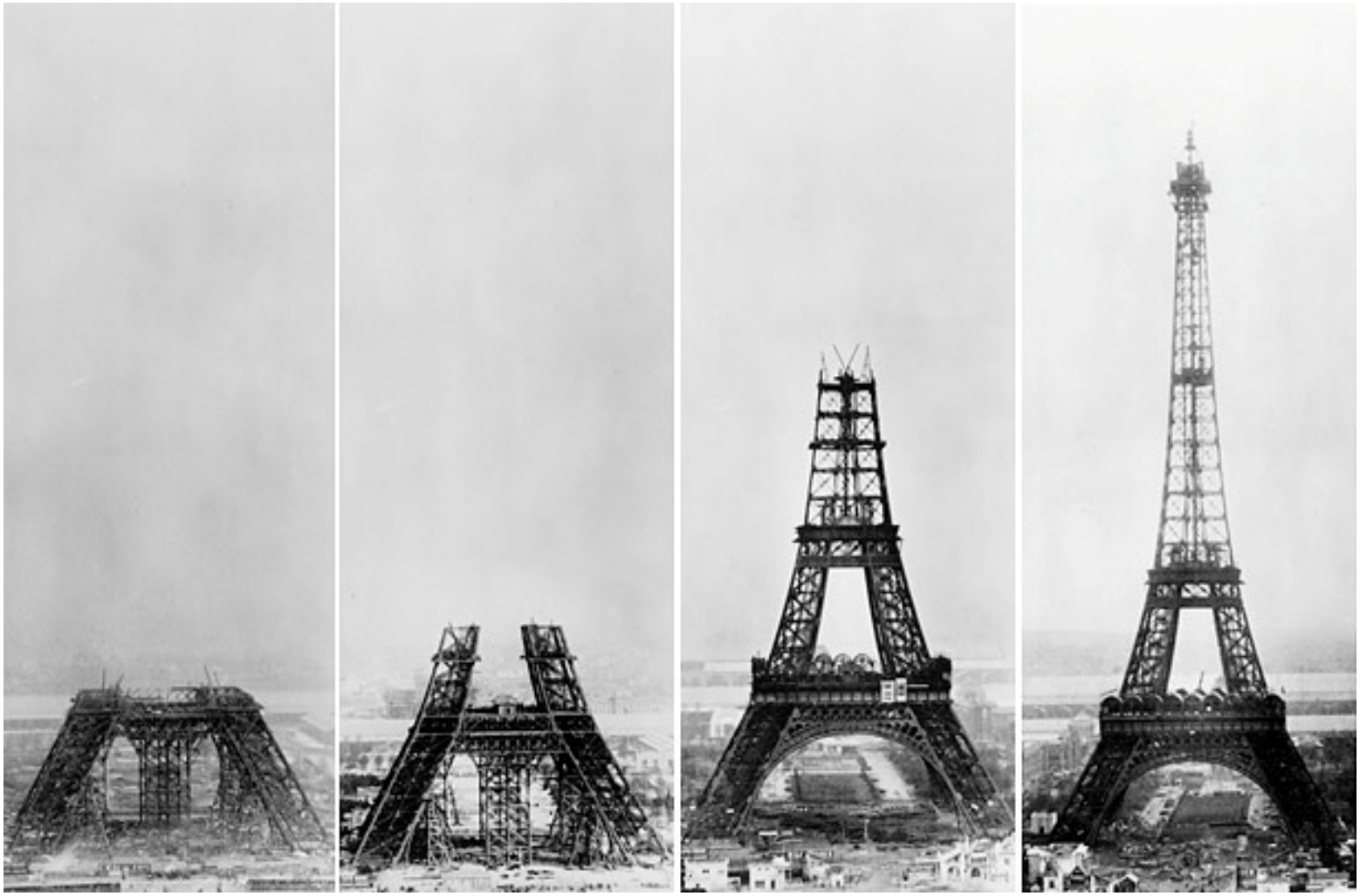
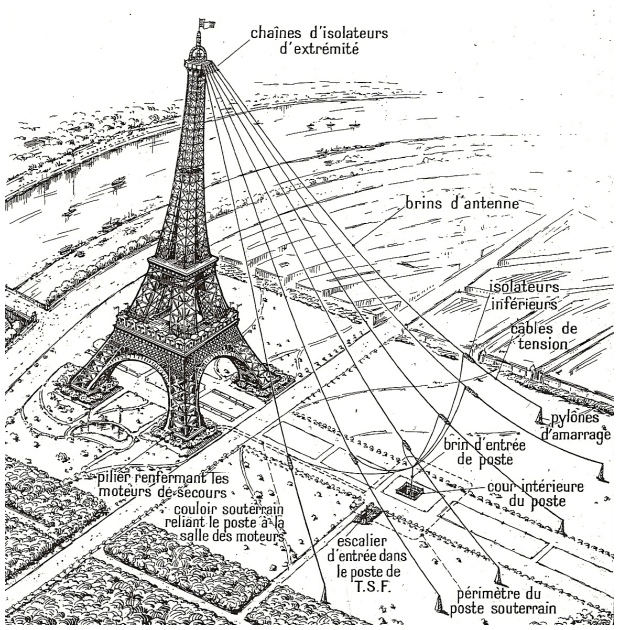
CS/ECE 439: Wireless Networking

