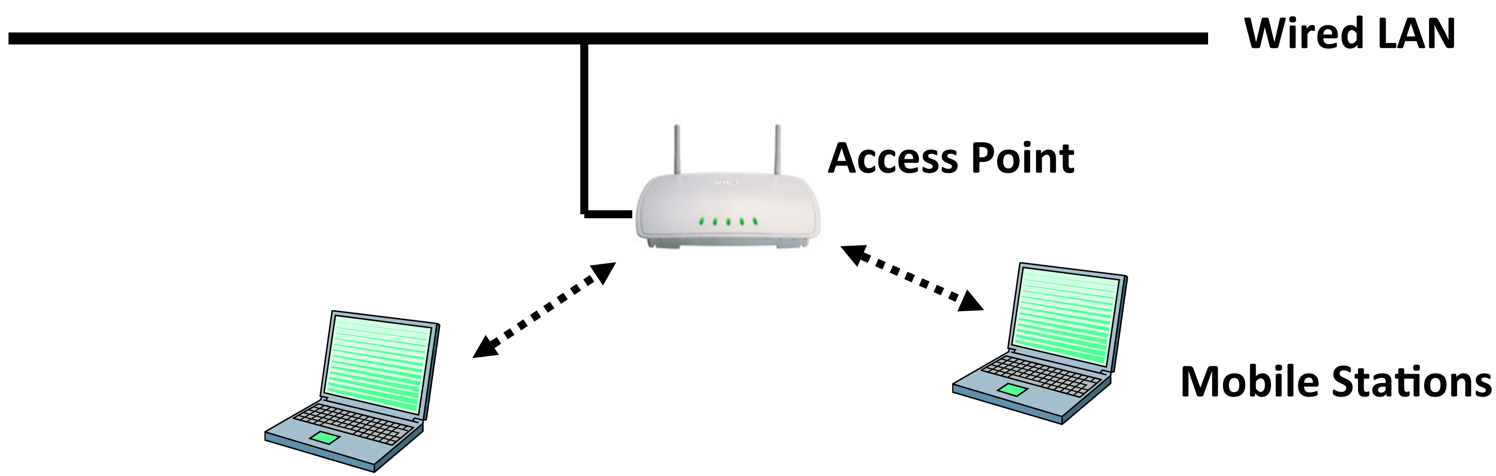
Reference Model (2)

- Physical Medium Dependent (PMD) sublayer
  - Defines a method for transmitting and receiving data through the medium, including modulation and coding
  - Dependent on whether DSSS, FHSS or IR is used
- Physical Layer Convergence Procedure (PLCP) sublayer
  - Maps MAC layer PDUs into a packet suitable for transmission by the PMD sublayer
  - Performs carrier sensing
- MAC sublayer
  - Defines access mechanism, based on CSMA
  - Performs fragmentation and encryption of data packets

IEEE 802.11b

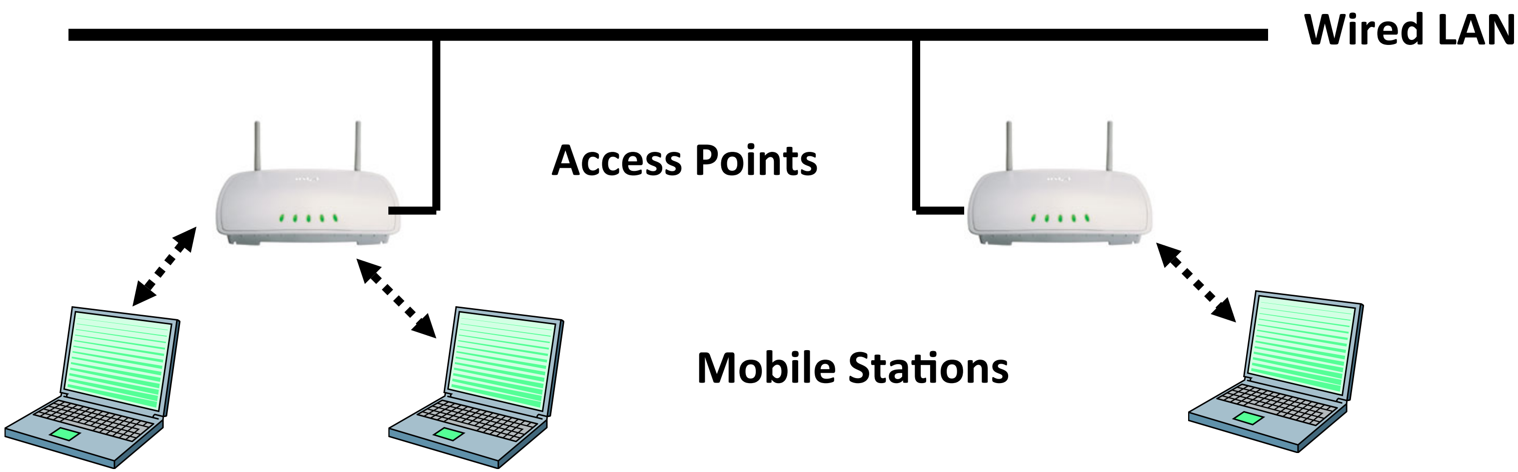
- Standard released in 1999
- 2.4 – 2.483 GHz band
- Uses DSSS
- Data rates of up to 11 Mbps
  - Data rates are automatically adjusted for noisy conditions, so can operate at 1, 2, 5.5 or 11 Mbps
- Modes of operation
  - Infrastructure-based
  - Ad-hoc
- Most widely implemented to date

