Spring ‘18 Course Preview: COS 463 *Wireless Networks*

COS 418: Distributed Systems
Lecture 22
Kyle Jamieson

[Selected content adapted from H. Hassanieh and P. Steenkiste]

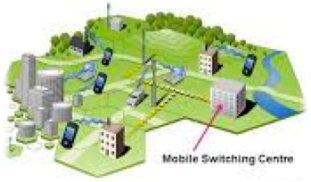
Wireless is increasingly prevalent

Smart Home

- Health and Fitness
- Virtual Reality
- UAVs
- Internet of Things Sensors

Vehicular Networks

Cellular Networks



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Increasing wireless connectivity demand

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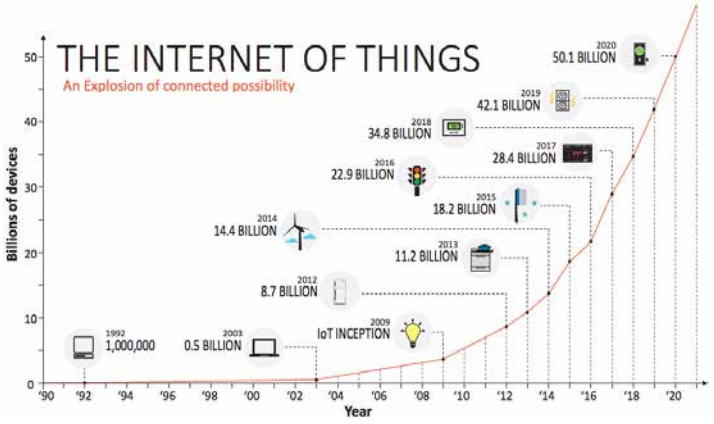
Billions of wireless devices



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Industrial Impact: Cisco Meraki

- Founders Biswas, Bicket, Aguayo PhD candidates who left program
  - Initial products: **mesh networking** technology from grad school
- Pivot three years later
  - Focus on **cloud-managed Wi-Fi**

Roofnet Mesh Network

- Cisco acquisition, new Cisco Wi-Fi product line
- **Takeaway:** Wireless technology → **industry impact**

Course Contents

- **Wireless From the Transport Layer Downwards**
  - Transport over wireless, Mesh, wireless routing etc.
- **Overcoming Bit Errors**
  - Error Detection and Correction, Convolutional Codes, "Rateless" codes
- **An Introduction to the Wireless Channel**
  - Noise, Multipath Propagation, spectrum, sampling, filter etc.
- **Practical wireless communication systems**
  - OFDM, channel estimation, MIMO etc.
- **Boutique topics**
  - Wireless interference, low power wireless communication system etc.

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Prerequisites and Administrivia

- Assume basic familiarity with computer networking concepts and programming
  - **COS 217** required
  - Knowledge of C and one other programming language helpful, but not required
  - Not open to freshmen
- COS 463 is a **COS systems-track** course

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Target audiences

- COS 463 is **cross-registered** with ELE (**ELE 463**)

1. COS students who want to extend their networking background to wireless communications
2. ELE students who want to extend their wireless communications knowledge to networks

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Modes of delivery

- **Lectures:** Introduce concepts, gain background knowledge
- **Precepts & Lab:** hands-on training on wireless systems
  - **Learning by doing**: building wireless systems with a software defined radio platform
  - Precepts and labs **closely coupled**

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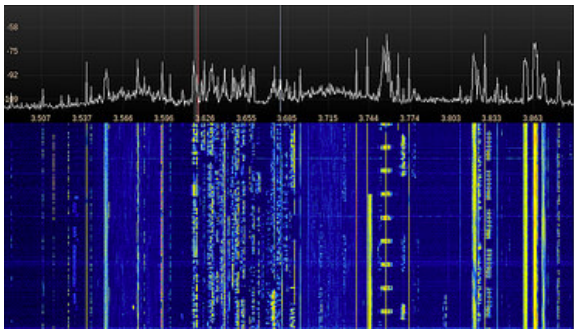
Lab sessions

- **Build real wireless networks** on software defined radio
  - C and/or Python knowledge helpful, but not required