Wireless Challenges

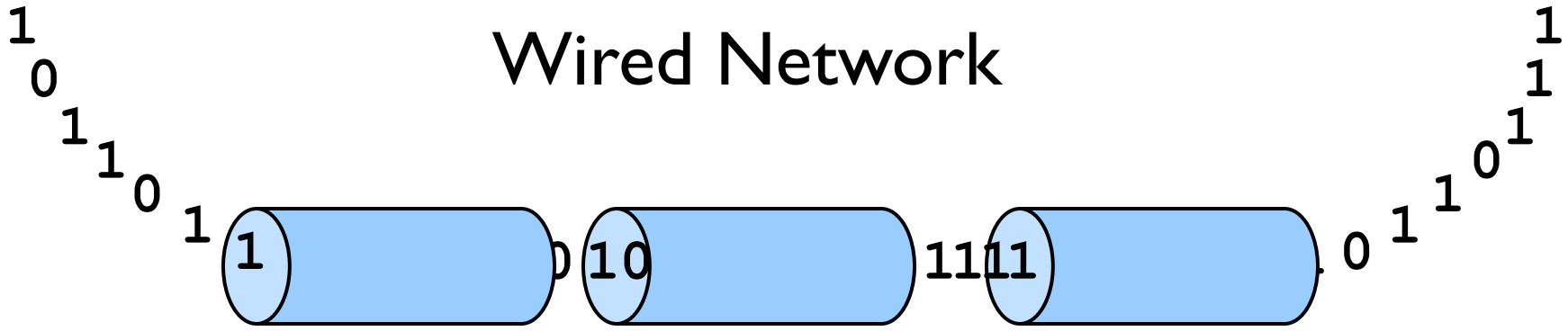
The Power of Radio



The Power of Radio



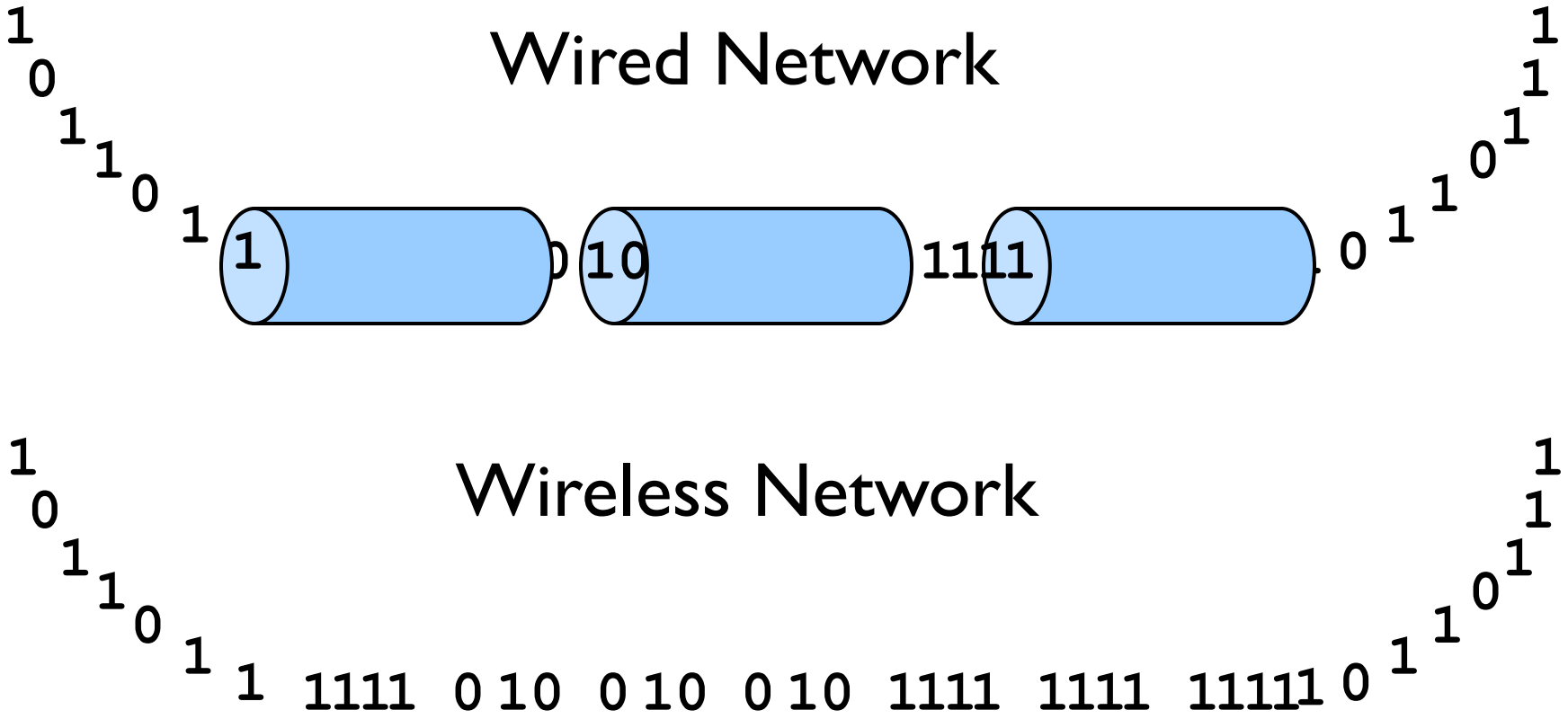
Why is wired networking challenging?



- Speed of light
- Shared infrastructure
- Things break
- Dynamic range
- Security

Getting the data through the pipes

Why is wireless networking challenging?



Same problems, but the pipes are gone!

Why use wireless?

There are no wires!

Several significant advantages

- No need to install and maintain wires
  - Reduces cost – important in offices, hotels, …
  - Simplifies deployment – important in homes, hotspots, …
- Supports mobile users
  - Move around office, campus, city, … - users get hooked
  - Remote control devices (TV, garage door, ..)
  - Cordless phones, cell phones, ..
  - WiFi, GPRS, WiMax, …

What's so hard about wireless?

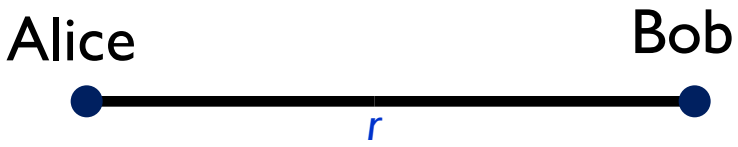
There are no wires!

- Wired networks
  - Links are constant, reliable and physically isolated
- Wireless networks
  - Links are variable, error-prone and share the ether with each other and other external, uncontrolled sources

Challenges of wireless

- Path loss
  - Signal attenuation as a function of distance
  - Signal-to-noise ratio (SNR — Signal Power/Noise Power) decreases, make signal unrecoverable
    - AKA SINR – Signal-to-Interference-Noise-Ratio
- Multipath propagation
  - Signal reflects off surfaces, effectively causing self-interference
- Internal interference (from other users)
  - Hosts within range of each other collide with one another's transmission
- External interference
  - Microwave is turned on and blocks your signal

