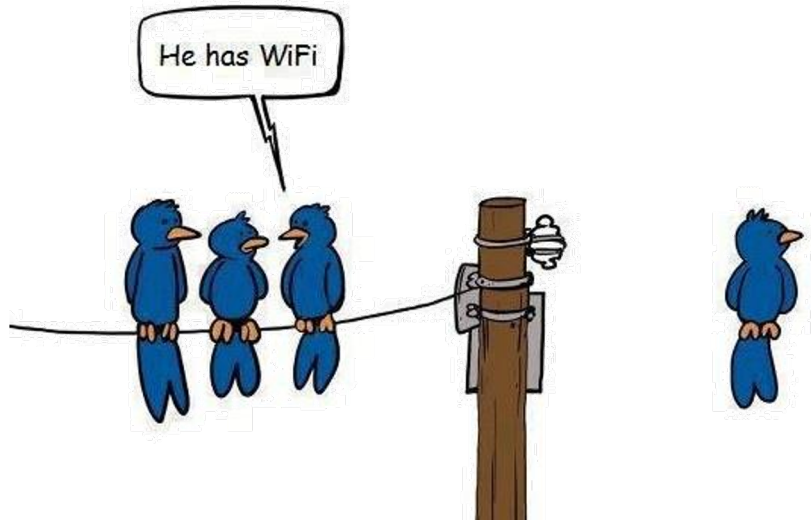
ECE 439: Wireless Networks

Lecture 1: Introduction & Logistics

Haitham Hassanieh

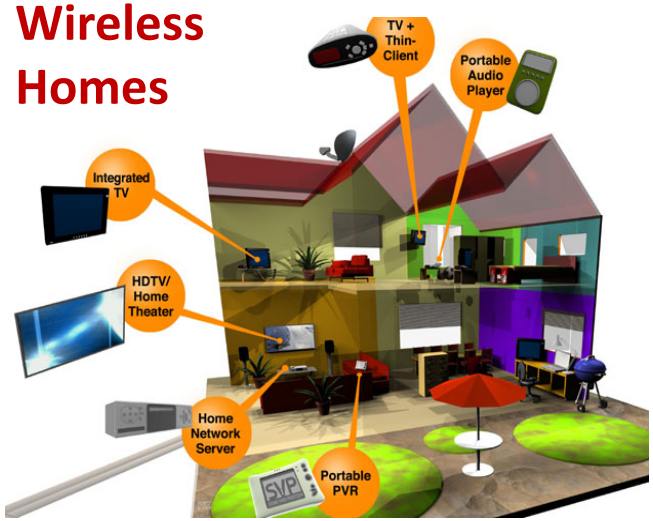


ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

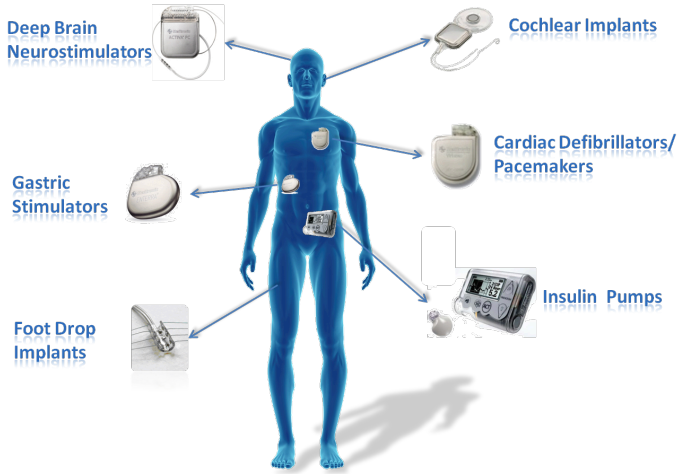
CSL:
COORDINATED
SCIENCE LAB

Wireless Networks Are Every Where

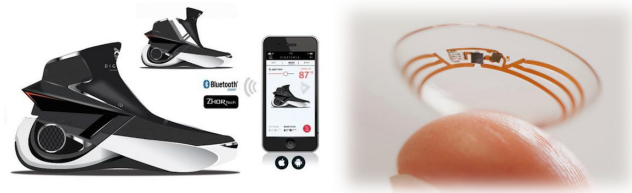
Wireless Homes



Wireless Biomedical Implants



Wireless Wearables



Cellular Networks

Wireless Sensors

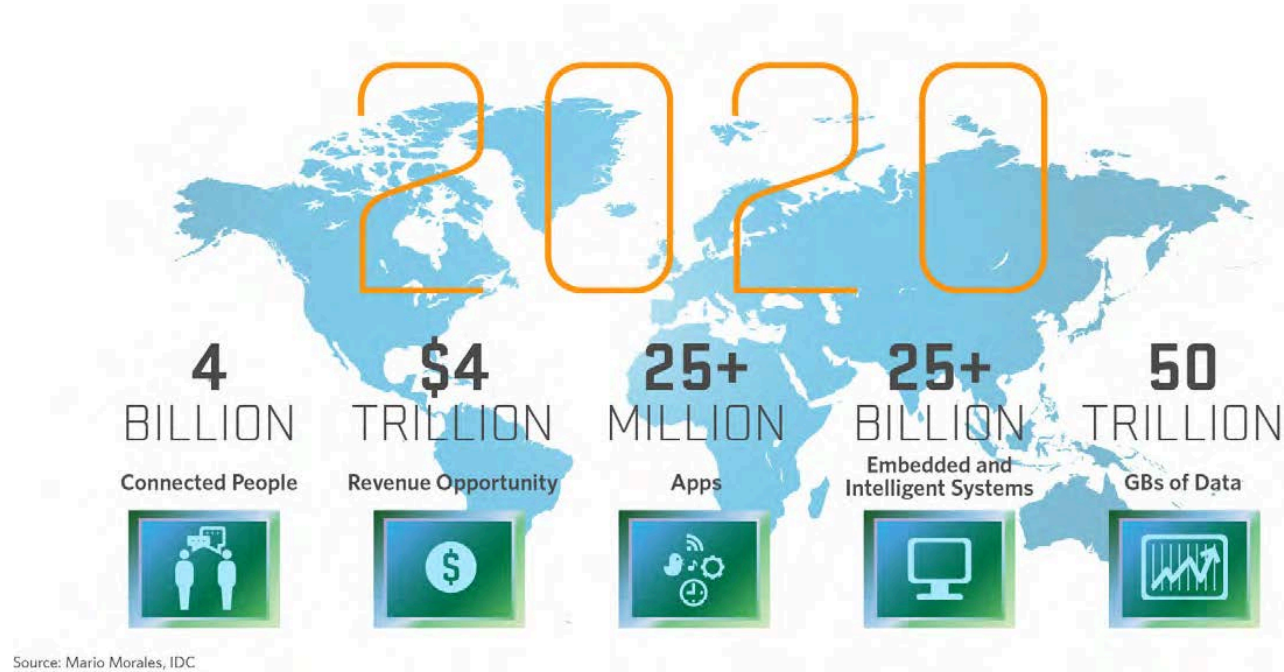
UAVs

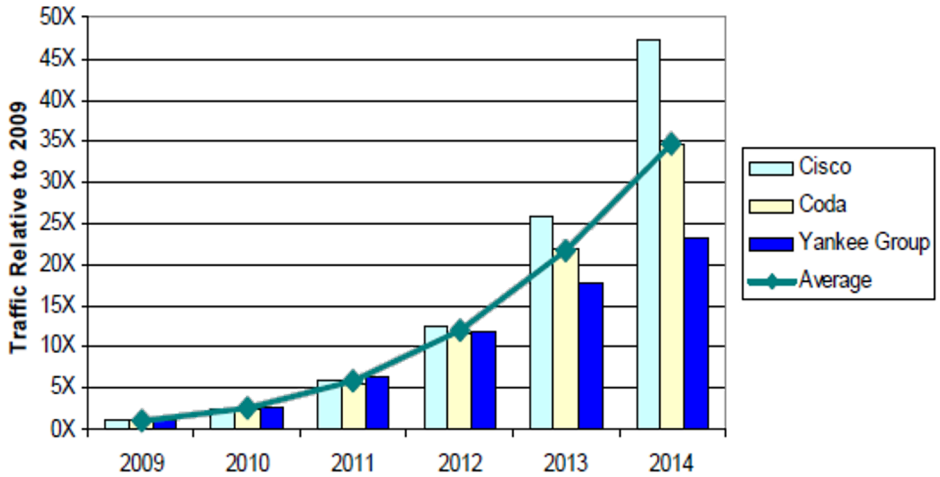
Wireless Data Centers

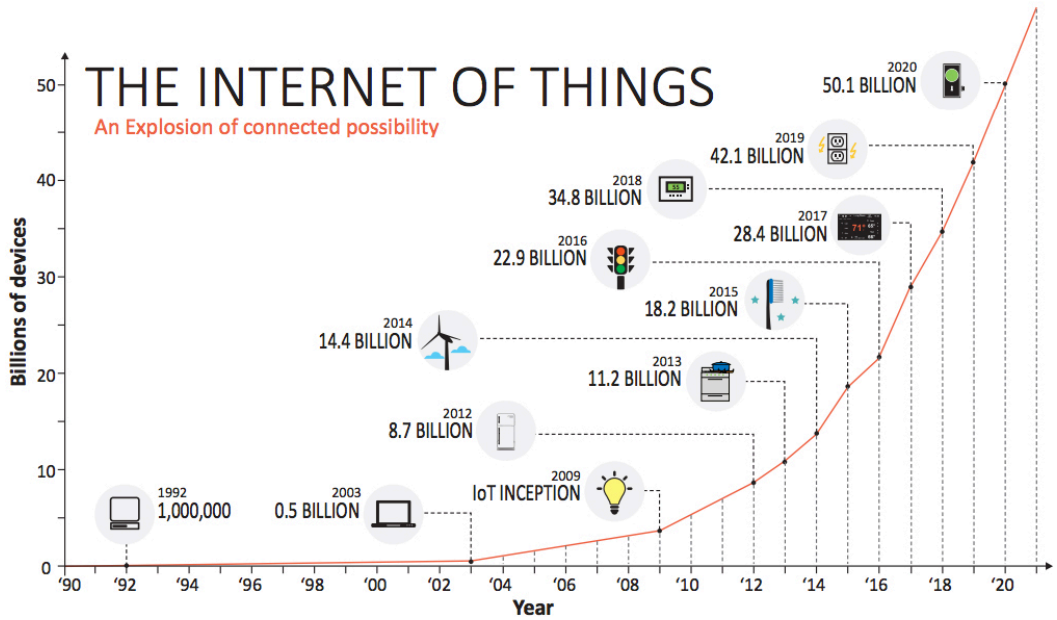
Wireless VR

Wireless Vehicles

Increasing Demand for Wireless Connectivity







Increasing Demand for Wireless Connectivity

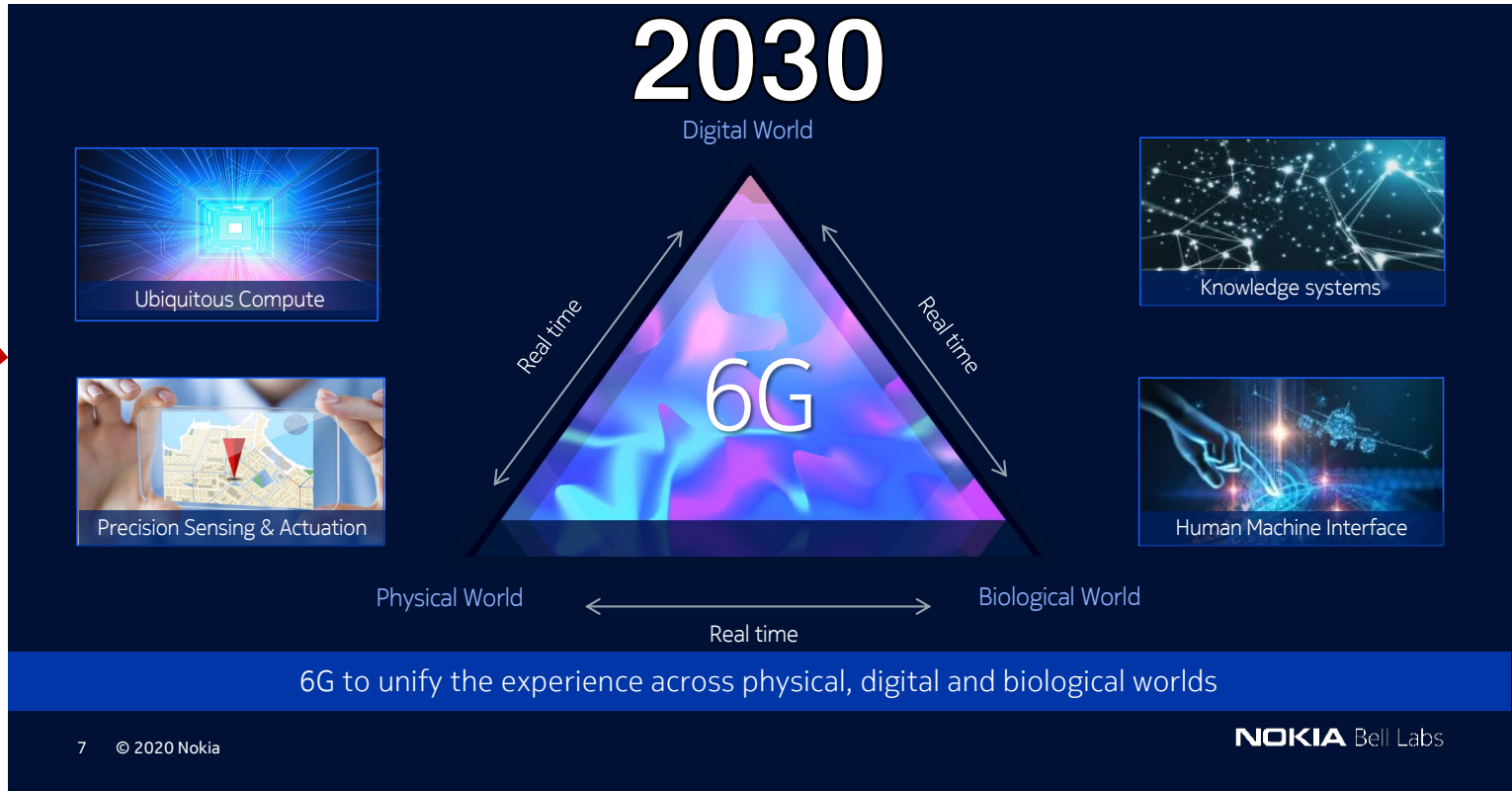
Connecting People

Increasing Demand for Wireless Connectivity

Connecting Everything

Increasing Demand for Wireless Connectivity

Connecting
+
Sensing
Everything



NOKIA Bell Labs

