# Lecture 02-1: Challenges in Wireless Networks

CS 356R

Intro to Wireless Networks

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Please, interrupt and ask questions AT ANY TIME !

# Why go Wireless?

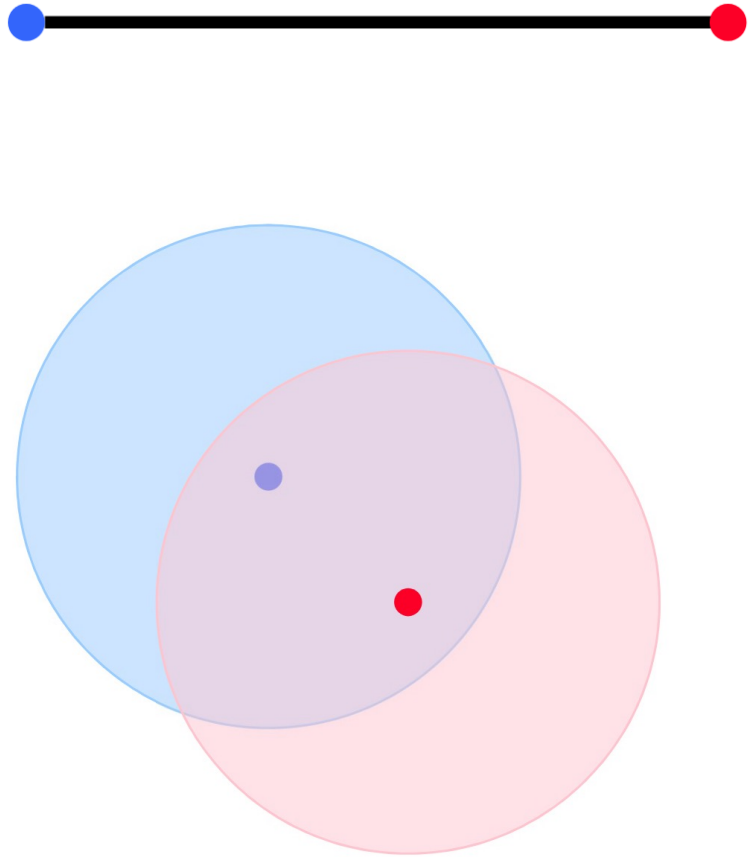
- **No need to install or maintain wires**
  - Reduce costs in offices, hotels,
  - Simplifies deployment (eg. Hotspots)
  - Last mile problem: Wireless Mesh vs wire
- **Can support mobility**
  - Users can move around office, city, airplane (continuous connection)
  - Cordless phones
  - Remote control (TV remote, garage opener)
  - WiFi and Cellular
  - Bluetooth, RFID, etc

# What is Hard about Wireless?

- In wired network links are constant, reliable and physically isolated
- No wires means none of that!
  - Link properties are extremely dynamic
  - Wireless links are error prone
  - More links in the system == more interference
  - Interference can come from outside the network

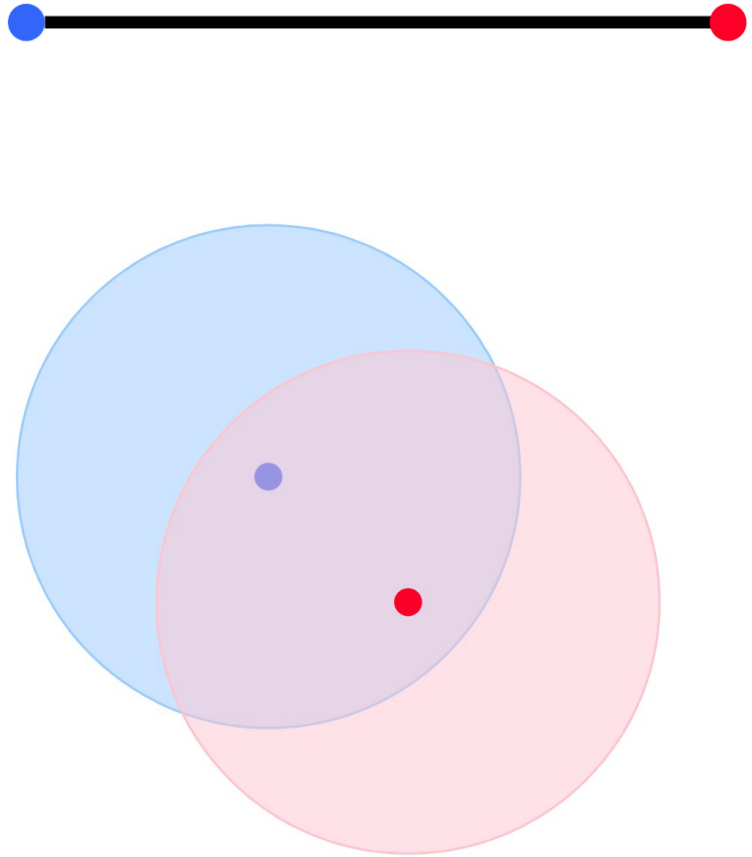
# Wireless is a shared medium while wire is an isolated one