Path Loss

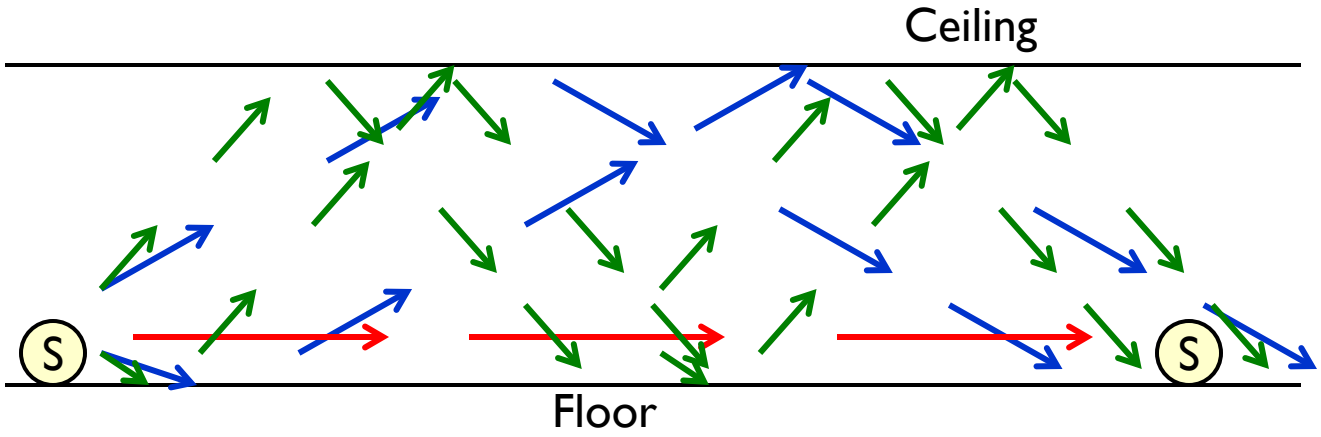


- Signal power attenuates by about ~r^2 factor for omnidirectional antennas in free space
  - r is the distance between the sender and the receiver
- The exponent in the factor is different depending on placement of antennas
  - Less than 2 for directional antennas
  - Faster attenuation
    - Exponent > 2 when antennas are placed on the ground
    - Signal bounces off the ground and reduces the power of the signal

Attenuation and Errors

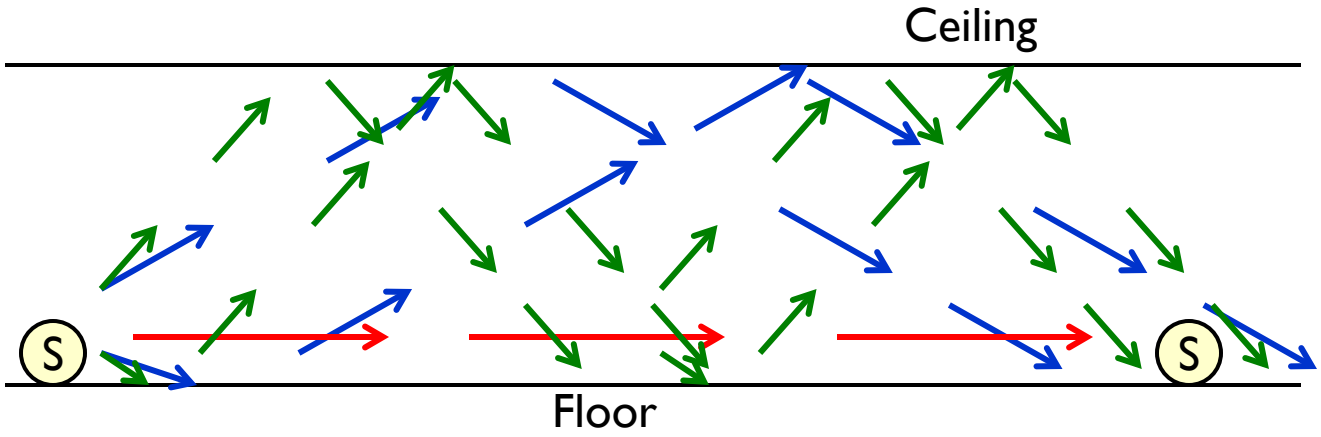
- Wired networks
  - Error rate = 10^{-10}
- Wireless networks
  - Not even close!
  - Signal attenuates with distance and is affected by noise
  - Probability of a successful reception depends on SINR = S/I+N
  - Modulation and coding schemes introduce redundancy to allow for decoding

Multipath Effects



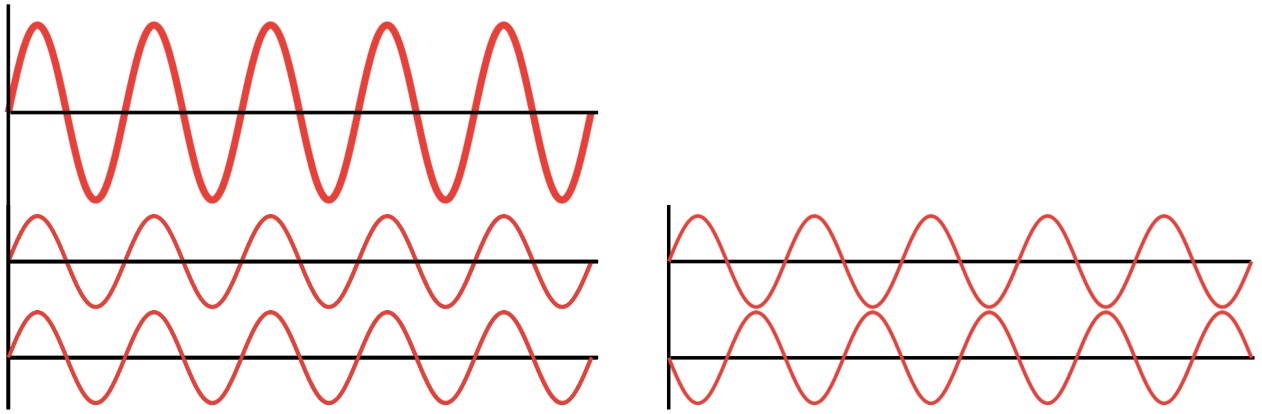
- Signals bounce off surfaces and interfere with one another
- What happens to the signals that take different paths?
  - Different distance = different attenuation = different signal strength