The past, present, and future

2G

Voice

The past, present, and future

2G

Voice

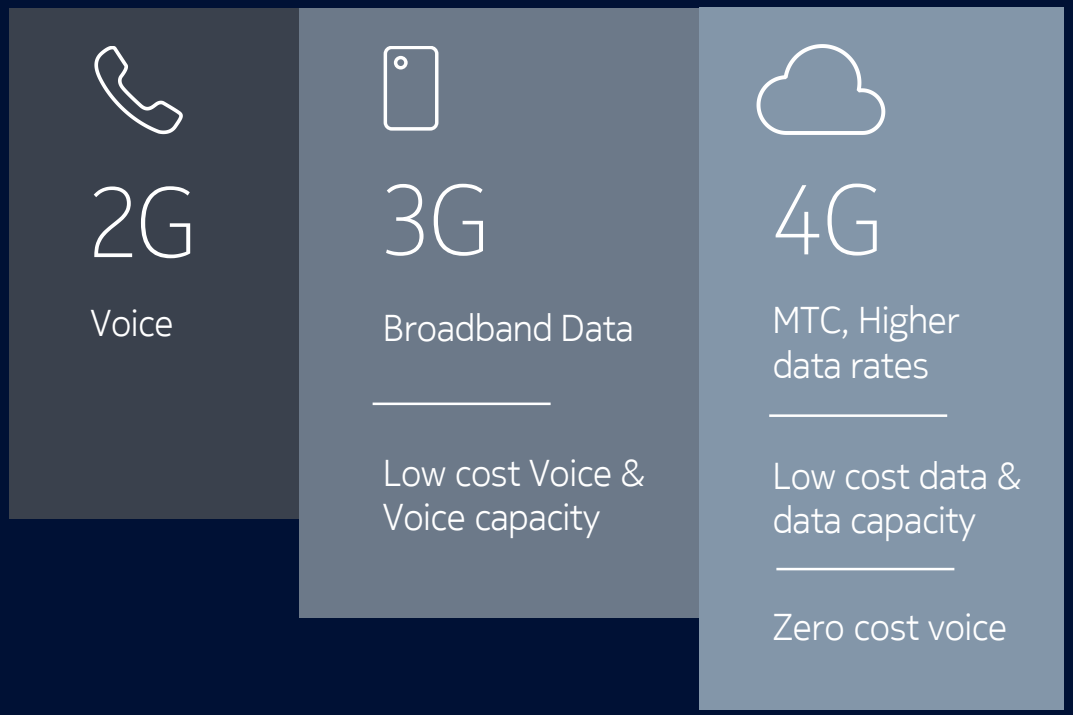
3G

Broadband Data

Low cost Voice &
Voice capacity

NOKIA Bell Labs

The past, present, and future



The past, present, and future

2G

Voice

3G

Broadband Data

Low cost Voice & Voice capacity

4G

MTC, Higher data rates

Low cost data & data capacity

Zero cost voice

5G

Industrial IoT, Higher data rates

Zero cost data & zero cost voice

MTC Optimized?

The past, present, and future

2G

Voice

3G

Broadband Data

Low cost Voice & Voice capacity

4G

MTC, Higher data rates

Low cost data & data capacity

Zero cost voice

5G

Industrial IoT, Higher data rates

Zero cost data & zero cost voice

MTC Optimized?

6G

RF Sensing, 100 Gbits/sec @ short range Gbps @ high speed

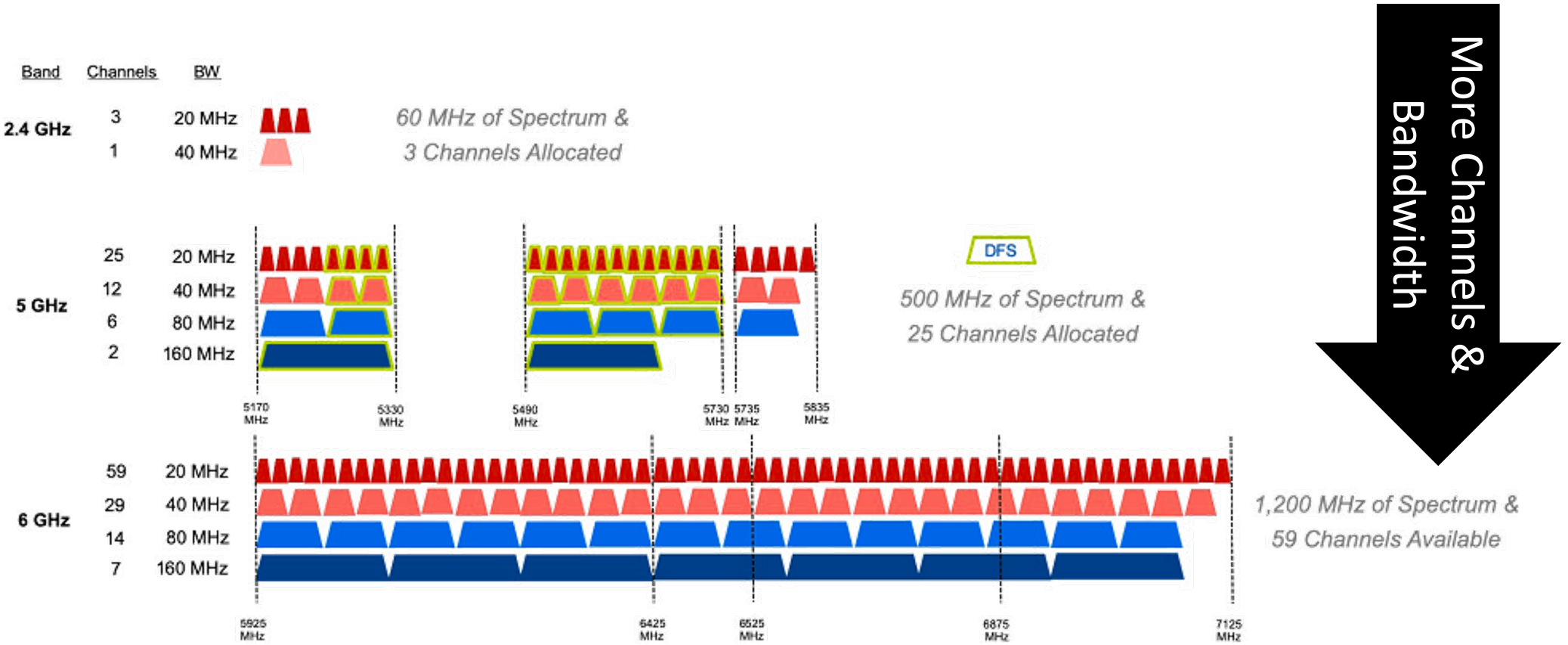
Industrial IoT optimized for low cost & perf.

Zero cost data, voice, massive MTC

