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

- Power vs. distance
- Tx Range
- Detection
- Interference
Signal attenuation

• Energy radiates in all directions
  – Consider a sphere \( (4 \times \pi \times r^2) \)

• SINR = Signal to Interference + Noise Ratio
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 $\text{SNR}_{\text{dB}} = 36$ and the channel bandwidth is 2 MHz. The theoretical channel capacity can be calculated as

\[
\text{SNR}_{\text{dB}} = 10 \log_{10} \text{SNR} \quad \rightarrow \quad \text{SNR} = 10^{\text{SNR}_{\text{dB}}/10} \quad \rightarrow \quad \text{SNR} = 10^{3.6} = 3981
\]

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

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

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
• Express 10 mW in dBW and dBm
Channel capacity

• Shannon’ law
  – $C = B \log (1 + \text{SINR})$

• Spectral efficiency: units of b/s/Hz

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)

Data Link Layer

- Medium Access Control (MAC) sublayer
- MAC sublayer management

Physical Layer

- Physical Layer convergence procedure (PLCP) sublayer
- Physical medium Dependent (PMD) sublayer
- PHY sublayer management
- station management
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

Wired LAN

Access Points

Mobile Stations

Wired LAN
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 stations, 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

IEEE 802.x LAN

Wireless Environment and Wireless 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

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

(From Cisco docs)
How to cover a space

180 Users per floor
30 mW transmitter power
3 Access Points
60 users per AP
11 Mbps data rate

180 Users per floor
5 mW transmitter power
18 Access Points
10 users per AP
11 Mbps data rate