COM-405: Mobile Networks

Lecture 1.0: Introduction & Logistics

Haitham Hassanieh

EPFL

SENS
Laboratory of SEnsing
& Networking Systems

Mobile Networks Are Every Where

WiFi

Only 25 Years Old

Cellular Networks

Only 24 Years with Internet Access

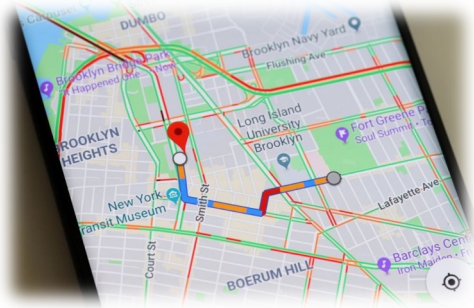
Mobile Internet Connectivity

Essential Part of Everyday Life

Transformed: Education, Business, Health, Commerce, News, Society, …

Democratized Access To Information

Localization & Navigation

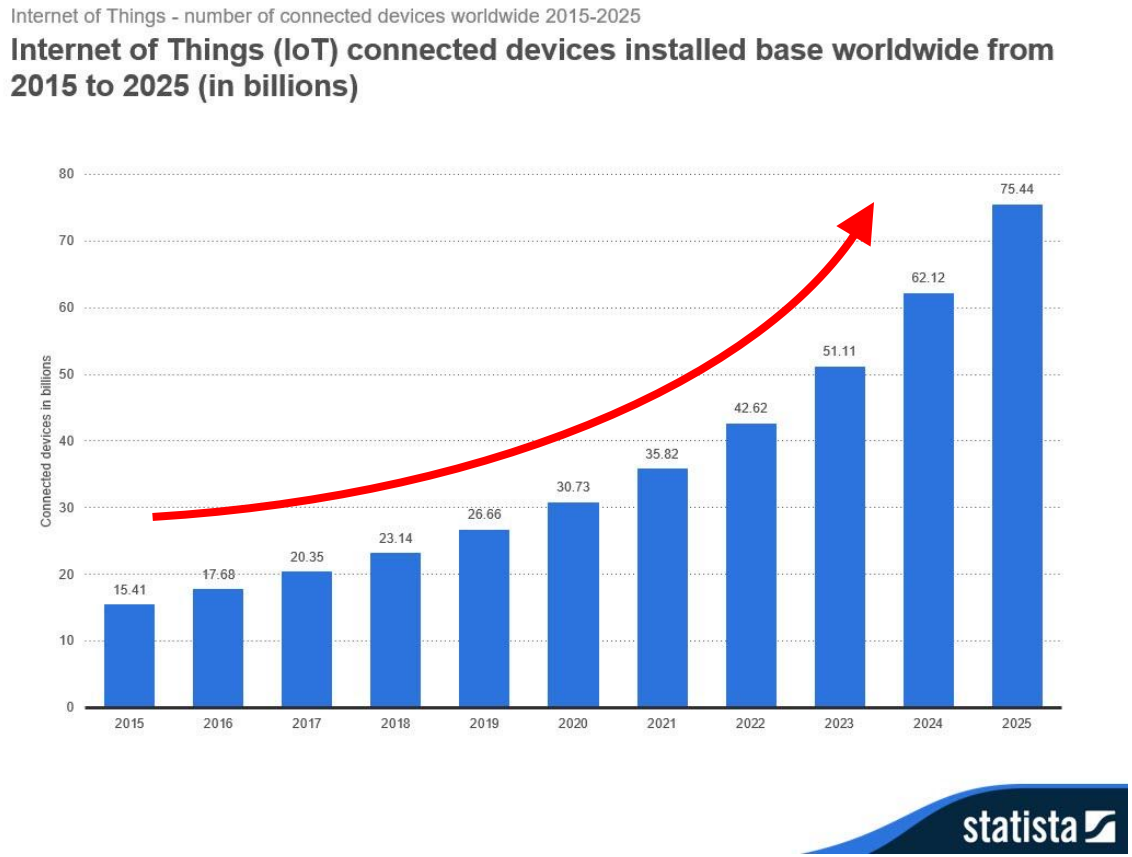


Video Conferencing

Allowed Us To Survive the Pandemic

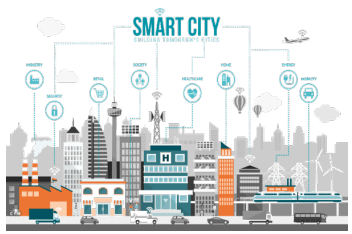
Huge Demand for Mobile Networks

30 Billion Connected IoT Devices & Counting



Agriculture

Smart Cities



Smart Homes

Manufacturing

Health Care

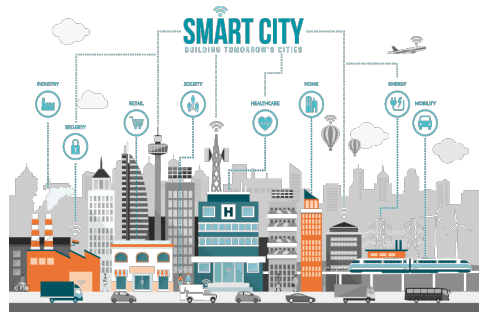
Green Energy

Huge Demand for Mobile Networks

30 Billion Connected IoT Devices & Counting

Agriculture

Smart Cities



Smart Homes

Manufacturing

Health Care

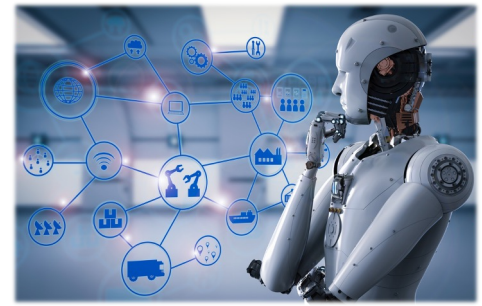
Green Energy

Emergence of Ultra High Data Rate Applications

Wireless VR

Connected Vehicles

Robotic Automation



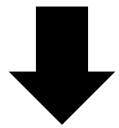
UAVs

Wireless Data Centers

Remote Surgery

Huge Demand for Mobile Networks

Need to support more users (devices) & Need higher data rates



Need more frequency bandwidth

Data Rate ∝ Bandwidth

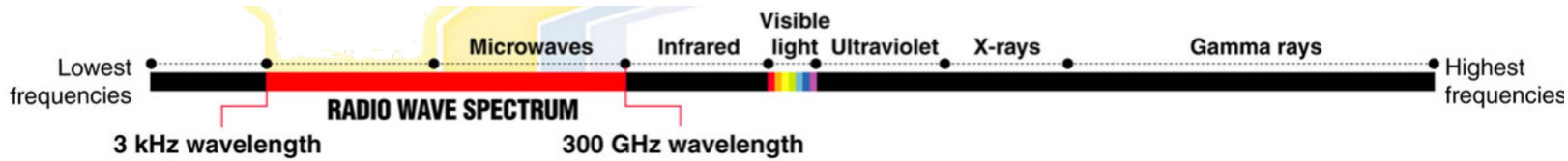
A device has 10 MHz of frequencies to communicate

(Rate at which I transmit or receive: 10 MHz ↔ 10 million samples per second)