- **Wire: signals are contained in a conductor (copper or fiber)**
  - Guides energy to destination
  - Protects signal from external signals
- **Wireless: signals are broadcasted over shared medium**
  - Energy is distributed in space
  - Signal must compete with many other signals in same frequency band

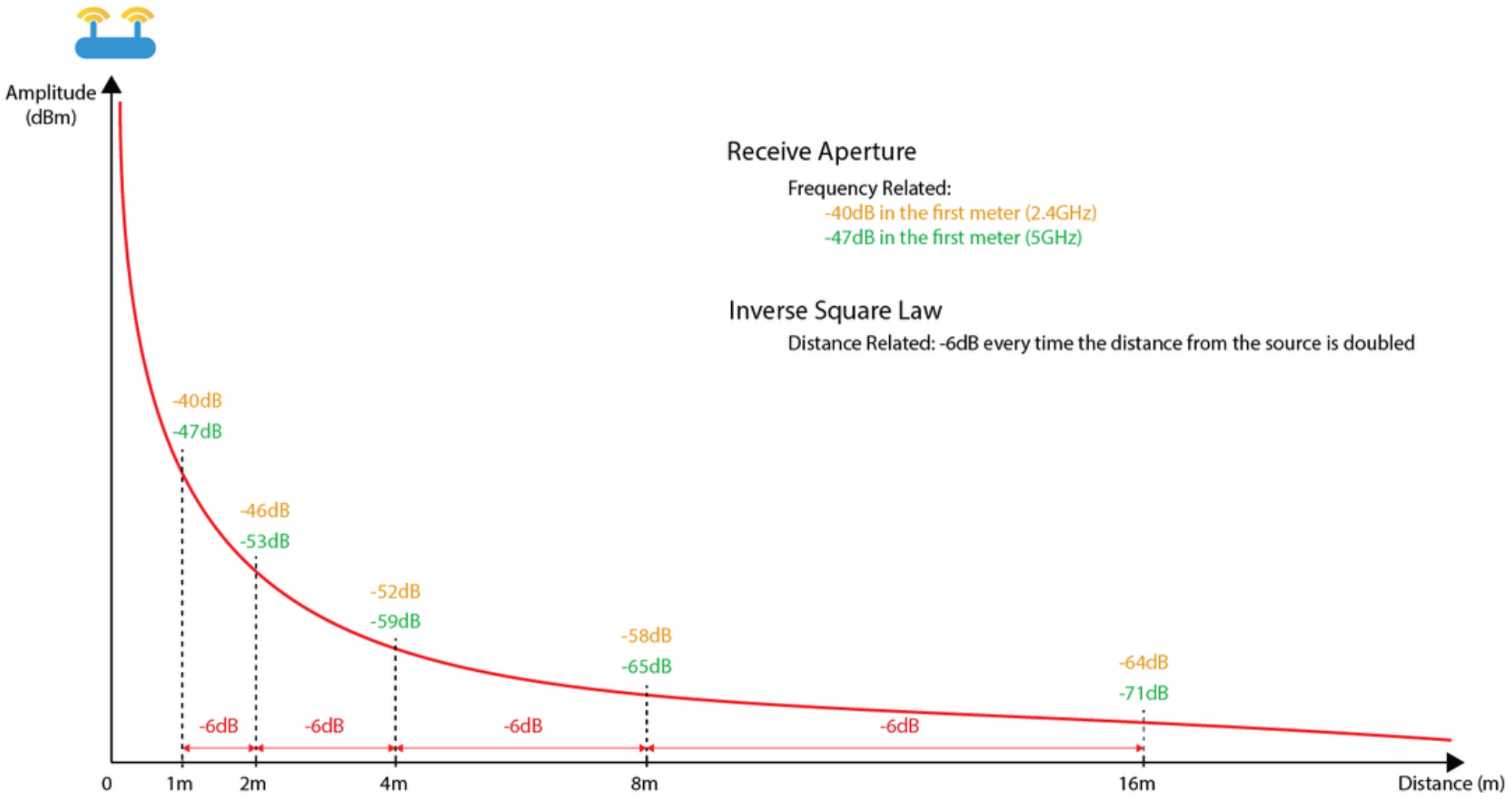


# Wireless has far greater attenuation and errors than wired

- **Wired**
  - Bit errors are $10^{-10}$ or less
  - Fiber has 1dB per km attenuation
  - -20 dBm tx → -21 dBm rx
- **Wireless**
  - Far from that
  - Wifi has 100 dB per km attenuation
  - -20 dBm tx → -120 dBm