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Goals of the Class

1. **Understand wireless networks'** design and architecture
   - From **signals** to **bits** to **datagrams**
   - **Understand** design choices and tradeoffs
2. Understand how the design of **wireless networks** **interacts with** the rest of the **wired Internet**
3. Gain proficiency in **building real** wireless networks

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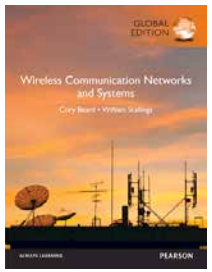
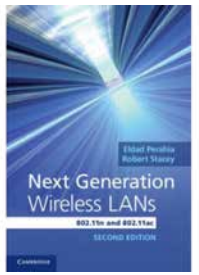
Readings

- **Text book**: Cory Beard and William Stallings, ***Wireless Communication Networks and Systems***
- **Reference material**: Eldad Perahia, Robert Stacey, ***Next Generation Wireless LANs***





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Class Grading

- Mid-term exam: **20%**
- Final exam: **30%**
- Lab programming assignments: **40%**
- Class participation: **10%**
  - Precept attendance and participation
  - Activity on Piazza

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Today

1. **How do wireless and wired networks differ?**
2. What makes wireless interesting?
3. What new services does wireless enable?

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Wireless is less reliable

- In wired networks, link **bit error rate** is **10^{-12} and less**
- Wireless networks are **far from that target**
  - Bit error rates of **10^{-6} and above** are common!
- ***Why?***

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Today

1. **How do wireless and wired networks differ?**
   - **A *shared* wireless medium**
   - Multipath propagation
   - Mobility
2. What makes wireless interesting?
3. What new services does wireless enable?

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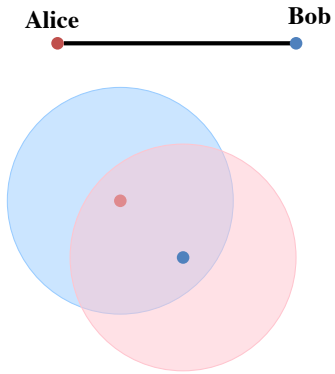
Wireless is a shared medium

- Transmitters broadcast
- Devices can operate either in transmit or receive mode
- How do you **coordinate access** to the medium?



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Why is a **point-to-point** link the **wrong abstraction** for building **wireless networks?**

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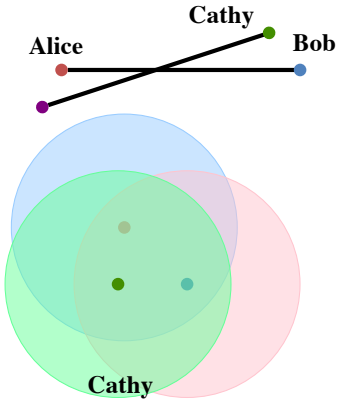
Reason #1: Interference

- **Noise** is naturally present in the environment from many sources
- **Interference** can be from other users of the same technology, other technologies altogether
- Impacts the throughput users can achieve



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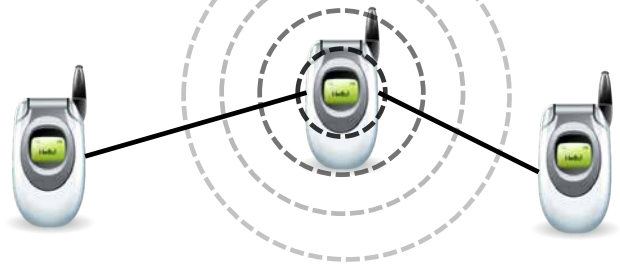
Traditional wireless network design

- Mimics **wired network** design
  - Assumes wireless links are **point-to-point**



- **But** most wireless links have a **broadcast nature**

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Reason #2: Can leverage broadcast

- Want to **exchange packets,** but **out of direct range**

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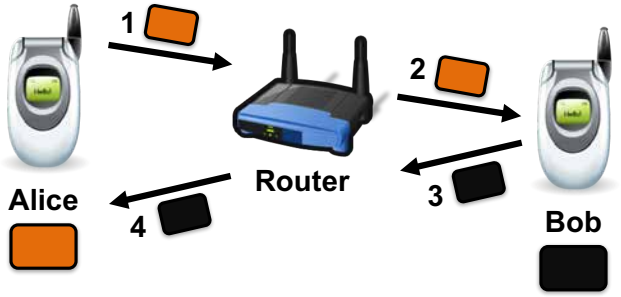
Solution using wired abstraction