Infrastructure Mode (1)



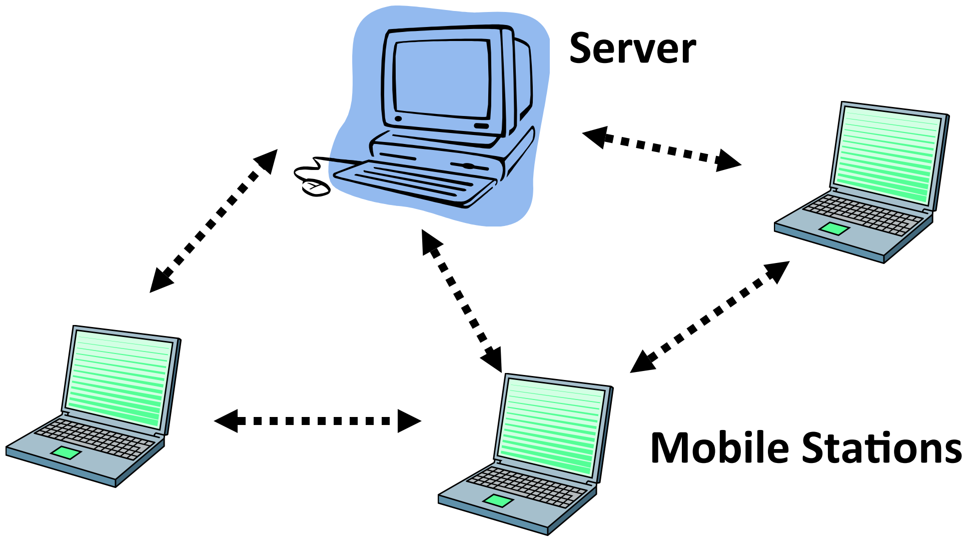
- Basic Service Set (BSS)
- Access point serves as a local bridge
- Stations communicate through the access point, which relays frames to/from mobile stations

Infrastructure Mode (2)



- Extended Service Set (ESS)
- A set of infrastructure BSSs
- Access points communicate among themselves to forward frames between BSSs and to facilitate movement of stations between BSSs