Each new generation is about optimizing the new use case of the previous generation to reduce cost and introduction of new use cases

NOKIA Bell Labs

WiFi Standards from WiFi 1 to WiFi 6



WiFi 1 — More MIMO Antennas — WiFi 5/6

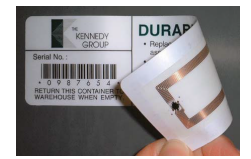
IoT Technologies

Wi Fi

Bluetooth®

NFC

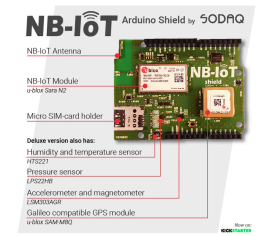
RFID



Cellular

NB-IoT

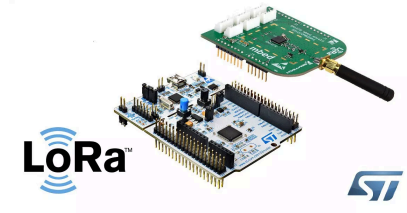
LTE-M



sigfox

LoRa™

neul



ZWAVE®

ZigBee®

Many Motivations for Wireless

- Unrestricted mobility / deployability
  - Unplugged from power outlet
- Significantly lower cost
  - No cable layout, service provision
  - Low maintenance
- Ease
  - Direct communication with minimum infrastructure

No Free Lunch

- Numerous challenges
  - Channel fluctuation
  - Lower bandwidth
  - Limited Battery power
  - Disconnection due to mobility
  - Interference for other nodes
  - Scalability
  - Security
  - …

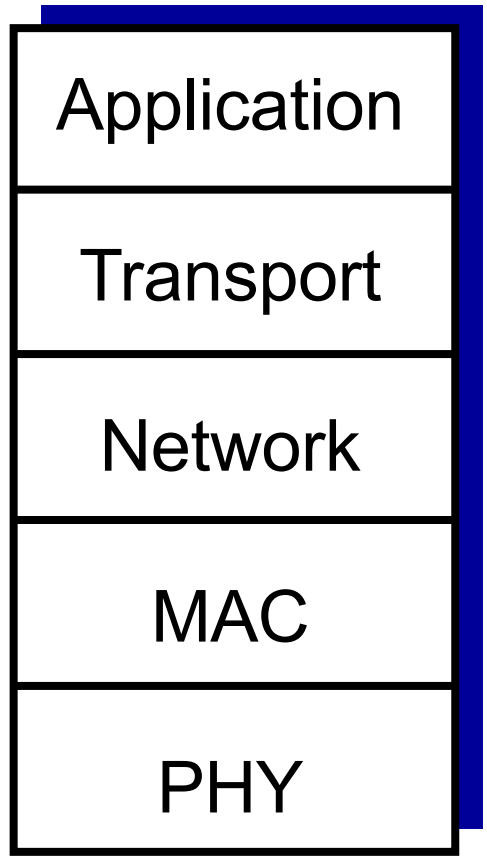
Question Is …

Can’t we use the rich “wireline” knowledge ?

