COM-405: Mobile Networks

Lecture 1.0: Introduction & Logistics

Haitham Hassanieh

Laboratory of SEnsing
& Networking Systems

Mobile Networks Are Every Where

WiFi

Cellular Networks

Only 25 Years Old

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

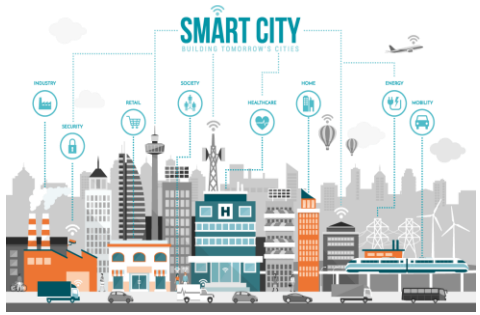
Allowed Us To Survive the Pandemic

Huge Demand for Mobile Networks

30 Billion Connected IoT Devices & Counting

Agriculture

Smart Cities



Smart Homes

Manufacturing

Health Care

Green Energy

Emergence of Ultra High Data Rate Applications

Wireless VR

Connected Vehicles

Robotic Automation

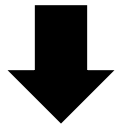
UAVs

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

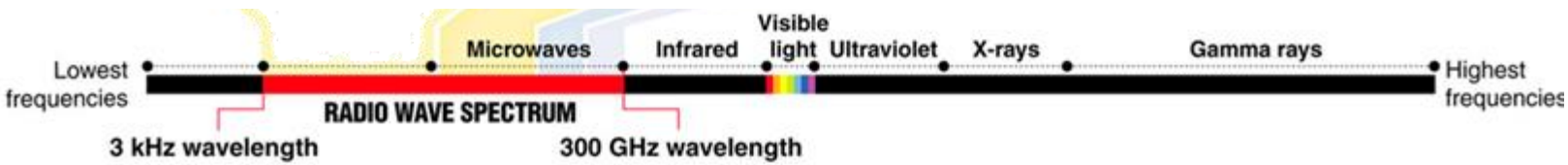
A device has 10 MHz of frequencies to communicate