Ad Hoc Mode

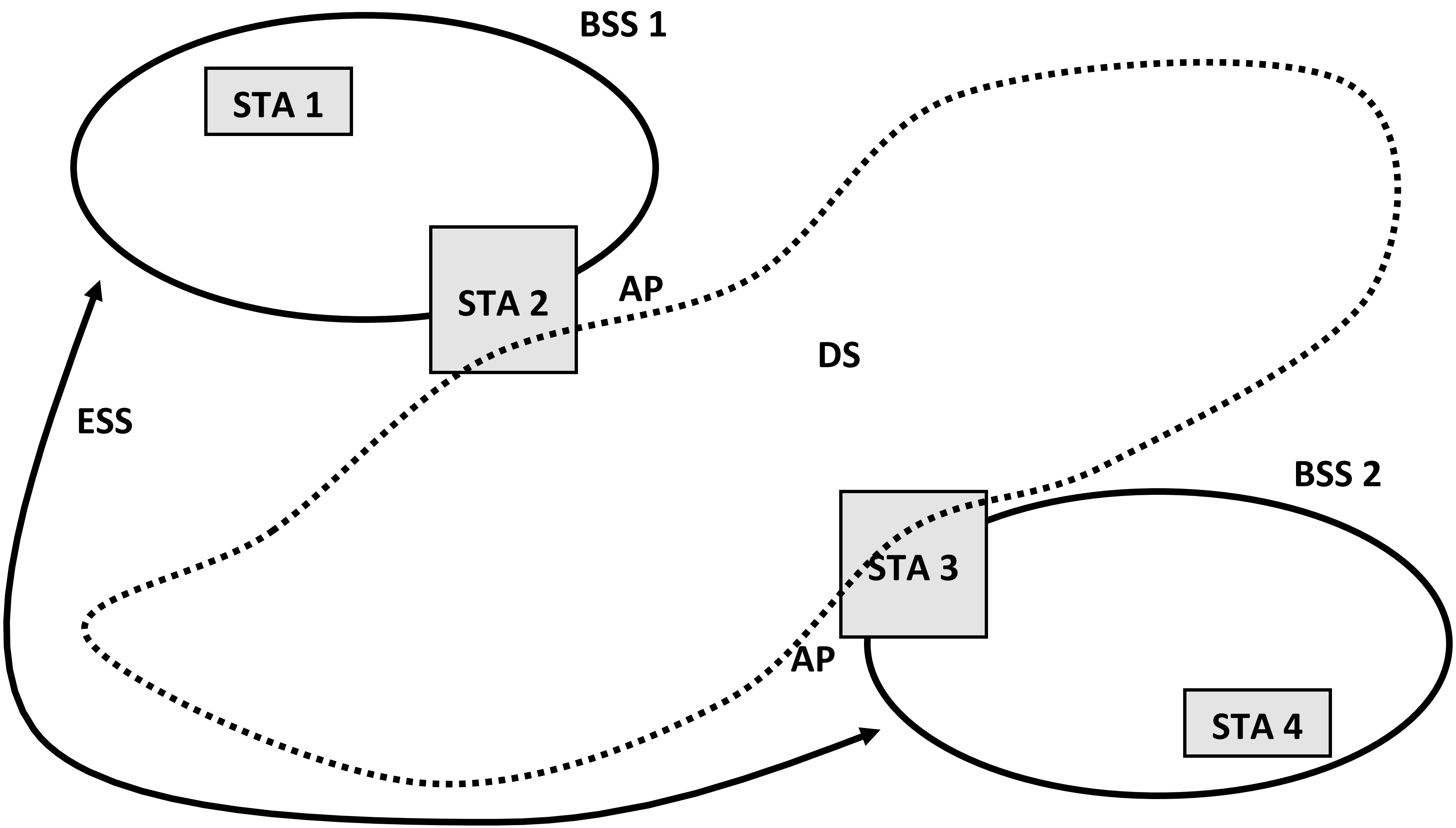


- Independent Basic Service Set (IBSS) or Peer to Peer
- Stations communicate directly with each other
- When no direct link is feasible between two station, a third station may act as a relay (multi-hop communications)

