CS/ECE 439: Wireless Networking

Survey and Projects

Survey and Class Presentation

- ▸ **What is a survey?**
  - ▸ A broad, structured overview of a specific area.
- ▸ **When would this help me?**
  - ▸ You are working for a company that is exploring a new wireless technology or market
  - ▸ You could be asked to prepare a 30 minute presentation to introduce to area
  - ▸ You are writing your first paper on a research project you just finished
  - ▸ You need to write a short related work section that includes a survey of existing work in the areas relevant to your research

Survey and Class Presentation

‣ **What isn't a survey?**

- ‣ Survey != set of paper summaries
  - ‣ Survey should present the "big picture" using the papers as examples
- ‣ Critical thinking
  - ‣ Published != 100% correct!

‣ **Resources**

- ‣ Cite your sources!
- ‣ Excessive reuse or un-cited copied text = plagiarism

Fall 2020

Survey and Class Presentation

- **Deliverables**
  - ~25 minute presentation
  - Questions during and after presentation

- **Milestones**
  - October 2
    - Team information and proposed topic
  - Monday office hours the week before your presentation
    - Draft slides for feedback
    - Mandatory meeting with me
    - Doodle pool will be posted to select presentation days

© CS 439 Staff, University of Illinois

Class Project

▸ **Considerations**
  ▸ Concrete outcomes
  ▸ Learn something
▸ **You should have the necessary background to complete the project**
  ▸ Do not attempt a project at the physical layer if your only background in this area is just the few lectures in this course.
  ▸ Do not attempt a project that involves kernel or driver hacking if you have limited programming experience.
▸ **The project needs to be feasible**
  ▸ Must be reasonable given the time available
  ▸ Access to the necessary infrastructure
▸ **Build a team with diverse skills to cover theoretical and practical topics**

© CS 439 Staff, University of Illinois

Class Project - Deliverables

- **Project Proposal**
  - ~ 2-3 pages
  - The more information you give, the more feedback you will get
- **Due September 25**
- **Include**
  - Names of team members
  - Project topic and title
  - Description of activities that will be performed as part of the project
  - Expected results
  - Include at least five related papers with standard bibliographic references
  - Equipment and resources needed
  - Project plan
  - Rough list of milestones, responsibilities of team members, qualifications

© CS 439 Staff, University of Illinois   Fall 2020

Class Project - Deliverables

▸ **Project Checkpoint 1 – Extended Project Proposal**
  ▸ Due October 16
  ▸ Approximately five pages, normal font, normal margins
  ▸ Mandatory project meetings

▸ **Include**
  ▸ Progress so far, what was completed, any results
  ▸ Problems encountered
  ▸ Changes in the project plan
  ▸ Build on initial proposal
  ▸ Focus on challenges and your approach.
  ▸ Why is your problem is interesting?
  ▸ Limitations of current approaches.
  ▸ Approach and evaluation plan

© CS 439 Staff, University of Illinois

Class Project - Deliverables

- ## Checkpoint 2 – Status Report
  - Due November 13
  - Build on your extended proposal
  - Indicate any changes to your approach to your research project
  - Include implementation details and initial results
  - Mandatory projects meetings

© CS 439 Staff, University of Illinois

Class Project - Deliverables

- **Final Project**
  - Due December 9
  - 12-15 pages
    - Normal fonts (10 point), Normal margins (an inch each side), Normal sized figures
  - SPELLCHECK and organize references
- **Bring it all together**
  - What is the problem
  - Why is this problem important?
  - How are you going to solve/evaluate this problem?
  - What is different from other people's work?
  - What are your contributions?

Fall 2020

Class Project - Deliverables

▸ **Final Project**

- ▸ Content suggestions
  - ▸ Abstract: (1/4 page)
  - ▸ Intro: (1 page)
  - ▸ Motivation and background: (2 - 3 pages)
  - ▸ Approach: (1 - 2 pages)
  - ▸ Evaluation/Implementation: (3 - 4 pages)
  - ▸ Conclusions and future directions: (1/2 page)
  - ▸ References (1/2 page)
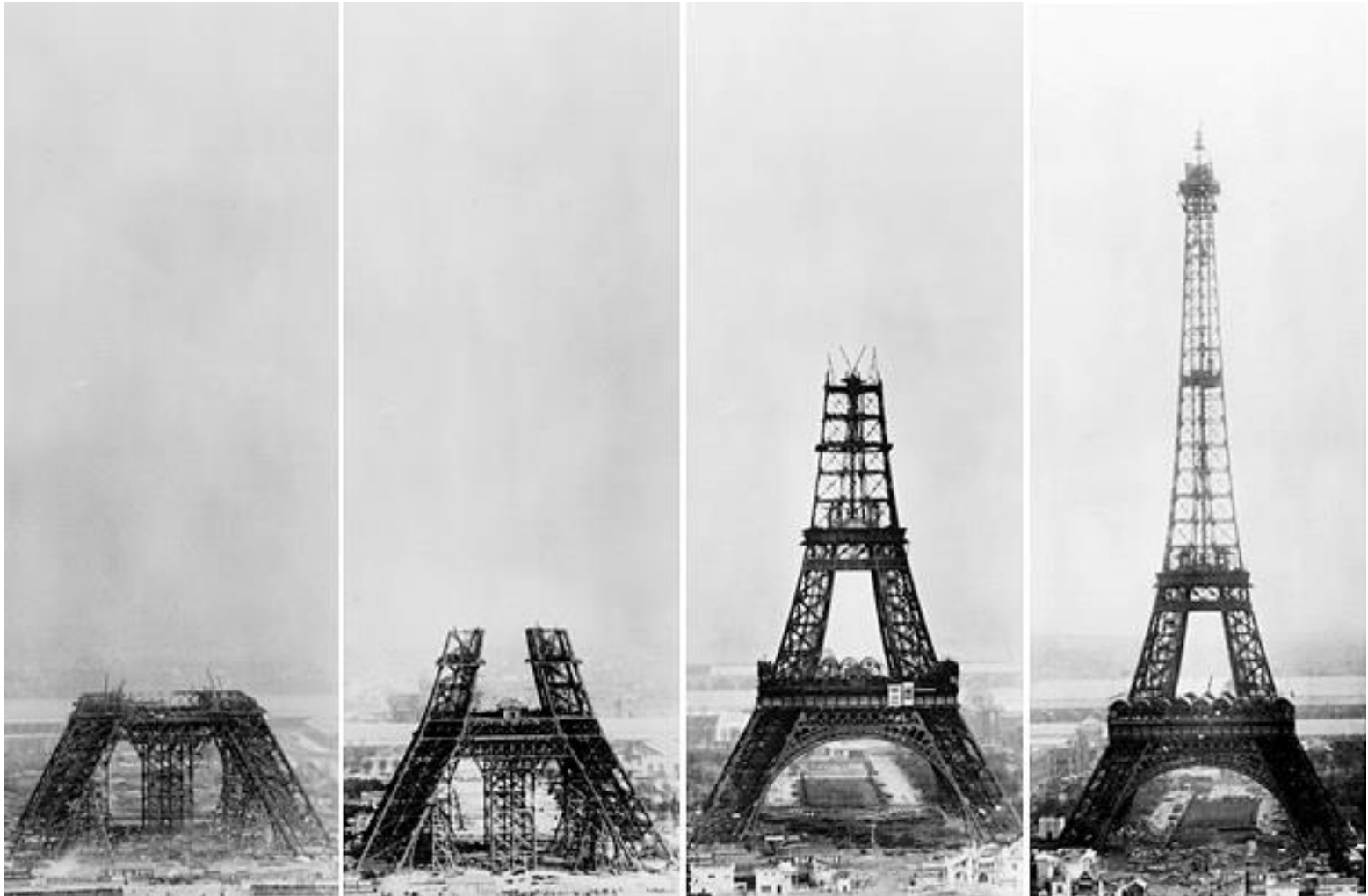
▸ **Project Presentation**