In solving the wireless challenges

Internet Protocol Stack

- *Application:* supporting network applications
  - FTP, SMTP, HTTP
- *Transport:* process-process data transfer
  - TCP, UDP
- *Network:* routing of packets from source to destination
  - IP, routing protocols
- *Link/MAC:* data transfer between neighboring network elements
  - Ethernet, 802.11 (WiFi), PPP
- *Physical:* bits "on the wire"



The Answer

Wireless channel: A dispersive medium

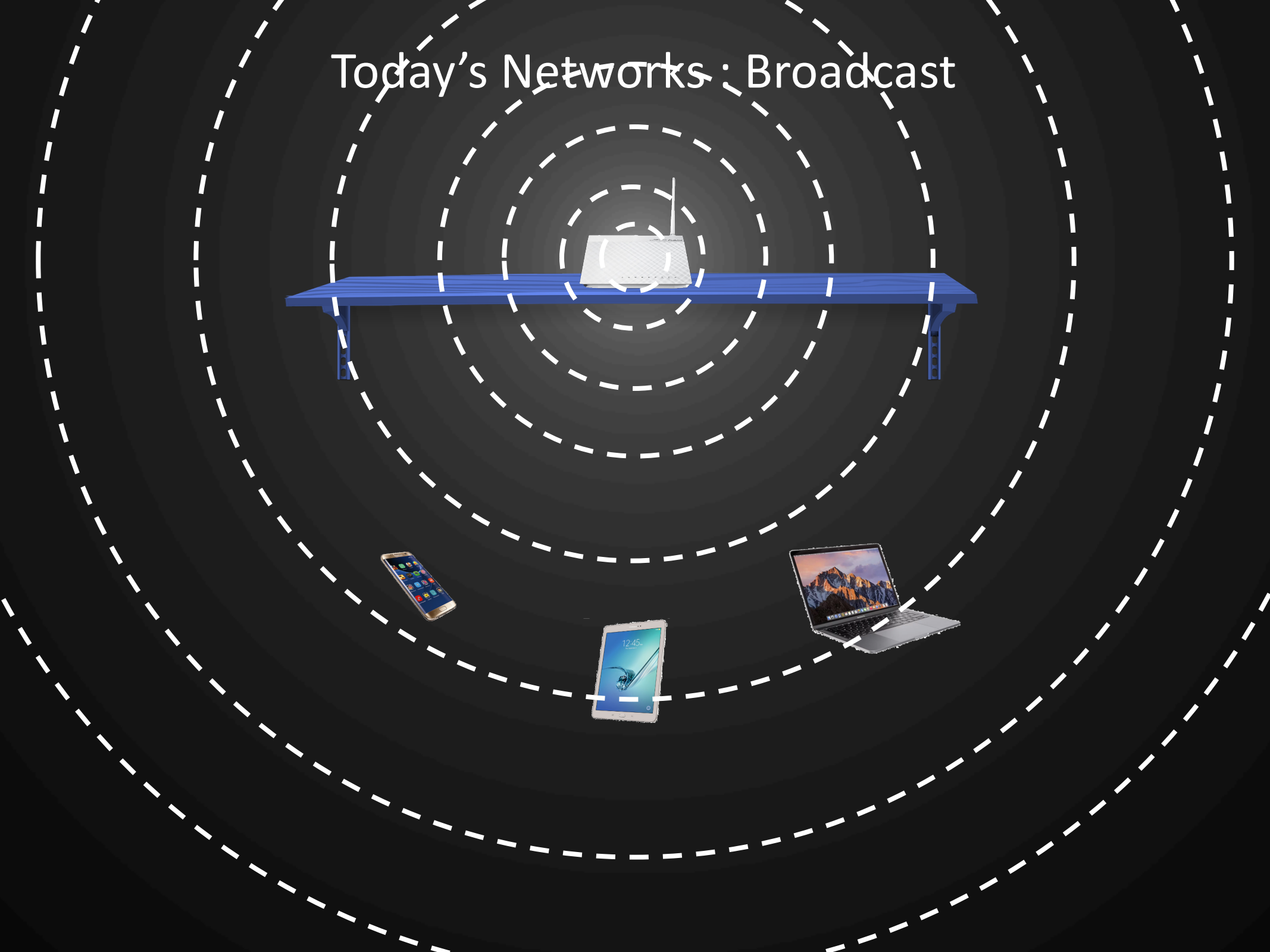
The PHY and MAC layer completely dissimilar

