Wireless Networking

CS 407
One paragraph project description due NOW
The Networking Stack

The Seven Layers of OSI

- Physical Layer
- Data Link Layer
- Network Layer
- Transport Layer
- Session Layer
- Presentation Layer
- Application Layer

Transmit Data: Physical Link → Physical Layer → Data Link Layer → Network Layer → Transport Layer → Session Layer → Presentation Layer → Application Layer

Receive Data: Application Layer → Presentation Layer → Session Layer → Transport Layer → Network Layer → Data Link Layer → Physical Layer → Physical Link
What do they do?

The Seven Layers of OSI

- Physical Layer
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- Network Layer
- Transport Layer
- Session Layer
- Presentation Layer
- Application Layer

Interact with apps
Rendering content
Group of flows
End-to-end
Addressing, routing
Channel contention
Signal to bits
Why use layers?

• Separation of functions
• Modularity and providing an abstraction of a function to higher layers
  – A good software engineering practice

• Can change the implementation of one layer without affecting any other layer as long as we keep to the API exposed by the layer
What does each layer do?

- Physical – Convert bits to signals and vice versa
- Data link – How to contend for a channel, especially important in wireless environments
- Network – Addressing, routing, especially getting packets from point A to B
- Transport – mostly with reliable, in-order delivery
- Session – handle a group of flows
- Presentation – How to render content on the screen (browser)
- Application – how applications specifically communicate between endpoints
What matters?

TCP/IP Stack

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Examples

The Seven Layers of OSI

- Browser
- HTTP
- TCP, UDP
- IP
- 802.11 (WiFi)
- 802.11 (WiFi)

TCP/IP Stack

- Interact with apps
- Rendering content
- Group of flows
- End-to-end
- Addressing, routing
- Channel contention
- Signal to bits

Physical Link
TCP

- Transmission Control Protocol
- Connection-oriented
- Reliable
- Congestion Control
- Flow Control
- “End-to-end” semantics

- Source and Destination IP and port numbers
UDP

- User Datagram Protocol
- Connectionless
- Unreliable

- Source and Destination IP and port numbers
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 graph

Diagram showing:
- Tx Range
- Detection
- Interference
Signal attenuation

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

• \(\text{SINR} = \text{Signal to Interference + Noise Ratio}\)
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.
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.
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

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

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

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

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

$$C = 2 \text{ MHz} \times \frac{36}{3} = 24 \text{ Mbps}$$
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 = deciBel(s)
- dBm = 10 \log_{10} (\text{power in mW})
- dBW = 10 \log_{10} (\text{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

• Check
Spatial re-use

• Macrocell vs Microcell vs Pico/Femtocells