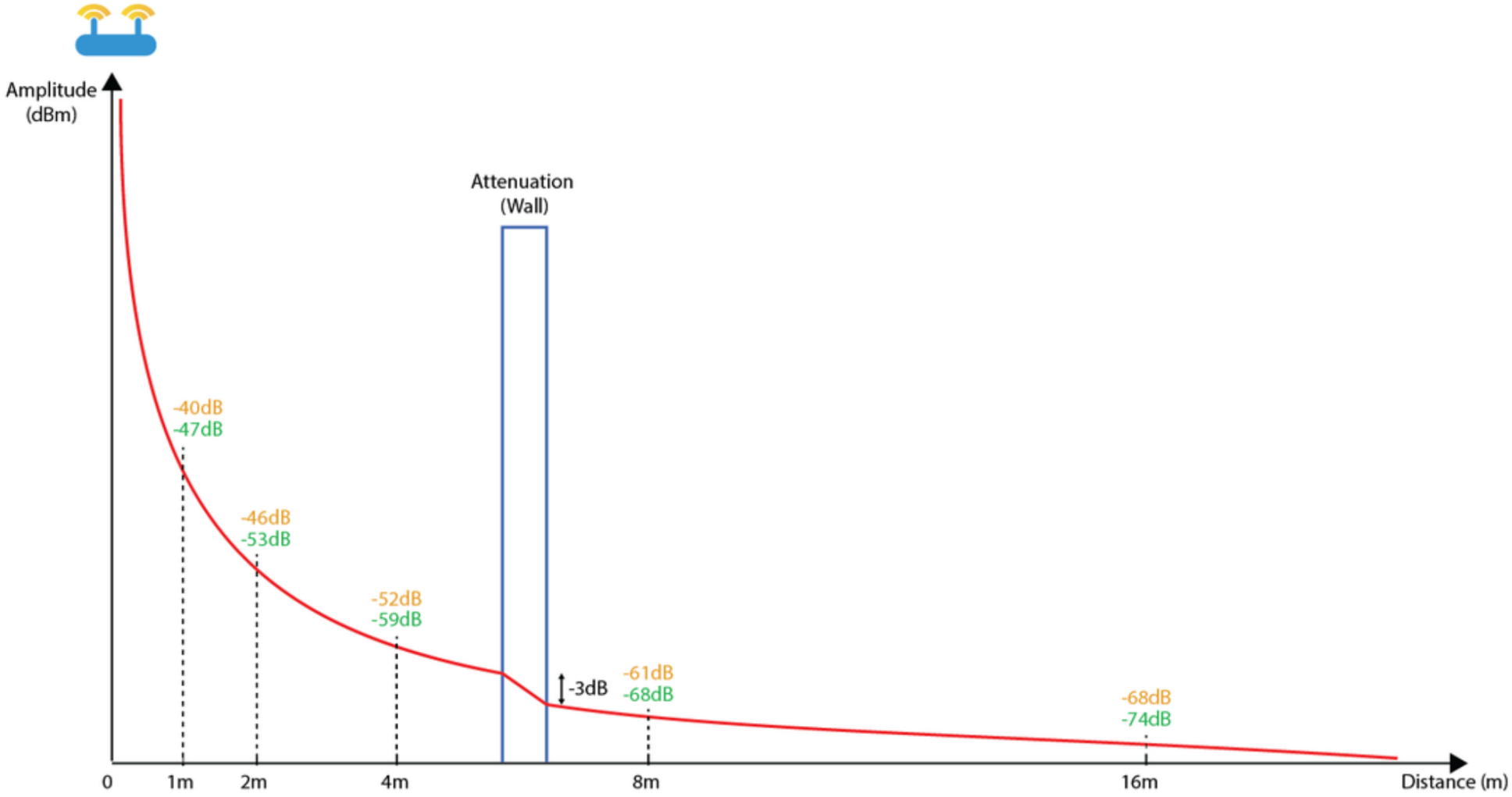


# WiFi free space attenuation




https://semfionetworks.com/blog/free-space-path-loss-diagrams/

# WiFi attenuation with a wall




https://semfionetworks.com/blog/free-space-path-loss-diagrams/

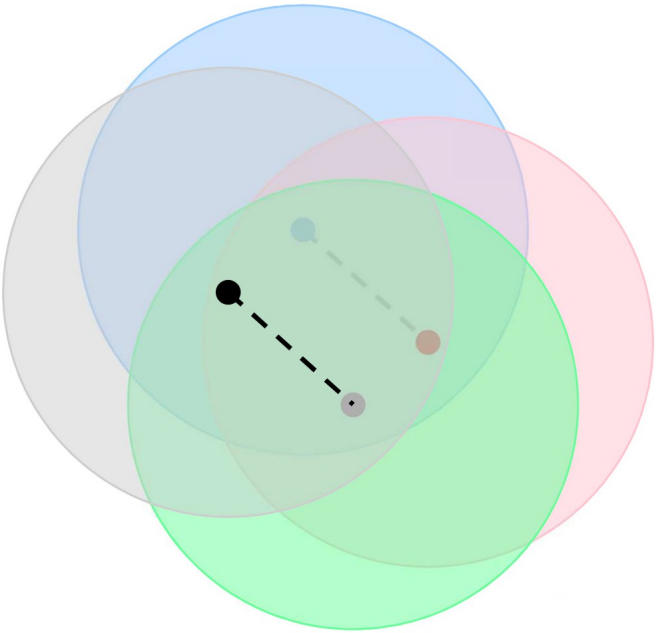
# Wireless signal

- Attenuates with distance
- Affected by noise and interference from competing signals
- Obstacles further attenuate the signal
- Probability of a successful reception depends on SINR
  - "signal to interference and noise ratio"