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

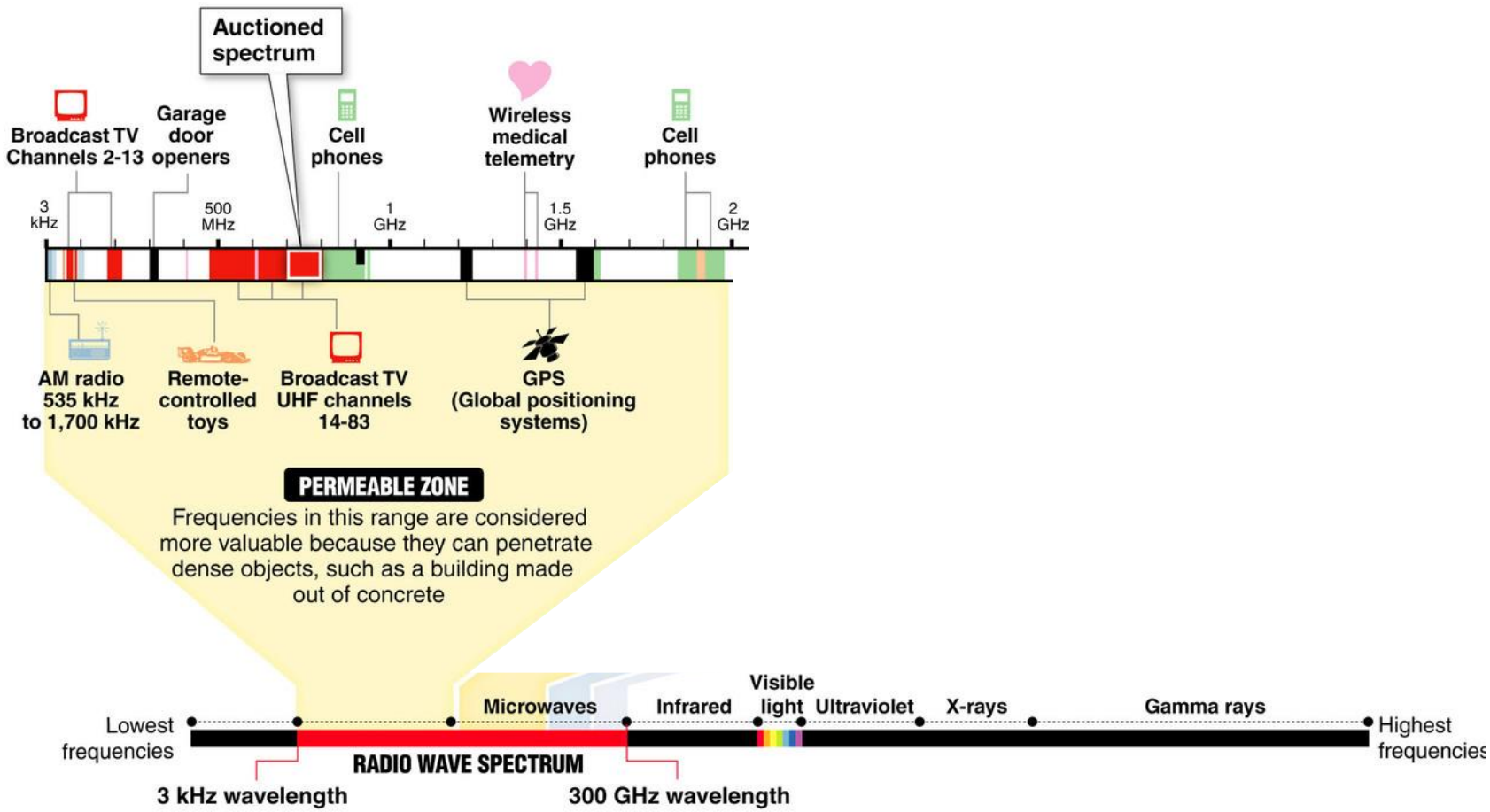
Increase data rate by 10×

Increase # of users by 10x

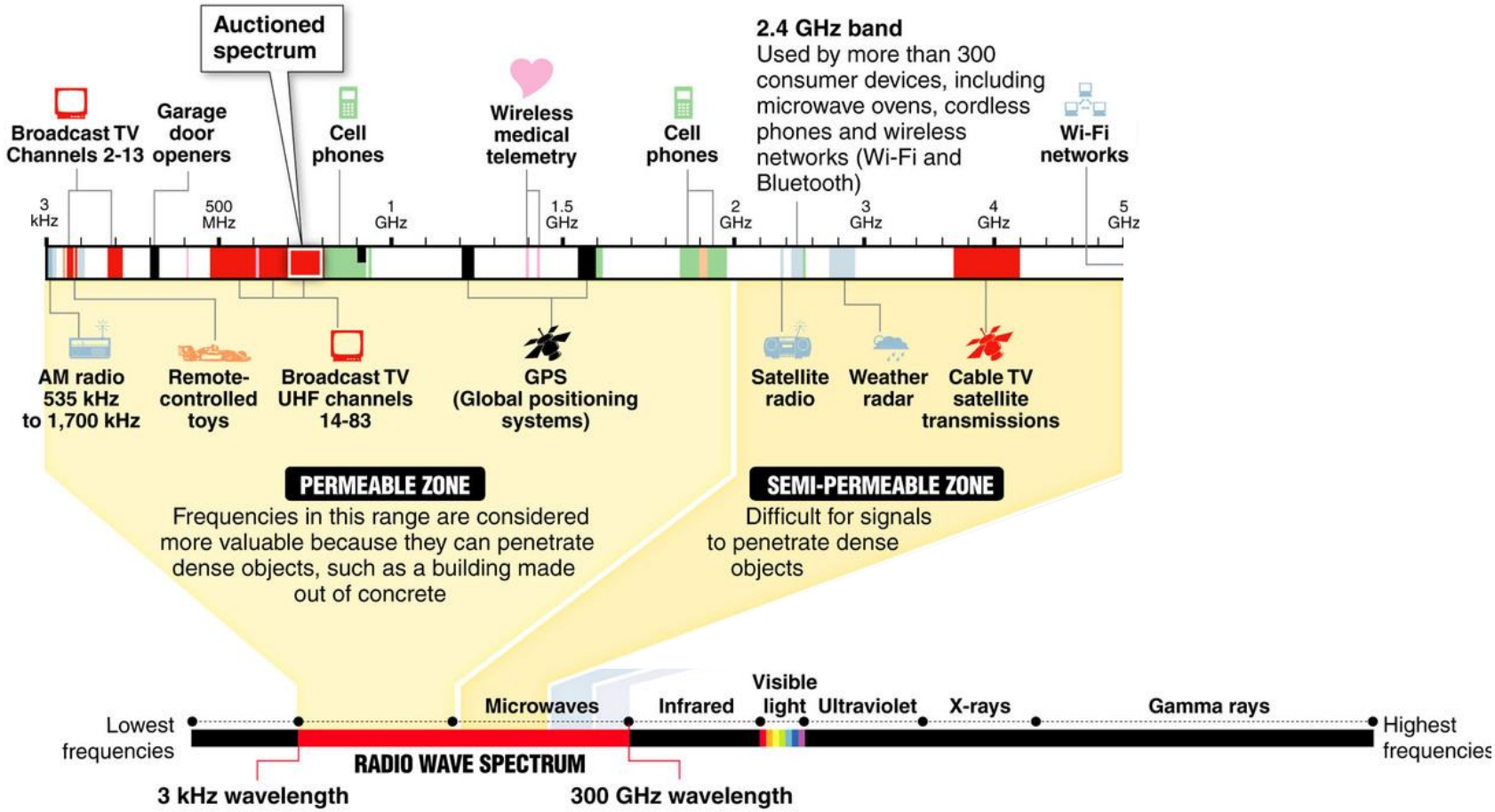
The Wireless Spectrum



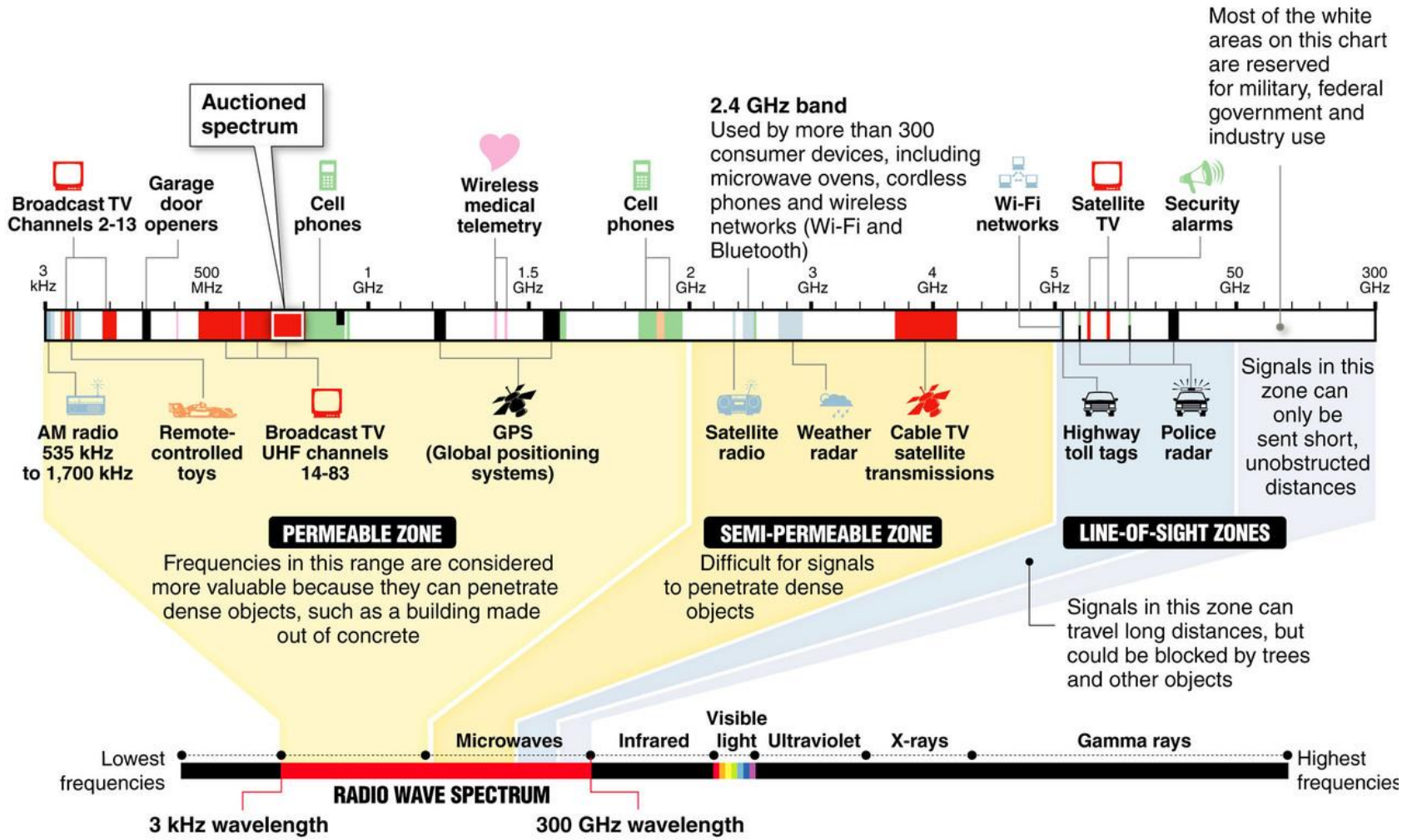
The Wireless Spectrum



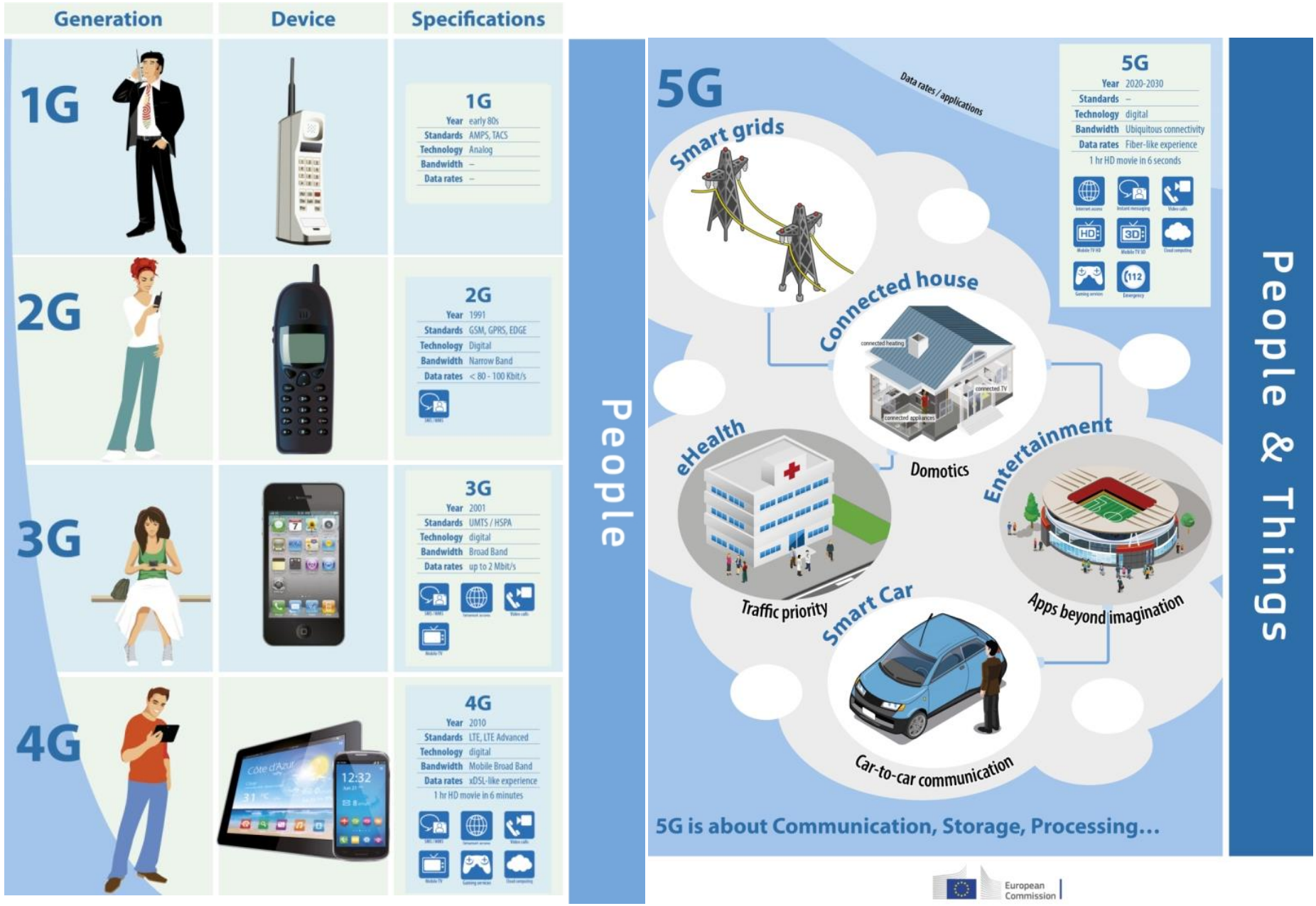
The Wireless Spectrum



The Wireless Spectrum

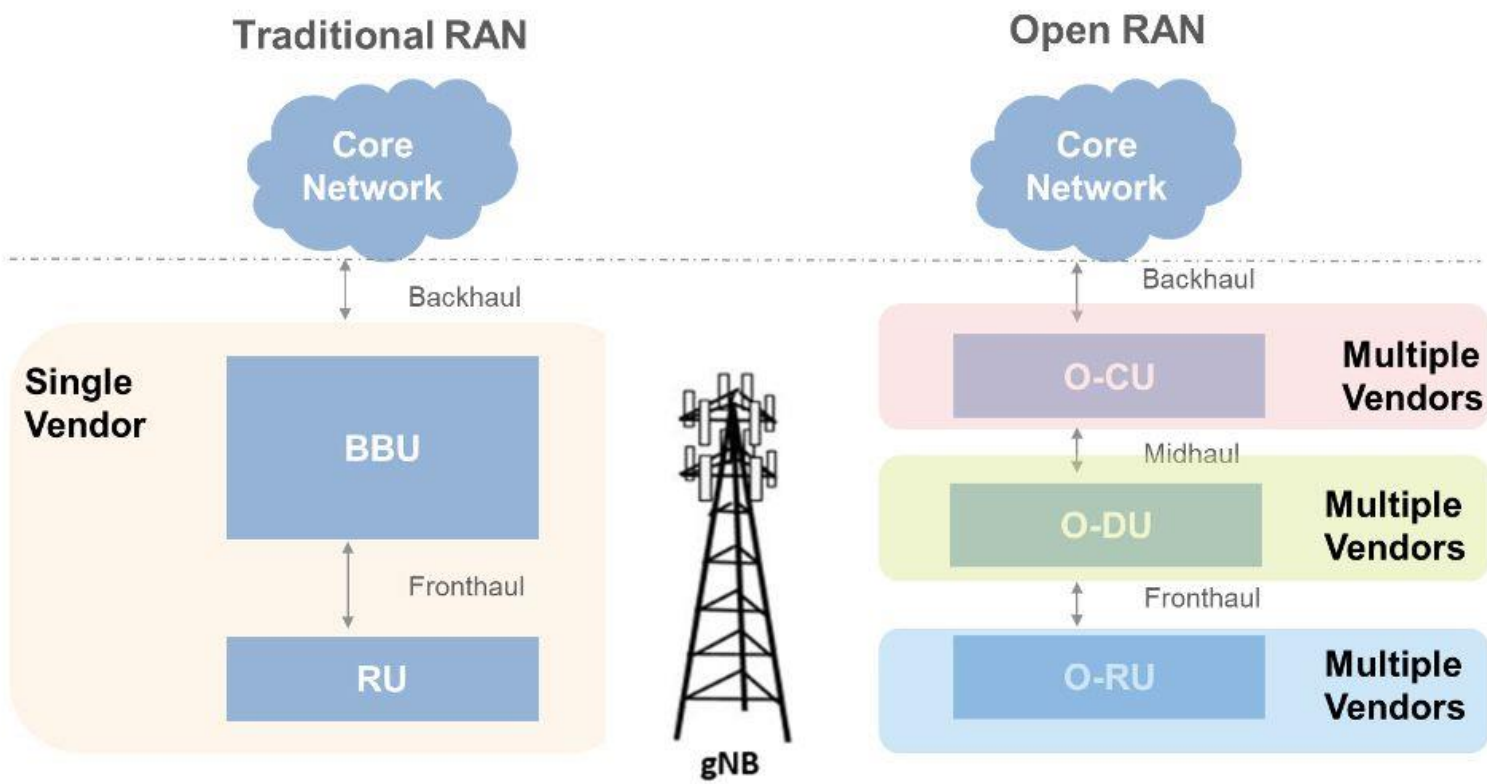


Cellular Networks from 1G to 5G



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

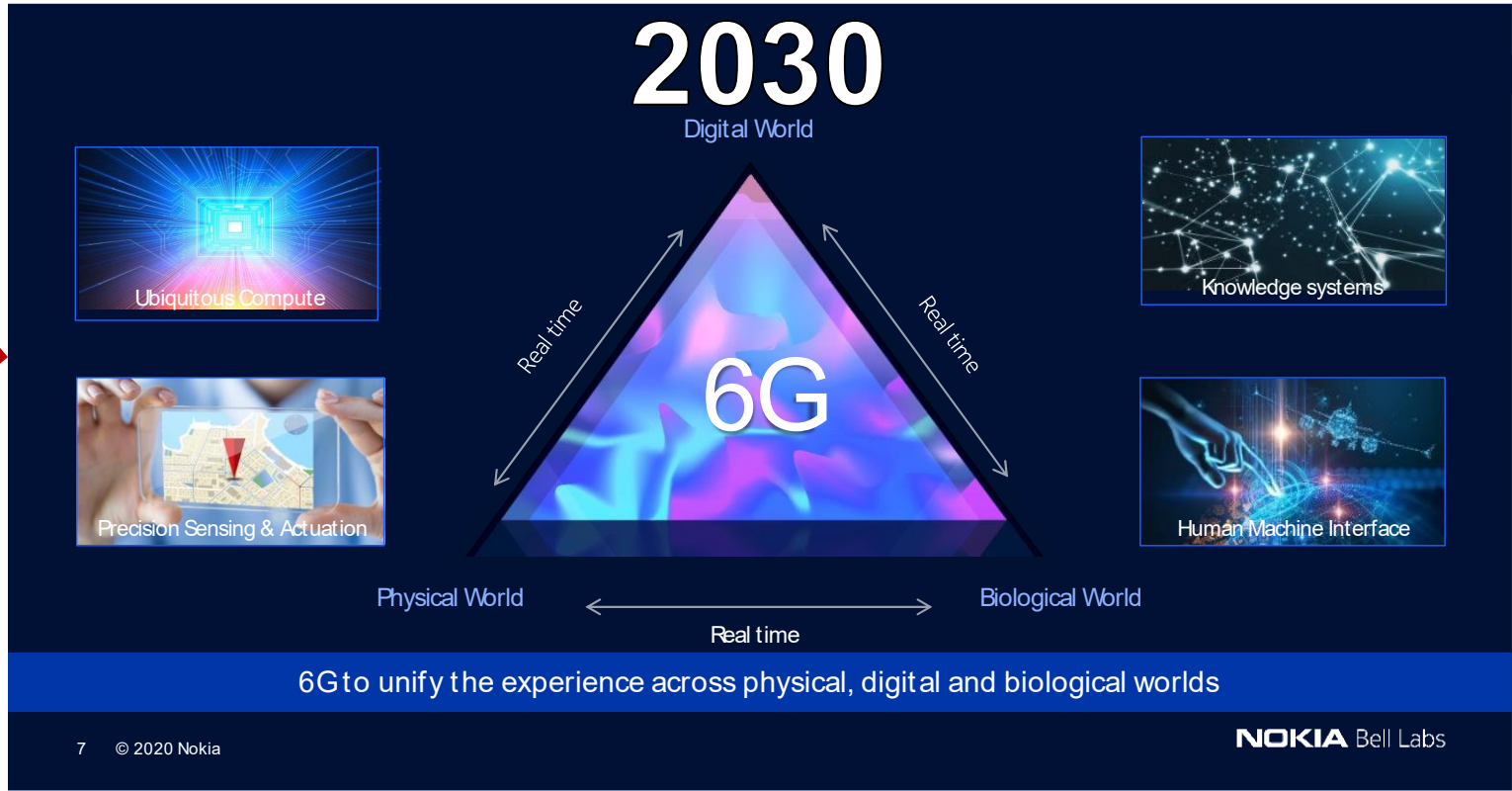
Connecting People