- Requires **four transmissions** in total

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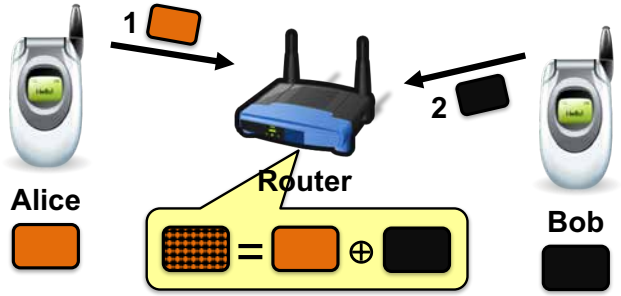
Idea: Router combines the packets



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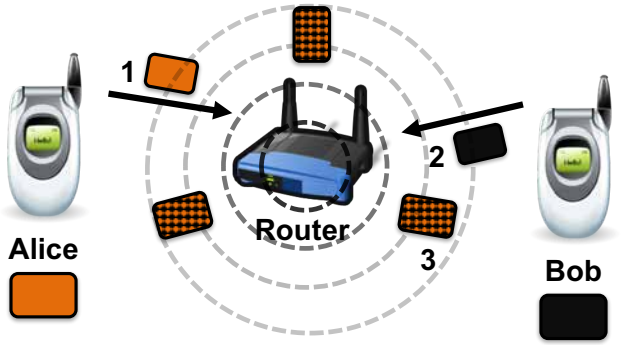
Router broadcasts the combination



- Requires just **three transmissions** in total

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Sumary: Shared medium is very different

- Wireless' shared medium is **very different** than point-to-point wired links
- So need to **think about wireless networks differently**
- **Interference** is a **major problem**
- But also can leverage **broadcast nature** of wireless
  - **Four** to **three** transmissions **increases throughput**
  - Serve **more users** or **increase app performance**
    - **Better Skype calls**

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Today

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   - **Multipath propagation**
   - Mobility
2. What makes wireless interesting?
3. What new services does wireless enable?

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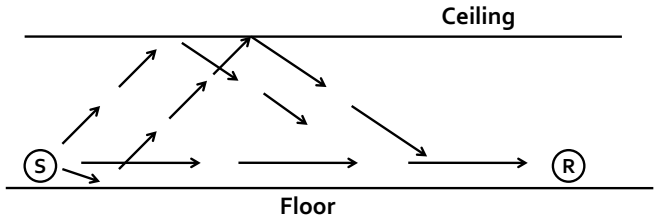
Multipath propagation



- Signal **bounces off surface** and **interferes with itself**
- **Can be constructive** or **destructive,** depending on the respective path lengths
- Can be **more than two paths**

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Today

1. **How do wireless and wired networks differ?**
   - A *shared* wireless medium
   - Multipath propagation
   - **Mobility**
2. What makes wireless interesting?
3. What new services does wireless enable?

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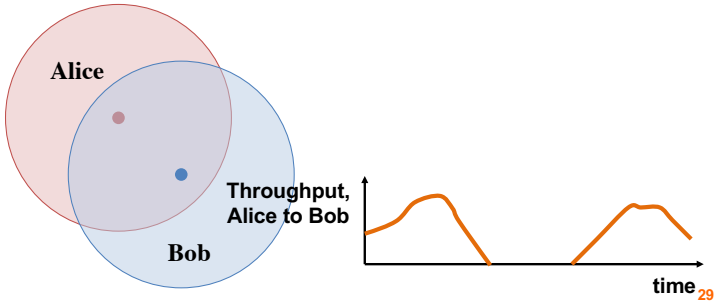
Mobility affects link throughput

- Quality of transmission depends on distance, other factors
- Affects the **throughput** mobile users achieve
- Worst case: ***Outages***, periods with **no connectivity!**