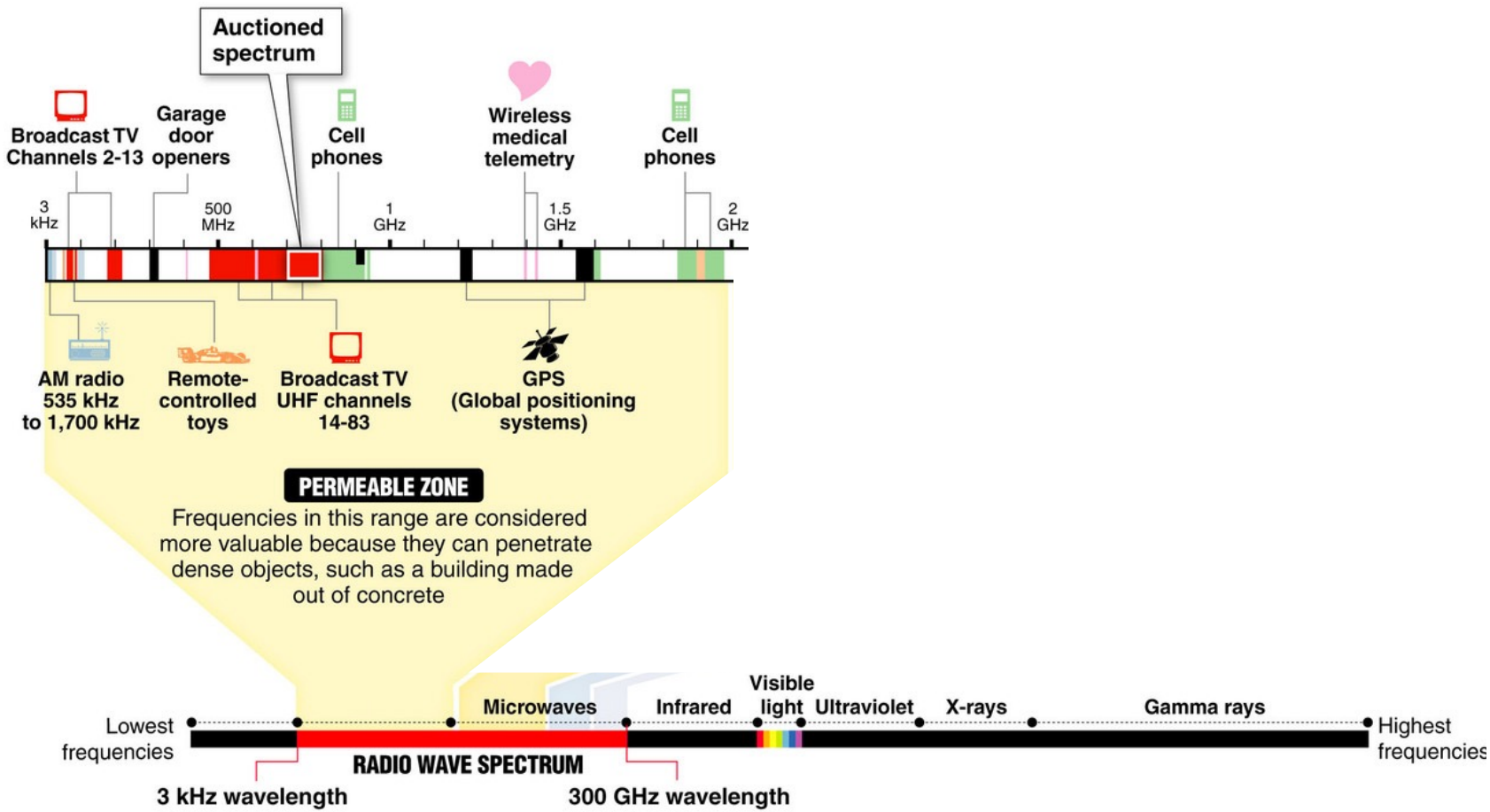
Increase data rate by 10×

Increase # of users by 10x

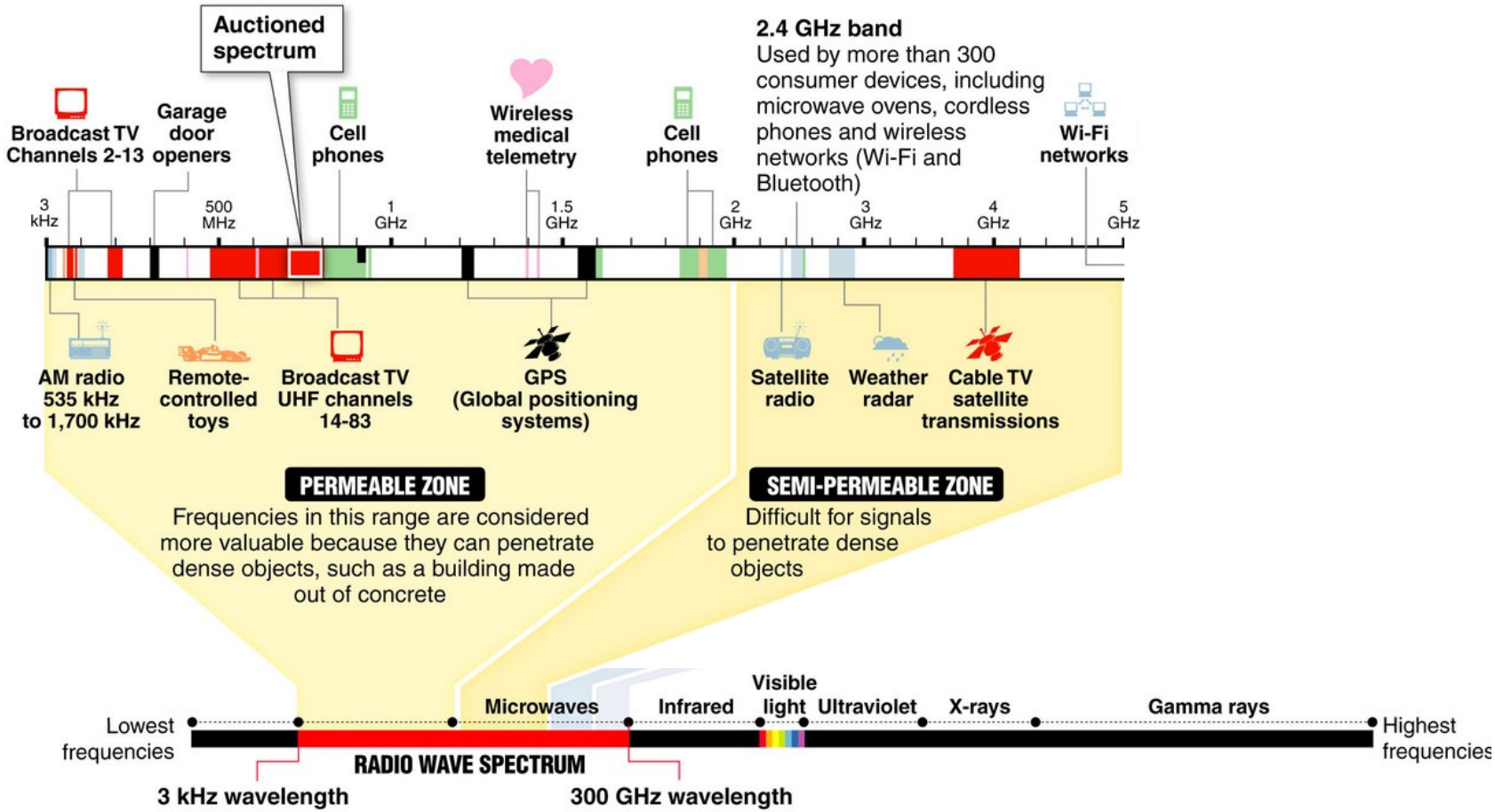
The Wireless Spectrum



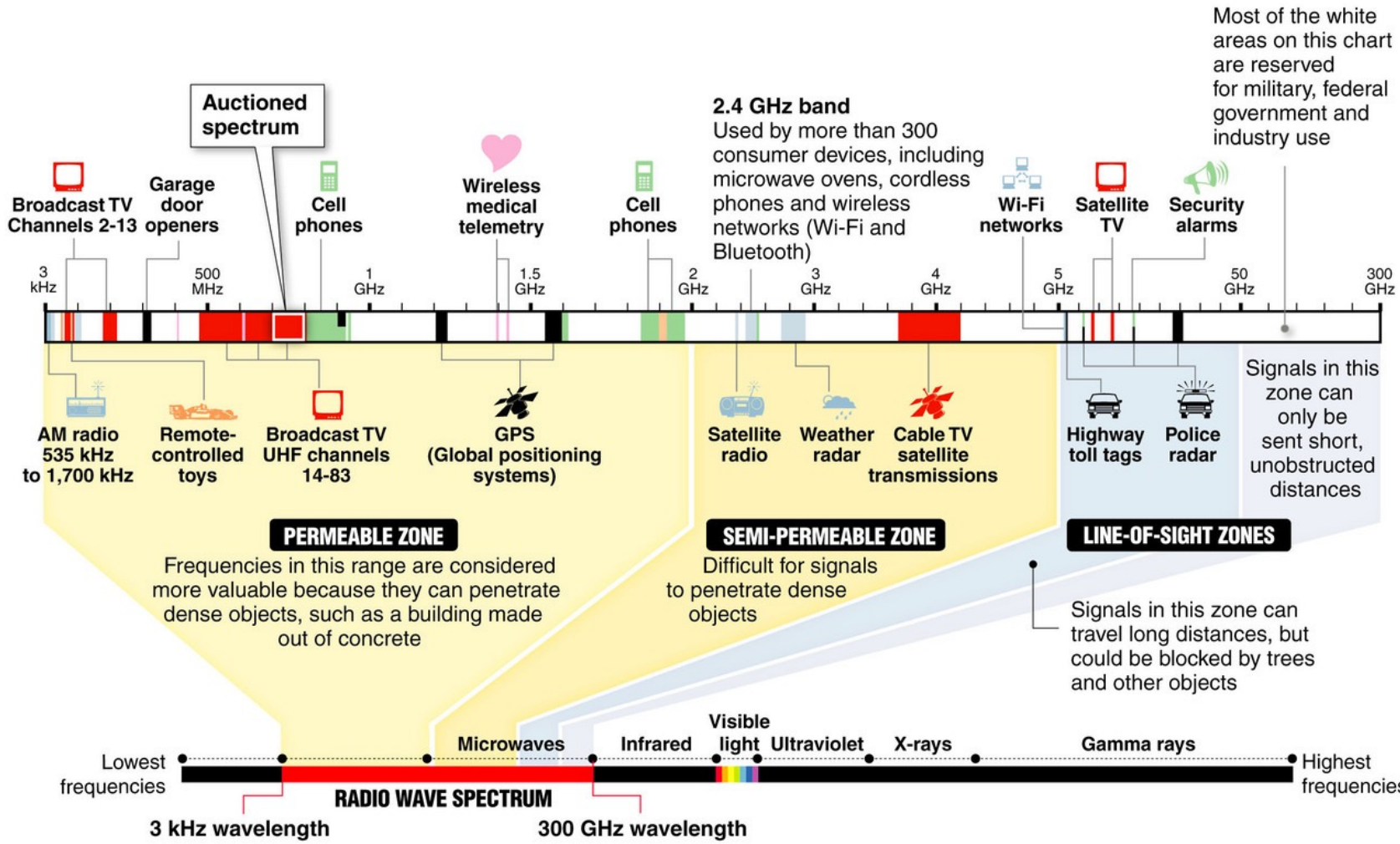
The Wireless Spectrum



The Wireless Spectrum



The Wireless Spectrum



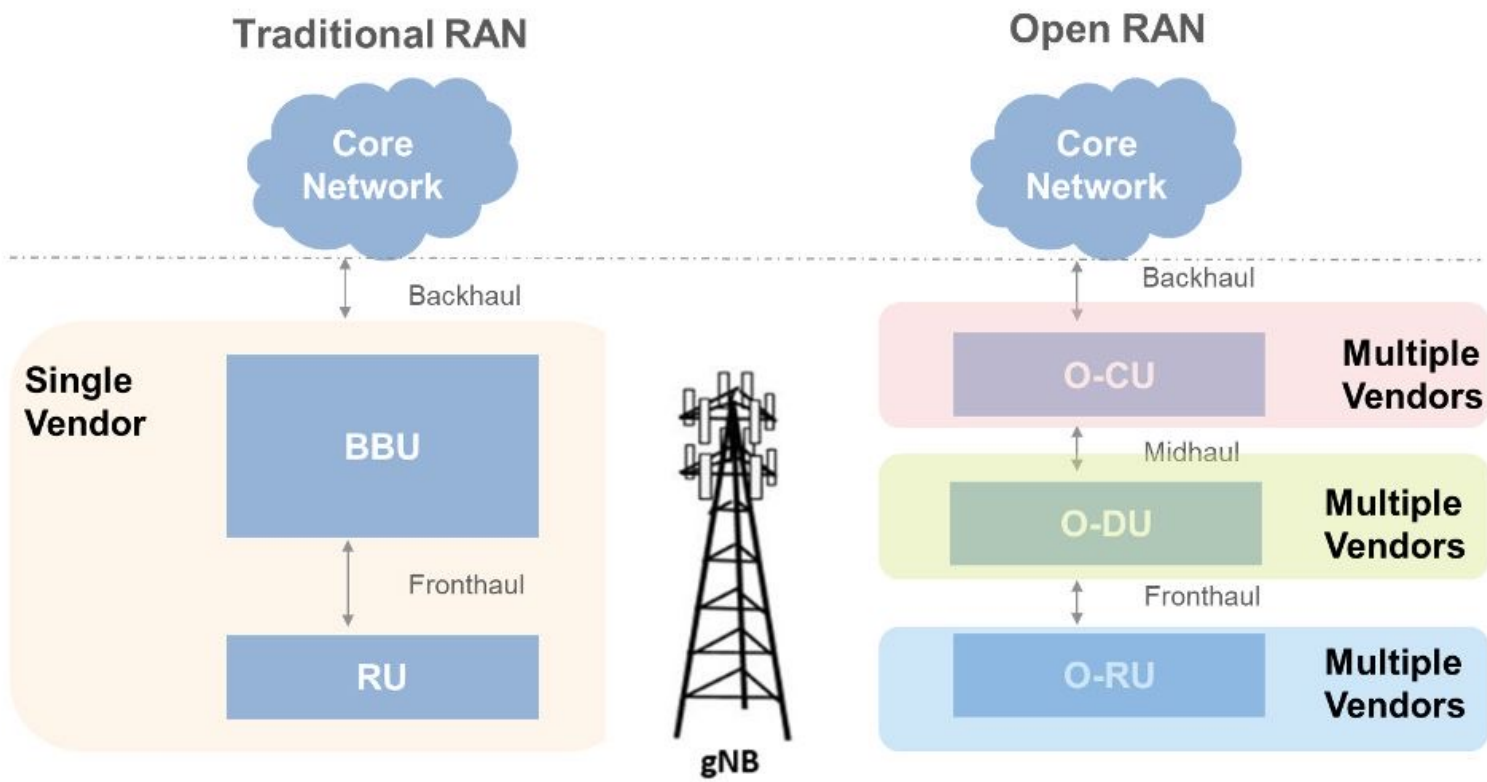
More Bandwidth

More Range

Cellular Networks from 1G to 5G

5G OpenRAN & Virtual RAN

- Implement RAN (Radio Access Network) network functions in software rather than hardware.
- More flexibility in changing network functions
- Open the RAN through standarized interfaces.