Increasing Demand for Mobile Networks

Connecting Everything

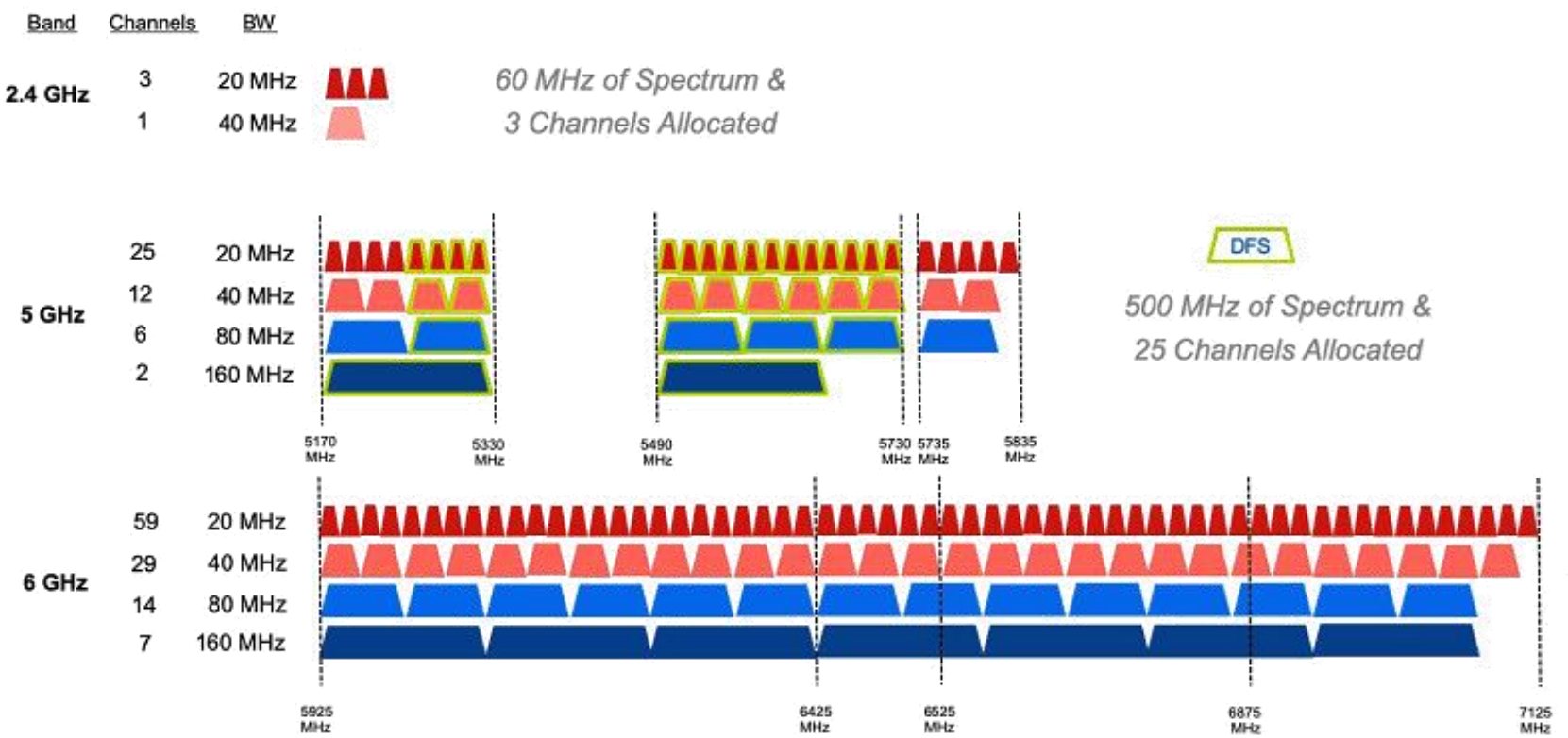
Increasing Demand for Mobile Networks

Connecting + Sensing Everything



NOKIA Bell Labs

WiFi Standards from WiFi 1 to WiFi 6



More Channels & Bandwidth

WiFi 1 — More MIMO Antennas — WiFi 5/6

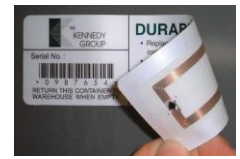
IoT Technologies

Wi Fi

Bluetooth

NFC

RFID



Cellular

NB-IoT

LTE-M

sigfox

LoRa

neul

Z-WAVE

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
  - …

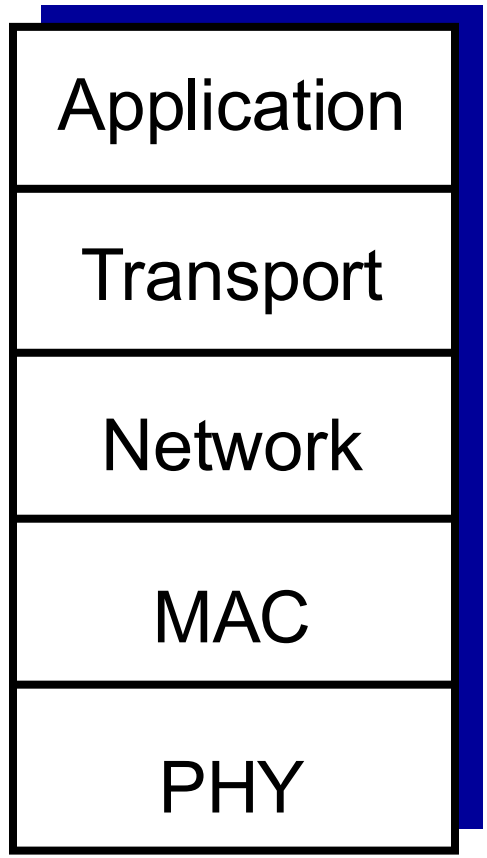
Question Is …

