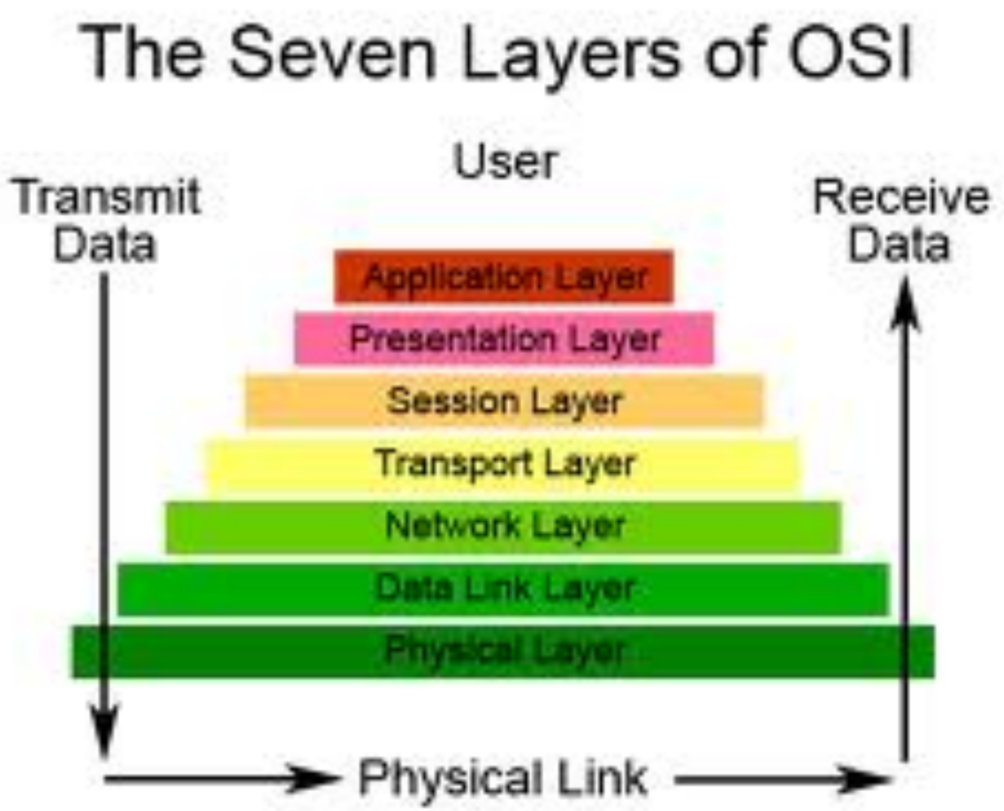
Wireless Networking

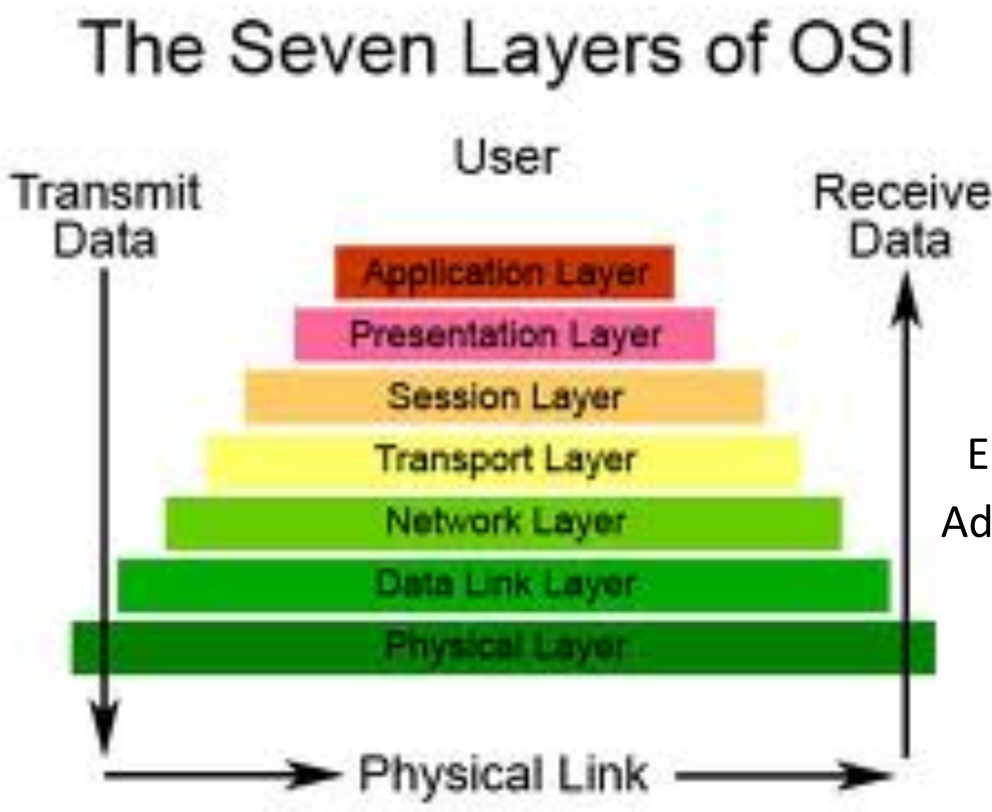
CS 407

One paragraph project description due NOW