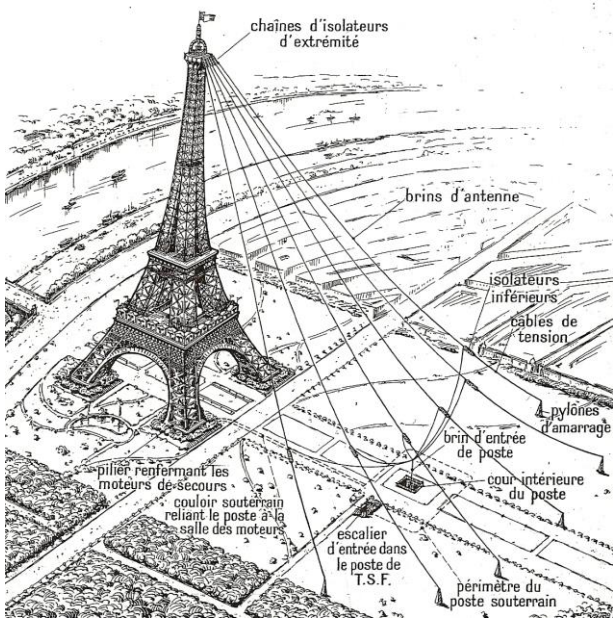- ▸ Last week of the semester or during finals time slot
- ▸ Poster session

© CS 439 Staff, University of Illinois   Fall 2020

CS/ECE 439: Wireless Networking

Wireless Challenges

The Power of Radio

© CS 439 Staff, University of Illinois

The Power of Radio

© CS 439 Staff, University of Illinois

Why is wired networking challenging?
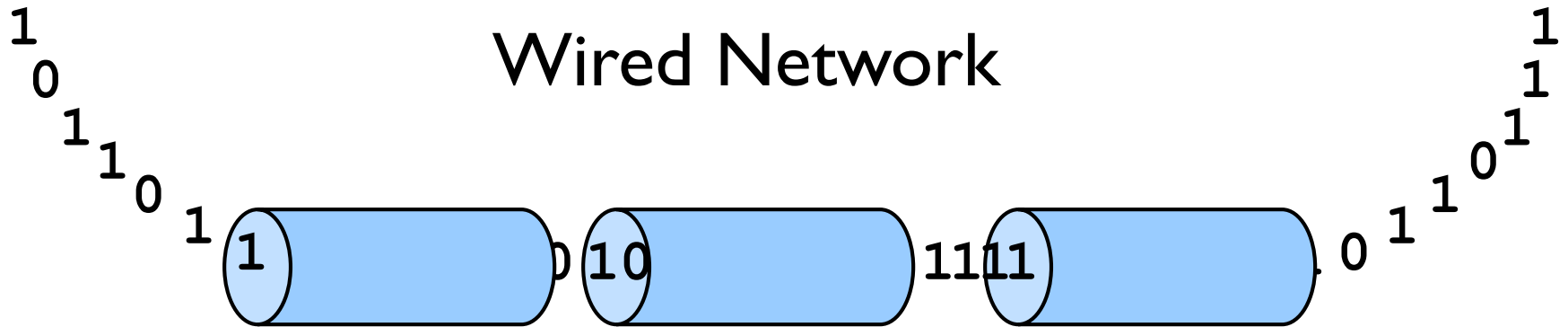
Wired Network

1 0 1 1 0 1

1 0 10 1111 0 1 0 1 1 0 1 1 0 1
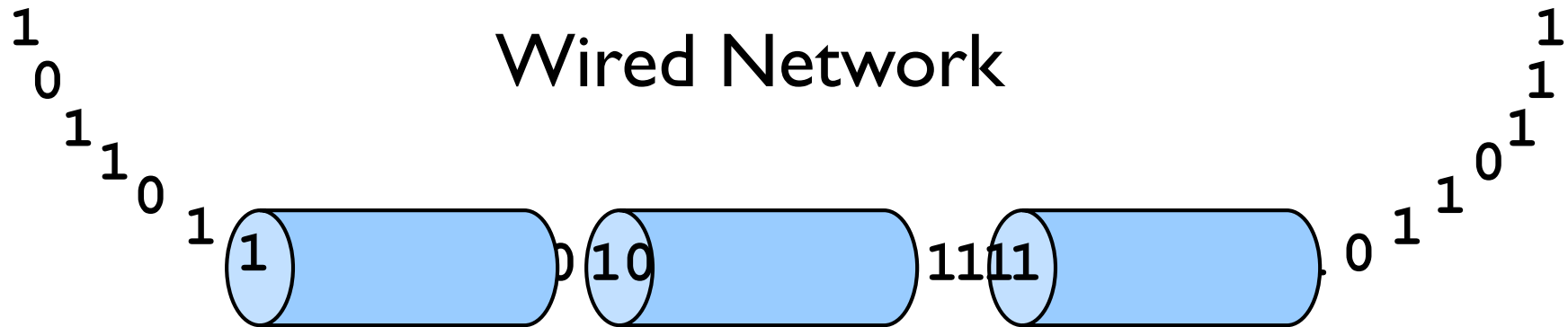
- Speed of light
- Shared infrastructure
- Things break
- Dynamic range
- Security

Getting the data through the pipes

Why is wireless networking challenging?