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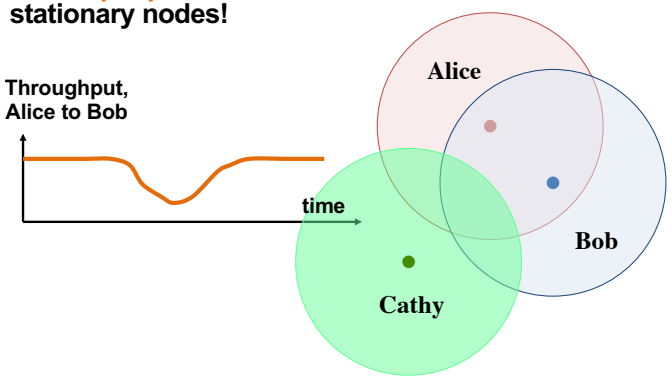
Mobility matters, even for stationary users

- **Mobile people, devices** affect wireless channel of **stationary nodes!**



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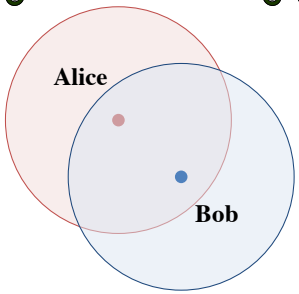
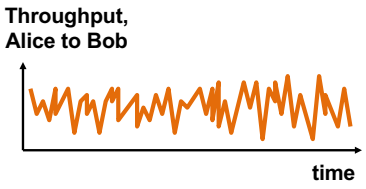
And it gets worse...

- Impact of mobility on transmission is **complex**
  - **Multipath effects**
- Mobility also affects addressing and routing

Cathy





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Today

1. How do wireless and wired networks differ?

2. **What makes wireless interesting?**
   - **Deep Intellectual challenges**
   - Cross-layer design

3. What new services does wireless enable?

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Some things are well understood…

Q: *What's the capacity of a point-to-point link?*
- **Bits/second** can "reliably" communicate

- Before Shannon:
  - *Only way to make probability of bit error arbitrarily small is to reduce the rate of communication.*

- After Shannon (with some assumptions):
  - **Up to some rate *C* (Shannon Capacity), coding can make chance of bit error arbitrary small!**

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…others aren't understood well at all!

*Q: What's the capacity of a wireless **network**?*

A [Information theory]: " "
A [Computer networks]: "Let's build a better medium access control protocol!"

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Today

1. How do wireless and wired networks differ?

2. **What makes wireless interesting?**
   - Deep Intellectual challenges
   - **Cross-layer design**

3. What new services does wireless enable?

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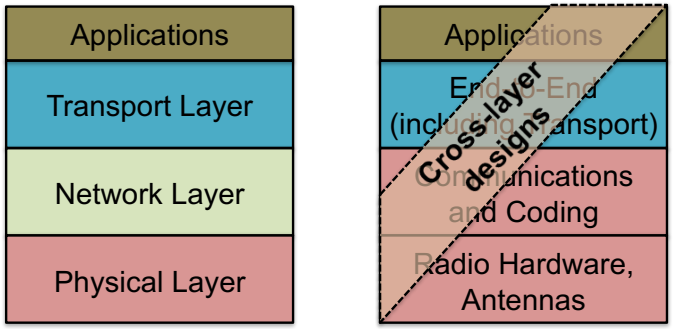
The argument for cross-layer design

- **Traditional approach:** Optimize **within** layers
- **New Approach:** Design and optimize **across** layers



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Why is layer separation **sub-optimal?**

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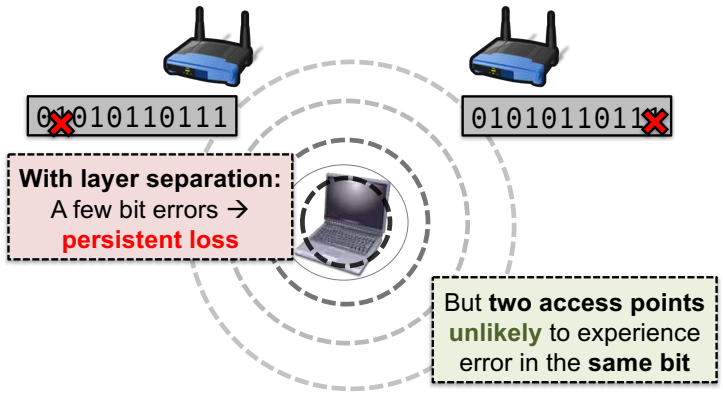
Scenario: Laptop in a "dead spot"