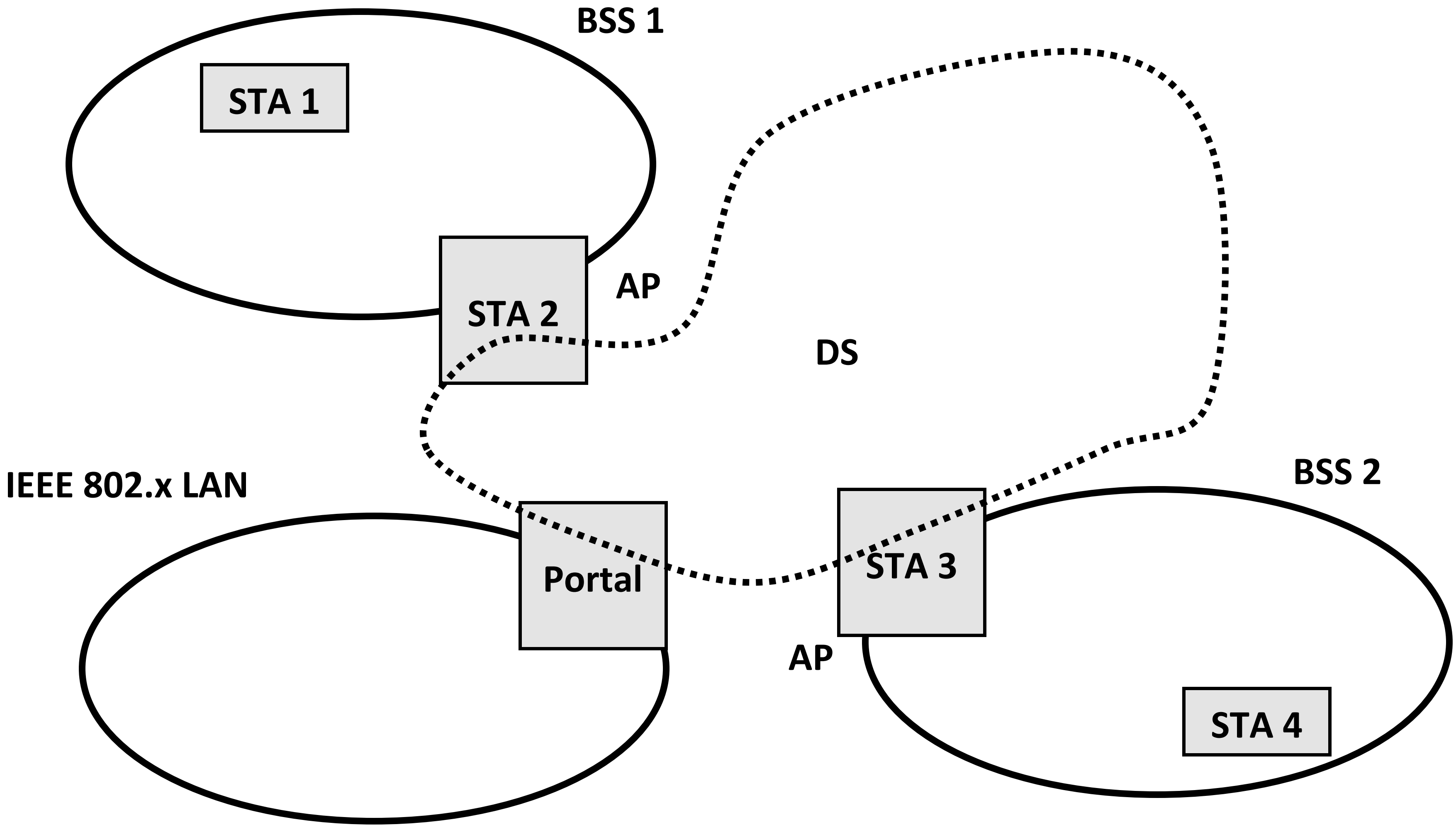
Distribution Systems

- The architectural component used to interconnect BSSs is the distribution system (DS)
- DS enable mobile device support
  - Address-to-destination mapping
  - Seamless integration of several BSSs
- In practice, an access point implements DS services

Distribution Systems and Access Points



Integration with Wired LANs



Association

- To deliver a message within the DS, must know which AP to access for a given mobile station
- Before a station is allowed to send a message through an AP, it must associate itself with that AP
  - At any given time, a station must be associated with no more than one AP
  - An AP may be associated with multiple stations
- As it moves between BSSs, a mobile station may reassociate itself with a different AP