# How to increase network capacity?

- Wire: add more links

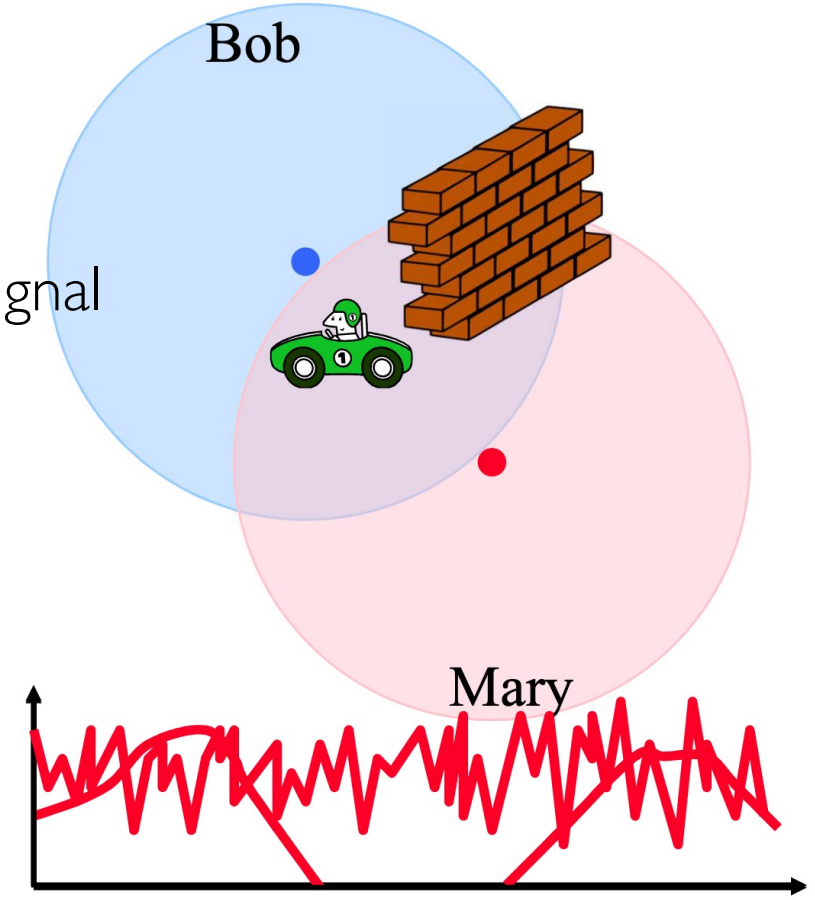
- Wireless: adding more links increase interference
  - Frequency reuse can help (subject to spatial limitation)
  - Use different frequencies (subject to frequency limitation)