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

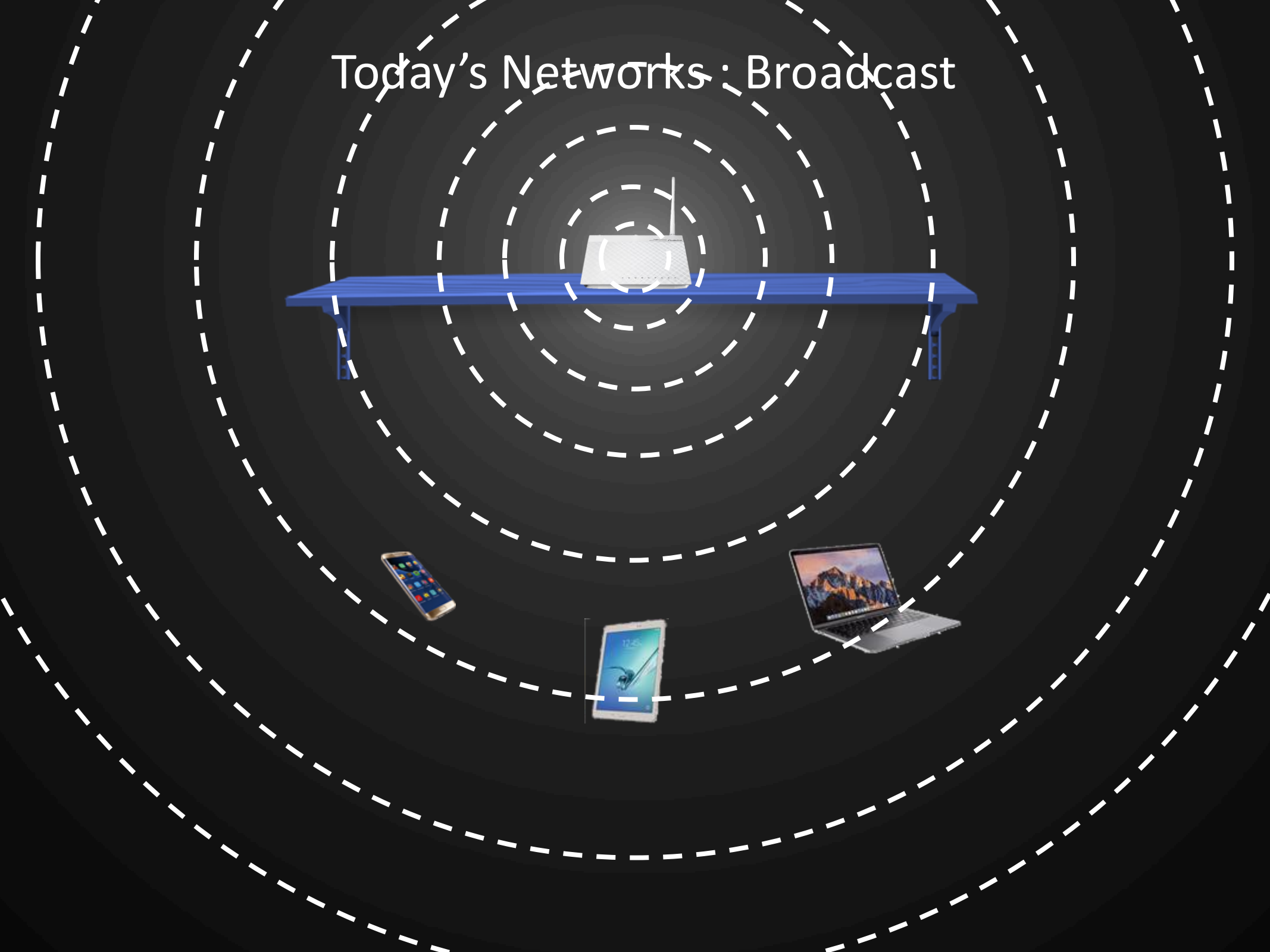
The PHY and MAC layer completely dissimilar

The whole game changes

Even New Challenges with

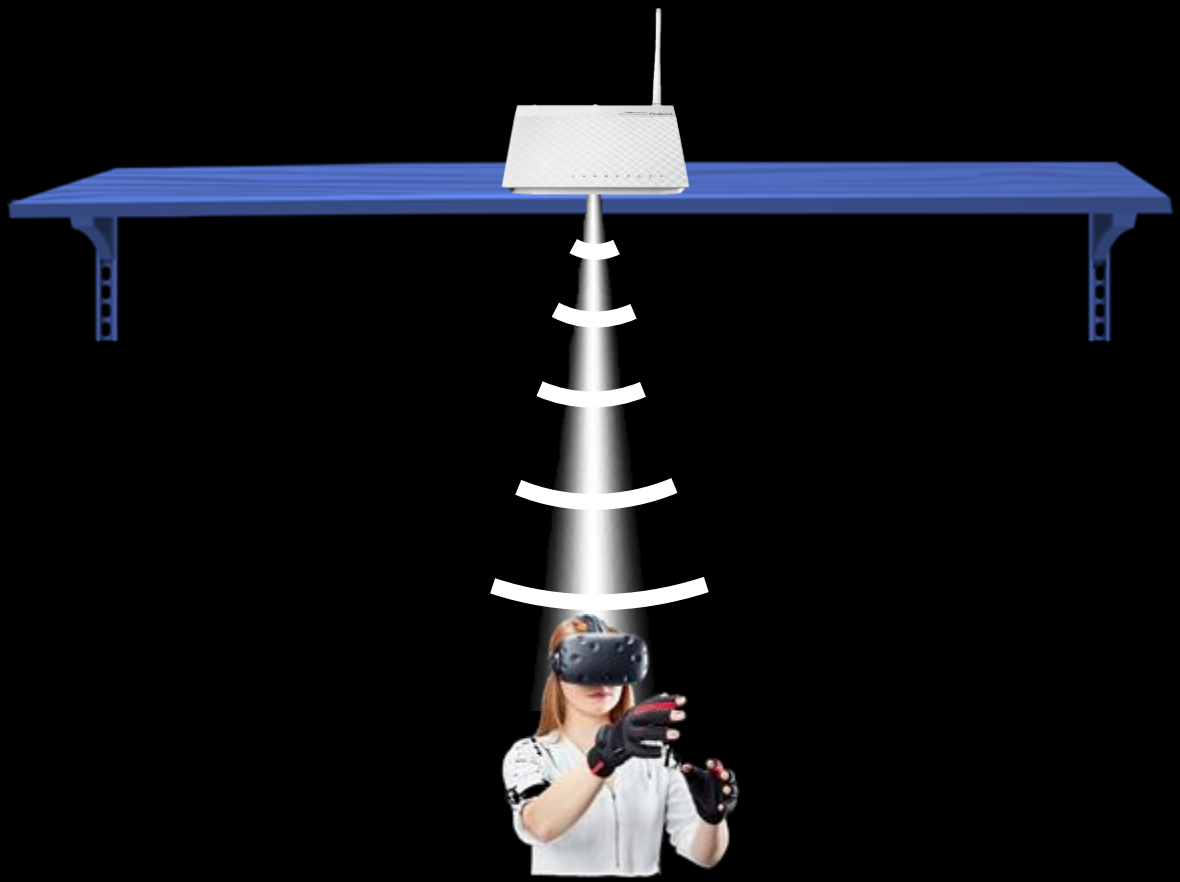
5G, IoT, Implants, Sensing…

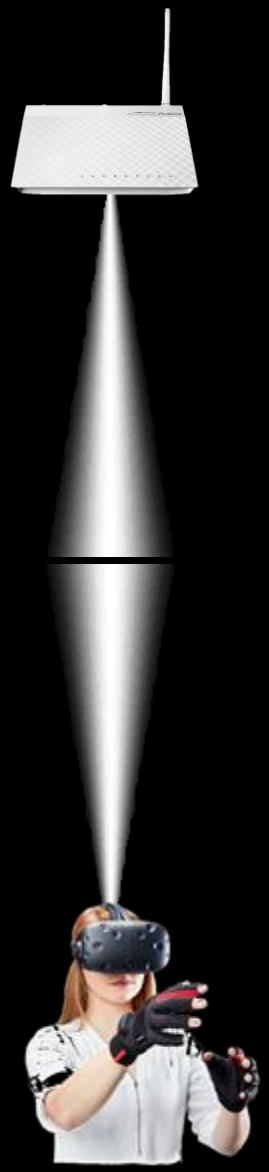
Today's Networks : Broadcast



5G changes how wireless systems operate

5G: Narrow-beam Antennas

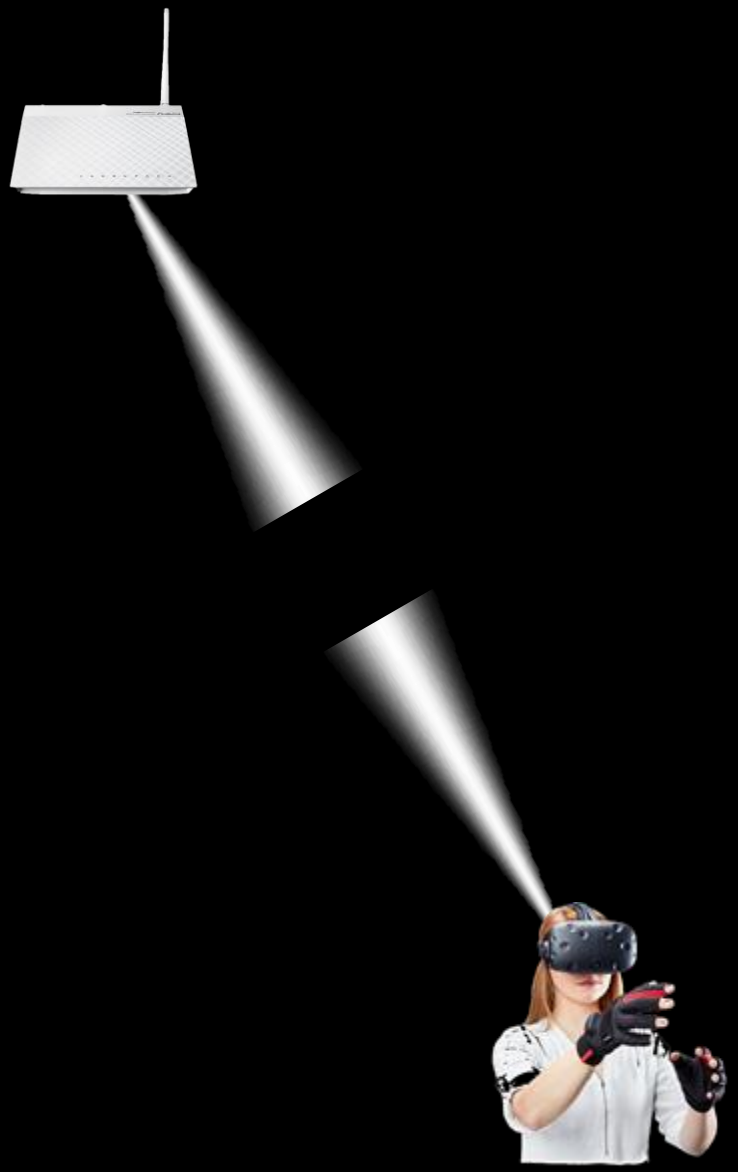




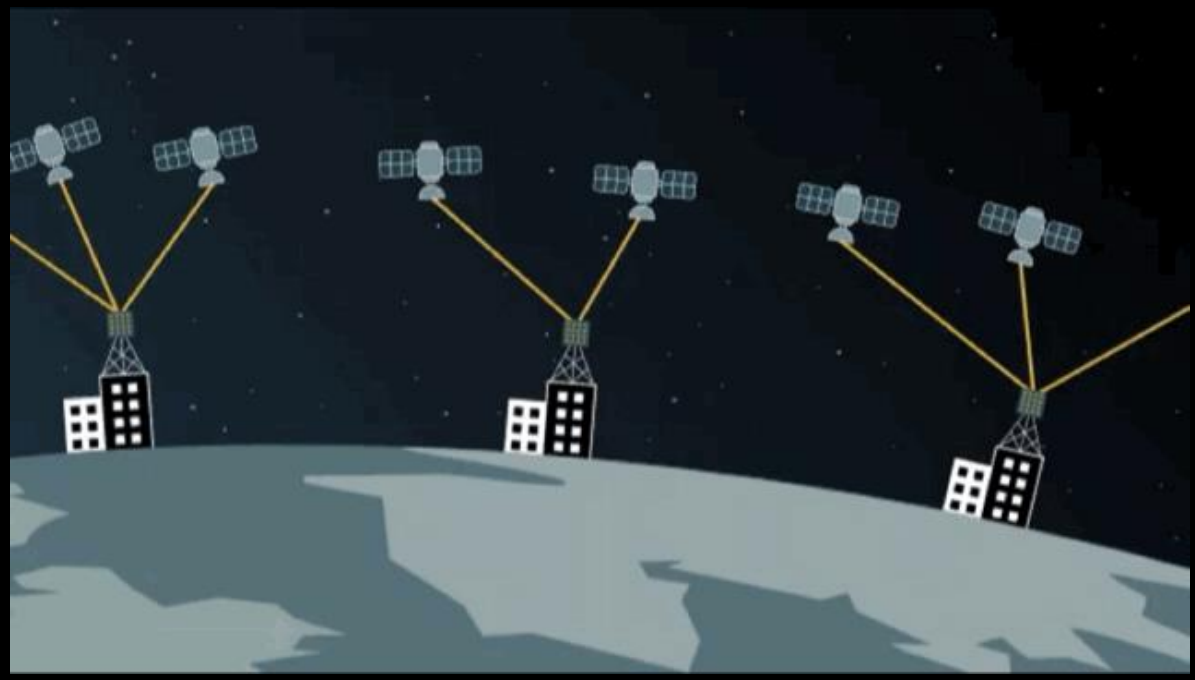
Need to quickly find the right beam alignment and track the user.