Increasing Demand for Mobile Networks

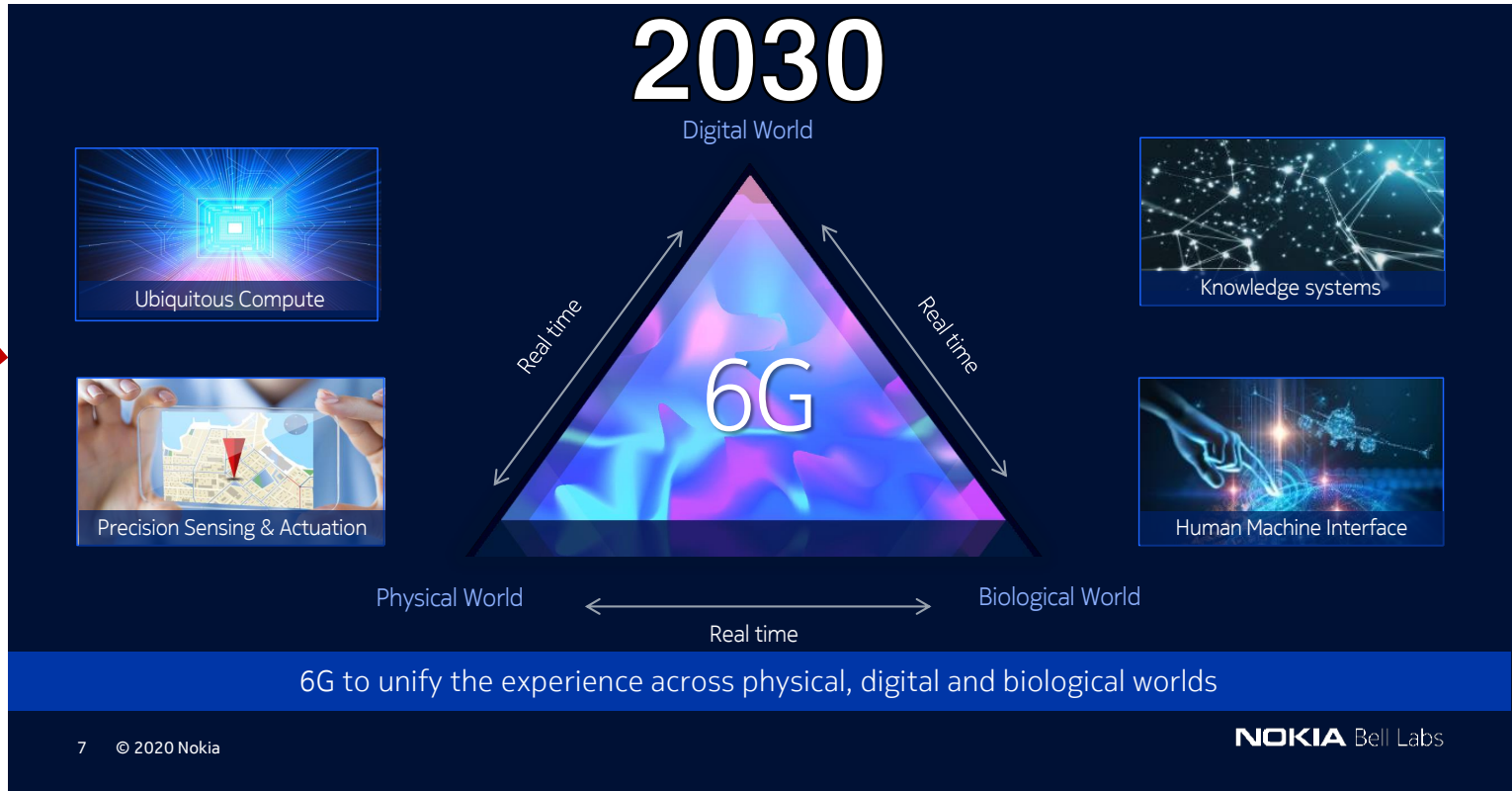
Connecting People

Increasing Demand for Mobile Networks

Connecting Everything

Increasing Demand for Mobile Networks

Connecting
+
Sensing
Everything



NOKIA Bell Labs

The past, present, and future

2G

Voice

The past, present, and future

2G

Voice

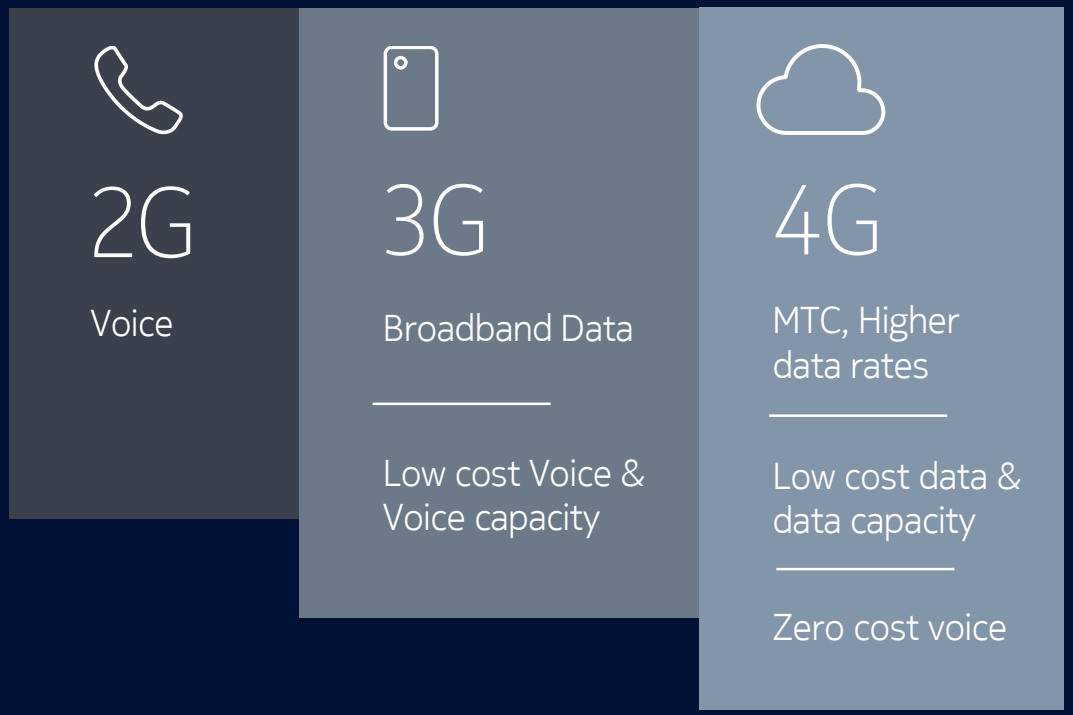
3G

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

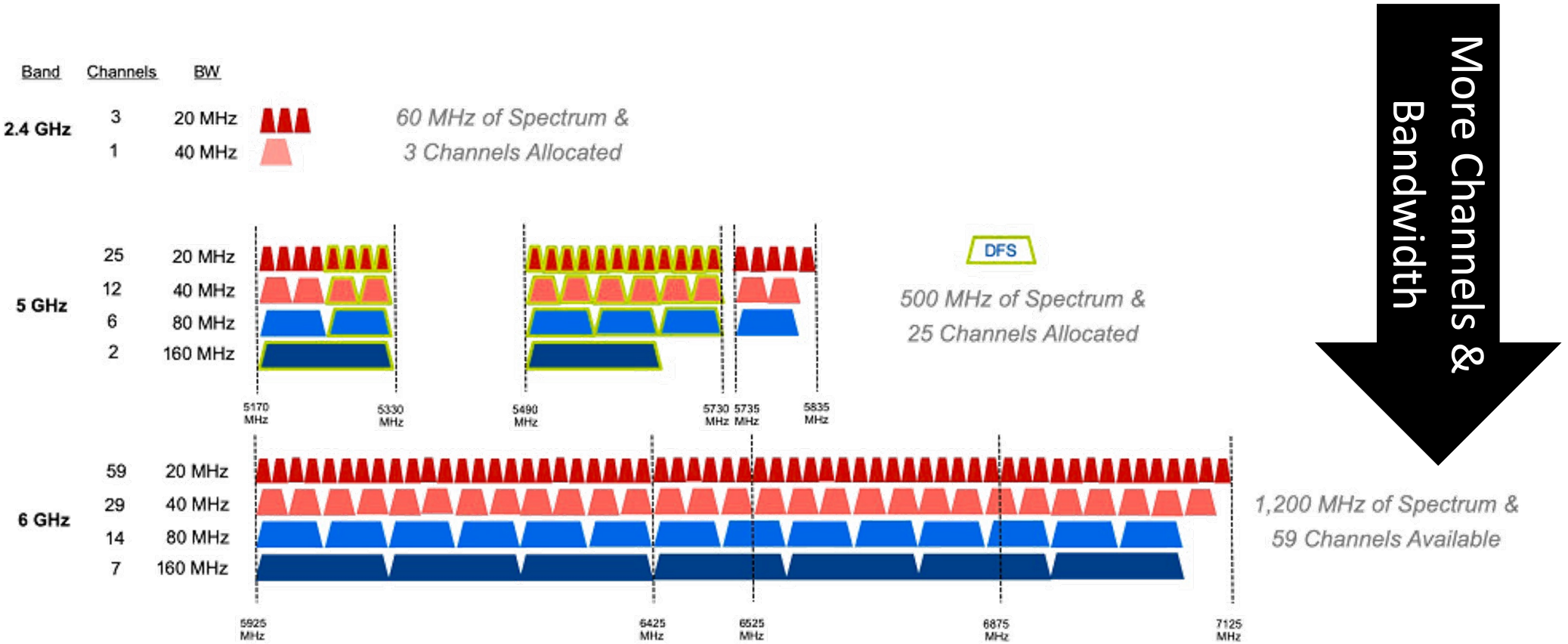
Industrial IoT optimized for low cost & perf.

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

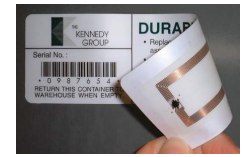
IoT Technologies

Wi Fi

Bluetooth®

NFC

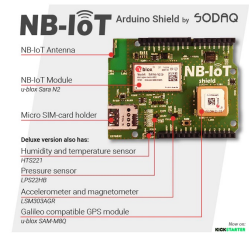
RFID



Cellular

NB-IoT

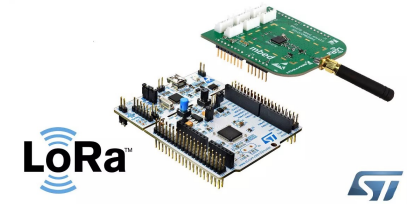
LTE-M



sigfox

LoRa™

neul



LoRa™

LoRa™ Smart Agriculture Applications

ZWAVE®

ZigBee®

Many Motivations for Mobile Networks

- 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
  - …

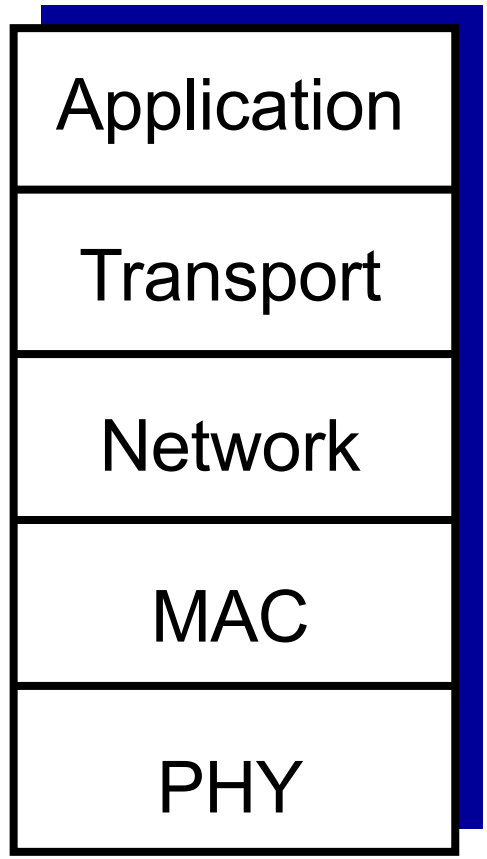
Question Is …

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

In solving the mobile networks 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

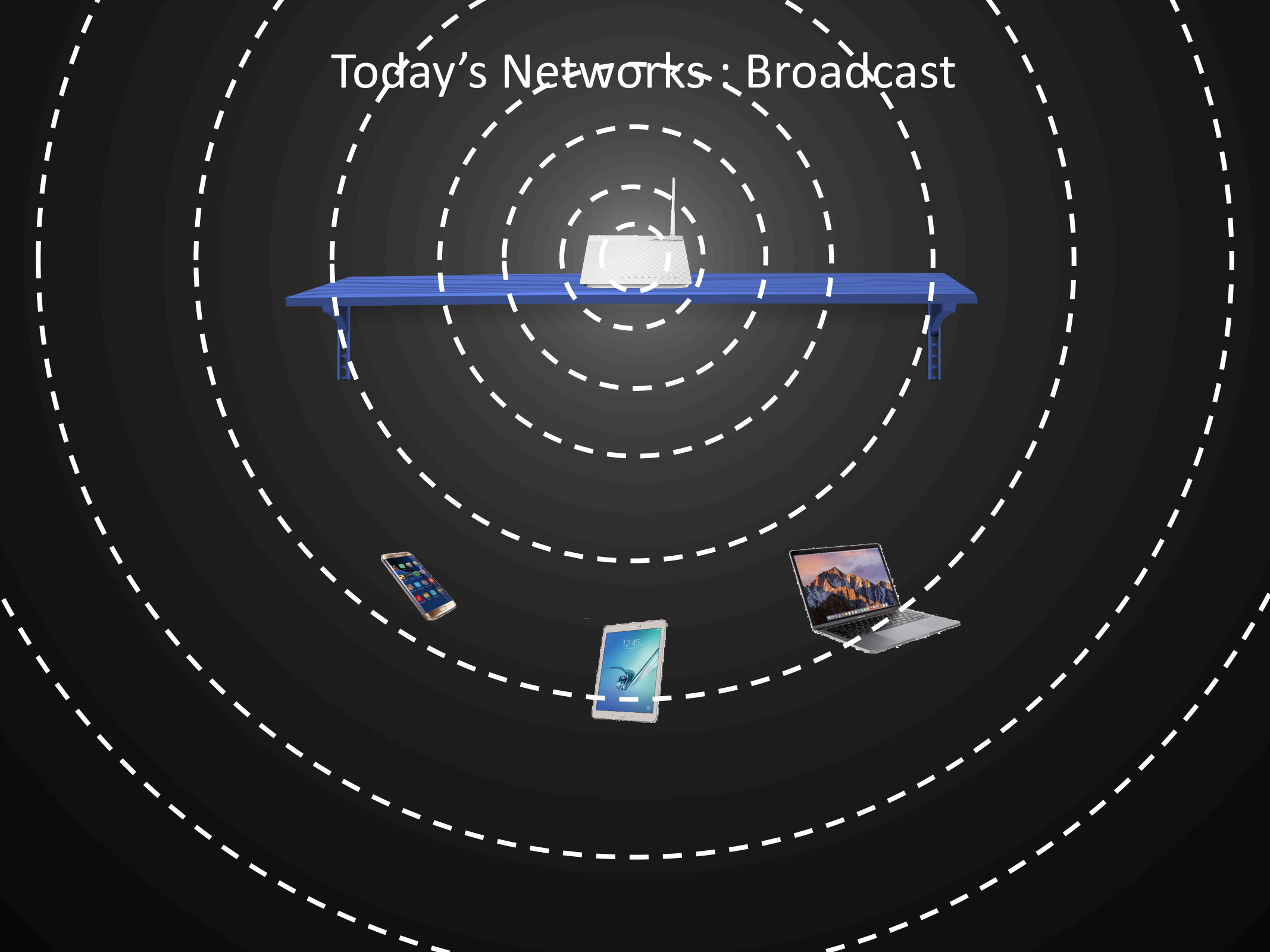
The PHY and MAC layer completely dissimilar