**Network capacity in wireless network is fundamentally limited**

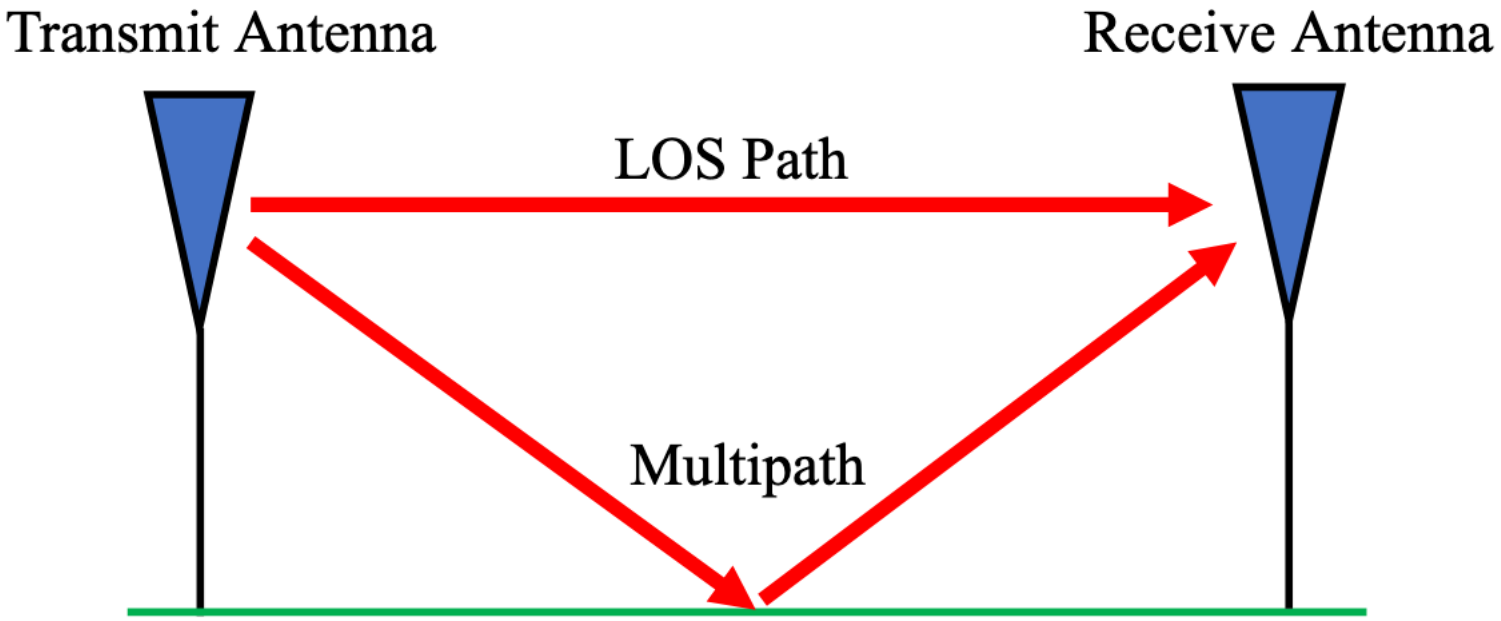
# Mobility affects link throughput

- **Quality of the transmission depends on distance and obstacles blocking "line of sight"**
  - "slow fading": channel changes slower than transmitted signal
- **Reflections off obstacles combined with mobility can cause rapid change in signal**
  - "fast fading": channel changes rapidly within a symbol