Authentication

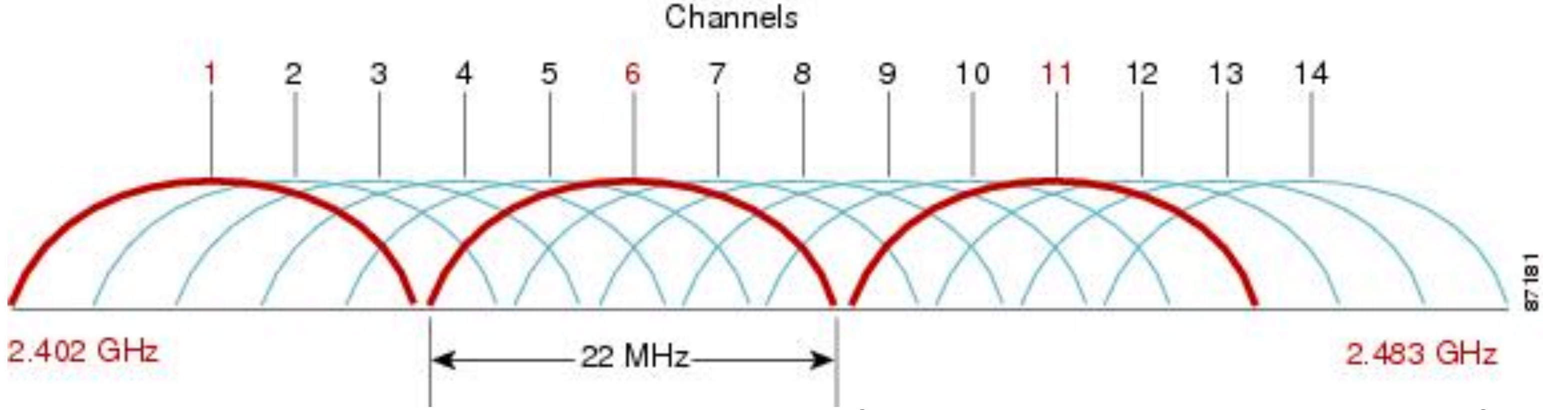
- 802.11 provides link-level authentication between stations
- 802.11 also supports shared key authentication
  - Requires that wired equivalent privacy (WEP) be enabled
  - Identity is demonstrated by knowledge of a shared, secret, WEP encryption key
- Typically, authentication is performed at association with an AP

Privacy

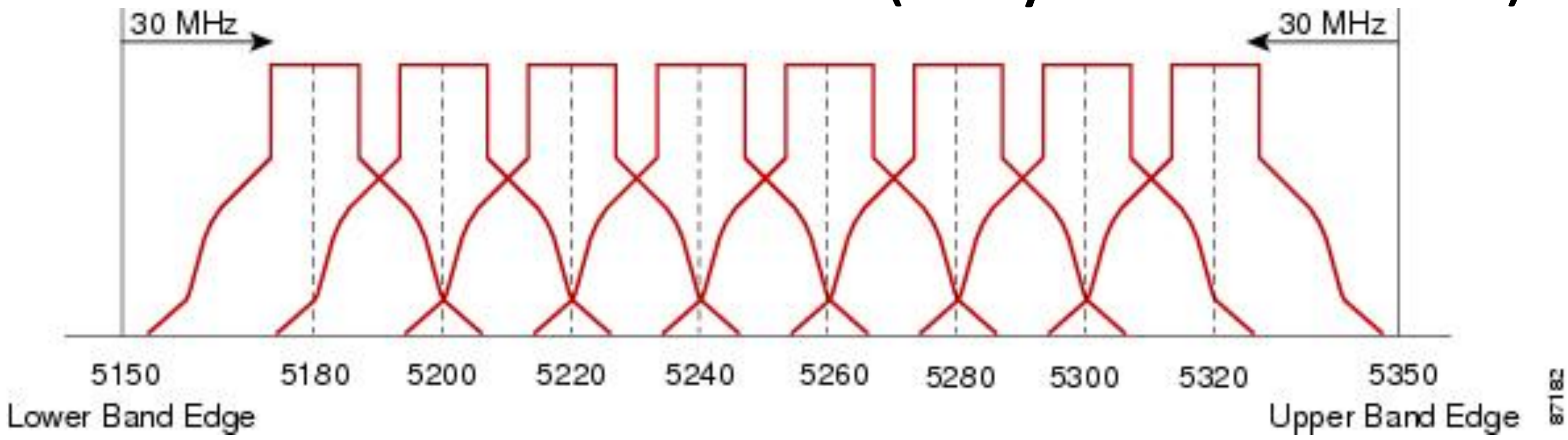
- Default state is "in the clear" – messages are *not* encrypted
- Optional privacy mechanism, WEP, is provided
  - Goal is to achieve a level of security at least as good as in a wired LAN
- Note that encryption provided by WEP is relatively easy to break