Suffers in case of:

- Mobility
- Blockage
- Multi-users



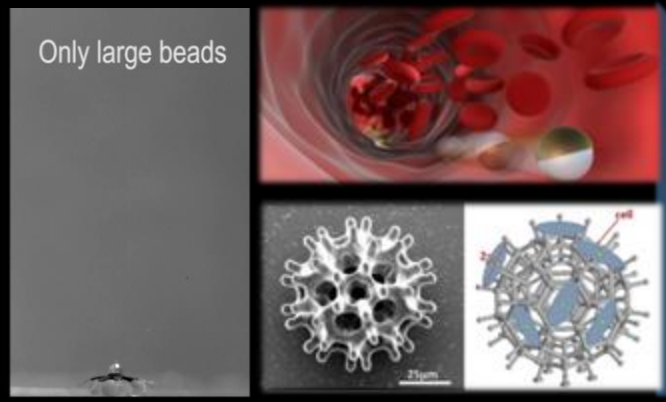
Satellite Networks



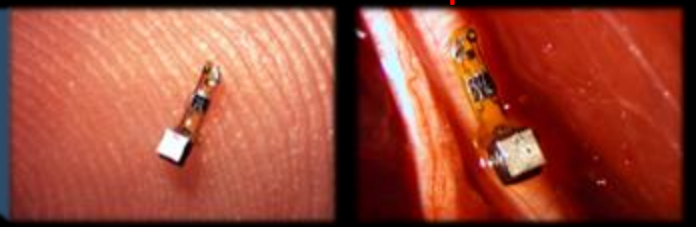
In Body Networking & Sensing

Micro and Nano Bio Implants

Microrobots for drug delivery

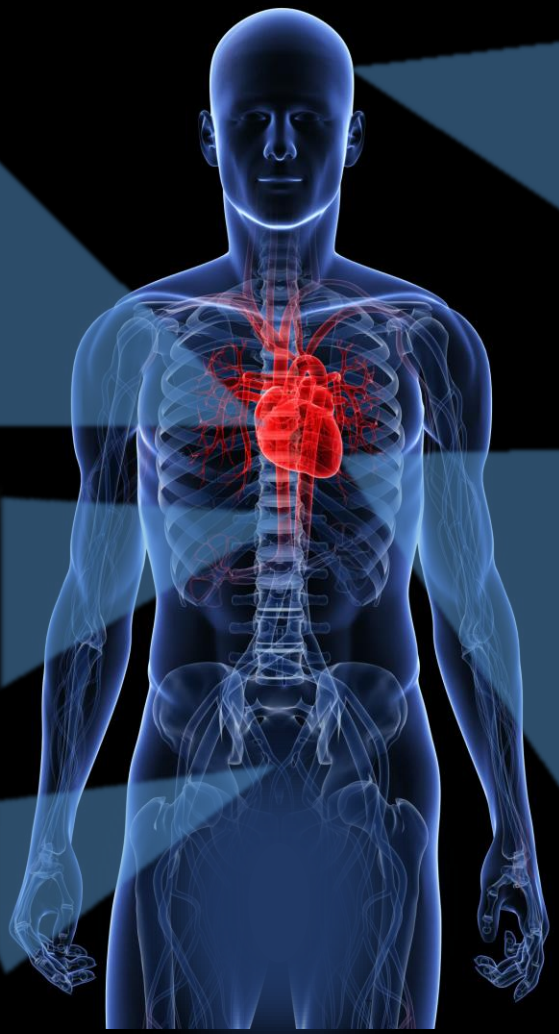


Micro Brain Implants

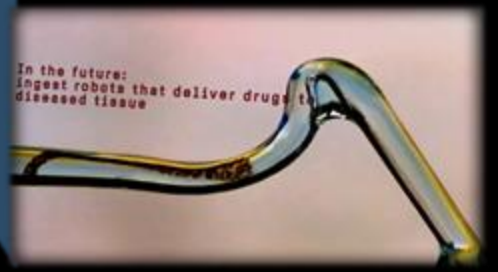


Bio-MEMS
Lab-On-Chip for
In body Diagnosis

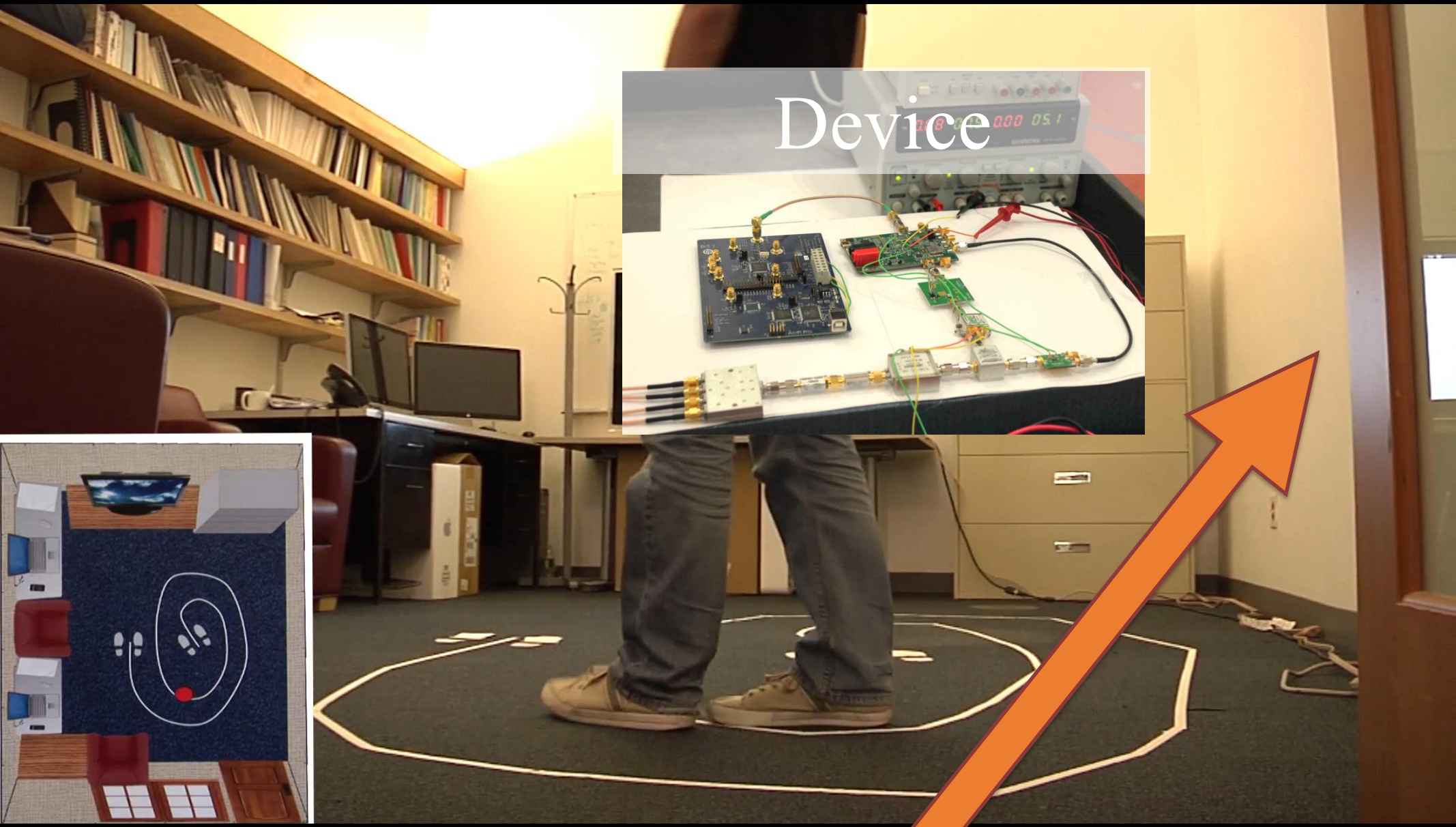
Contraception
Micro-Implants



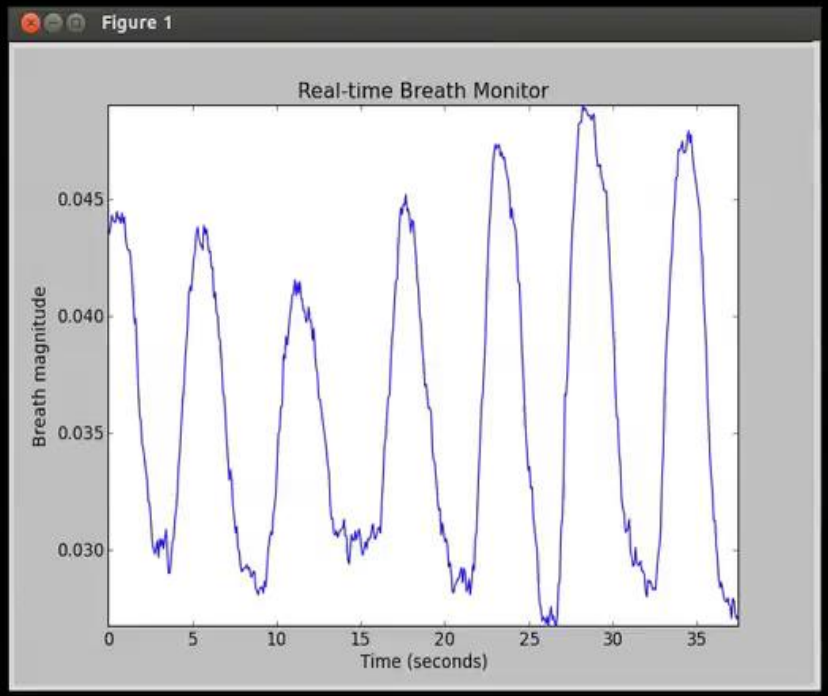
Nano-Implants
that can move in
the blood vessels