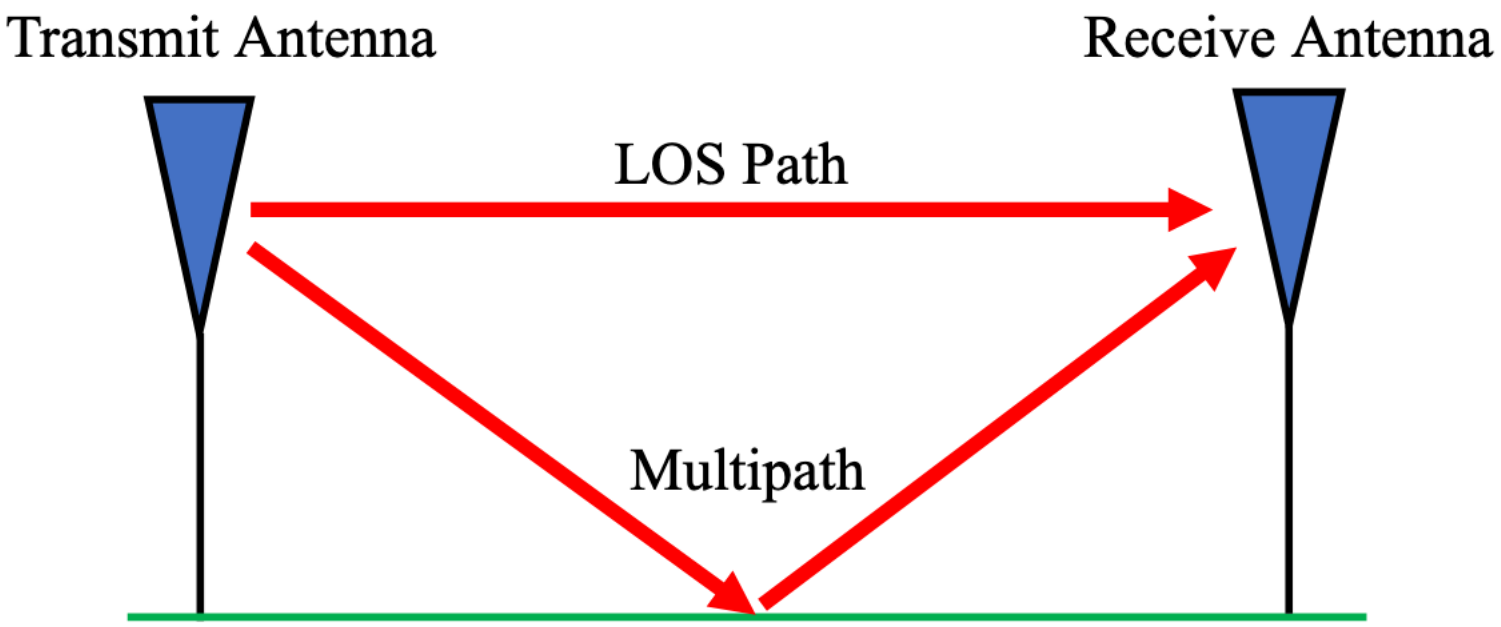


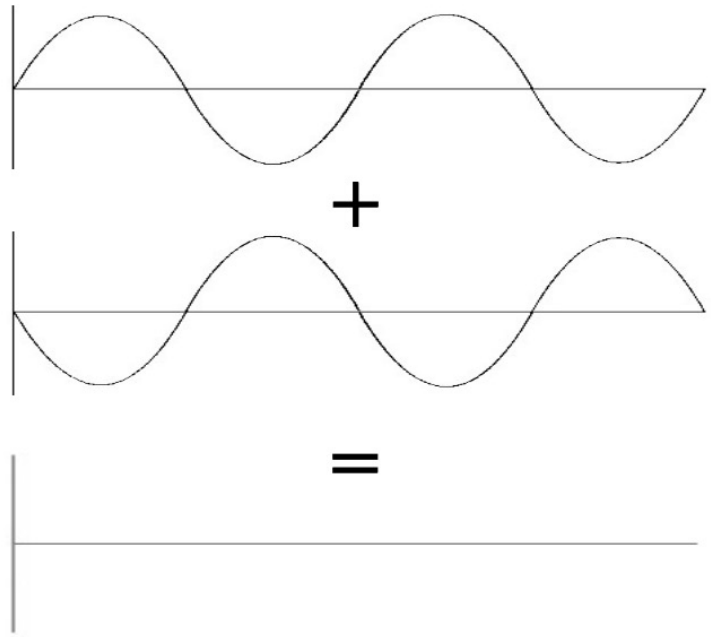

Hard to predict signal!