Multipath Effects



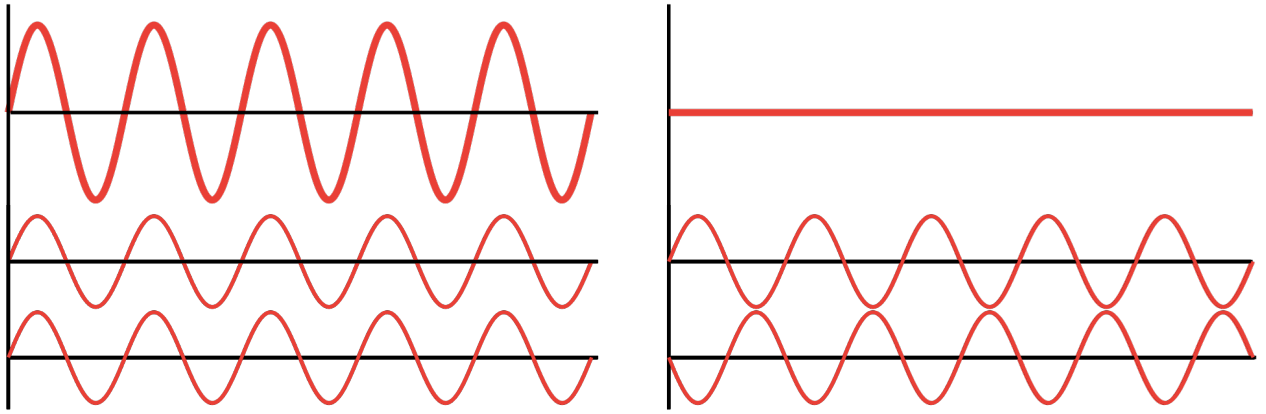
- Signals bounce off surfaces and interfere with one another
- What happens to the phase of the different signals?
  - Different distance = different travel time = different place in received signal

Multipath Effects



- What if signals are still in phase at the receiver?
  - In phase signals enhance the received signal strength!

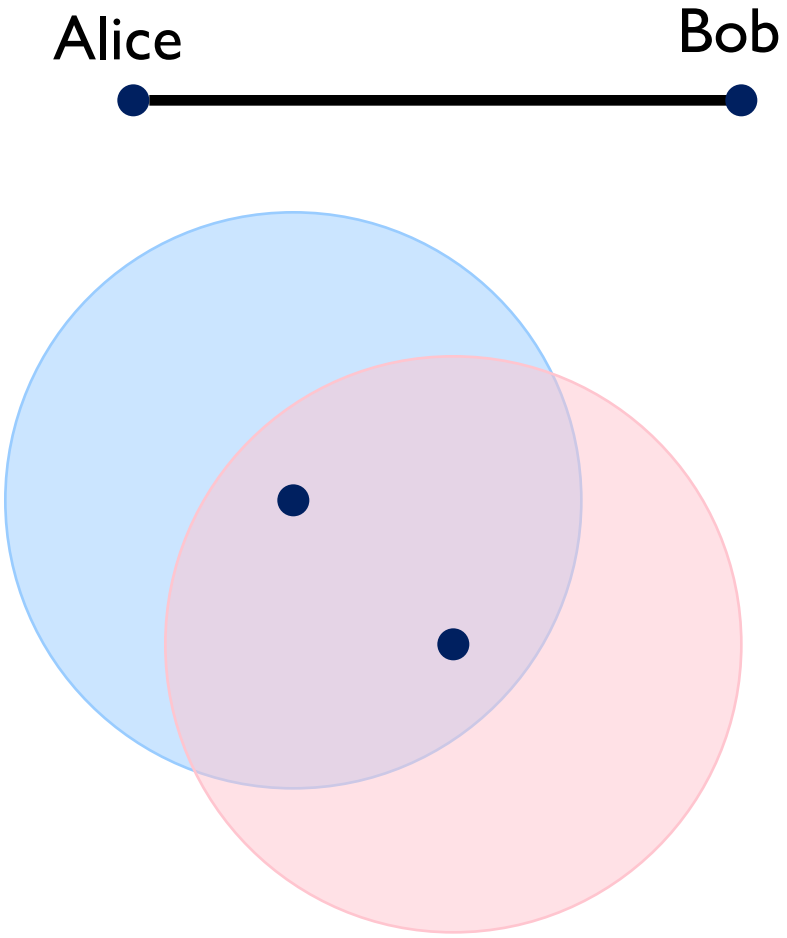
Multipath Effects



- What if signals are out of phase?
  - Orthogonal signals cancel each other and nothing is received!

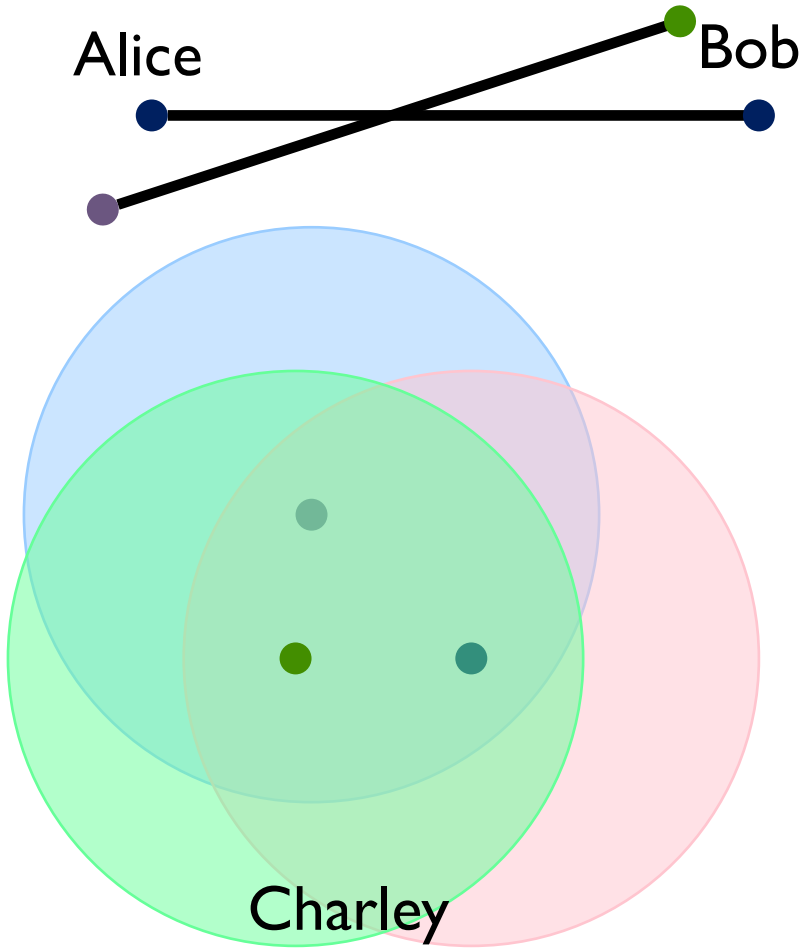
Wireless is a shared medium

- Transmitters broadcast
- Devices can operate either in transmit or receive mode
  - Current research is trying to overcome this limitation
- How do you coordinate access to the medium?