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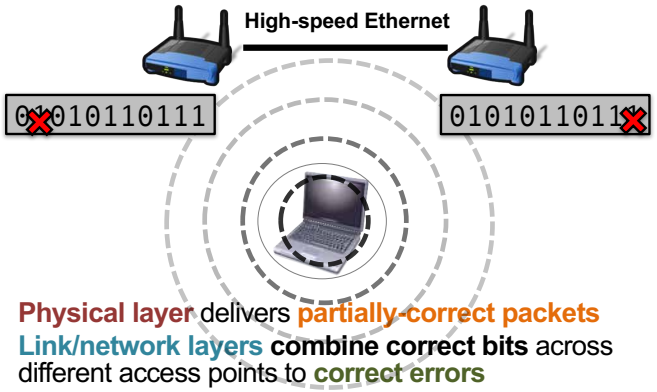
Solution: A cross-layer Approach



- **Physical layer** delivers **partially-correct packets**
- **Link/network layers** **combine correct bits** across different access points to **correct errors**

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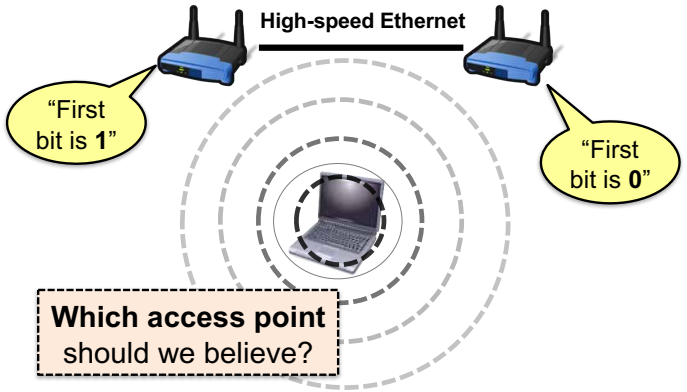
A challenge for bit combining



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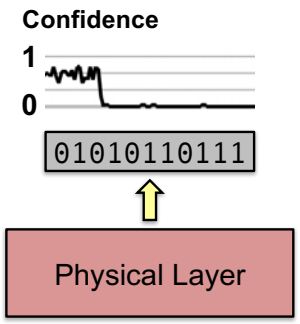
Idea: Network cooperates with PHY layer

- Physical layer **already estimates probability of correctness (*confidence*)** in each 0/1 bit decision
- **Idea: Expose confidence** to the higher layers



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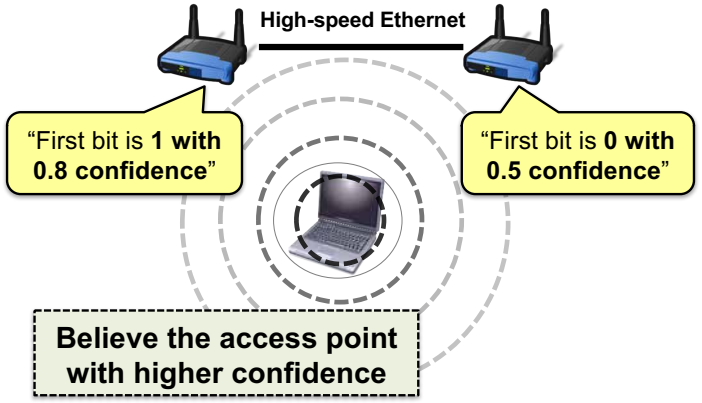
Solution: Use confidences across layers



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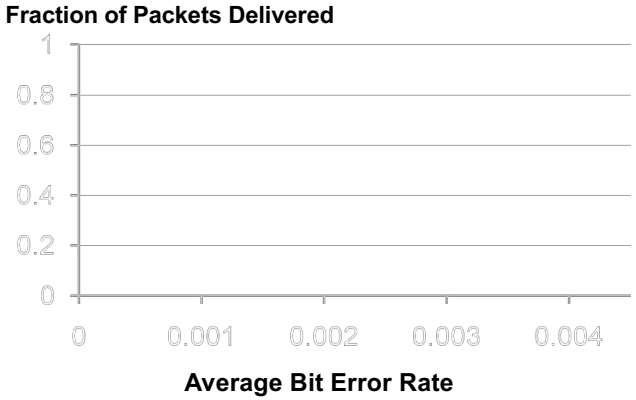
Experiment: Packet delivery v. poor coverage