# Wireless channel suffers from multipath

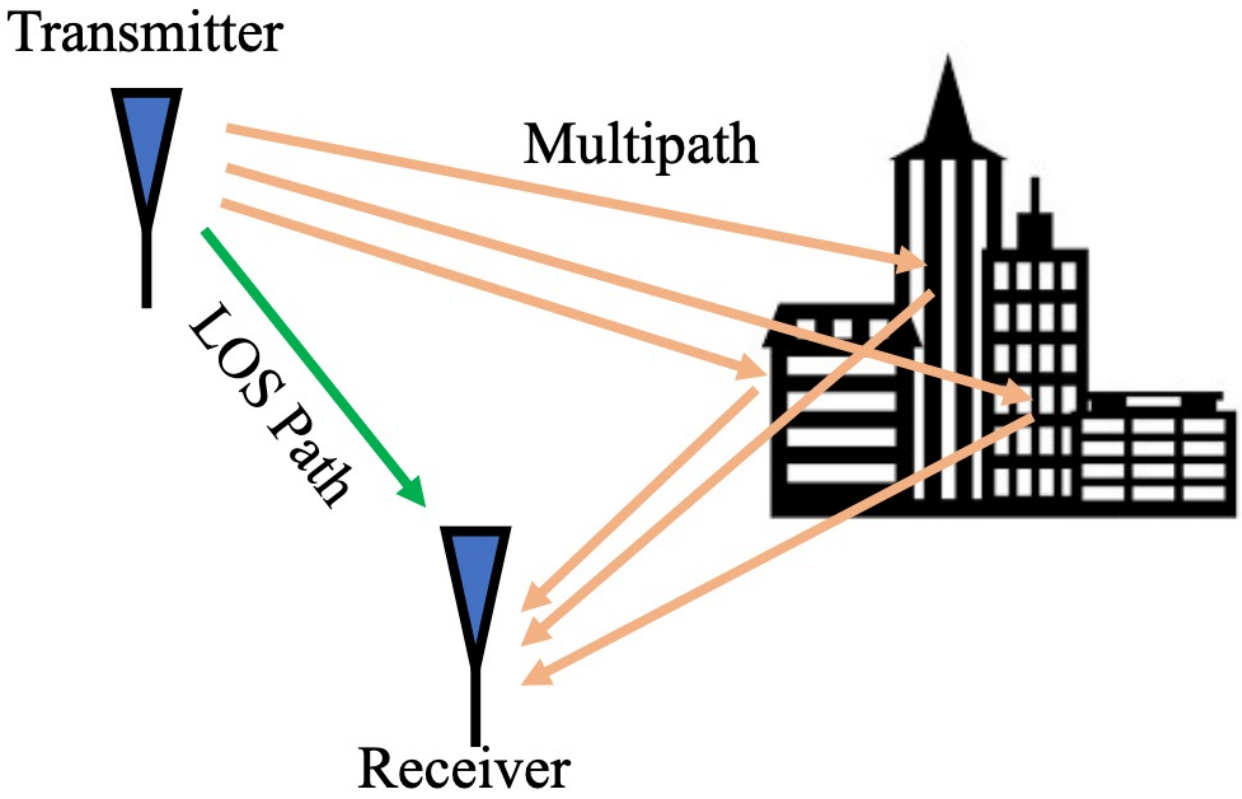


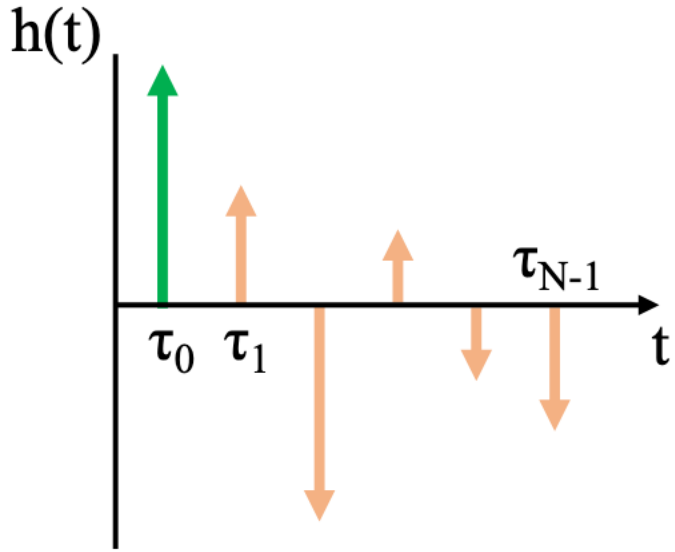
# Wireless channel suffers from multipath fading



# Multipath fading



# Wire vs Wireless

## Wire

- Physical link properties are fixed and specified in standards
- Designed for low error rates and throughput is fixed and known
- Link layer is simple and optimized for the physical layer
- Internet was designed assuming low error rates

## Wireless

- Physical link properties can change rapidly in unpredictable ways
- Error rates vary a lot and throughput is very dynamic
- How do you design an efficient link layer protocol?
- How well will higher layer protocols work?

# What does this all mean?

- **Wireless link layer protocols must optimize throughput across an unknown and dynamic transmission medium**
  - Important to understand what causes the changes

- **Wireless "links" as observed by layers 3+ will be unavoidably different from wired links**
  - Variable bandwidth and latency
  - Intermittent connectivity
  - Must adapt to changes in connectivity and bandwidth
  - Design question: Wireless-aware layer 3+ protocols?

**Understanding the physical layer is the key to making wireless networks work well**


Any questions regarding the course?

# Backup Slides

# Ways to combat challenges in wireless channel

- Modulation: sends digital data in a signal format that sends as many bits as possible for the current wireless channel
- Channel coding or error control coding: adds extra bits to a signal so that error can be detected and corrected
- Adaptive modulation and coding: dynamically adjusts the modulation and coding to current channel condition
- Equalization: conteracts multipath effects
- Multiple-input multiple-output (MIMO): leveraging multiple antennas to point signals strongly in certain directions, send simultaneous signals in multiple directions or send parallel streams of data
- Direct sequence spread spectrum …
- OFDM …

# Acknowledgement

Slides adopted from Dr. Peter Steenkiste, CMU