The whole game changes

Even New Challenges with

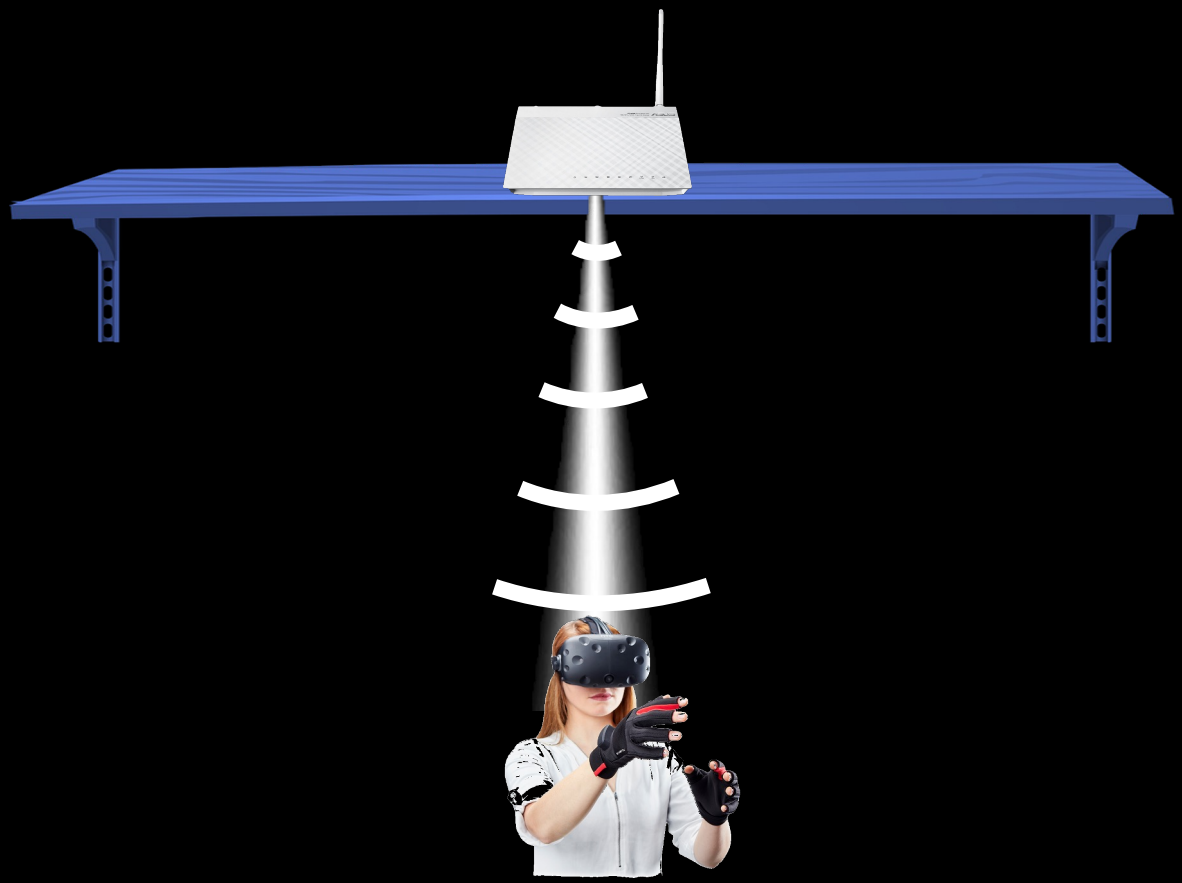
5G, IoT, Implants, Sensing…

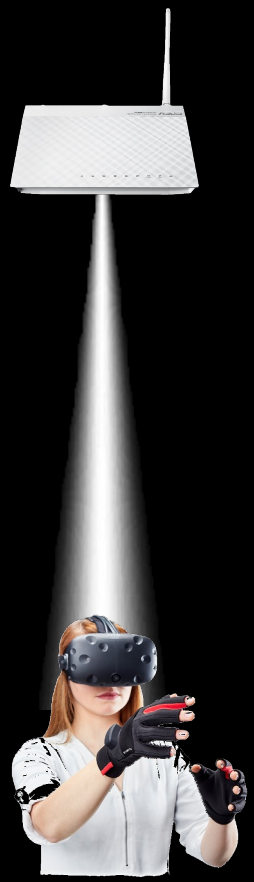
Today's Networks : Broadcast

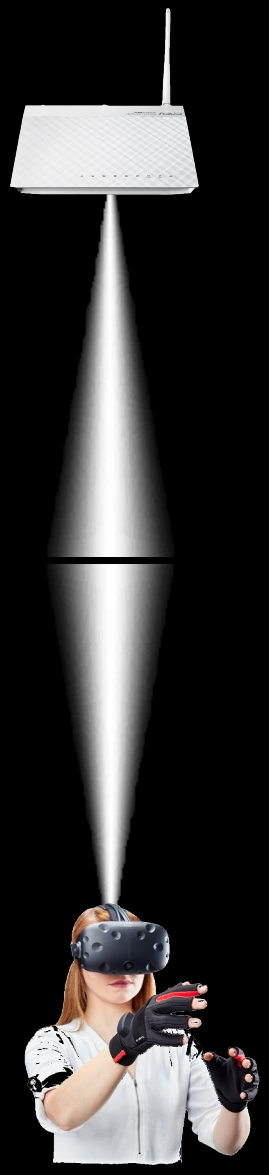


5G changes how wireless systems operate

5G: Narrow-beam Antennas



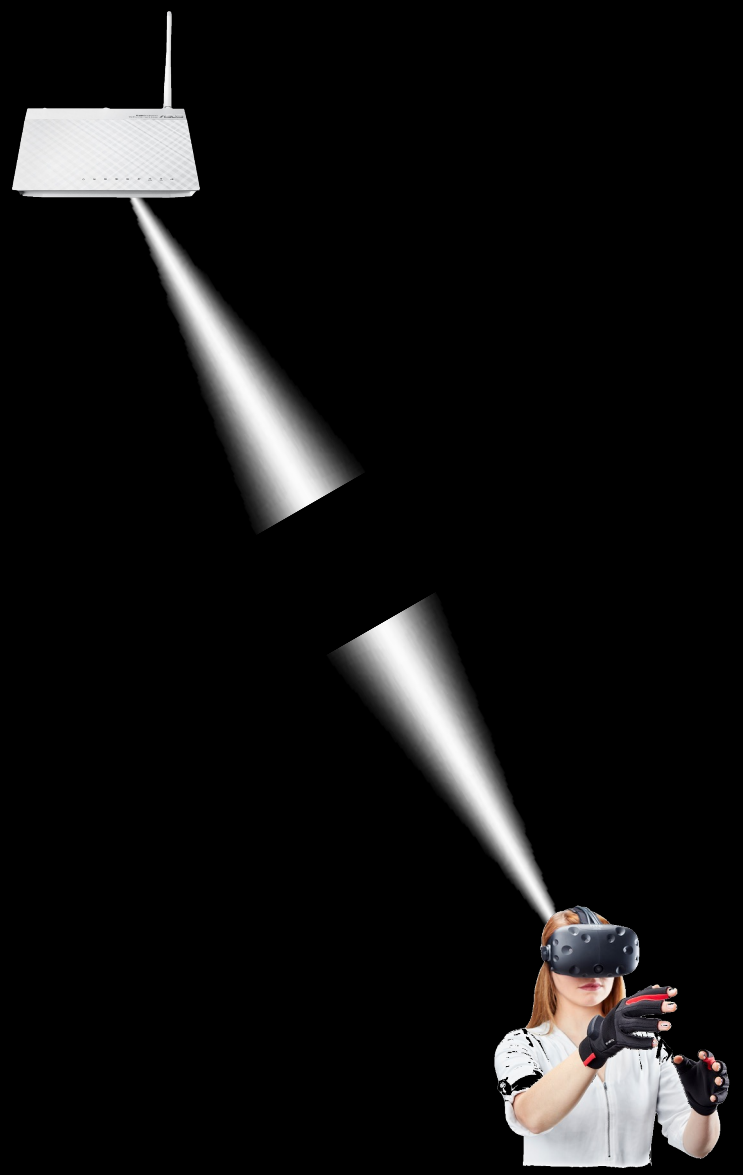




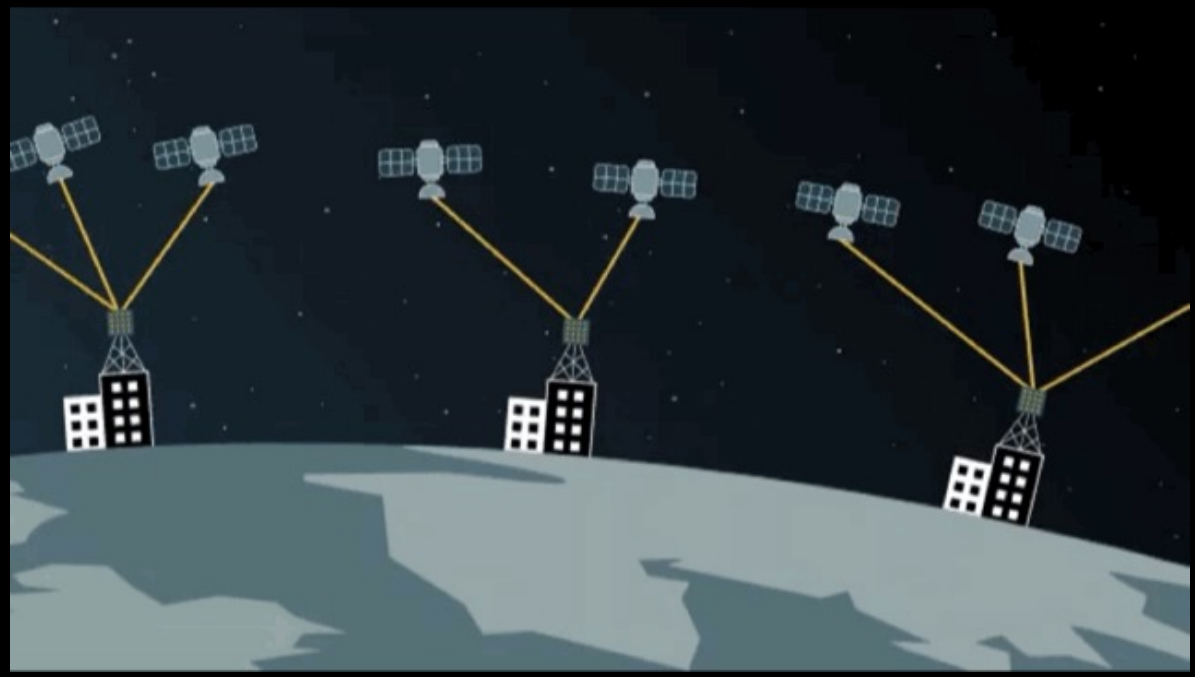
Need to quickly find the right beam alignment and track the user.