802.11 channels

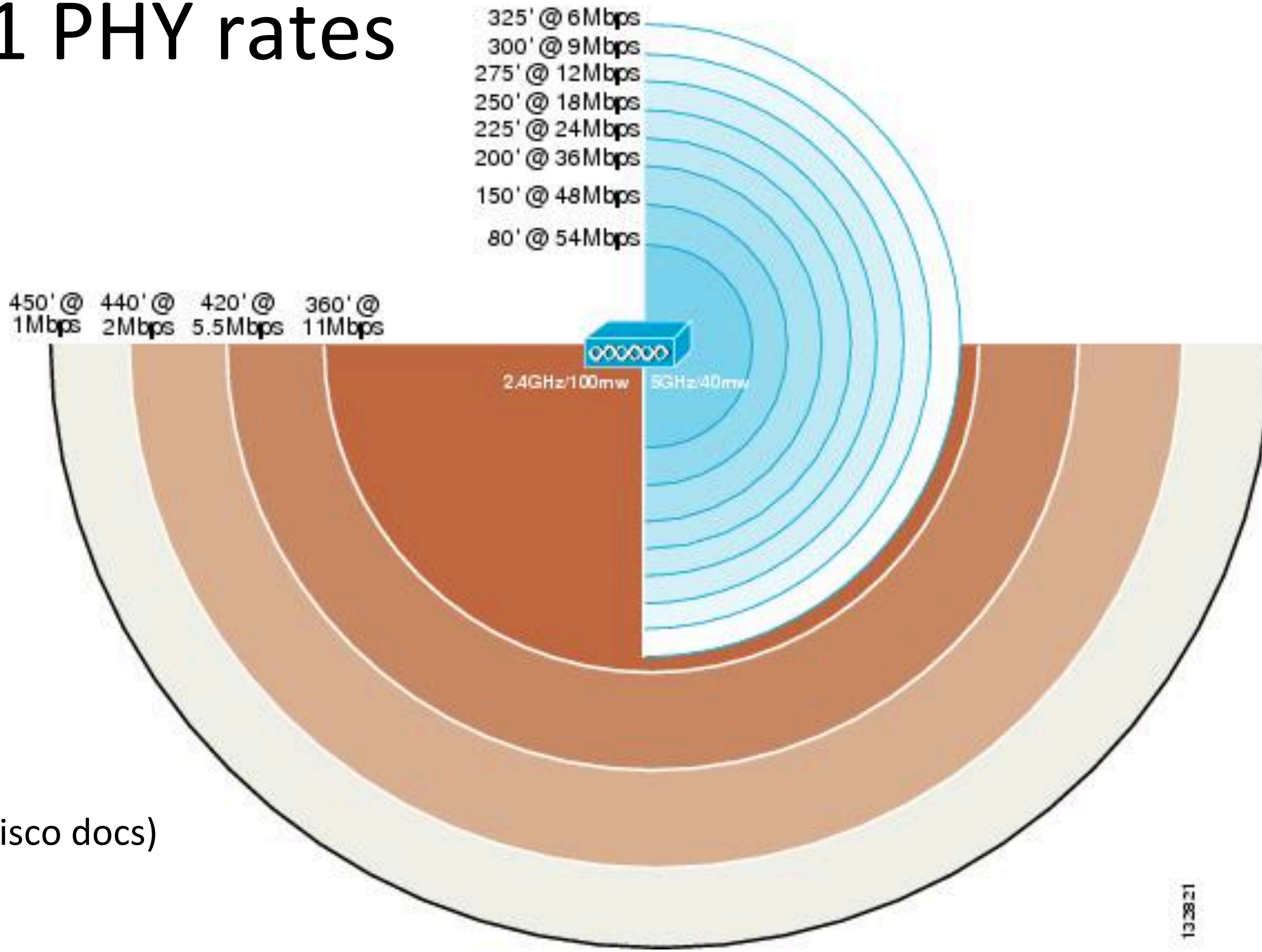
- 11 channels in 2.4 GHz (in the US)



- More channels in 5 GHz (only some shown)



802.11 PHY rates



(From Cisco docs)

- PHY rate depends on SNR (which often depends on distance from transmitter)

How to cover a space