1
0
1
1
0
1

Wired Network

1

0 10

1111

0

1
0
1
1
0
1
1
0
1

1
0
1
1
0
1

Wireless Network

1   1111   0 10   0 10   0 10   1111   1111   11111   0

1
0
1
1
0
1
1
0
1
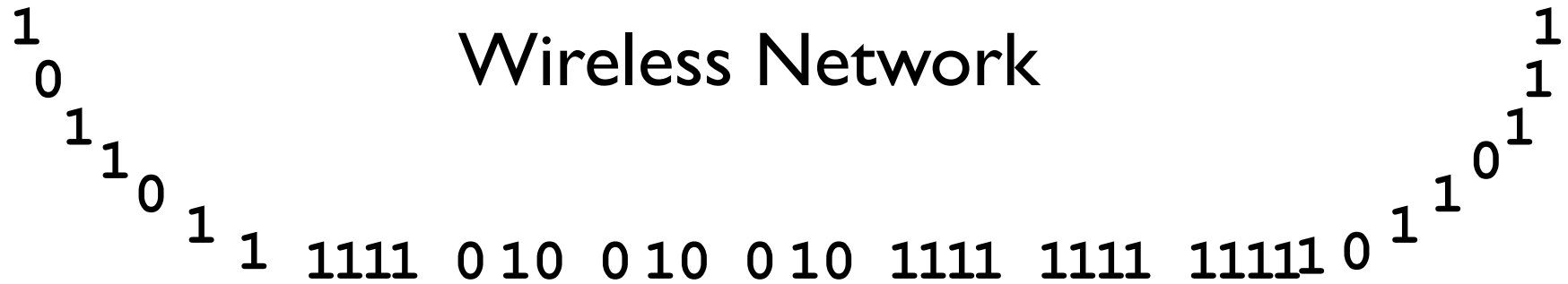
Same problems, but the
pipes are gone!

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, …

© CS 439 Staff, University of Illinois   Fall 2020

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

© CS 439 Staff, University of Illinois   Fall 2020

Path Loss

Alice   Bob

r
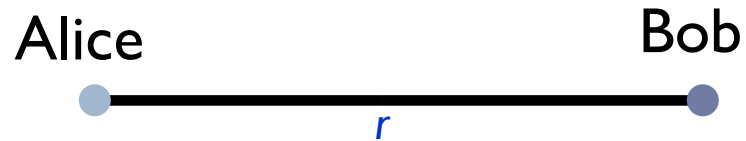
▸ Signal power attenuates by about $\sim r^2$ factor for omnidirectional antennas in free space

    ▸ 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
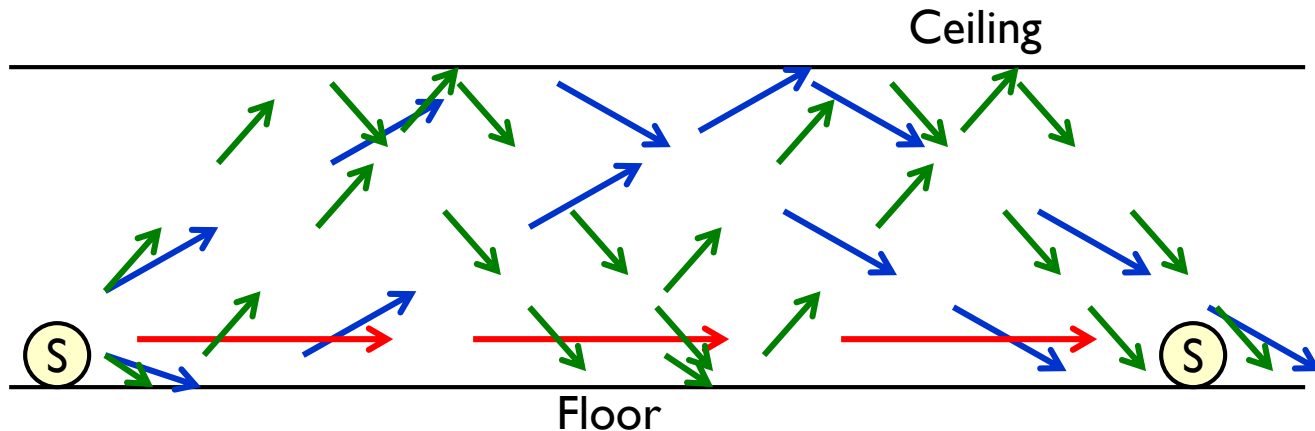
Attenuation and Errors