The Networking Stack



What do they do?



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

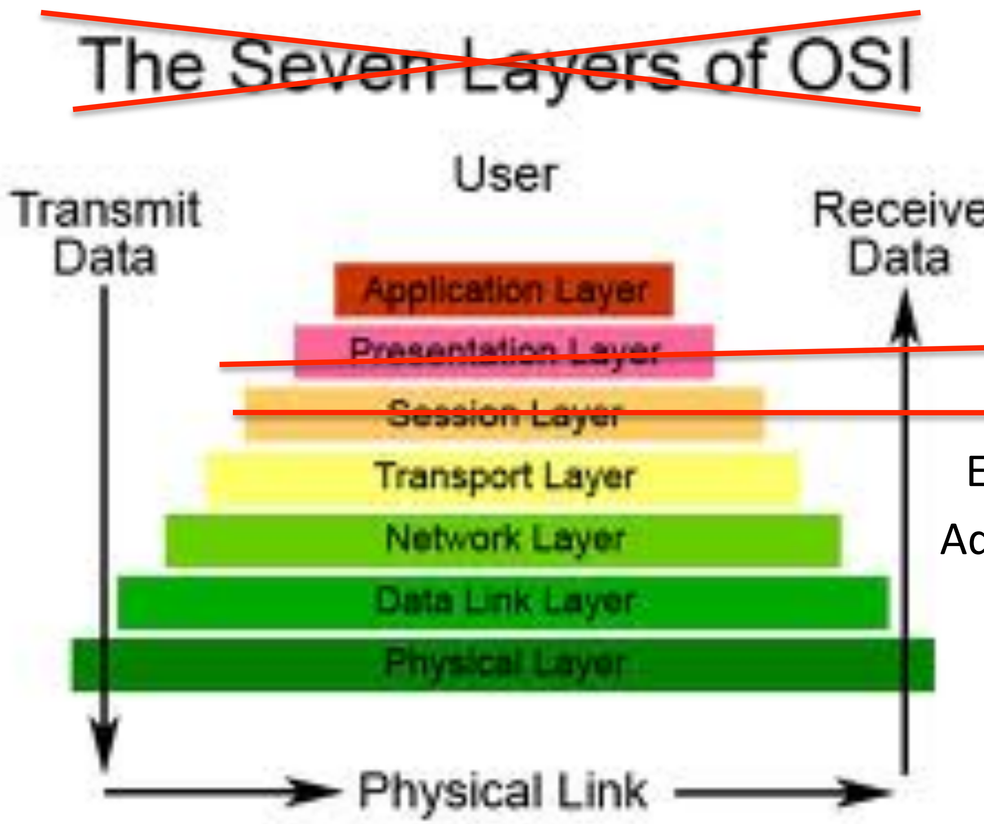
Why use layers?