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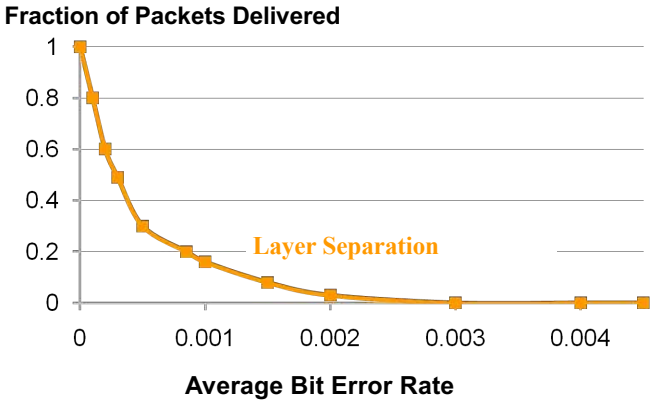

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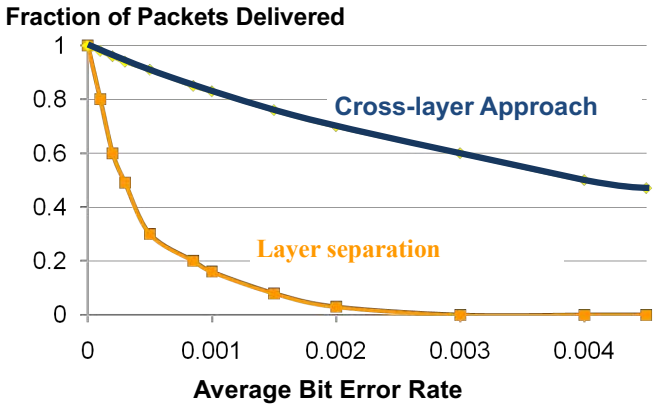
Experiment: Packet delivery v. poor coverage



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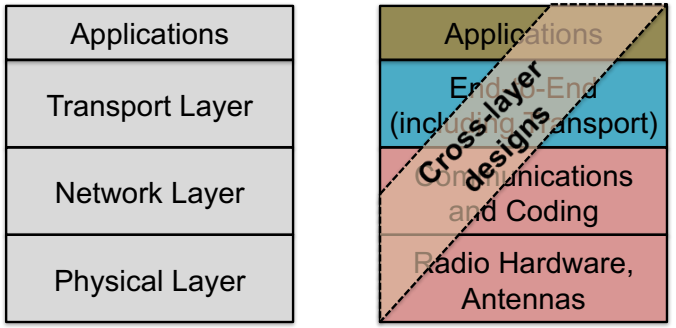
Fundamental change in network architecture

- **Traditional approach:** Optimize **within** layers
- **New Approach:** Design and optimize **across** layers



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Today

1. How do wireless and wired networks differ?
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New Services: Wireless localization

- GPS does not work indoors → **use Wi-Fi to localize**


Indoor Navigation


Business Analytics


WiFi Geofencing


Indoor Robotic Navigation

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Localization and RFID tags

Localize Everything and Anything!

Battery-free stickers to tag any and every object

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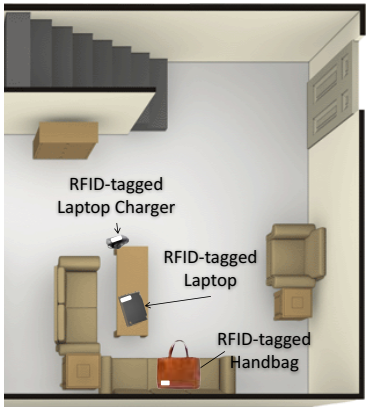
Smart homes



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How do we get virtual touch screens?