Alice   Bob

▸ **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
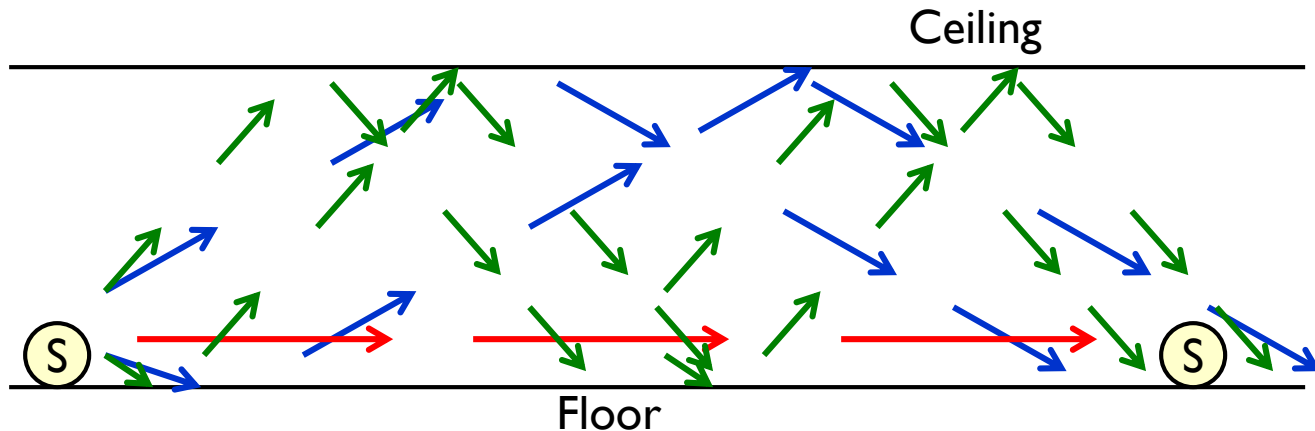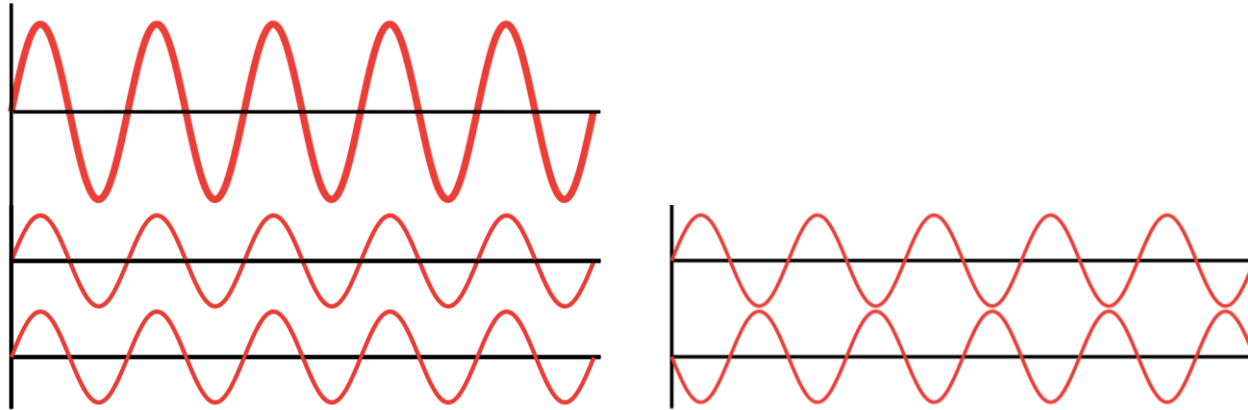
Multipath Effects

- ▶ 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

© CS 439 Staff, University of Illinois   Fall 2020

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

© CS 439 Staff, University of Illinois   Fall 2020

Multipath Effects

▶ What if signals are still in phase at the receiver?

  ▶ In phase signals enhance the received signal strength!

© CS 439 Staff, University of Illinois   Fall 2020

Multipath Effects
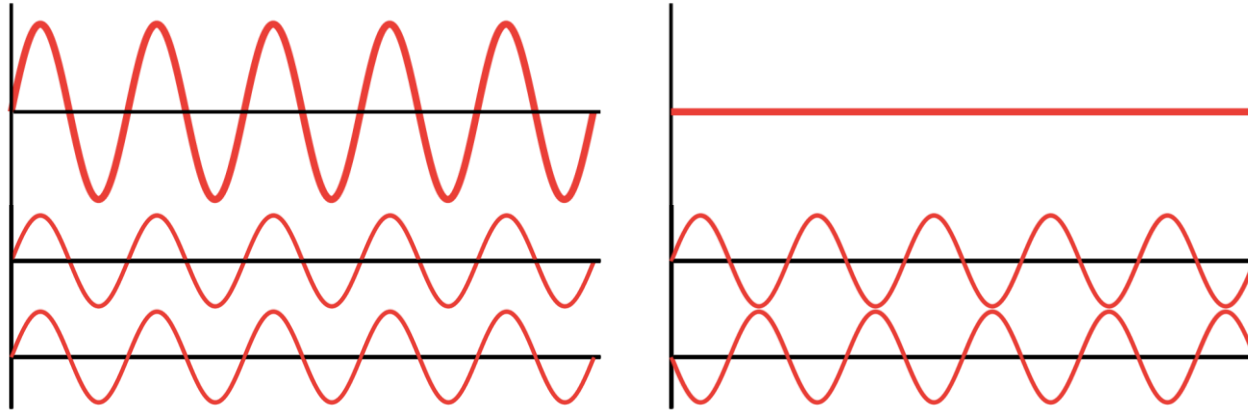
▸ **What if signals are out of phase?**

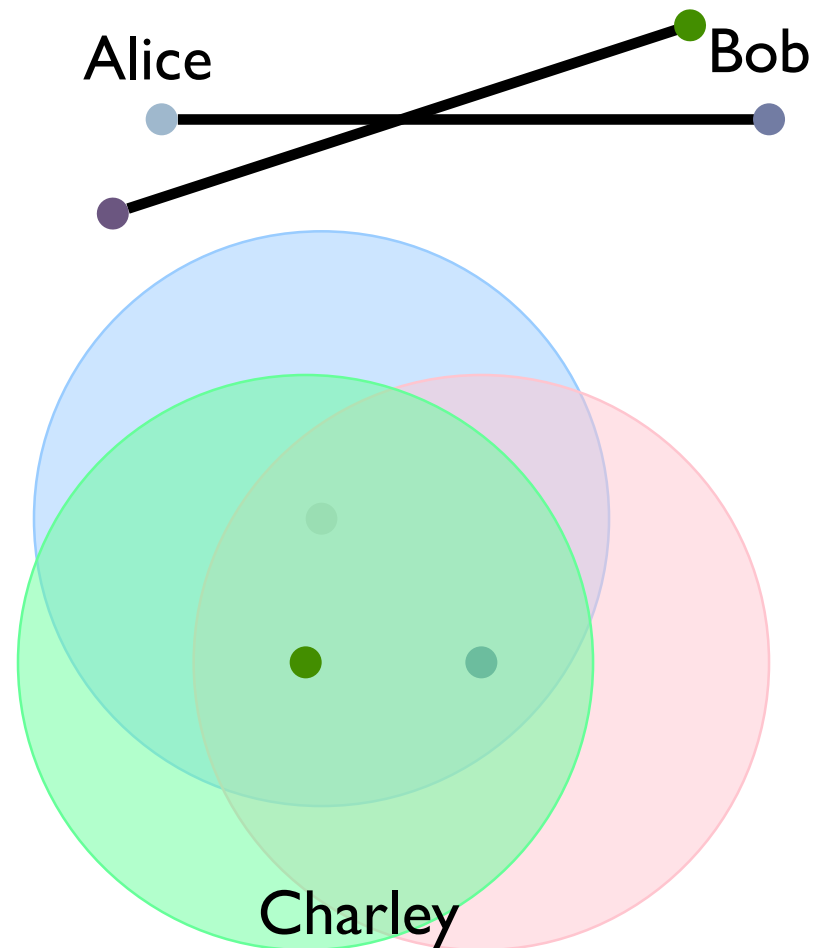   ▸ Orthogonal signals cancel each other and nothing is received!