The whole game changes

Even New Challenges with

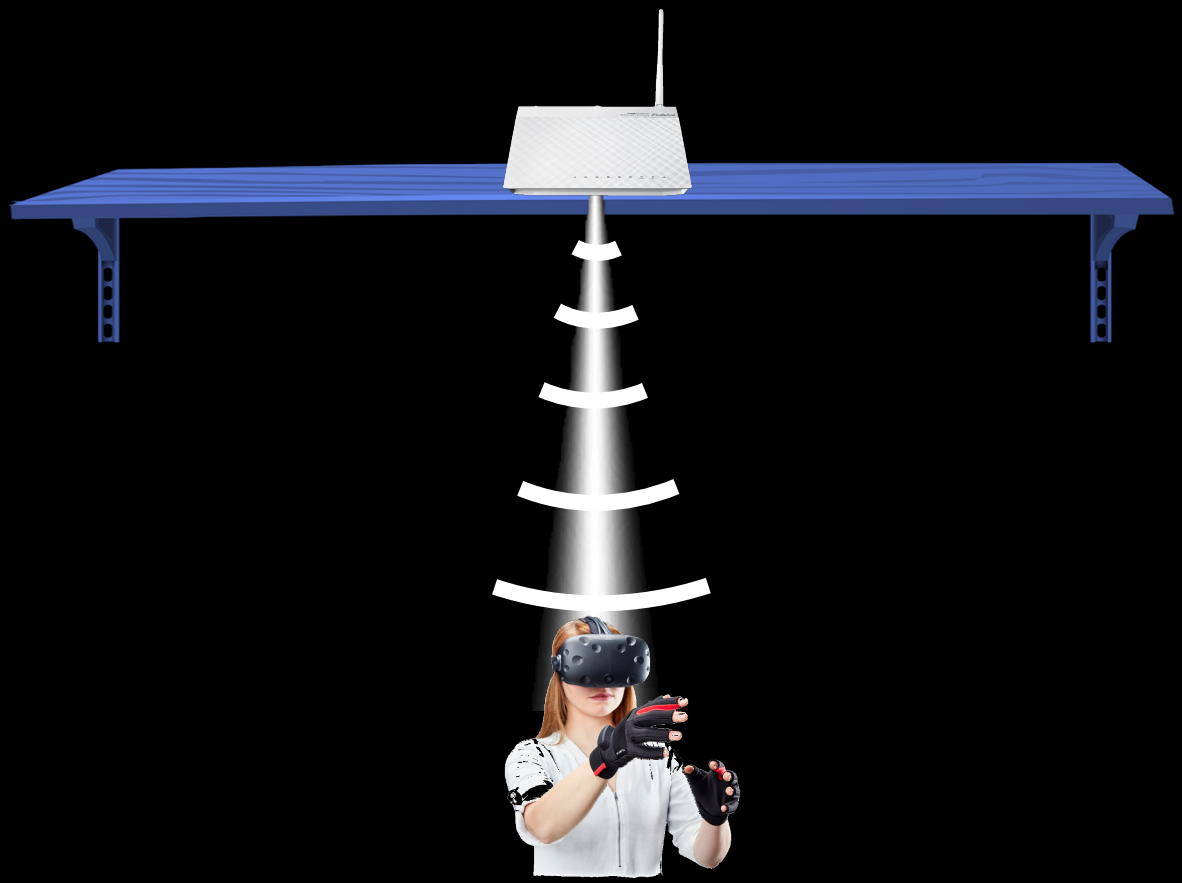
5G, IoT, Implants, Sensing…

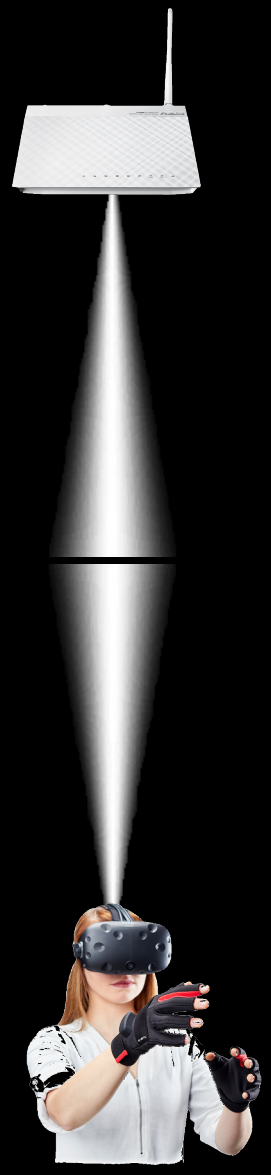
Today's Networks : Broadcast



5G changes how wireless systems operate

5G: Narrow-beam Antennas

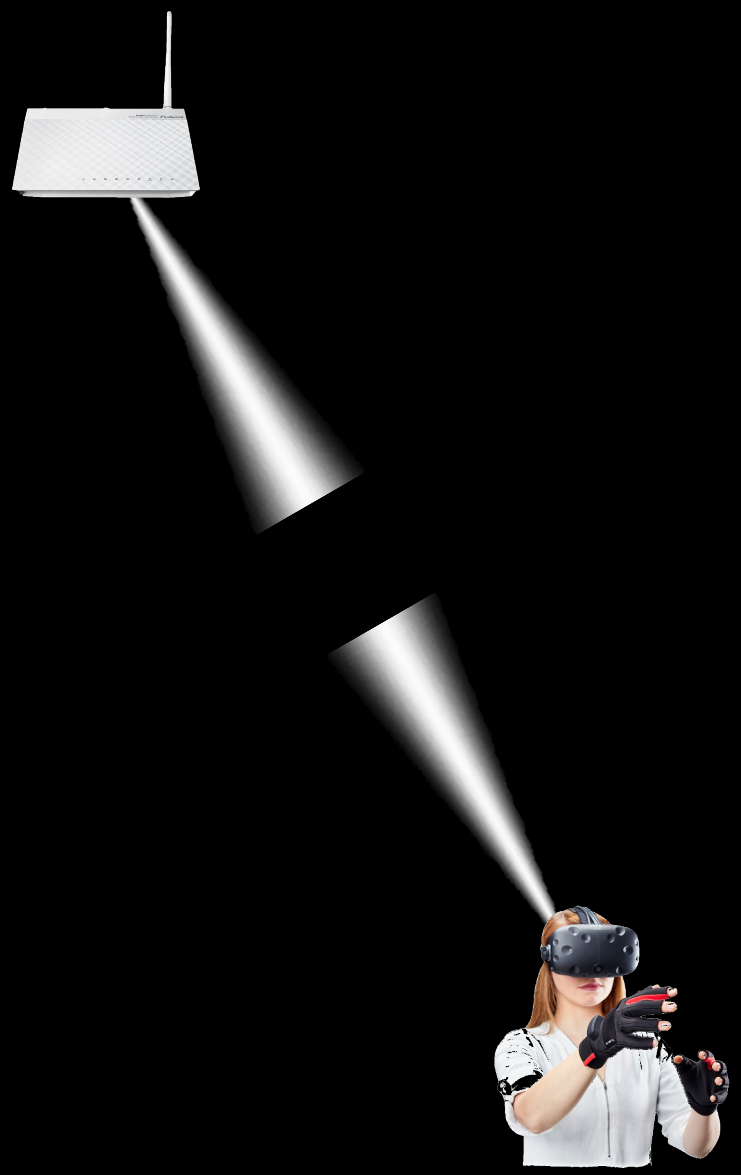




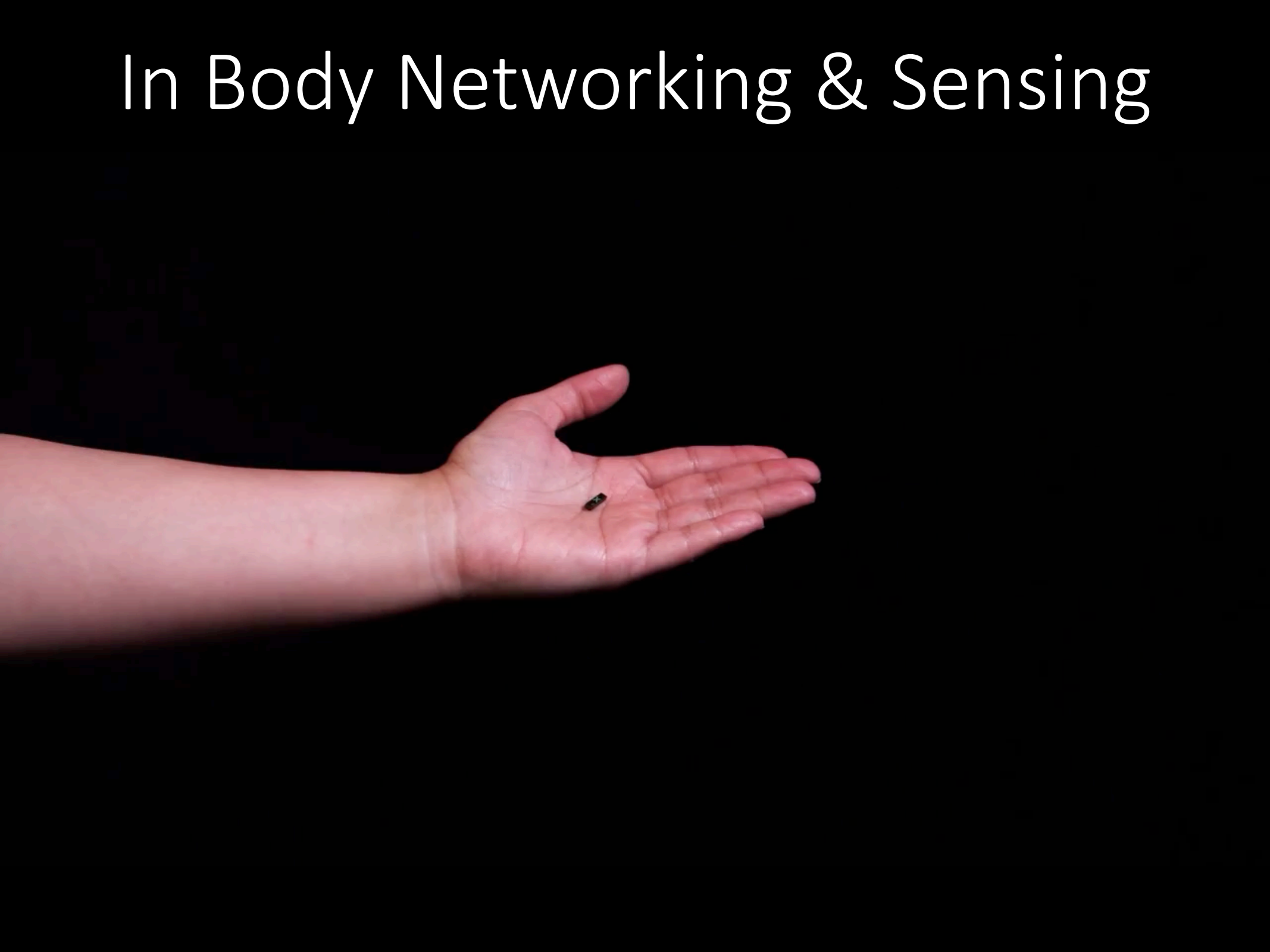
Need to quickly find the right beam alignment and track the user.