Suffers in case of:

- Mobility
- Blockage
- Multi-users



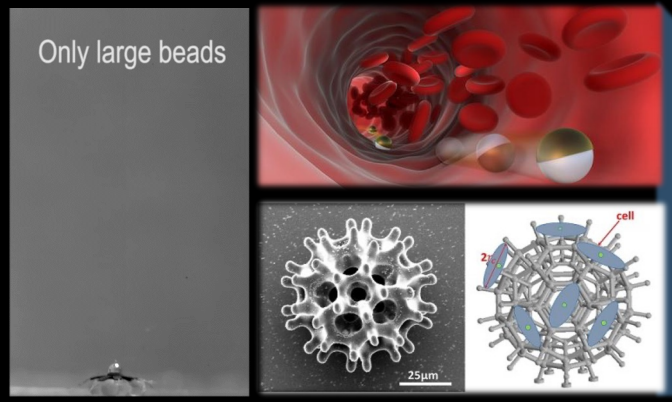
Satellite Networks



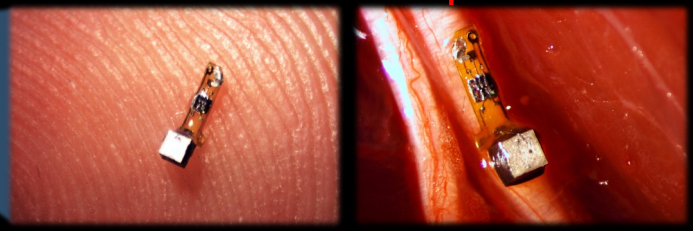
In Body Networking & Sensing

Micro and Nano Bio Implants

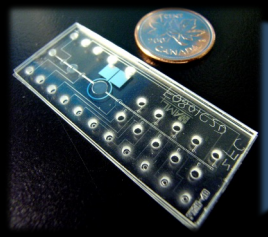
Microrobots for drug delivery



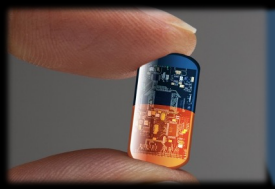
Micro Brain Implants

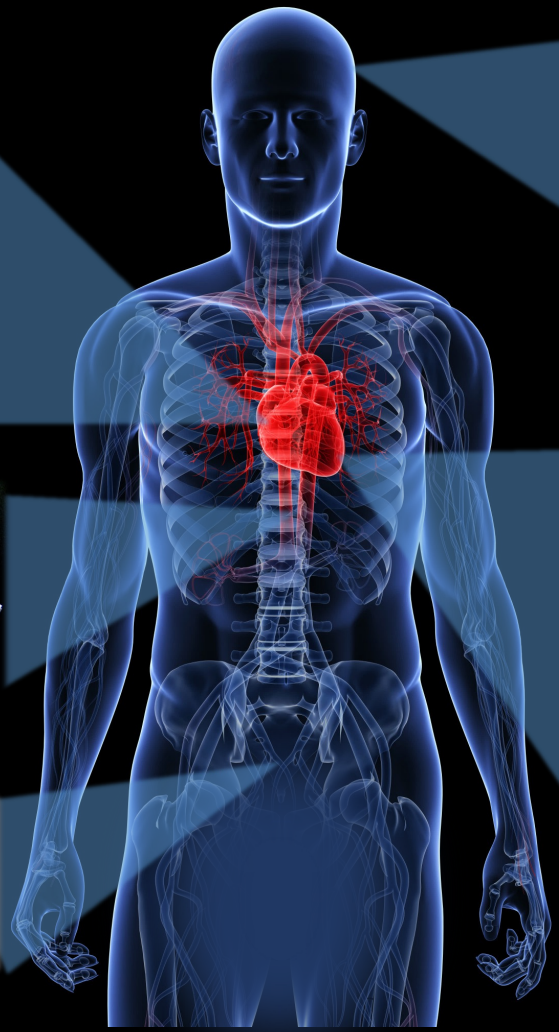


Bio-MEMS
Lab-On-Chip for
In body Diagnosis

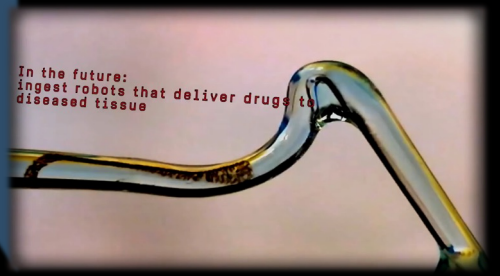


Contraception
Micro-Implants





Nano-Implants
that can move in
the blood vessels

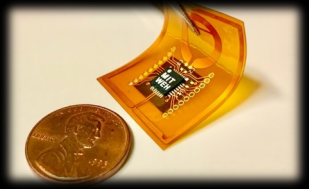


Micro and Nano Bio Implants

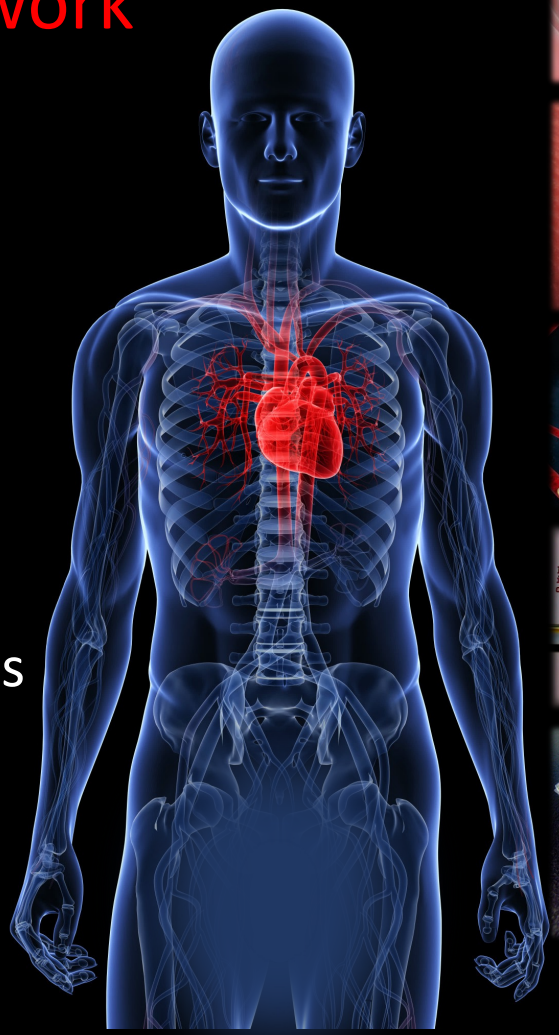
How to communicate with and network Nano & Micro Implants?

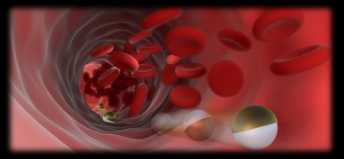
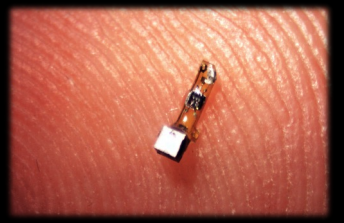
Traditional implants use wireless

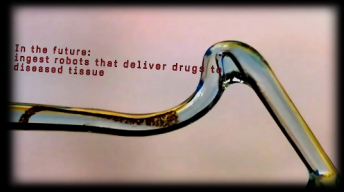


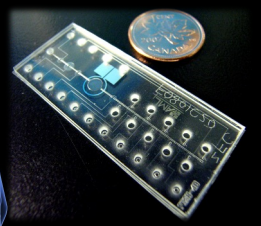


- Large form factor for nano and micro implants
- Requires powerful external device
- Cannot network implants inside the body

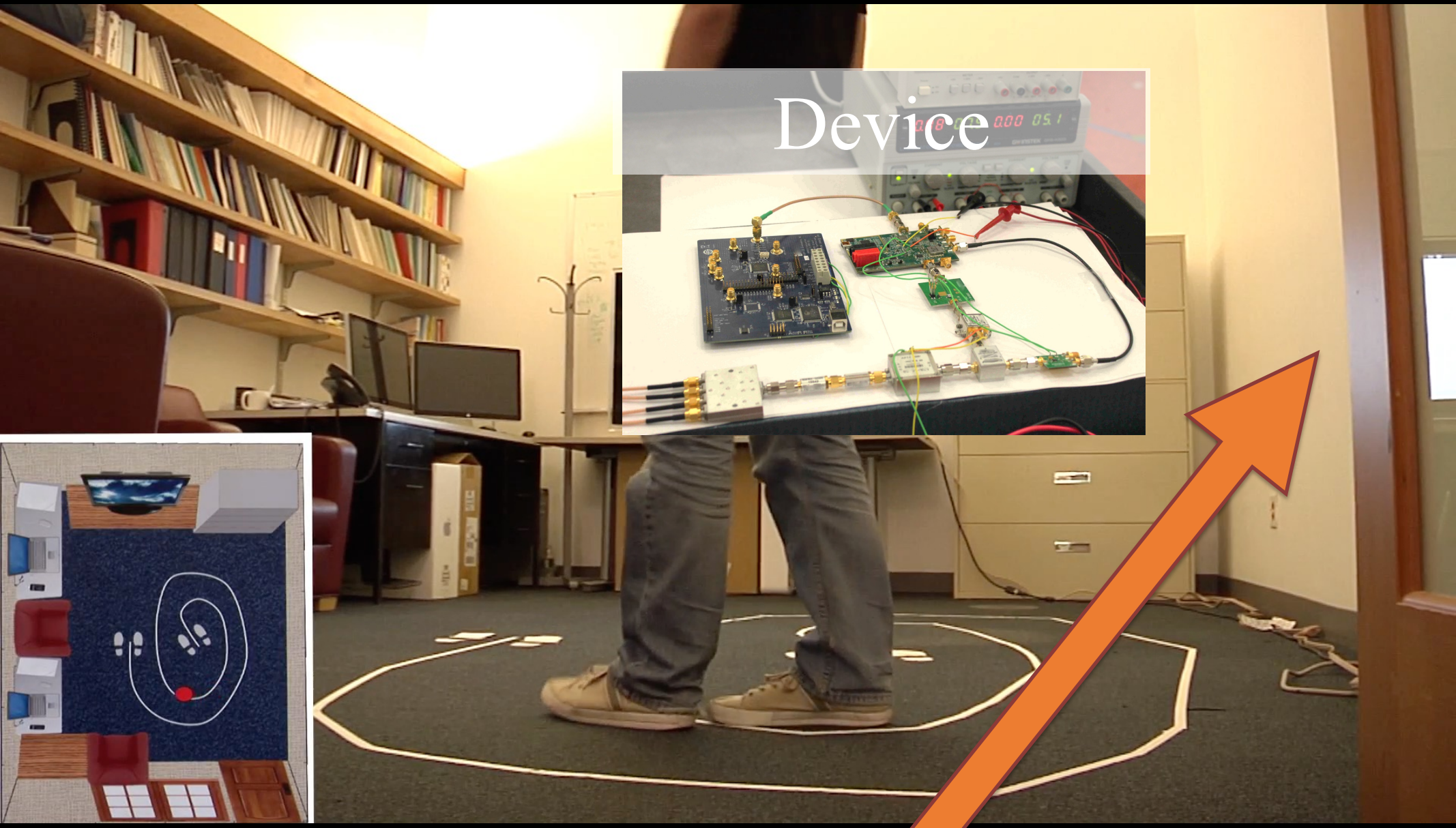






Wireless Sensing



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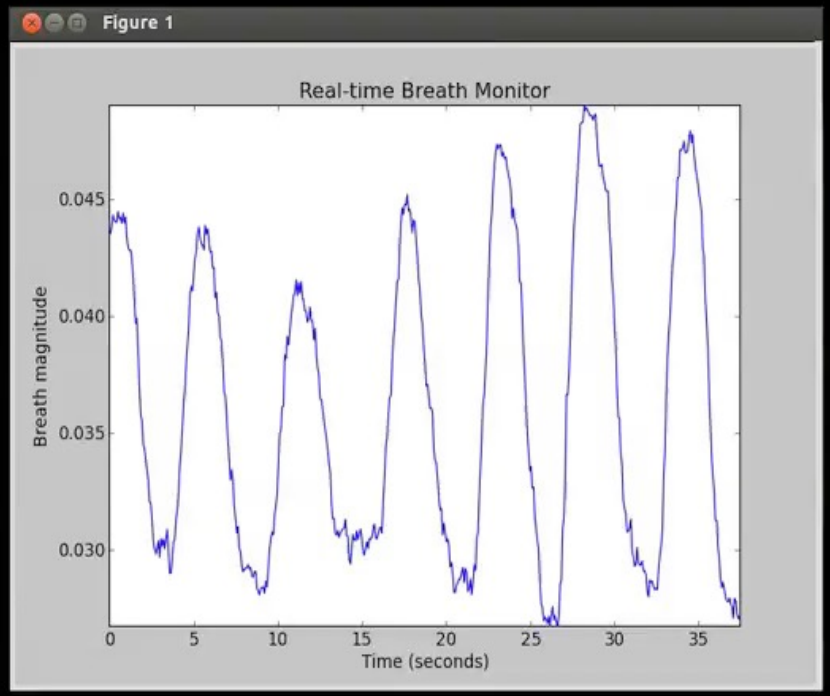