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?

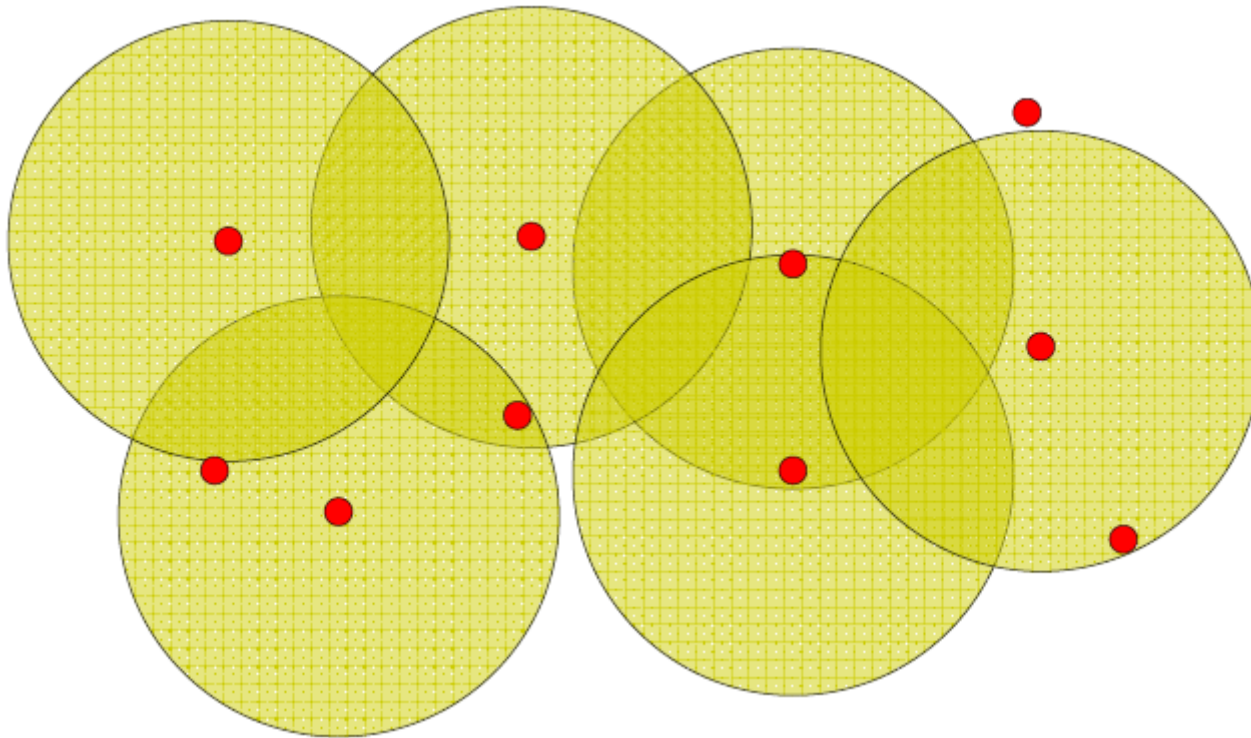Alice   Bob

© CS 439 Staff, University of Illinois   Fall 2020
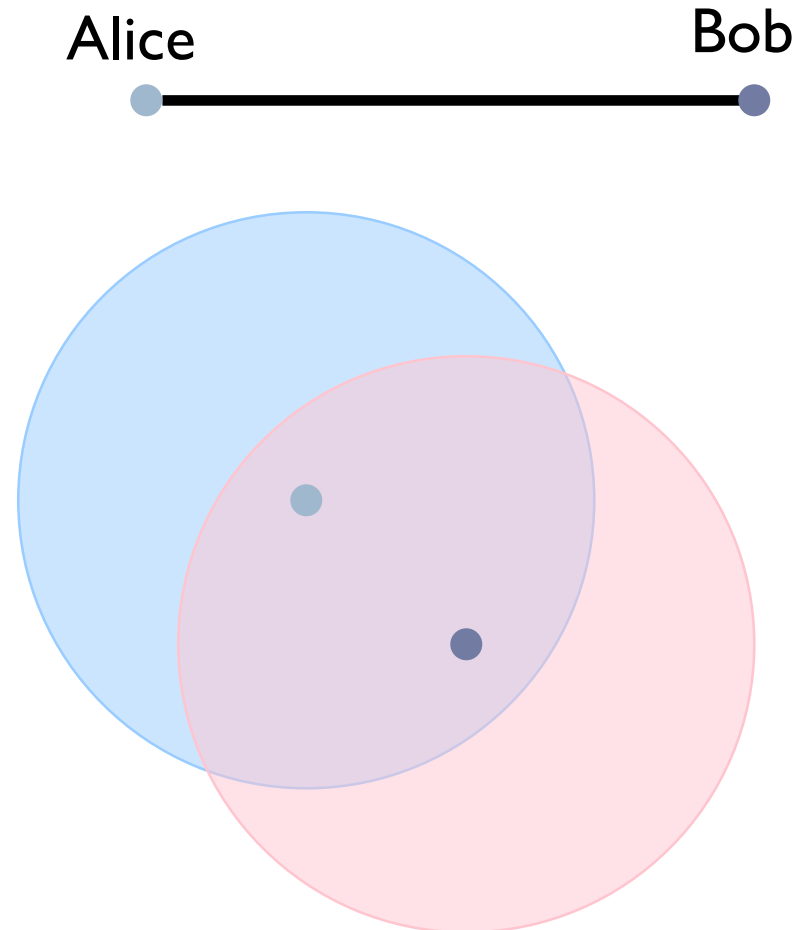
Interference
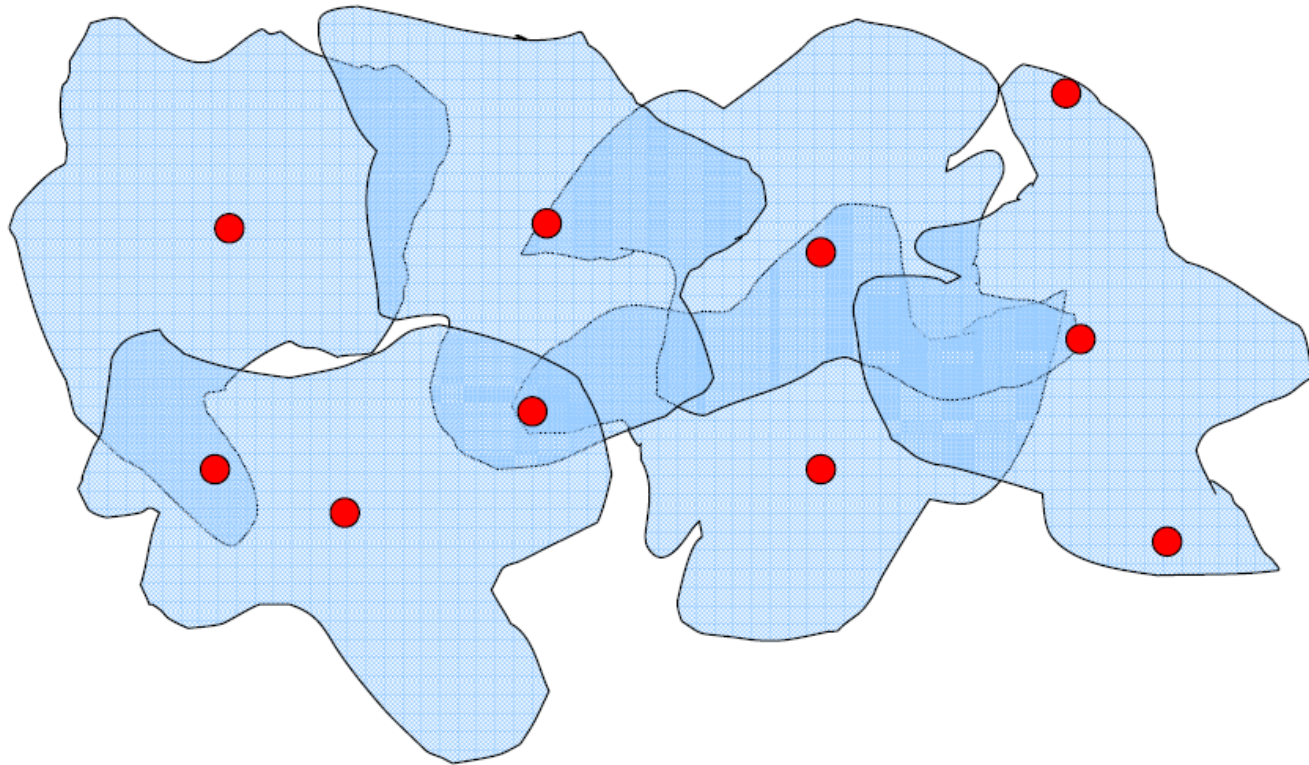
▸ Noise is naturally present in the environment from many sources

▸ Interference can be from other users or from malicious sources

▸ Impacts the throughput users can achieve

Alice

Bob

Charley

© CS 439 Staff, University of Illinois

Fall 2020

What is a Wireless "Link", really?

© CS 439 Staff, University of Illinois   Fall 2020

What is a Wireless "Link", really?

© CS 439 Staff, University of Illinois   Fall 2020

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

© CS 439 Staff, University of Illinois   Fall 2020

Spread Spectrum

▶ **Direct Sequence Spread Spectrum**

  ▶ Spread th

  ▶ Originally

  ▶ 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