Wireless Sensing



Wireless Sensing

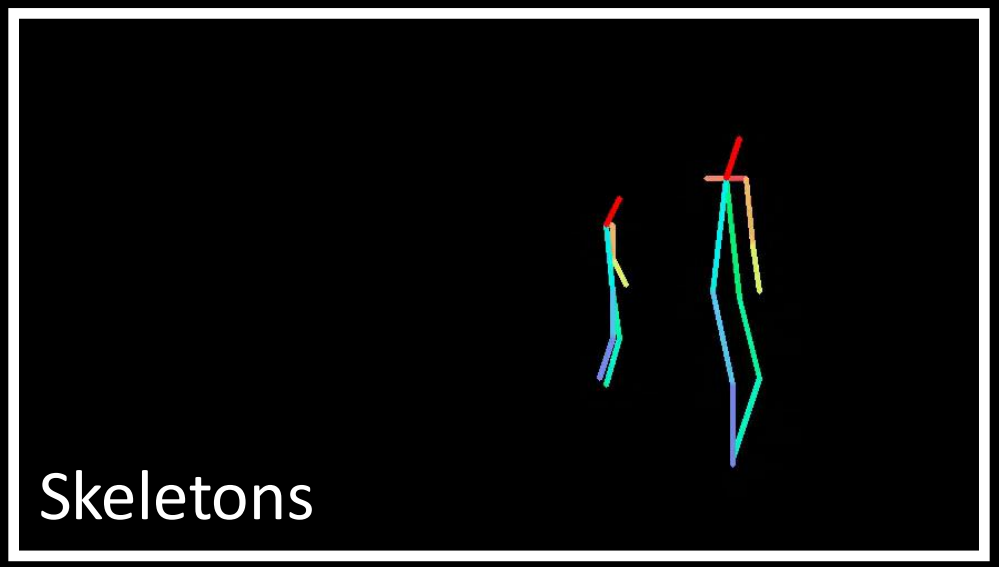


Through-wall poses
using **only** RF

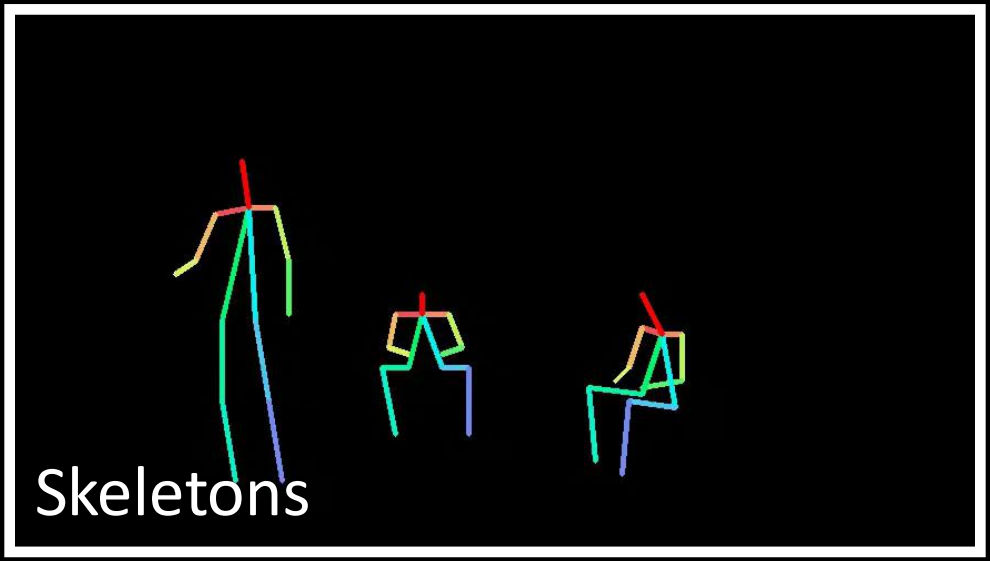
Skeletons

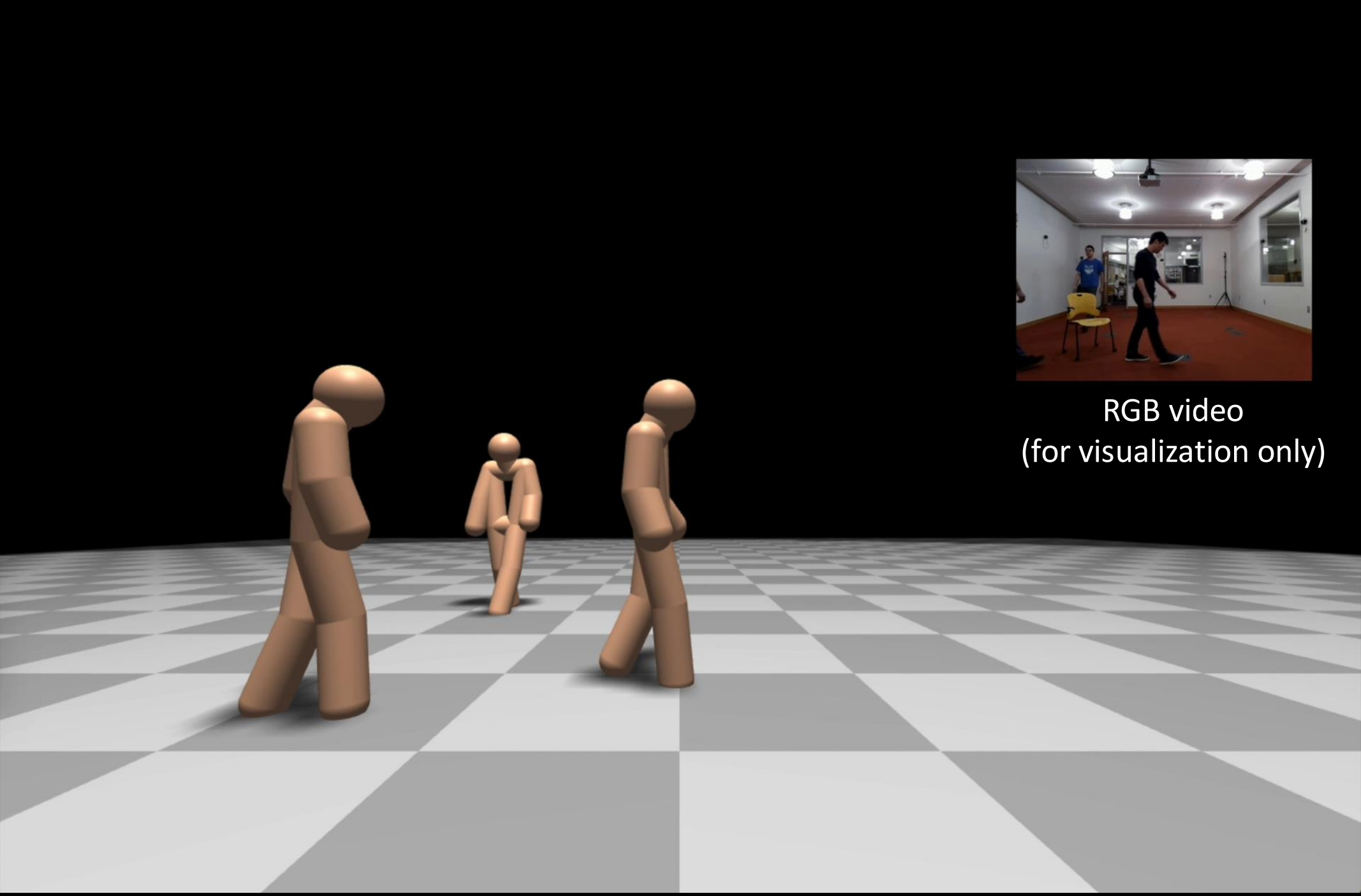
Confidence Maps

Works in bad lighting

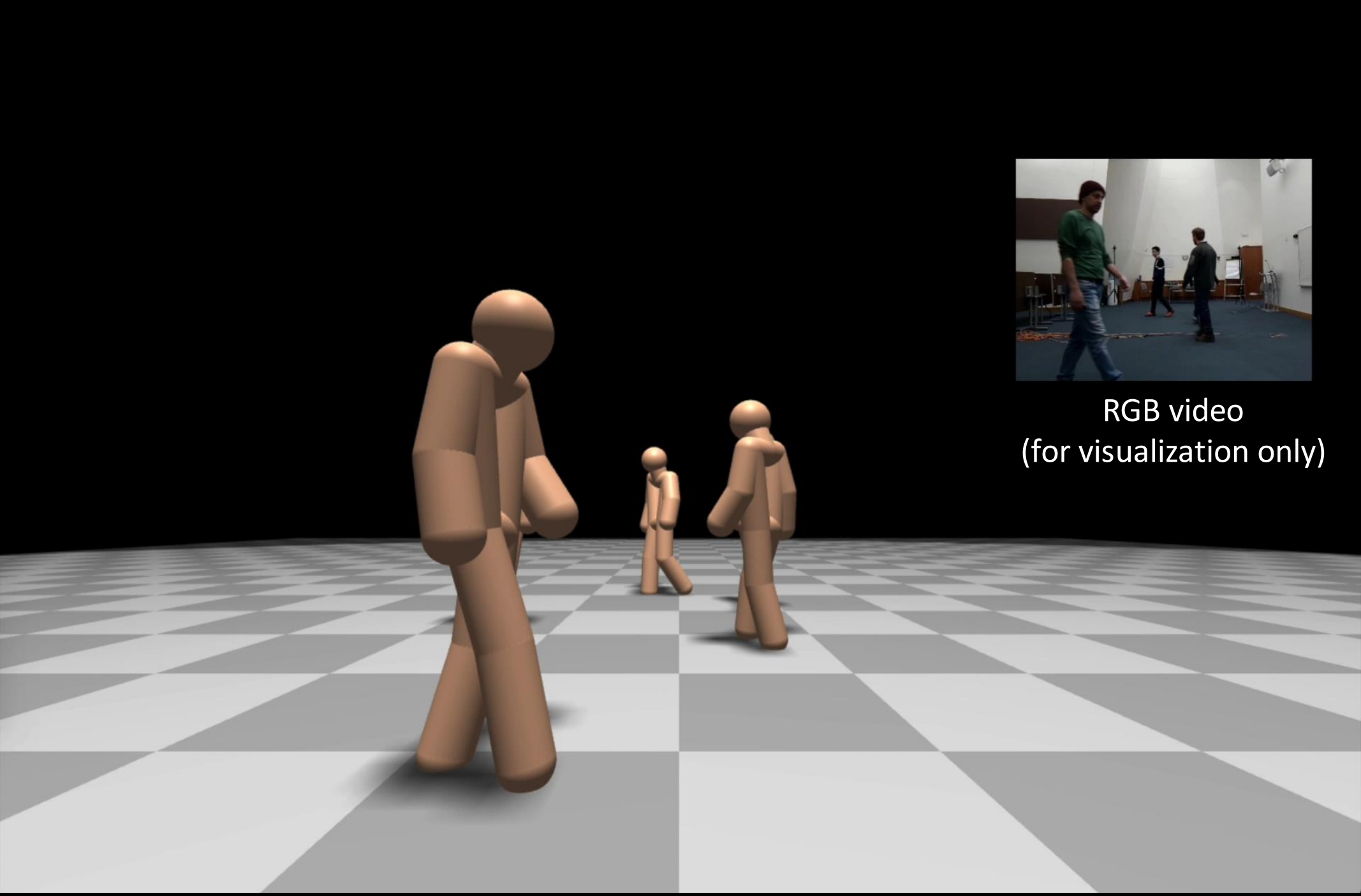


Works with different environment and daily activities





RGB video
(for visualization only)