Occlusion is a fundamental challenge for vision

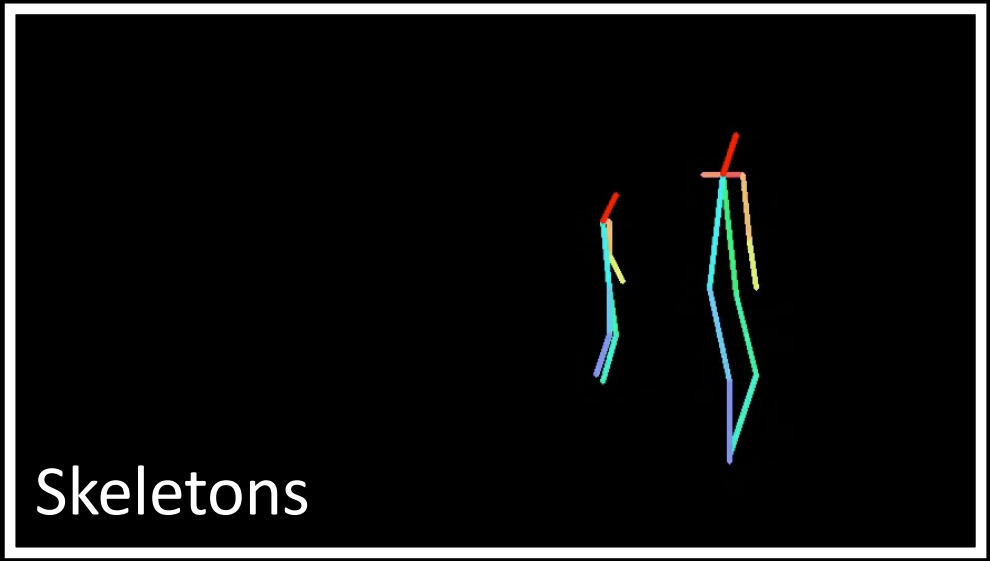
Vision also fails in bad lighting conditions

Through-wall poses
using **only** RF

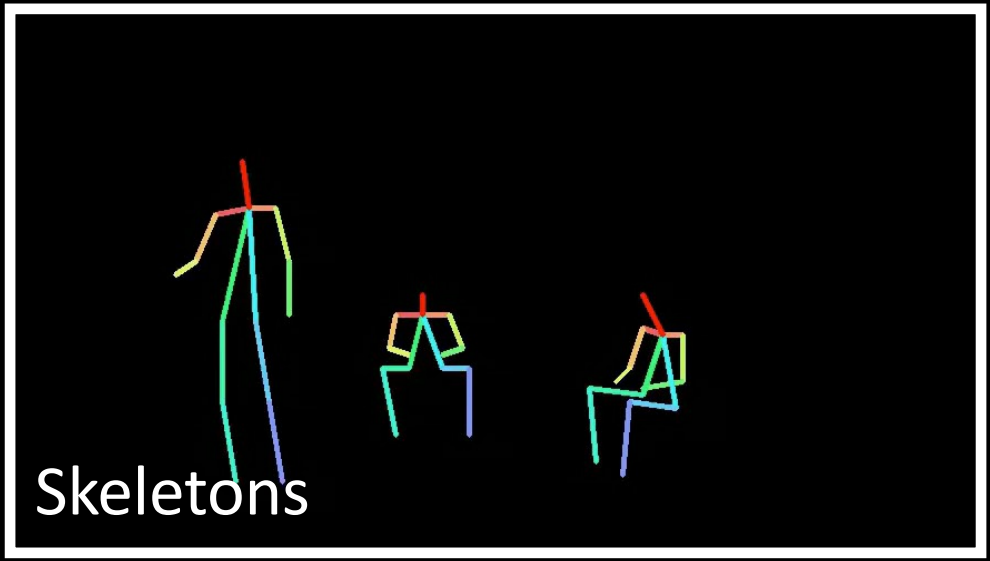
Skeletons

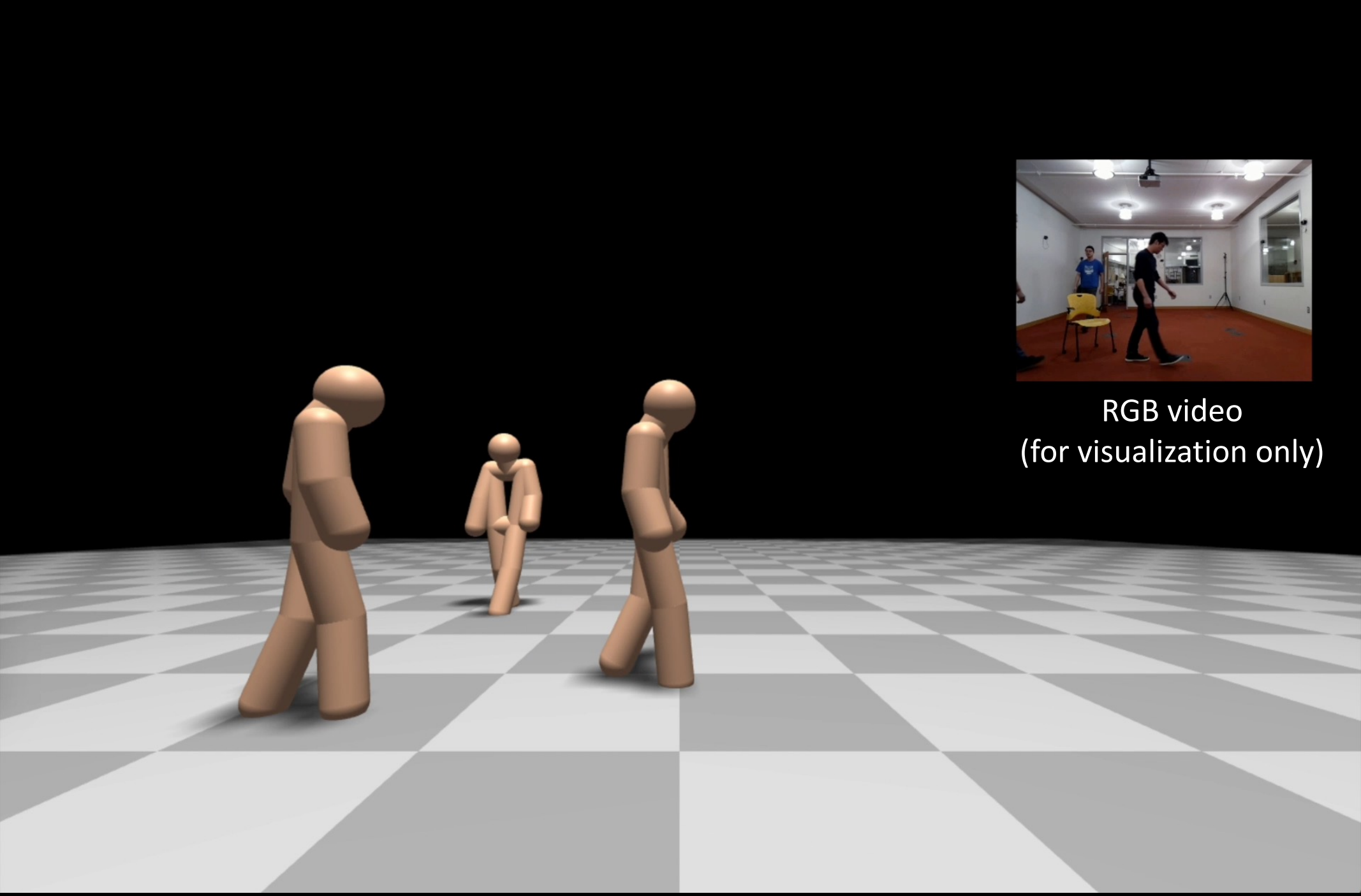
Confidence Maps

Works in bad lighting

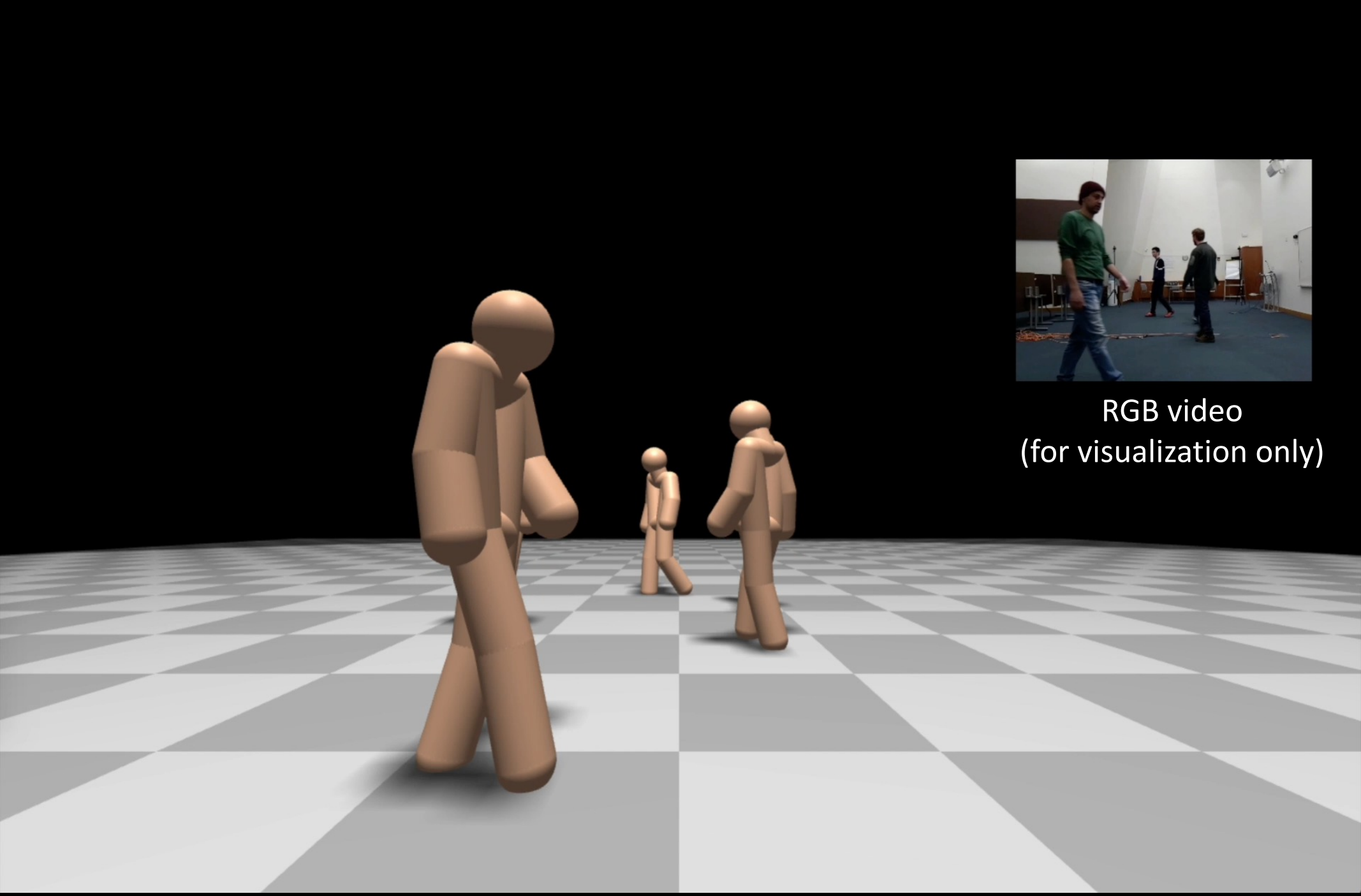


Works with different environment and daily activities





RGB video
(for visualization only)



RGB video
(for visualization only)

Rising Interest in Fully Autonomous Driving

Honda to invest $2.8bn in GM's self-driving car unit

4 October 2018

GM has done extens

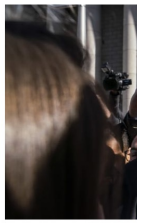
Honda is to invest
driving unit, GM C
autonomous vehi

Elon Musk to investors: Self-driving will make Tesla a $500 billion company

PUBLISHED THU, MAY 2 2019·6:01 PM EDT | UPD

Lora Kolodny
@LORAKOLODNY

KEY POINTS • Citibank and Golc



Elon Musk, chief executive offic
media outside federal court in
Natan Dvir | Bloomberg | Getty Ima

Google Has Spent Over $1.1 Billion on Self-Driving Tech

Qualcomm snapdragon ride platform

Qualcomm eyes self-driving cars with Snapdragon Ride Platform at CES 2020

The company has developed its first system for autonomous vehicles, as well as new offerings for automakers to do things like deliver services.