© CS 439 Staff, University of Illinois   Fall 2020

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

© CS 439 Staff, University of Illinois   Fall 2020

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

© CS 439 Staff, University of Illinois   Fall 2020

Communication Characteristics

▸ Rate

  ▸ Defines the communication speeds

▸ Frequency

  ▸ Defines the behavior in the physic̶a̶l̶ ̶e̶n̶v̶ironment

▸ Range

  ▸ Defines the physical comm̶u̶n̶i̶c̶ation area

▸ Power

  ▸ Defines the cost i̶n̶ ̶t̶e̶r̶m̶s of energy

Everything is inter-related!

© CS 439 Staff, University of Illinois   Fall 2020

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**

© CS 439 Staff, University of Illinois Fall 2020

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

 Fall 2020

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

Alice   Bob

© CS 439 Staff, University of Illinois   Fall 2020
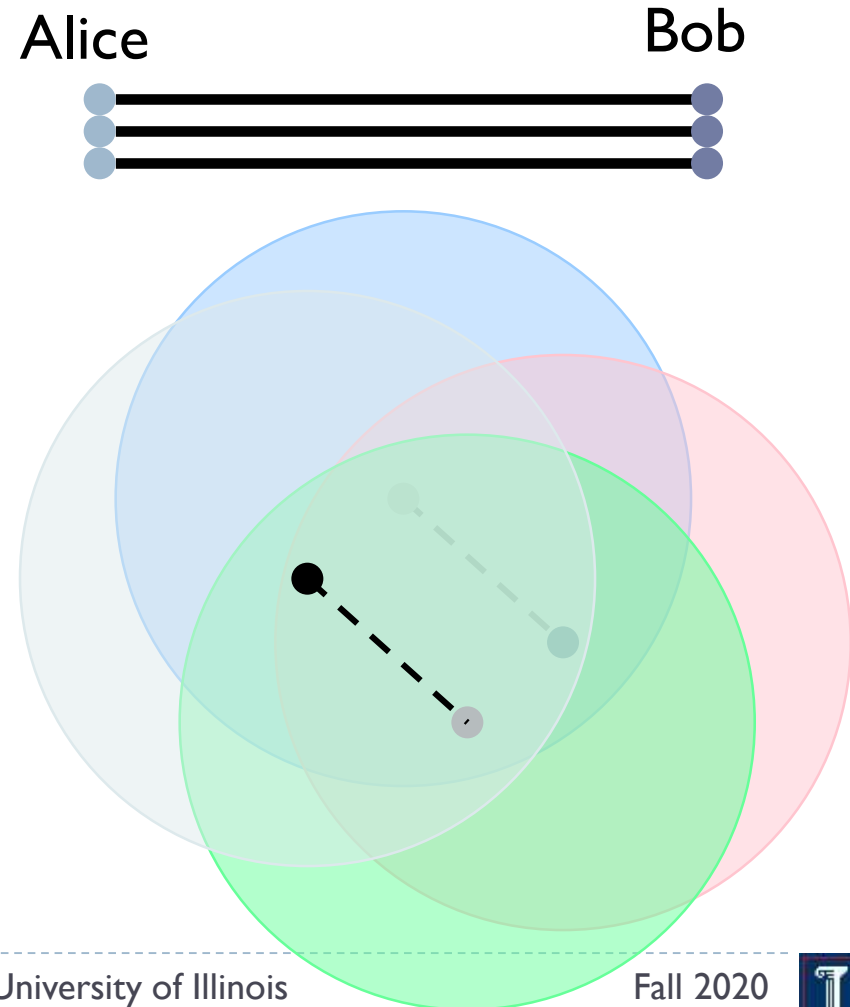
Cellular architecture