Suffers in case of:

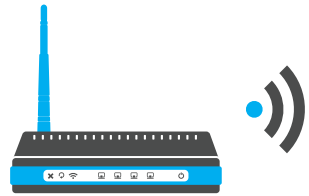
- Mobility
- Blockage
- Multi-users

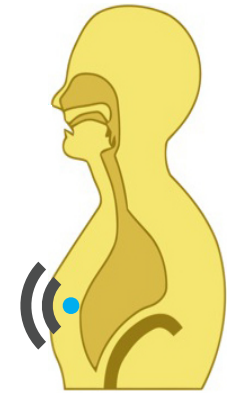


In Body Networking & Sensing

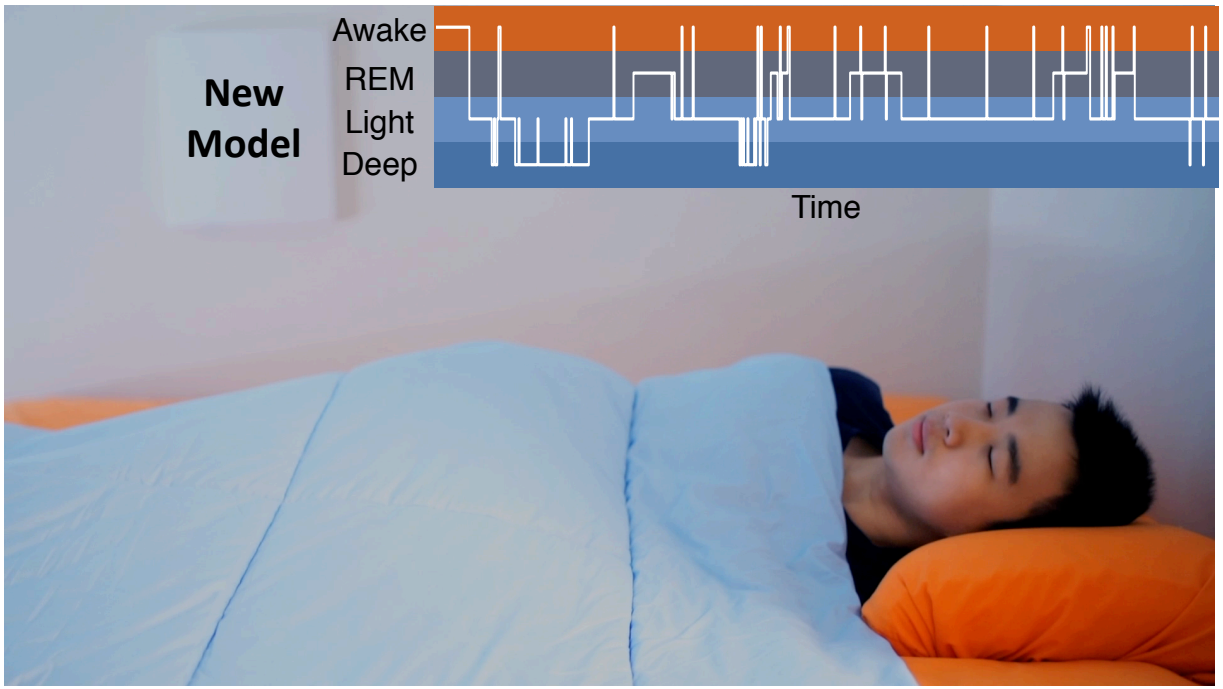


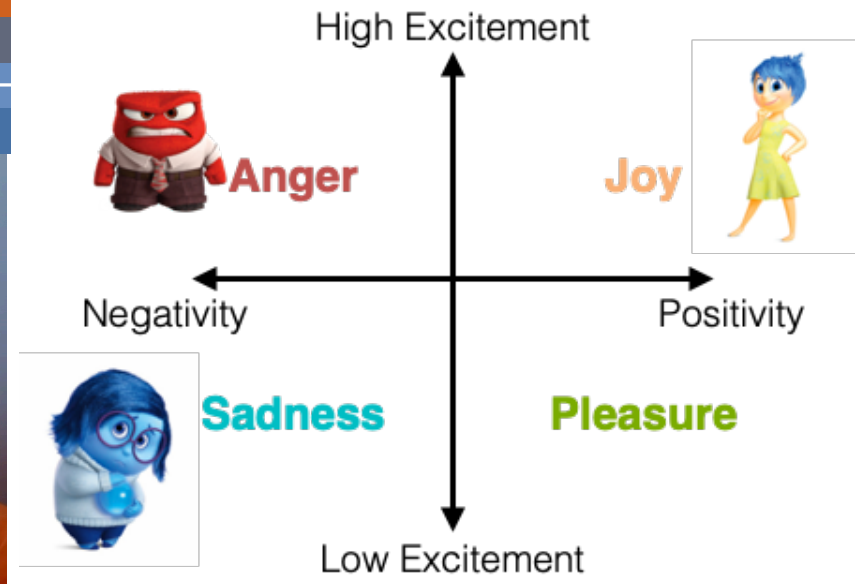
Sensing Emotions & Sleep Stages



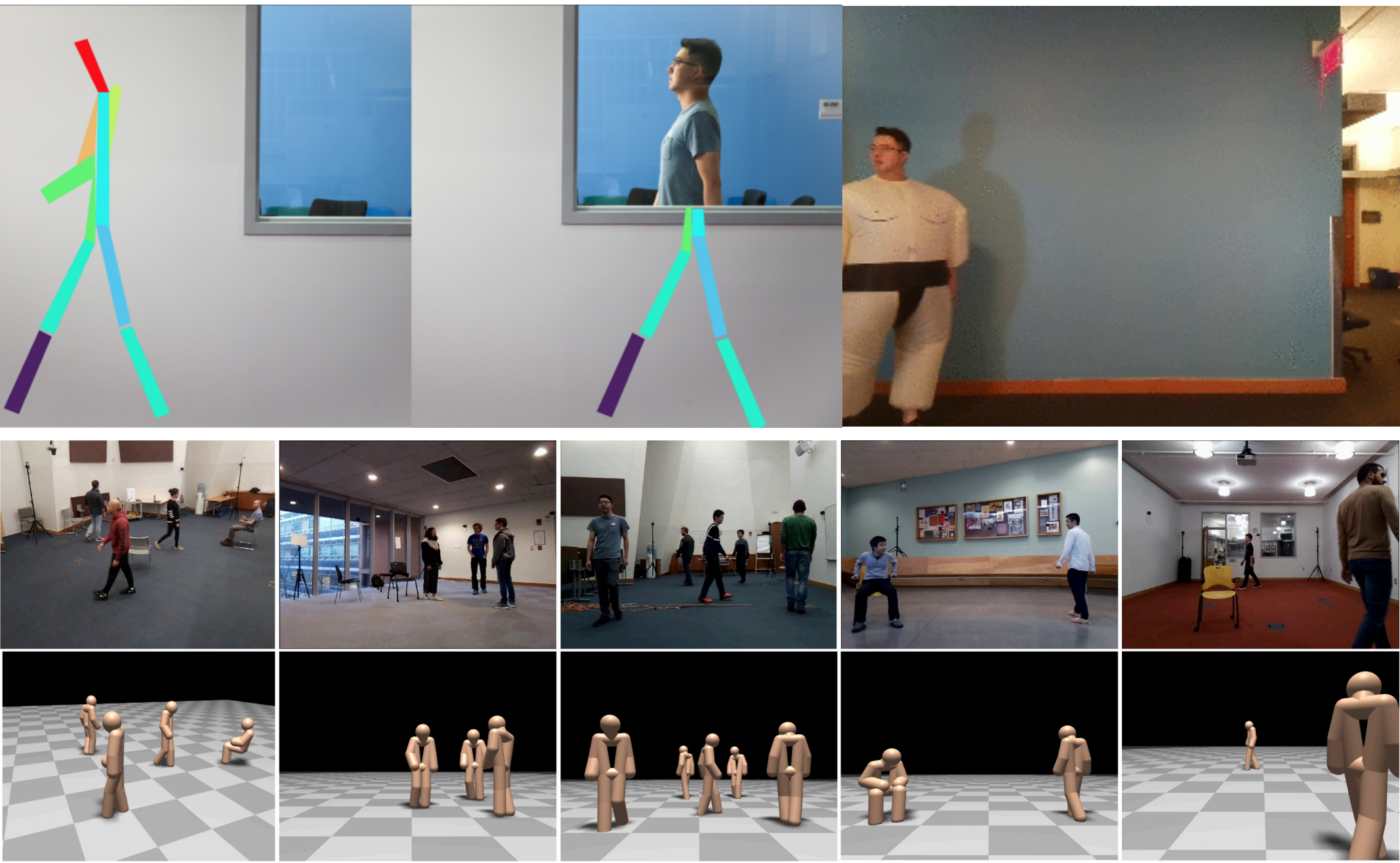


RF signals reflect off body and change with physiological signals

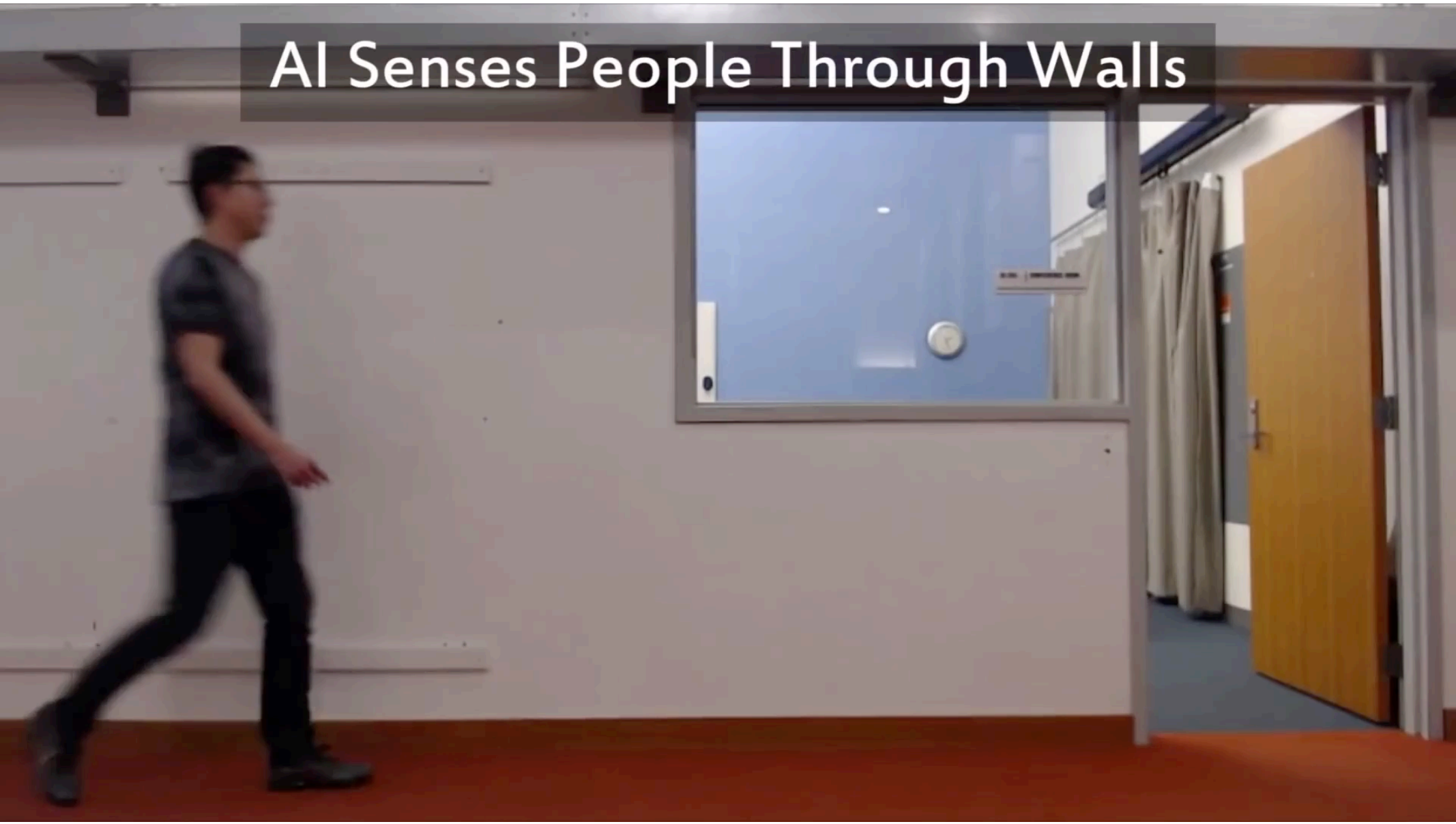


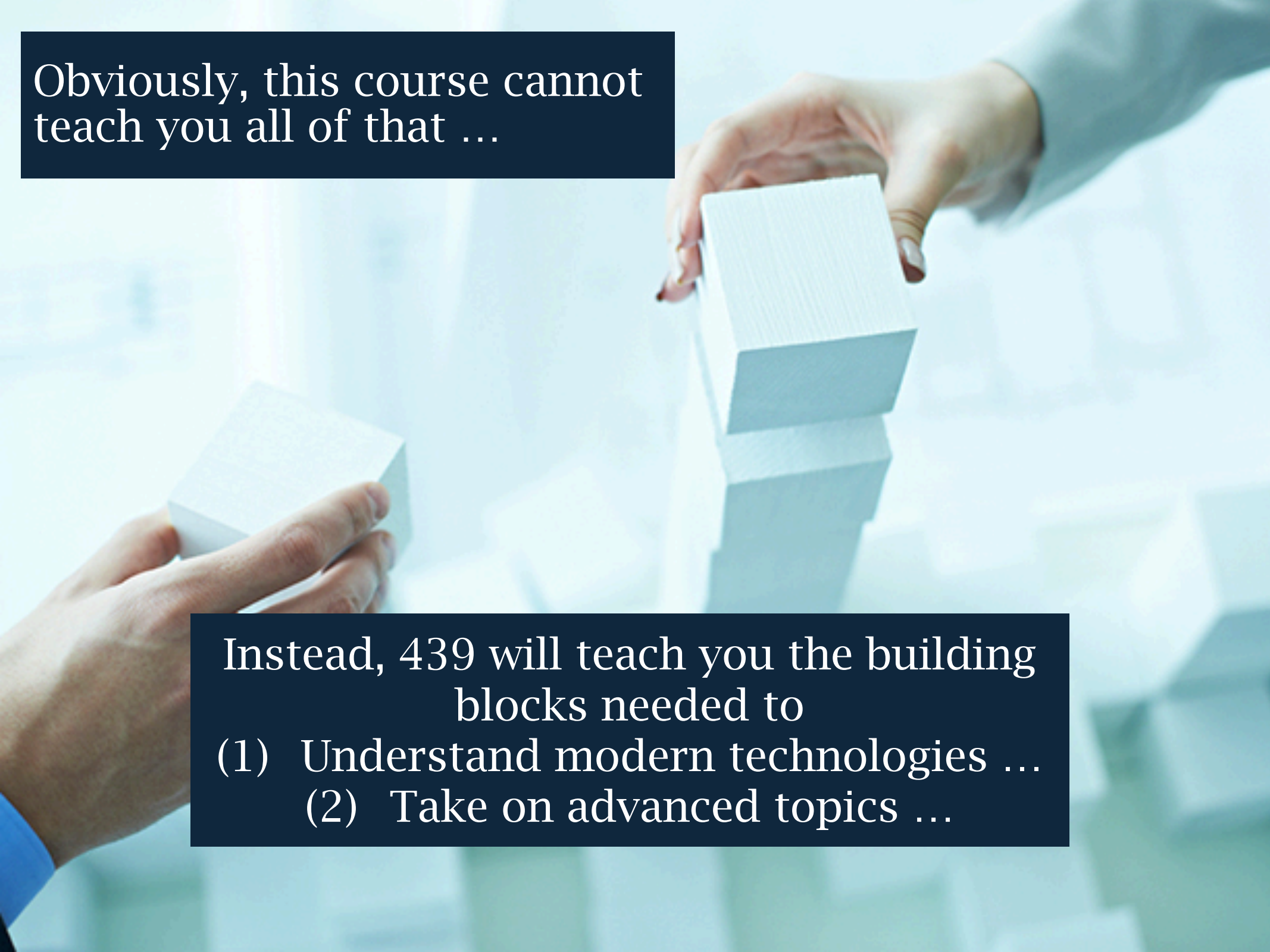


Wireless Sensing of Human Posture & Activities



Wireless Sensing of Human Posture & Activities




Obviously, this course cannot teach you all of that …
Instead, 439 will teach you the building blocks needed to
(1) Understand modern technologies …
(2) Take on advanced topics …

Course Information

- Staff
  - Instructor: Haitham Hassanieh
  - Office hours: Tuesday after class: 10:50am – 11:30am

  - TA: Jitian Zhang
  - Office hours: Friday 4:30pm – 5:30pm

- Communicate with us through Piazza. Do not send emails as it will take days to get a reply. http://piazza.com/illinois/spring2021/ececs439

Course Information

- Material
  - Lectures: Slides, Notes, or Combination of Slides and Notes
  - Piazza for discussions & questions
  - Gradescope for submitting homework
  - Lectures will be recorded and posted on Piazza the next day
  - We will not be using Compass

- Prerequisites
  - Any undergraduate networking, wireless, communications or RF class
  - Basic math and signal processing: probability, Fourier, …
  - Matlab or C programming.