Shara Tibken Jan. 6, 2020 11:32 a.m. PT

ES LISTEN · 03:15

Automotive is a big focus for Qualcomm.

WIRED

Snow and Ice Pose a Vexing Obstacle for Self-Driving Cars

Most testing of autonomous vehicles until now has been in sunny, dry climates. That will have to change before the technology will be useful everywhere.

Forbes

Weather Creates Challenges For Next Generation Of Vehicles

Jim Foerster Contributor
Science

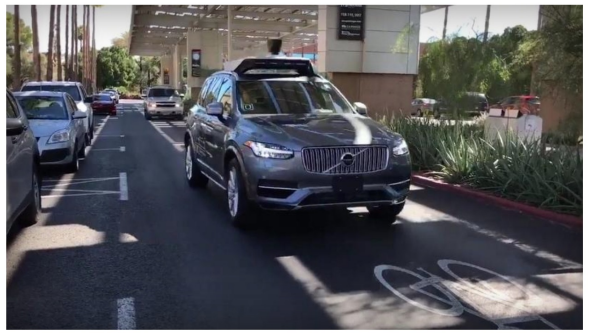
Bloomberg Businessweek

Self-Driving Cars Can Handle Neither Rain nor Sleet nor Snow

les solve inclement conditions,
that can see below the ground.

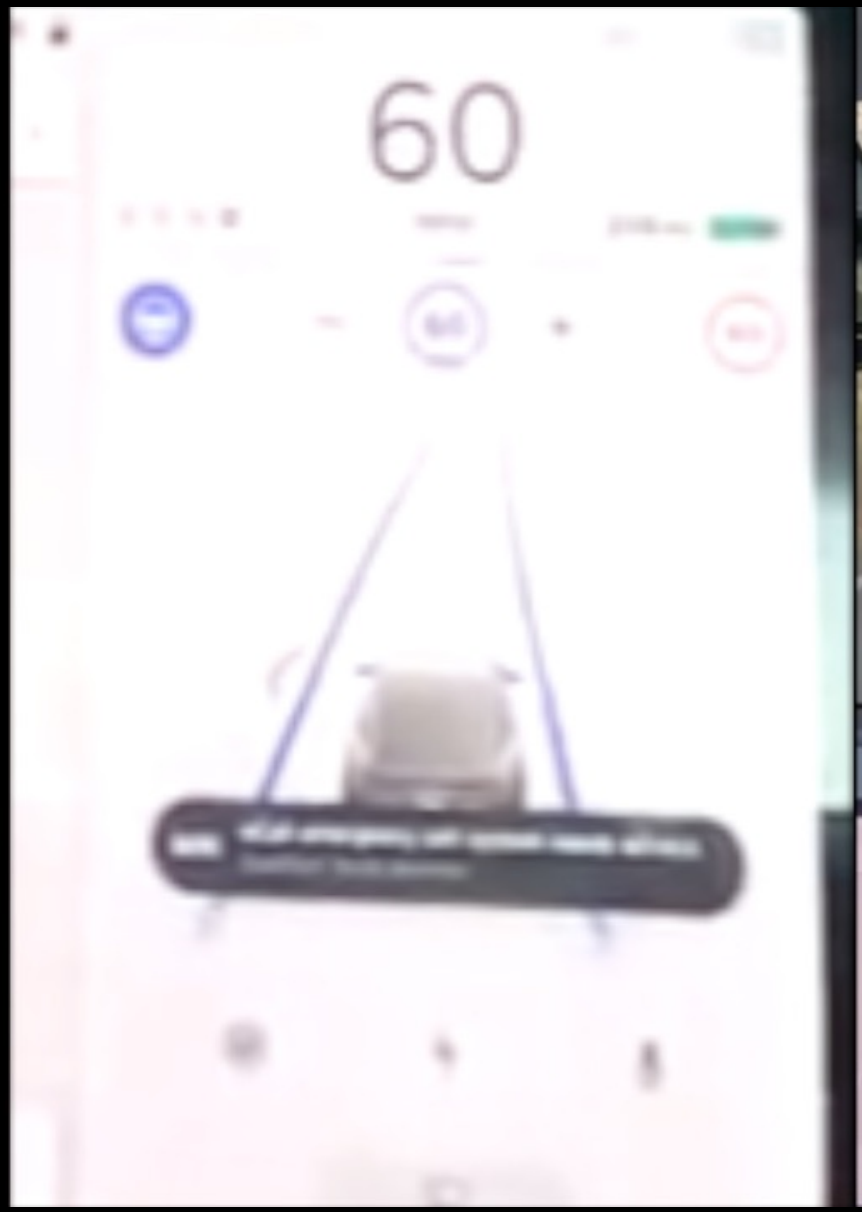
Self-Driving Cars Still Can't Handle Snow, Rain, or Heavy Weather

By Joel Hruska on October 30, 2018 at 4:53 pm | 88 Comments

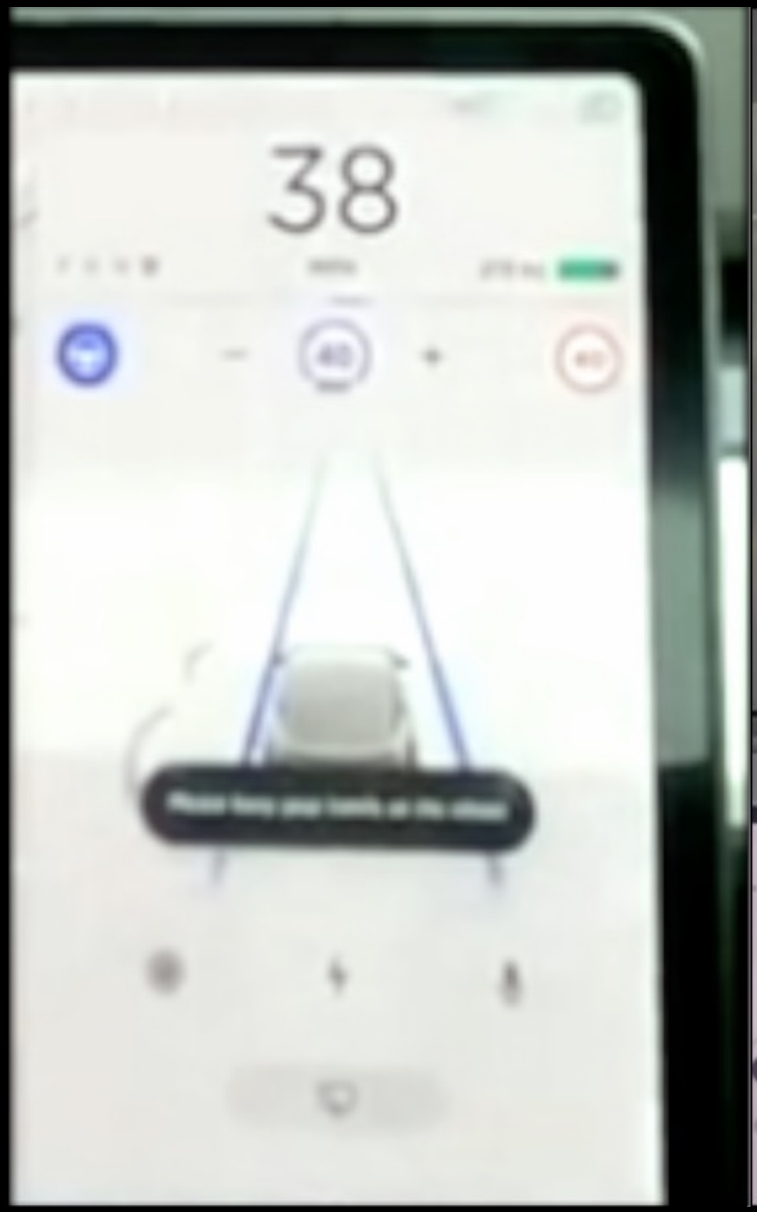


If you listen to the companies deploying self-driving vehicle technology, the date for full deployment and L5 capability (full self-driving, no need for driver intervention at all) is just