▸ **Deploy cells**

  ▸ Different frequencies

▸ **Challenge**

  ▸ Provide consistent service even at the edge of the cell

  ▸ Deal with intensity given the capacity of the cell

© CS 439 Staff, University of Illinois
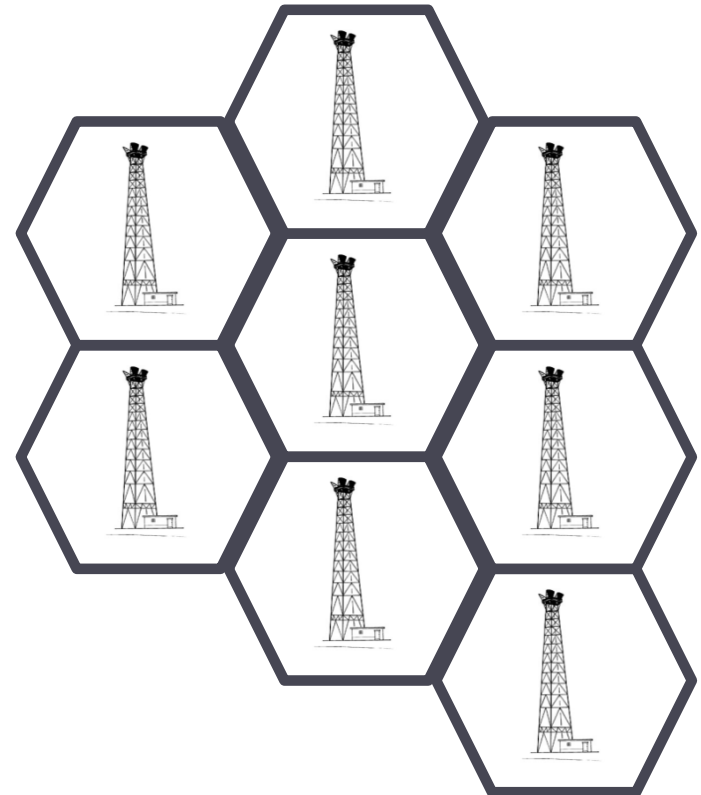
Wi-Fi architecture

▶ Could be chaotic or managed

▶ Limited spectrum – service guarantees hard to make

▶ Channel assignment, power control


© CS 439 Staff, University of Illinois

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!

Alice

Bob

© CS 439 Staff, University of Illinois   Fall 2020
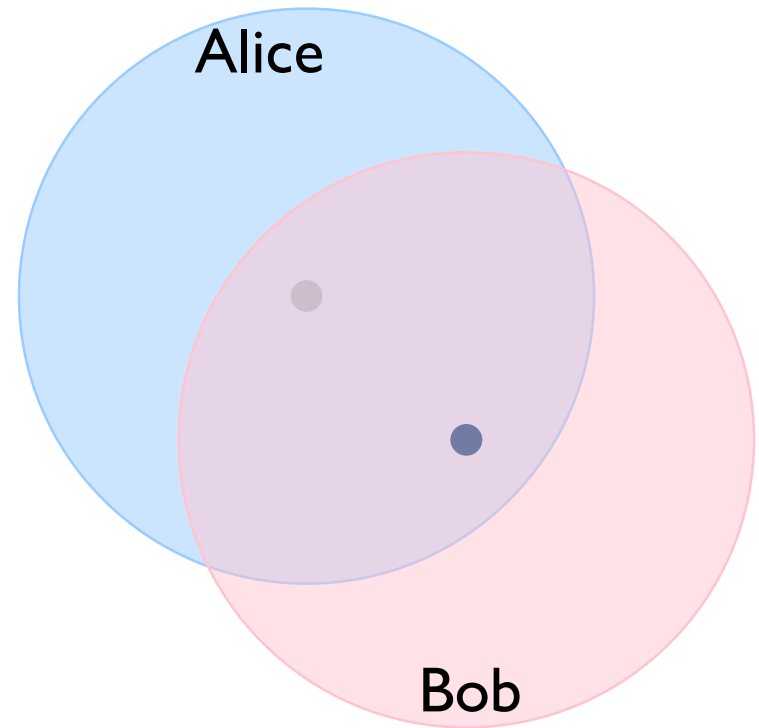
Mobility is an Issue even for Stationary Users