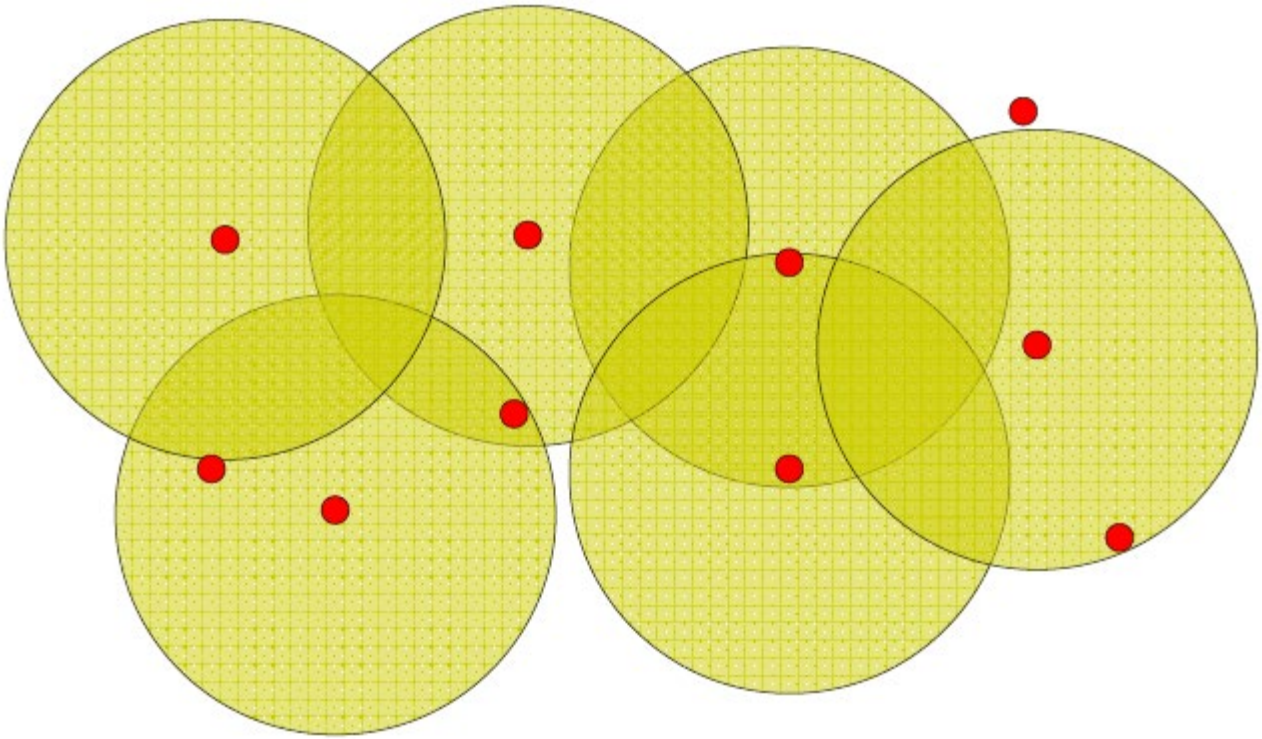


Interference

- Noise is naturally present in the environment from many sources
- Interference can be from other users or from malicious sources
- Impacts the throughput users can achieve



What is a Wireless “Link”, really?



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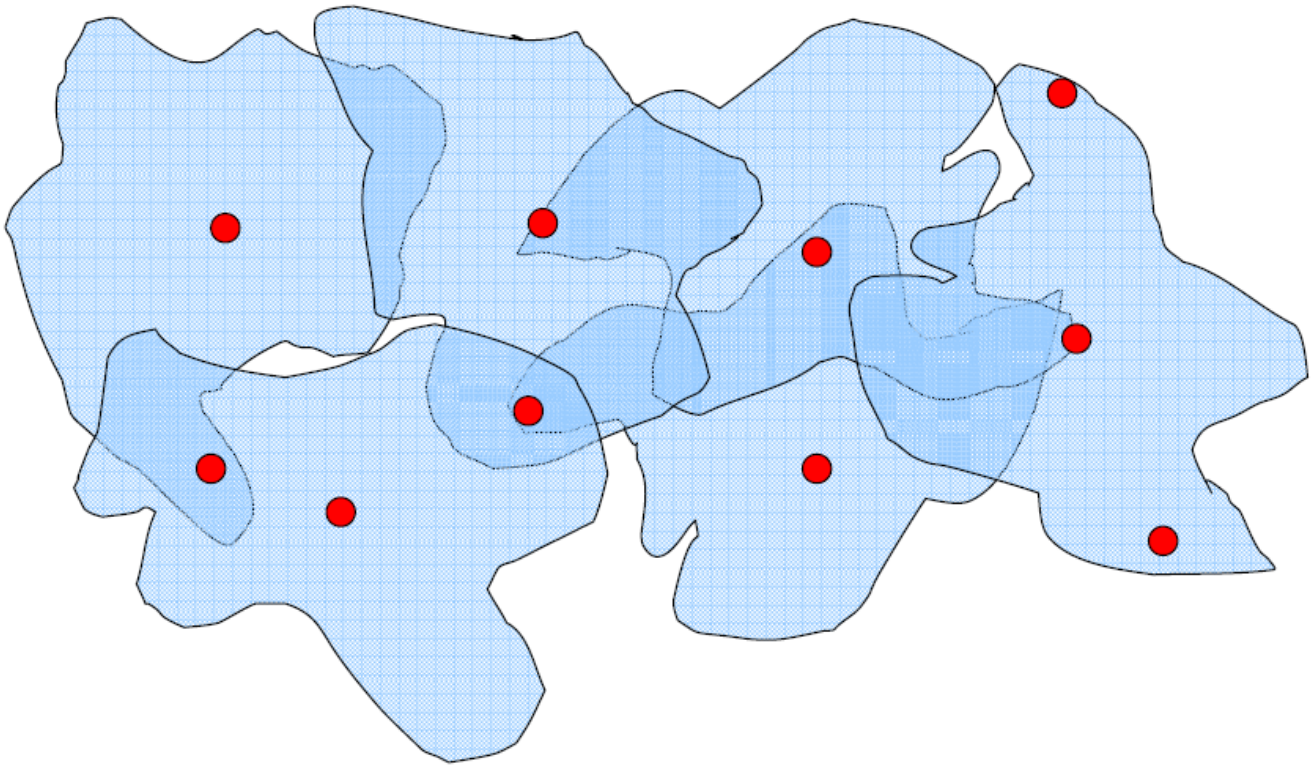