- 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

Interact with apps

Rendering content

Group of flows

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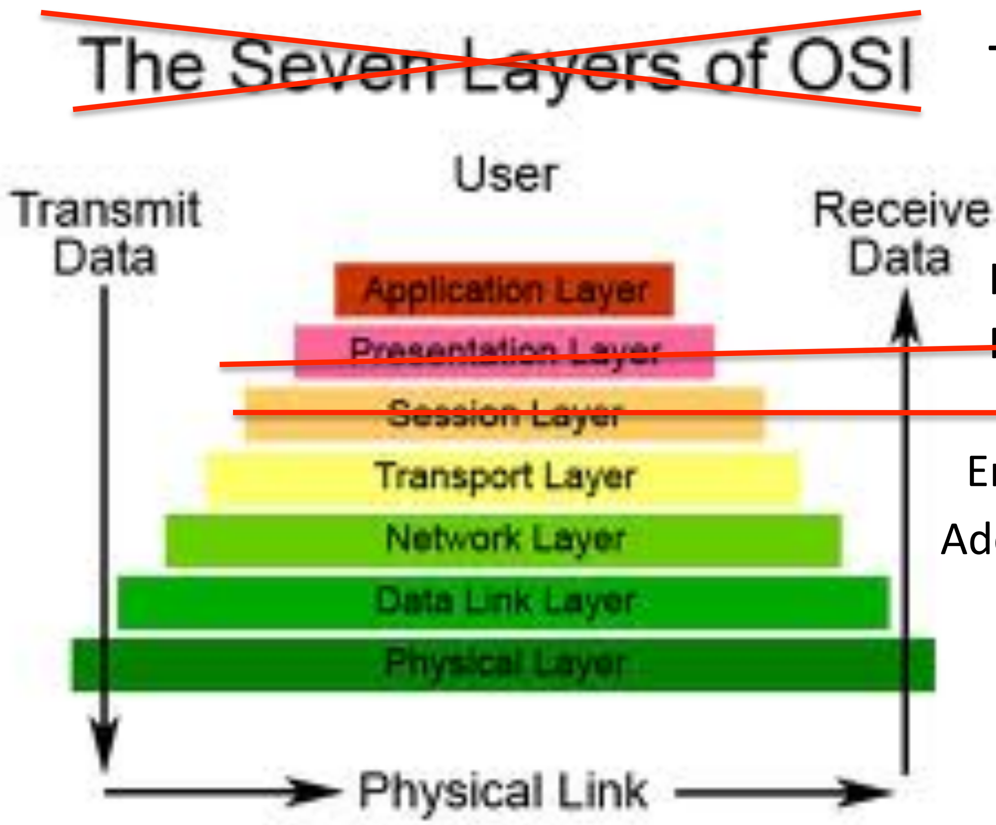
Examples