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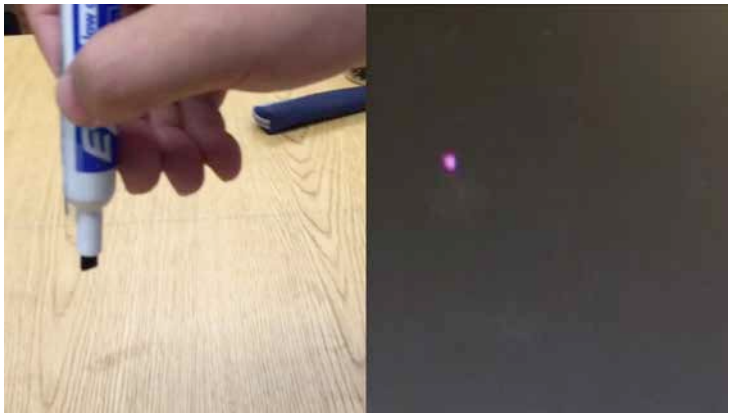
RFID motion tracking in the air



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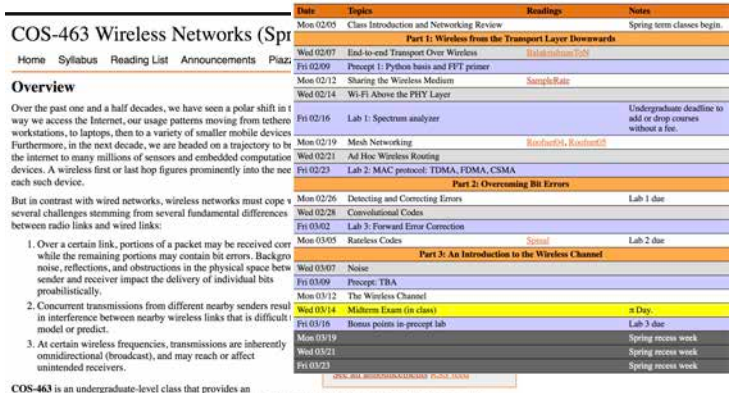
For further information: Class Website

www.cs.princeton.edu/courses/archive/spring18/cos463



COS-463 Wireless Networks (Spr

Home Syllabus Reading List Announcements Piaz

Overview

Over the past one and a half decades, we have seen a polar shift in t way we access the Internet, our usage patterns moving from tethere workstations, to laptops, then to a variety of smaller mobile devices Furthermore, in the next decade, we are headed on a trajectory to be the internet to many millions of sensors and embedded computation devices. A wireless first or last hop figures prominently into the nee each such device.

But in contrast with wired networks, wireless networks must cope v several challenges stemming from several fundamental differences between radio links and wired links:

1. Over a certain link, portions of a packet may be received corr while the remaining portions may contain bit errors. Backgro noise, reflections, and obstructions in the physical space betw sender and receiver impact the delivery of individual bits proabilistically.
2. Concurrent transmissions from different nearby senders resul in interference between nearby wireless links that is difficult t model or predict.
3. At certain wireless frequencies, transmissions are inherently omnidirectional (broadcast), and may reach or affect unintended receivers.

COS-463 is an undergraduate-level class that provides an

Date	Topics	Readings	Notes
Mon 02/05	Class Introduction and Networking Review		Spring term classes begin.
	Part 1: Wireless from the Transport Layer Downwards		
Wed 02/07	End-to-end Transport Over Wireless	RabinkinJon06	
Fri 02/09	Precept 1: Python basis and FFT primer		
Mon 02/12	Sharing the Wireless Medium	SampleRate	
Wed 02/14	Wi-Fi Above the PHY Layer		
Fri 02/16	Lab 1: Spectrum analyzer		Undergraduate deadline to add or drop courses without a fee.
Mon 02/19	Mesh Networking	RoofnetO4, RoofnetO5	
Wed 02/21	Ad Hoc Wireless Routing		
Fri 02/23	Lab 2: MAC protocol: TDMA, FDMA, CSMA		
	Part 2: Overcoming Bit Errors		
Mon 02/26	Detecting and Correcting Errors		Lab 1 due
Wed 02/28	Convolutional Codes		
Fri 03/02	Lab 3: Forward Error Correction		
Mon 03/05	Rateless Codes	Spinal	Lab 2 due
	Part 3: An Introduction to the Wireless Channel		
Wed 03/07	Noise		
Fri 03/09	Precept: TBA		
Mon 03/12	The Wireless Channel		
Wed 03/14	Midterm Exam (in class)		π Day.
Fri 03/16	Bonus points in-precept lab		Lab 3 due
Mon 03/19			Spring recess week
Wed 03/21			Spring recess week
Fri 03/23			Spring recess week

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Monday topic:

Cluster Scheduling and Fairness

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