Wireless Bit Errors

- The lower the SNR (Signal/Noise) the higher the Bit Error Rate (BER)
- How can we deal with this?
  - Make the signal stronger
- Why is this not always a good idea?
  - Increased signal strength requires more power
  - Increases the interference range of the sender, so you interfere with more nodes around you
- Error correction can correct some problems

Spread Spectrum

- Direct Sequence Spread Spectrum
  - Spread the signal over a wider frequency band than required
  - Originally designed to thwart jamming
  - Original 802.11 uses 83 MHz in 2.4 GHz band
- Frequency-Hopped Spread Spectrum
  - Uses 80 1MHz sub-bands in 2.4 GHz band
  - Transmit over a random sequence of frequencies

Spread Spectrum

- Direct Sequence Spread Spectrum
  - Spread th
  - Originall
  - Original 8
- Frequency
  - Uses 80
  - Transmit

- Frequency hopping had many inventors
  - 1942: actress Hedy Lamarr and composer George Antheil patented Secret Communications System
  - Piano-roll to change between 88 frequencies, and was intended to make radio-guided torpedoes harder for enemies to detect or to jam
  - The patent was rediscovered in the 1950s during patent searches when private companies independently developed Code Division Multiple Access, a civilian form of spread-spectrum

Communication Characteristics

- Rate
  - Defines the communication speeds
- Frequency
  - Defines the behavior in the physical environment
- Range
  - Defines the physical communication area
- Power
  - Defines the cost in terms of energy

Communication Characteristics

- Rate
  - Defines the communication speeds
  - Channel Bandwidth
    - Defined by the specifications of the technology
  - Available Bandwidth
    - Defined by the current use of the communication channel
      - Channel competition – MAC layer
      - Bandwidth competition – Transport layer

Communication Characteristics

- Frequency/signal characteristics
  - Defines the behavior in the physical environment
    - Does the signal go through walls?
    - Is the signal susceptible to multipath fading?
  - Challenge
    - Many technologies use the same frequency

Communication Characteristics

- Range
  - Defines the physical communication area
  - May be affected by buildings, walls, people
  - May be affected by distance

Communication Characteristics

- Power
  - Defines the cost in terms of energy
  - Power can be adapted to save energy
    - Inversely affects range

Communication Characteristics

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Everything is inter-related!

Medium Access Control

- Different transmitters/receivers use:
  - Different frequencies
    - FDMA – Frequency Division Multiple Access
  - Different time slots
    - TDMA – Time Division Multiple Access
  - Different codes
    - CDMA – Code Division Multiple Access
  - Randomly access the medium
    - CSMA/CA – Carrier Sense Multiple Access/Collision Avoidance
- Main goal: avoid collisions while making efficient use of the medium

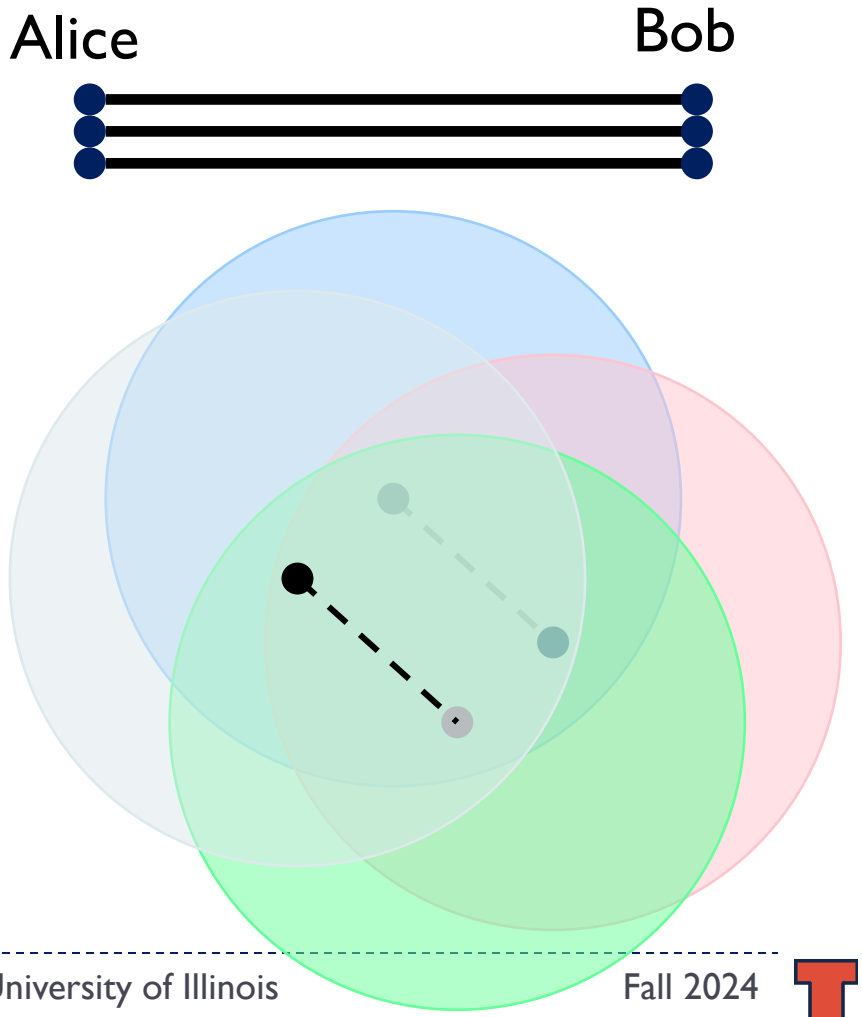
Wireless Losses

- Can be due to
  - Signal errors that lead to a packet that cannot be decoded

  OR
  - Corruption of the transmitted information due to collisions, SINR=S/(N+I) too low
- Understanding the reason behind a loss requires cross-layer information
  - Is it PHY?
  - Is it MAC?
- Information required by more than one layer