ground-penetrating WaveSense radar that can detect various
/ESENSE


60

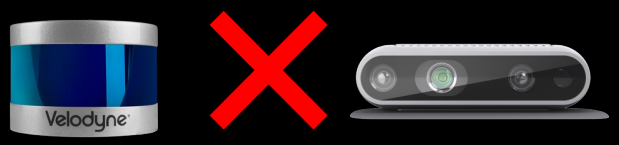

Tesla in Clear Conditions
60


38


Tesla in Fog
38


Tesla in Fog
27

Self-Driving Cars Rely on Cameras and LiDAR



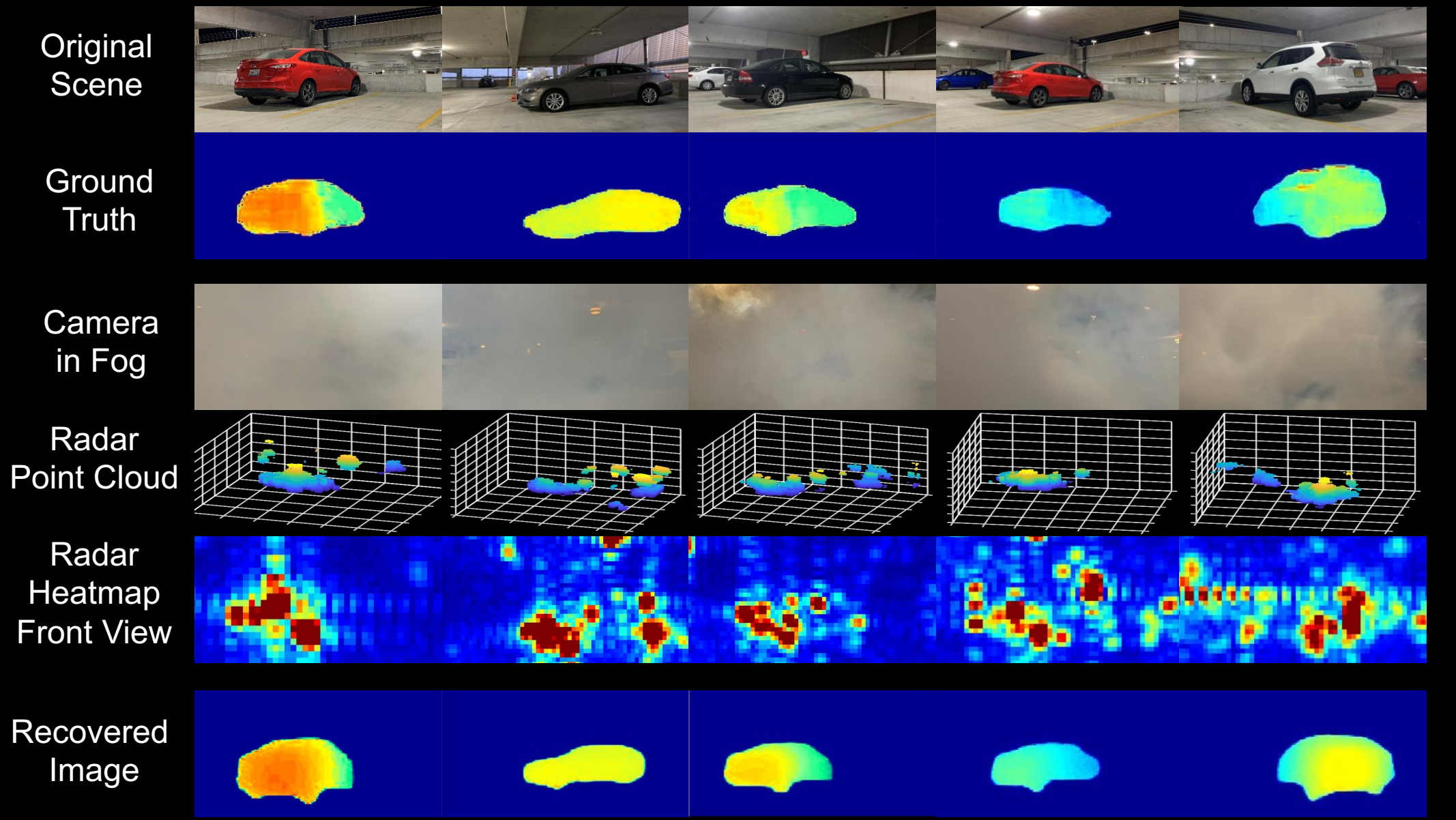
LiDAR

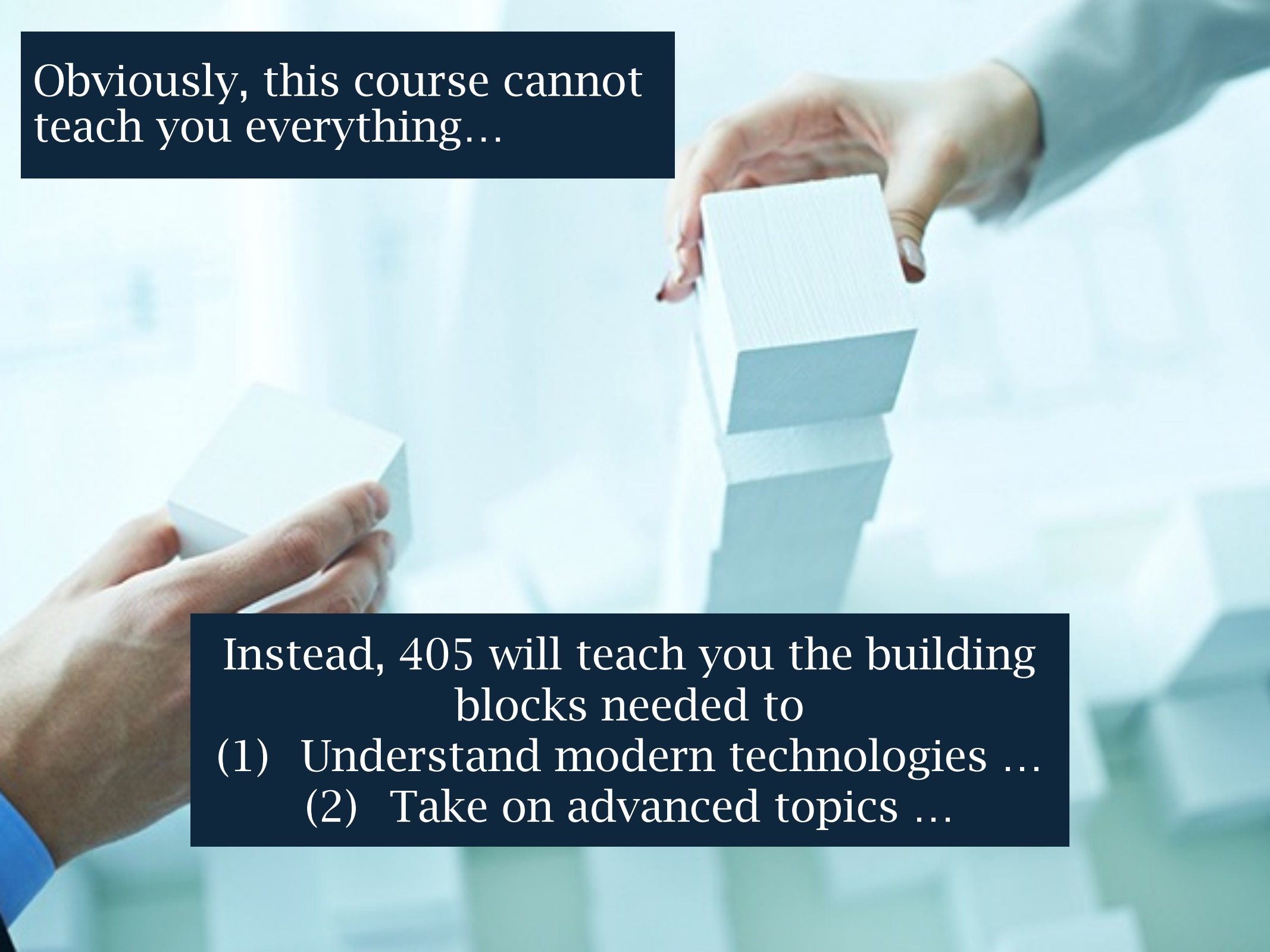
Camera

Millimeter Wave radar can function in adverse conditions

Millimeter Wave Radar

Wireless Imaging





Obviously, this course cannot teach you everything…

Instead, 405 will teach you the building blocks needed to
(1) Understand modern technologies …
(2) Take on advanced topics …

Course Information

- Staff
  - Instructor: Haitham Hassanieh
    - Bachelor: AUB
    - MS & PhD: MIT
    - Professor at UIUC for 6 years.
    - Moved to EPFL 2022
    - Run SENS Lab (Sensing and Networking Systems)
    - Research: Mobile and Wireless Networks
  - TAs:

Samah Hussein Youssef

Hailan Shanbhag

Arman Maghsoudnia

  - A/Es: TBD

Course Information

- Language: English
- Lectures: Tuesday 13:15 – 16:00 in CE 1 5
  - 60 ~ 90 min lecture
  - 10 min break
  - 60 ~ 90 min lecture
  - 10 min quiz on the previous lecture
- Exercise Sessions: Thursday 14:15 – 18:00 in BS 160
- Lab Sessions: Friday 9:15 – 11:00 in BC 02
- Recordings
  - CE 1 5 is not equipped with recording capabilities
  - We will do our best to record every lecture and upload it to https://mediaspace.epfl.ch/
  - **We cannot guarantee that we will always provide the recorded lecture! Many things can go wrong! Mic battery often runs out!**
  - Best option is to always come to class and have recordings as back up.

Course Information

❑ Resources:

- Moodle:
  - Look for COM-405
  - All material: slides, homework, Labs, previous exams, schedule…
  - Quizzes
  - Announcements
  - Questions

  DO NOT SEND QUESTIONS BY EMAIL. I MIGHT NOT RESPOOND. BETTER TO USE MOODLE.

- Media Space:

  - Lecture recordings

  - https://mediaspace.epfl.ch/channel/COM-405+Mobile+Networks/30796/subscribe

  - Make sure to check the LECTURES FALL 2024 playlist and not SPRING 2023

Course Information

- Quizzes:
  - 4 to 6 multiple choice or true or false questions.
  - Questions are about previous lecture.
  - Supposed to be somewhat easy.
  - Quiz is on Moodle:
    - **Please Bring Laptop or Smartphone to class to do the Quiz**.
  - We will manually open up the quiz in class 10 mins before the end of the lecture. It will be open for 30 mins max.

  - In the exceptional case that you cannot make it to the lecture, you can take the Quiz at home but you must take it during the time 13:50pm – 16:20pm

  - We will have 11 quizzes and we will count the top 10 grades
  - We will also have 2 surveys which count as bonus
  - You can miss submitting 3 quizzes without loosing any grades

Course Information

❑ Homework & Labs

- 3 Homework Assignments → Problem sets
- 4 Lab Assignments → Programming in python on Jupyter notebook
- Homeworks & Labs are meant to expand your knowledge and enforce what you learned in lectures. They are not meant to test your knowledge
  → **might include new concepts to teach you new ideas!**
- Homeworks can be submitted handwritten or typed on moodle.
  - If handwritten, please make sure to have good handwriting. Anything we do not understand, we do not correct.
- **Homework & Labs can be done in groups of 2.**
  - Can have different group every time.
  - Only one person submits
  - Make sure to write both names on the submission
- **Typically released Tuesday night and due on Friday at 6pm (2.5 weeks)**
- Late submission policy:
  - 0 – 24 hrs late: – 0 points penalty
  - 24 – 48 hrs late: – 20 points penalty
  - 48 – 72 hrs late: – 40 points penalty
  - > 72 hrs late: – 100 points penalty
  - **No negative grade**

Course Information

- Exam
  - The exam date is scheduled by the Service Académique.
  - Students must physically come at the exam.
  - In case of force majeure, please check with the section administration, not with the lecturer.
  - We will provide exam samples towards the end of the semester to give you an idea how the exam looks like.
  - Allow two A4 double sided cheat sheet
    - Must be handwritten
    - Must NOT be photocopied
  - More details about the exam later in the semester.

Course Information

- Grading
  - 10% Quizzes
  - 25% Homework
  - 30% Labs
  - 35% Final Exam
  - 2% Bonus 2 Surveys

Course Information

- Prerequisites
  - Any networking or communications class
  - Basic math and signal processing: probability, Fourier, …

- Books
  - There is no book for this class. We will mainly use lecture slides.
  - We recommend these references:
    - Miao et al. : Fundamentals of Mobile Data Networks Cambridge University Press, 2016.
    - A. Goldsmith: Wireless Communications, Cambridge University Press, 2005
    - D. Tse and P. Viswanath: Fundamentals of Wireless Communication, Cambridge University Press, 2005

Course Information

- Mobile Networks
  - Lies at the intersection of COM and CS (IN)
  - Combination between Communication Systems and Networking Systems.
  - Mobile networks are the result of a huge engineering effort, with tremendous, worldwide impact
  - Topic is heavily influences by:
    - Physics (propagation of Electomagnetic waves)
    - Electronics (feasibility/cost/power consumption/form factor)
    - Communications and Signal Processing
    - Networking (IP networks)
    - Economics
    - User acceptance and behavior
    - Legislation and regulation
  - The topic is evolving very fast

Course Information

- Tentative Schedule

Week	Date	Lecture	HW	Quiz
Week 1	Tue. 10 Sep	Intro + Radio Basics		Survey 1
	Fri. 13 Sep			
Week 2	Tue. 17 Sep	Wireless Channel + OFDM 1	LAB 1 OUT	Quiz 1
	Fri. 20 Sep			
Week 3	Tue. 24 Sep	OFDM 2 + Modulation 1	HW 1 OUT	Quiz 2
	Fri. 27 Sep			
Week 4	Tue. 1 Oct	Modulation 2 + Coding & Data Rates & Rate Adaptation		Quiz 3
	Fri. 4 Oct		**LAB 1 DUE**	
Week 5	Tue. 8 Oct	MIMO	LAB 2 OUT	Quiz 4
	Fri. 11 Oct			
Week 6	Tue. 15 Oct	MAC + Scheduling		Quiz 5
	Fri. 18 Oct		**HW 1 DUE**	
Break				
Week 7	Tue. 29 Oct	Cellular 1: 3G/4G/5G + Millimeter Wave Networks	HW 2 OUT	Survey 2
	Fri. 1 Nov		**LAB 2 DUE**	
Week 8	Tue. 5 Nov	Cellular 2: Planning + Handover + Slicing + ORAN + MPTCP		Quiz 6
	Fri. 8 Nov			
Week 9	Tue. 12 Nov	IoT + Wireless Localization 1	LAB 3 OUT	Quiz 7
	Fri. 15 Nov		**HW 2 DUE**	
Week 10	Tue. 19 Nov	Wireless Localization 2		Quiz 8
	Fri. 22 Nov			
Week 11	Tue. 26 Nov	Wireless Sensing + Imaging	HW 3 OUT & LAB 4 OUT	Quiz 9
	Fri. 29 Nov		**LAB 3 DUE**	
Week 12	Tue. 3 Dec	Adhoc Networks + Routing + Network Coding		Quiz 10
	Fri. 6 Dec			
Week 13	Tue. 10 Dec	Satellite Networking		Quiz 11
	Fri. 13 Dec		**HW 3 DUE**	
Week 14	Tue. 17 Dec	Advanced Topics: Full Duplex, Medical Implants, Intellegent Reflective Surfaces		
	Fri. 20 Dec		**LAB 4 DUE**	