TCP/IP Stack



Browser

HTTP — Interact with apps

~~Rendering content~~

~~Group of flows~~

TCP, UDP — End-to-end

IP — Addressing, routing

802.11 (WiFi) — Channel contention

802.11 (WiFi) — Signal to bits

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

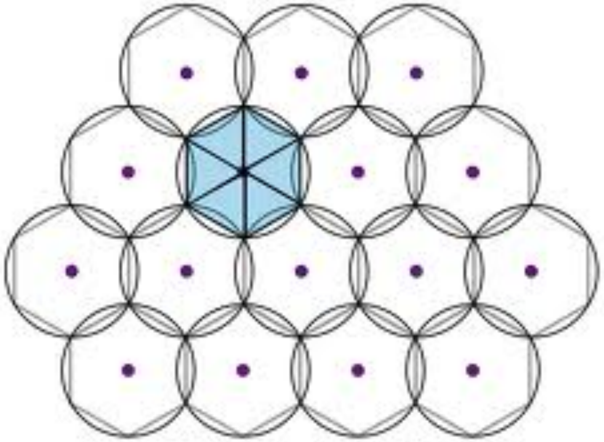
Tx power: ~0.1 W

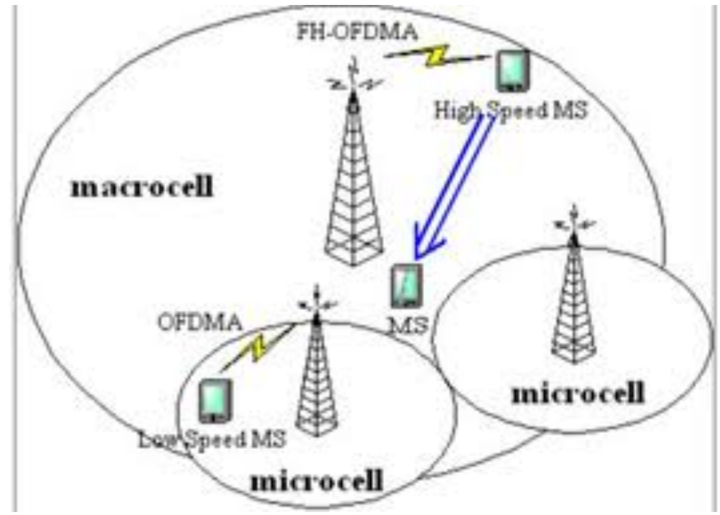
Protocols: Uncoordinated

Throughputs: ~ 1 Mbps – 100 Mbps

Cellular network planning

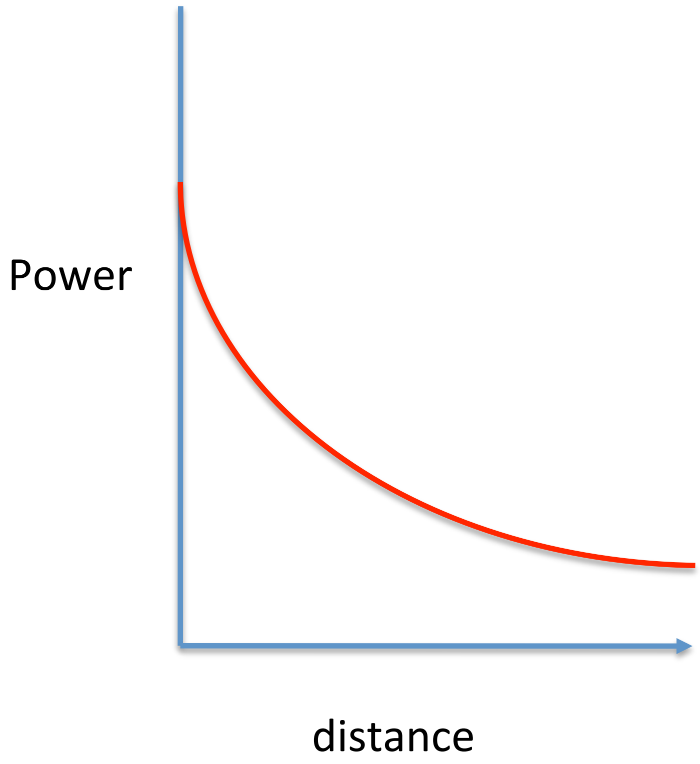
- Ideal - Hexagonal patterns

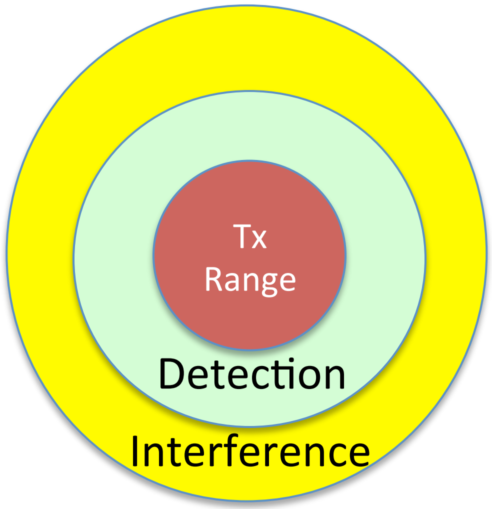




- In real life – Macro and Microcells

Signal attenuation





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