Zoom Polls

- We will be using zoom polls to ask you questions, get your feedback and make the class more lively.

- Idea: We put the question and option on the slides and use zoom polls for you to answer.

- 3 Types of questions:
  - True/False
  - Single Choice
  - Multiple Choice

- Let’s try it.

I am:

A. Undergraduate Student

B. M.S. Student

C. M.Eng. Student

D. Ph.D. Student

Which form of lecture your prefer?

A. Slides: Professor presents from slide

B. Notes: Professor writes notes

C. Combination of slides and notes

D. I am fine with either

Which off the following classes have you taken?

A. Computer Networks (ECE 438 or equivalent)

B. Digital or Wireless Communication (ECE 361, 461, 463, or equivalent)

C. IoT classes

D. RF, Radio, Antenna Classes

E. Signal Processing Classes

Which off these concepts are you already familiar with?

A. Network Protocol Stack

B. OFDM

C. FFT Algorithm

D. Mixers, PLLs, and LPF

E. Shannon’s Capacity

Course Information

- Grading
  - 40% Homework
  - 40% Take Home Exams
  - 20% Mini-Project

Course Information

❑ Homework

- 5 Homework Assignments
- Due Friday at 11:59pm
- Almost Every other week.
- Can be submitted handwritten or typed on Gradescope.
- In Groups of 1 or 2
- All group members should solve and discuss the entire assignment but can divide writing the final draft of the solution. This way if a conflict arises, you can just submit individually.
- Late submission policy:
  - 0 – 12 hrs late: – 0 points
  - 12 – 24 hrs late: – 5 points
  - 24 – 36 hrs late: – 15 points
  - 36 – 48 hrs late: – 25 points
  - 48 – 72 hrs late: – 50 points
  - > 72 hrs late: – 100 points

Course Information

❑ Take Home Exams:

- 2 Take Home Exams
- Released on Friday and due on Sunday evening.
- Must be done individually
- No late submissions allowed
- More details to follow

❑ Mini Project:

- In groups of 1 – 2.
- Choose between:
  - ➢ Writing a survey based on assigned research papers.
  - ➢ Building an OFDM TX, RX Chain in Matlab aka solve MP1 from the Graduate Wireless Networks Class.
- More details to follow

Class Webpage

https://courses.grainger.illinois.edu/ece439/sp2021/

ECE 439 (Spring 2021): Wireless Networks

General Information | Course Schedule & Materials

Course Description:

Wireless and mobile systems have become ubiquitous; playing a significant role in our everyday life. However, the increasing demand for wireless connectivity and the emergence of new areas such as the Internet of Things has led to new wireless technologies. This course gives an overview of wireless network architectures including cellular networks, local area networks, multi-hop wireless networks such as ad hoc networks, mesh networks, and sensor networks; capacity of wireless networks; medium access control, routing protocols, and transport protocols for wireless networks; mechanisms to improve performance and security in wireless networks; energy-efficient protocols for sensor networks.

The course will be taught online through Zoom. Students are expected to attend the live lectures and ask questions. However, in case of a conflict with another class, all lectures will be recorded and made available to students via Piazza.

Lecture Time & Location: Tuesday & Thursday 9:30 am - 10:50 pm US Central Time on Zoom.

Instructor: Haitham Hassanieh (haitham@illinois.edu)

TA: Jitian Zhang (jitianz2@illinois.edu)

Office Hours: Haitham: Tuesday 10:50 pm - 11:30 pm on Zoom.
Jitian: TBD

Zoom: All zoom links + Lecture videos are posted to Piazza.

Piazza: http://piazza.com/illinois/spring2021/ececs439/home

Gradescope: https://www.gradescope.com, Sign Up Code: **D5K48G**

Textbook: Lecture notes and slides, no textbook

Grading:

- **40% Homeworks:** 5 homeworks to be submitted on Gradescope. HWs typically released one week before the due date. HWs can be done in groups of 2.
- **40% Exams:** 2 take home exams covering different parts of the course. The exams will be released on Friday and are due Sunday night and must be done individually without any assistance.
- **20% Mini Project:** Student are asked to either build a full OFDM transmitter and receiver in Matlab or write a short survey based on papers assigned by the instructor.

ECE 439 (Spring 2021): Wireless Networks

General Information | Course Schedule & Materials

Note: This schedule is tentative and subject to change over time due to unforeseen events. Please check it regularly.

#	Monday	Tuesday	Wednesday	Thursday	Friday
1	Jan. 25	Jan. 26 **LEC 1:** Introduction	Jan. 27	Jan. 28 **LEC 2:** Math Review: Signals, Convolutions, Fourier Transforms, & Probability	Jan. 29
	Part 1: Wireless Radio, Channel, & Physical Layer				
2	Feb. 1	Feb. 2 **LEC 3:** Radio Basics : Up & Down Conversion, ADCs, DACs, PAs, LNAs	Feb. 3	Feb. 4 **LEC 4:** Wireless Channel	Feb. 5
3	Feb. 8	Feb. 9 **LEC 5:** Modulation 1	Feb. 10	Feb. 11 **LEC 6:** Modulation 2	Feb. 12 **HW 1 Due**
4	Feb. 15	Feb. 16 **LEC 7:** OFDM 1	Feb. 17 **Break (No Classes)**	Feb. 18 **LEC 8:** OFDM 2	Feb. 19
5	Feb. 22	Feb. 23 **LEC 9:** Coding	Feb. 24	Feb. 25 **LEC 10:** Rate Adaptation & Capacity	Feb. 26 **HW 2 Due**
6	Mar. 1	Mar. 2 **LEC 11:** MIMO 1	Mar. 3	Mar. 4 **LEC 12:**MIMO 2	Mar. 5
	Part 2: WiFi, BLE, 5G, IoT, & MAC Layer Network				
7	Mar. 8	Mar. 9 **LEC 13:** MAC 1: Alloha, CSMA	Mar. 10	Mar. 11 **LEC 14:** MAC 2: FDMA, TDMA, CDMA, OFDMA	Mar. 12 **Take Home Exam 1**
8	Mar. 15	Mar. 16 **LEC 15:** WiFi, Bluetooth, GSM, 3G & 4G	Mar. 17	Mar. 18 **LEC 16:** 5G: Millimeter Wave & Phased Arrays	Mar. 19
9	Mar. 22	Mar. 23 **LEC 17:** IoT 1: LoRA	Mar. 24 **Break (No Classes)**	Mar. 25 **LEC 18:** IoT 2: RFID	Mar. 26 **HW 3 Due**
	Part 3: Wireless Localization & Sensing				
10	Mar. 29	Mar. 30 **LEC 19:** GPS	Mar. 31	Apr. 1 **LEC 20:** Localization	Apr. 2
11	Apr. 5	Apr. 6 **LEC 21:** Radar: UWB & FMCW	Apr. 7	Apr. 8 **LEC 22:** Device Free Localization & Sensing	Apr. 9 **HW 4 Due**
	Part 4: Rounting, Transport Layer, & Cross Layer Networking				
12	Apr. 12	Apr. 13 **Break (No Classes)**	Apr. 14	Apr. 15 **LEC 23:** Routing 1: Wireless Mesh, Adhoc, &	Apr. 16

Topics in this Class

- Part 1: Wireless Radio, Channel, & Physical Layer (10 Lectures)
  - Components of the wireless radio
  - Wireless Channel
  - Modulation
  - OFDM
  - Coding
  - Rate Adaptation
  - Capacity
  - MIMO
- Part 2: WiFi, BLE, 5G, IoT, & MAC Layer (6 Lectures)
  - Aloha
  - CSMA/CA
  - FDMA
  - TDMA
  - CDMA
  - OFDMA
  - WiFi
  - BLE
  - Cellular: 3G, 4G, 5G
  - 5G Millimeter Wave
  - IoT: LoRA
  - IoT: RFIDs

Topics in this Class

- Part 3: Localization and Sensing (4 Lectures)
  - GPS
  - Localization
  - Radar: UWB, FMCW
  - Device Free Sensing
- Part 4: Routing, Transport Layer & Cross Layer (5 Lectures)
  - Mesh Networks
  - Adhoc Networks
  - Sensor Networks
  - Routing
  - Opportunistic Routing
  - Network Coding
  - TCP over Wireless
  - Cross Layer Networking

Questions?