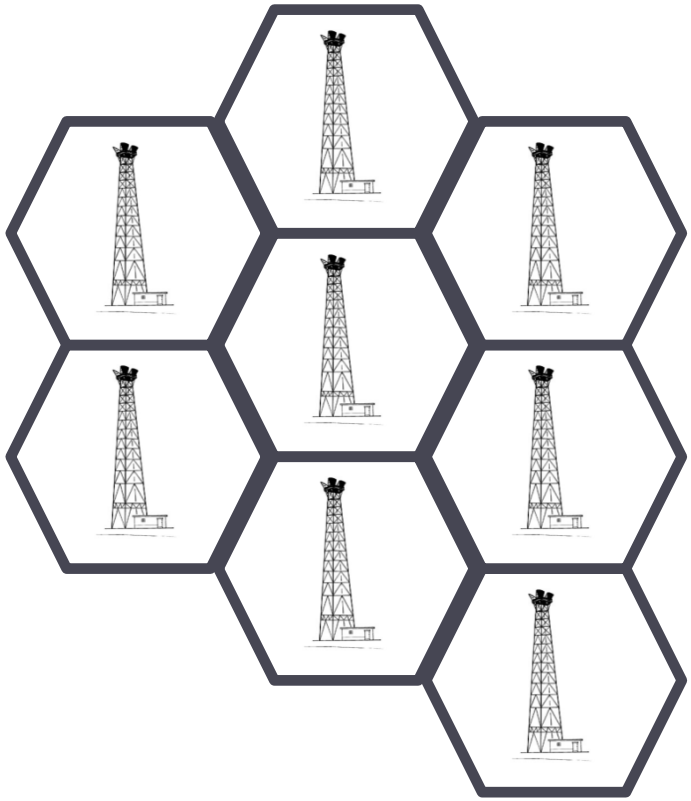
How Do We Increase Network Capacity?

- Easy to do in wired networks: simply add wires
  - Fiber is especially attractive
- Adding wireless "links" increases interference.
  - Frequency reuse can help … subject to spatial limitations
  - Or use different frequencies … subject to frequency limitations
- The capacity of the wireless network is fundamentally limited



Cellular architecture

- Deploy cells
  - Different frequencies
- Challenge
  - Provide consistent service even at the edge of the cell
  - Deal with intensity given the capacity of the cell

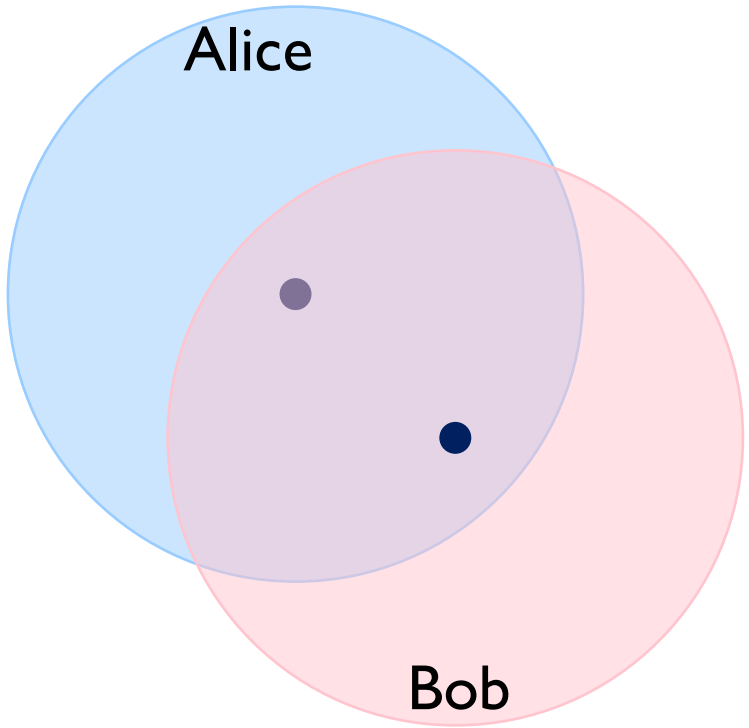


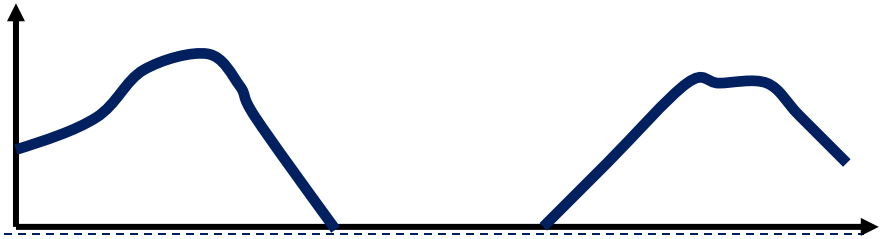
Wi-Fi architecture

- Could be chaotic or managed
- Limited spectrum – service guarantees hard to make
- Channel assignment, power control