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

Alice

Bob

Charley
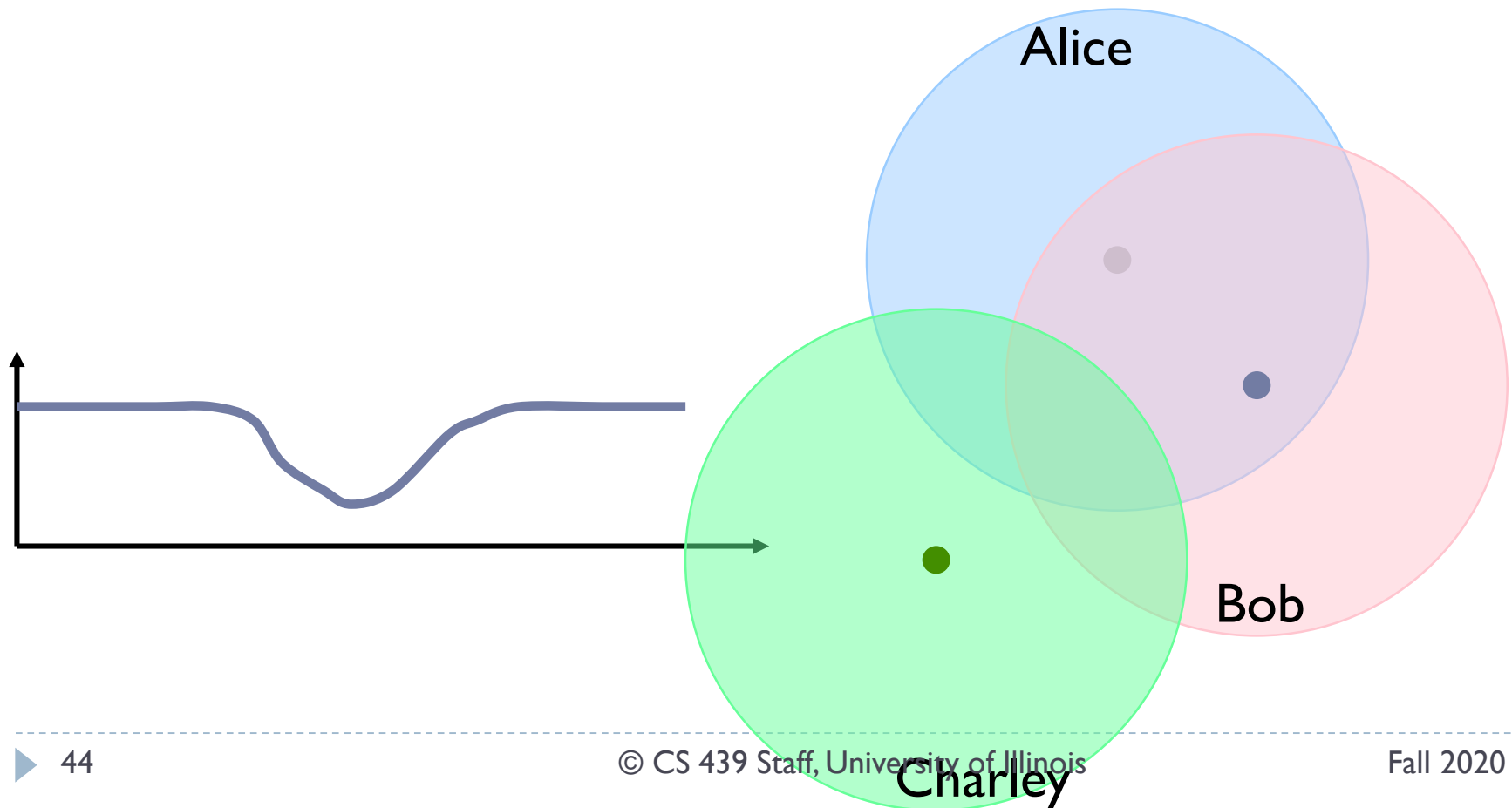
And It Gets Worse …

▸ The impact of mobility on transmission can be complex

▸ Mobility also affects addressing and routing

Alice

Bob
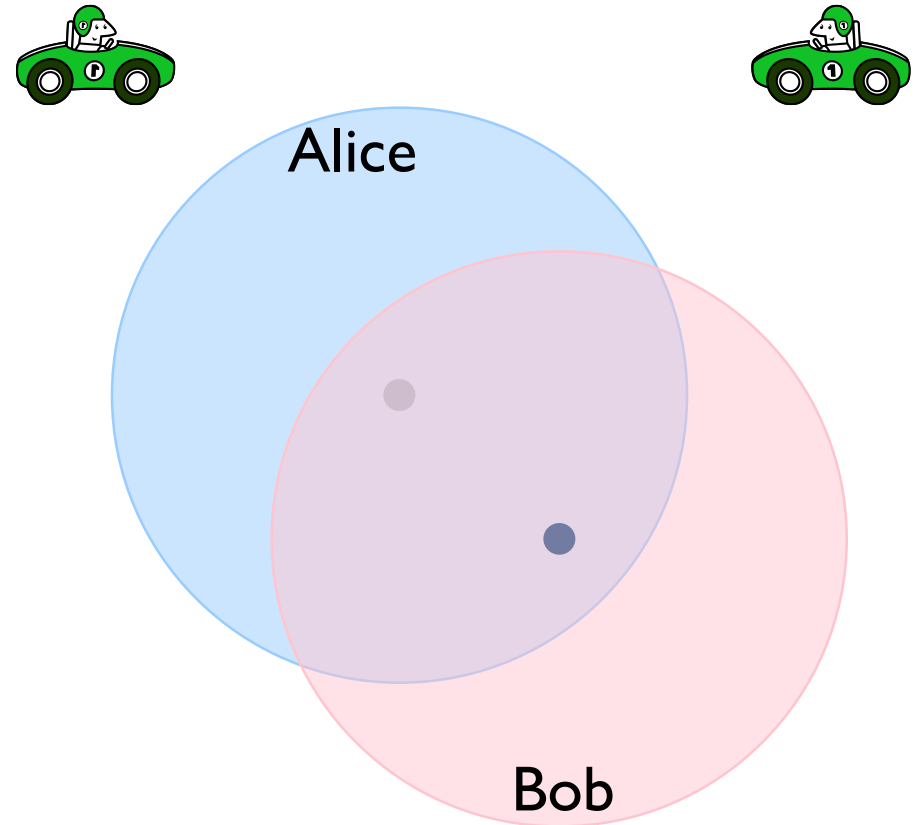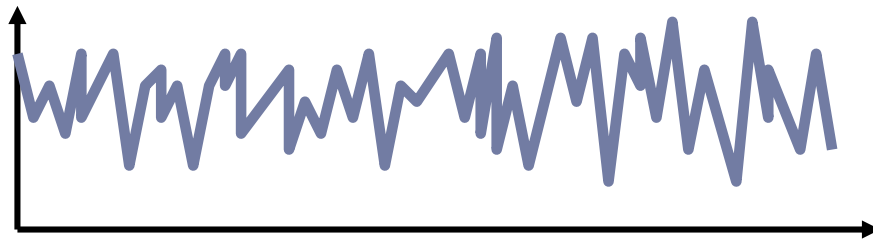
Wireless environments: a very naïve model

▶ 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