RGB video
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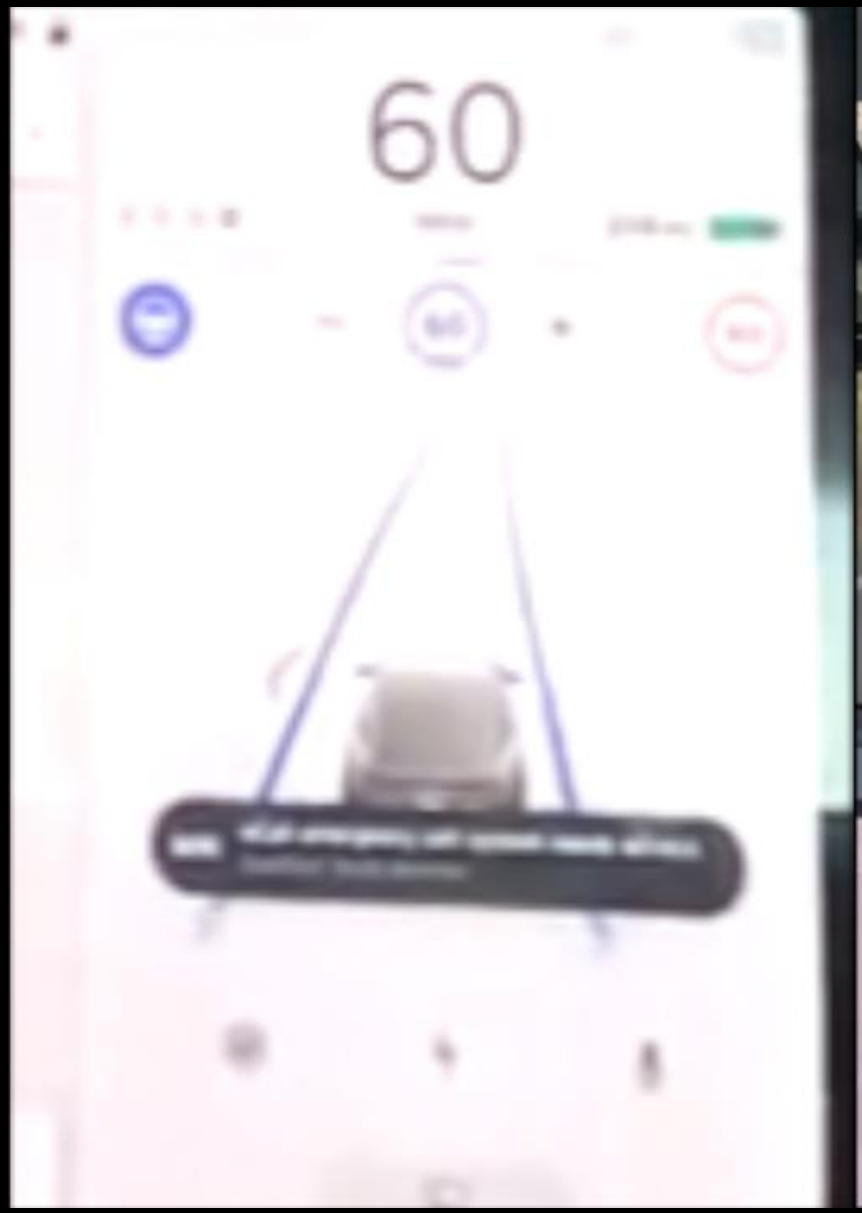
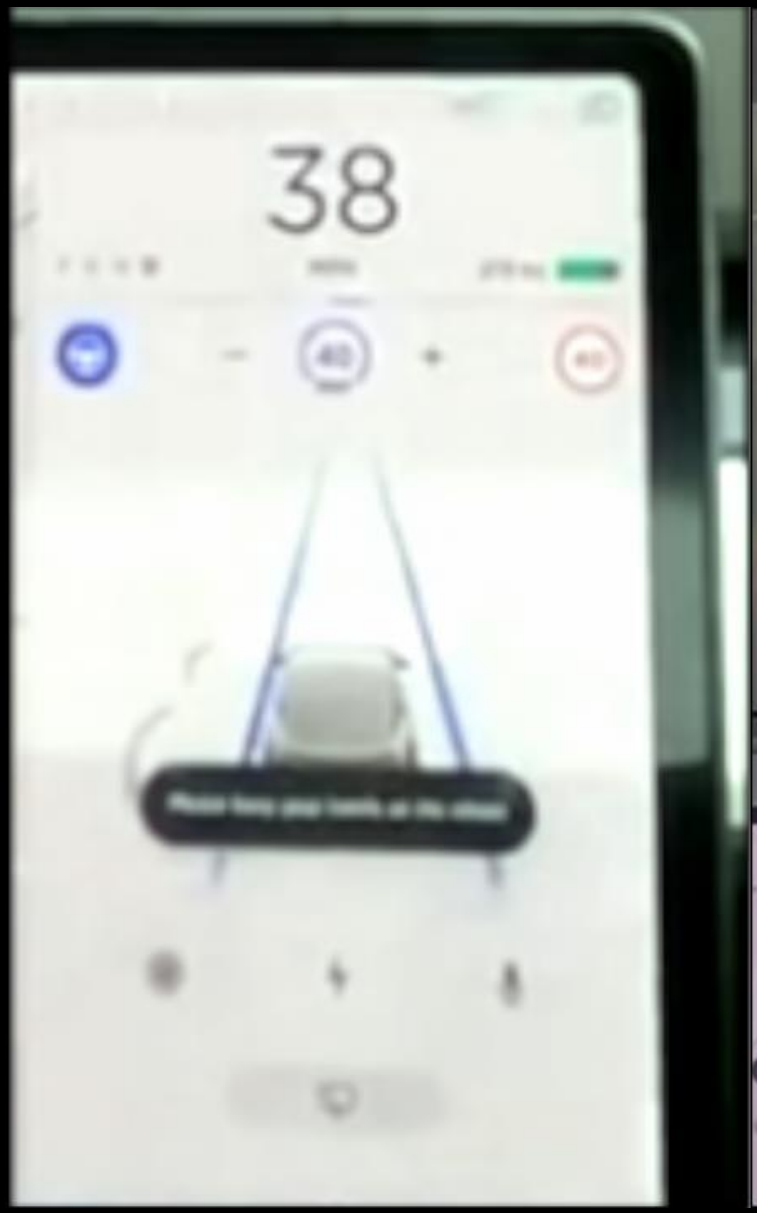