Mobility Affects the Link Throughput

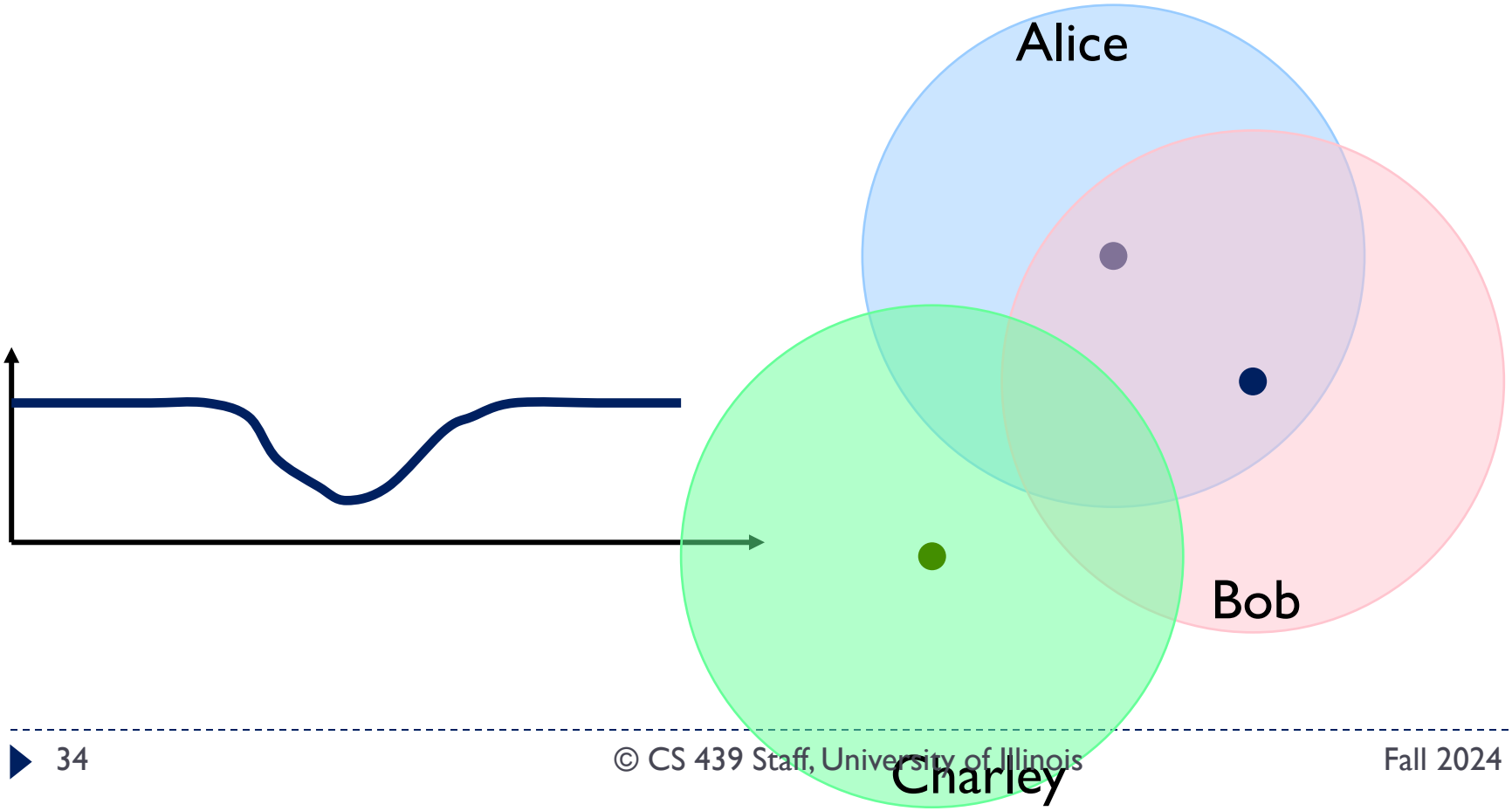
- Quality of the transmission depends on distance and other factors
  - Covered later in the course
- Affects the throughput mobile users achieve
- Worst case is no connectivity!





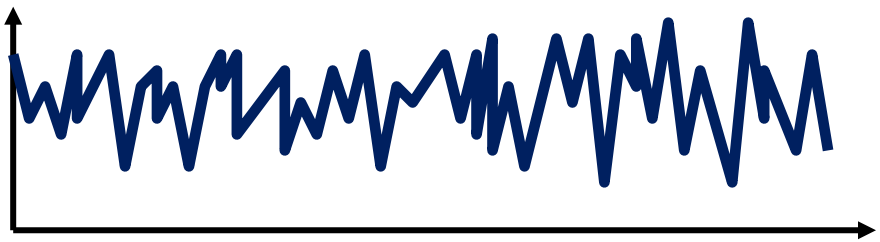
Mobility is an Issue even for Stationary Users

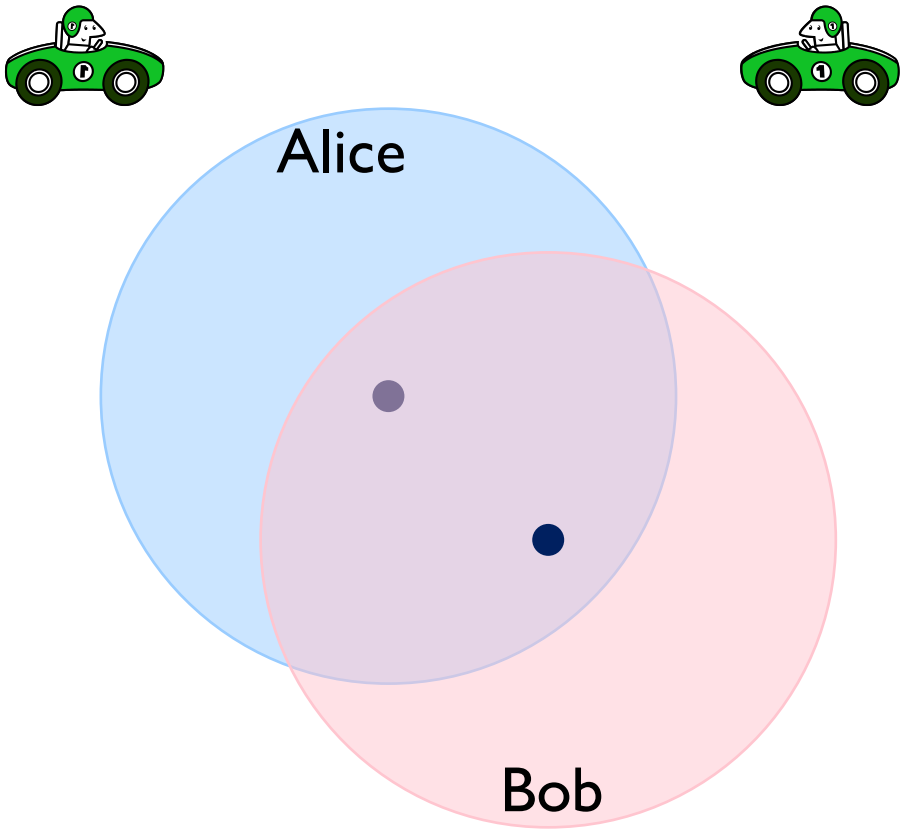
- Mobile people and devices affect the transmission channel of stationary nodes



And It Gets Worse …

- The impact of mobility on transmission can be complex
- Mobility also affects addressing and routing





Wireless environments: a very naïve model

- The world is flat
- A radio's transmission area is circular
  - Signal strength is a simple function of distance
- All radios have equal range
- If I can hear you, you can hear me (symmetry)
- If I can hear you at all, I can hear you perfectly
- Not all that different from wires, with broadcast communication added