60


Tesla in Clear Conditions
60


38


Tesla in Fog
38


Tesla in Fog
27

Self-Driving Cars Rely on Cameras and LiDAR

LiDAR

Camera

Fog

Sandstorm

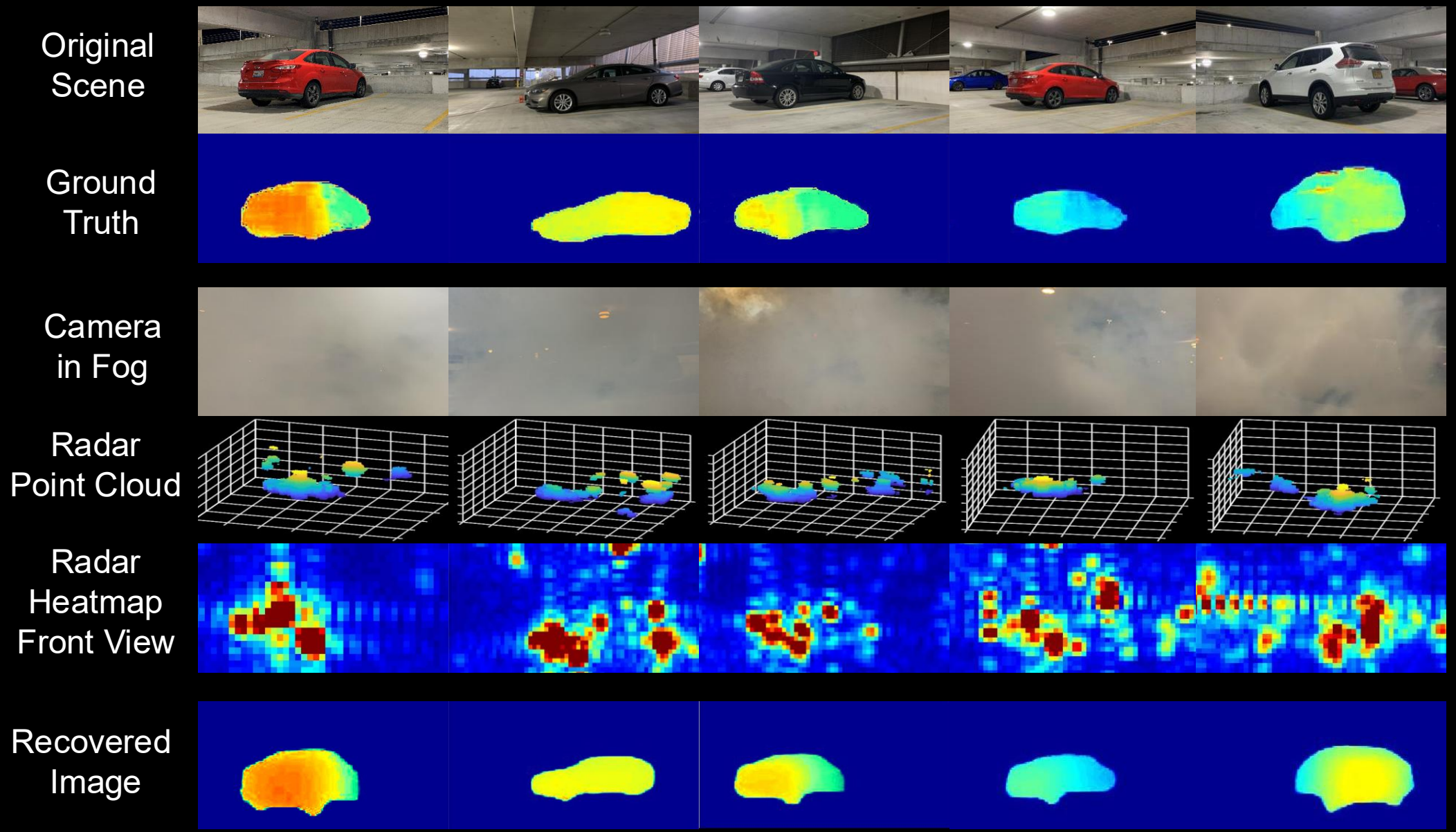
Blizzard

Low Lighting Conditions

Millimeter Wave radar can function in adverse conditions

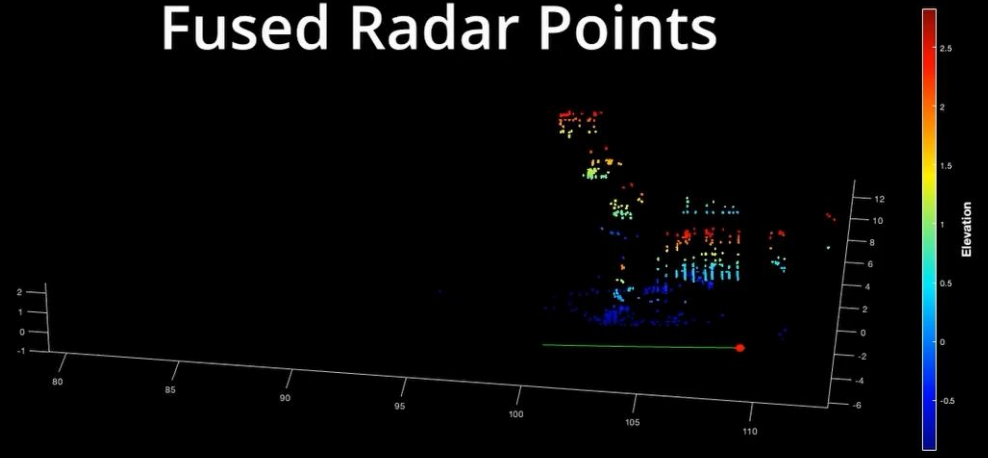
Millimeter Wave Radar

Wireless Imaging



3D shape Reconstruction from Autonomous Driving Radars

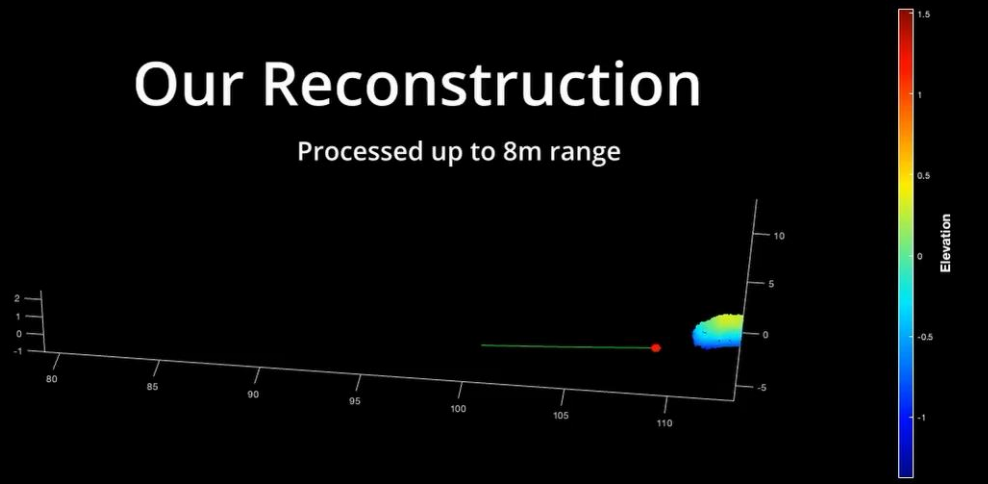
Fused Radar Points



Radar setup

Our Reconstruction

Processed up to 8m range



Video From radar PoV

Imaging Around the Corner

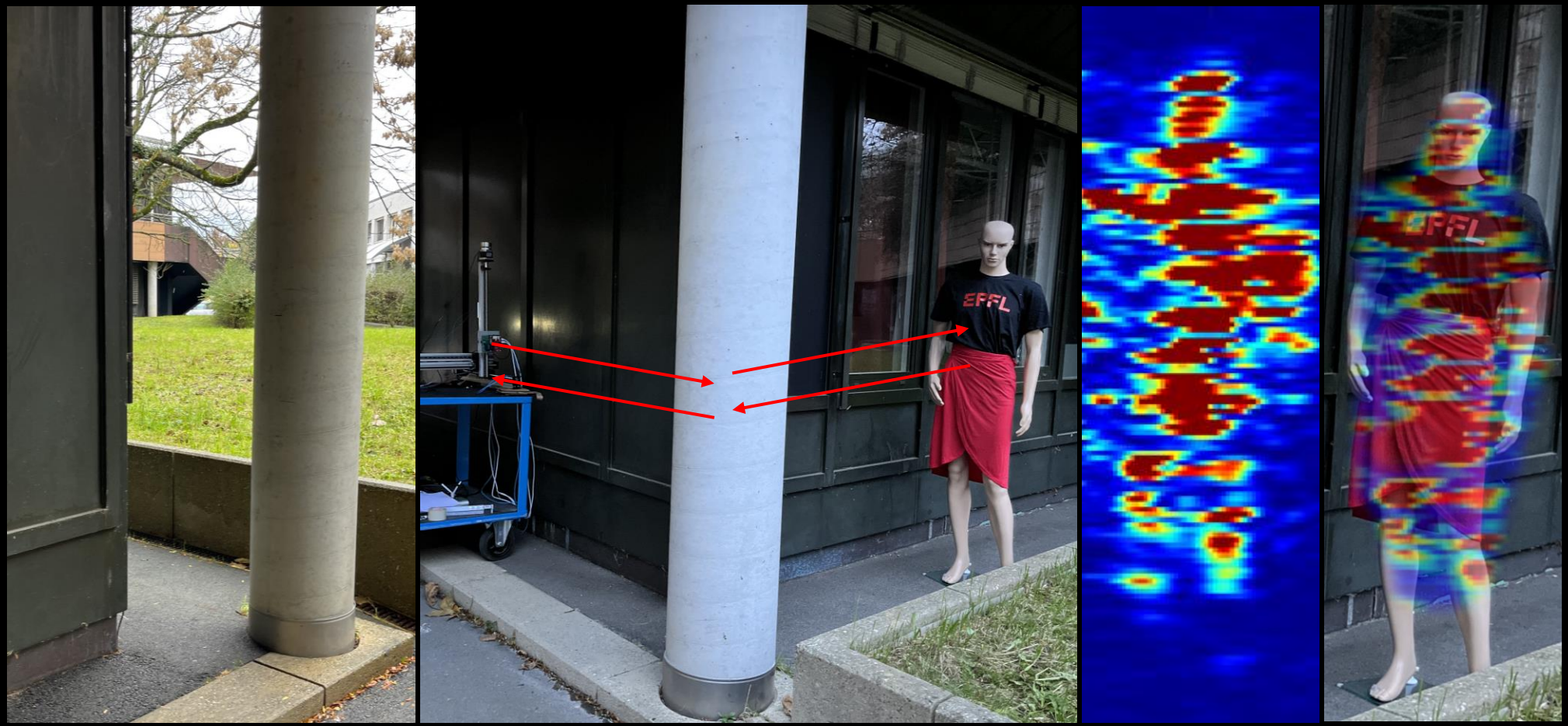
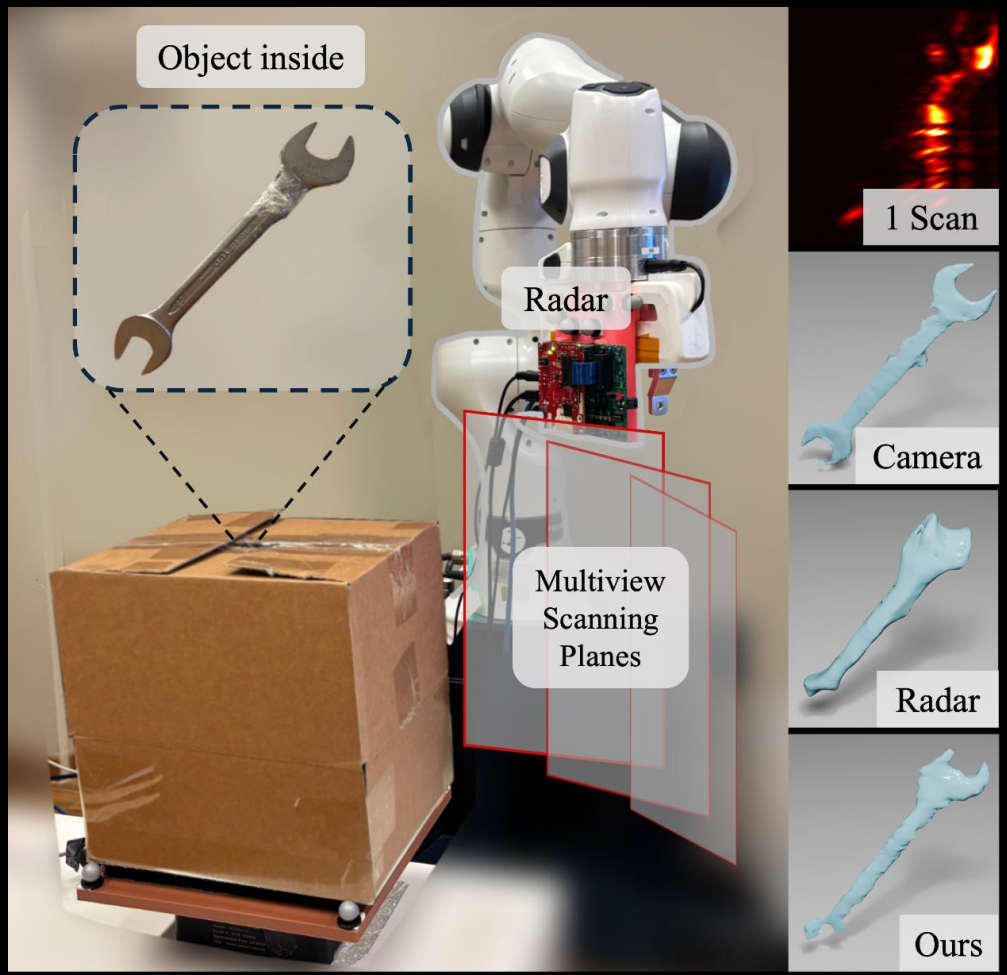
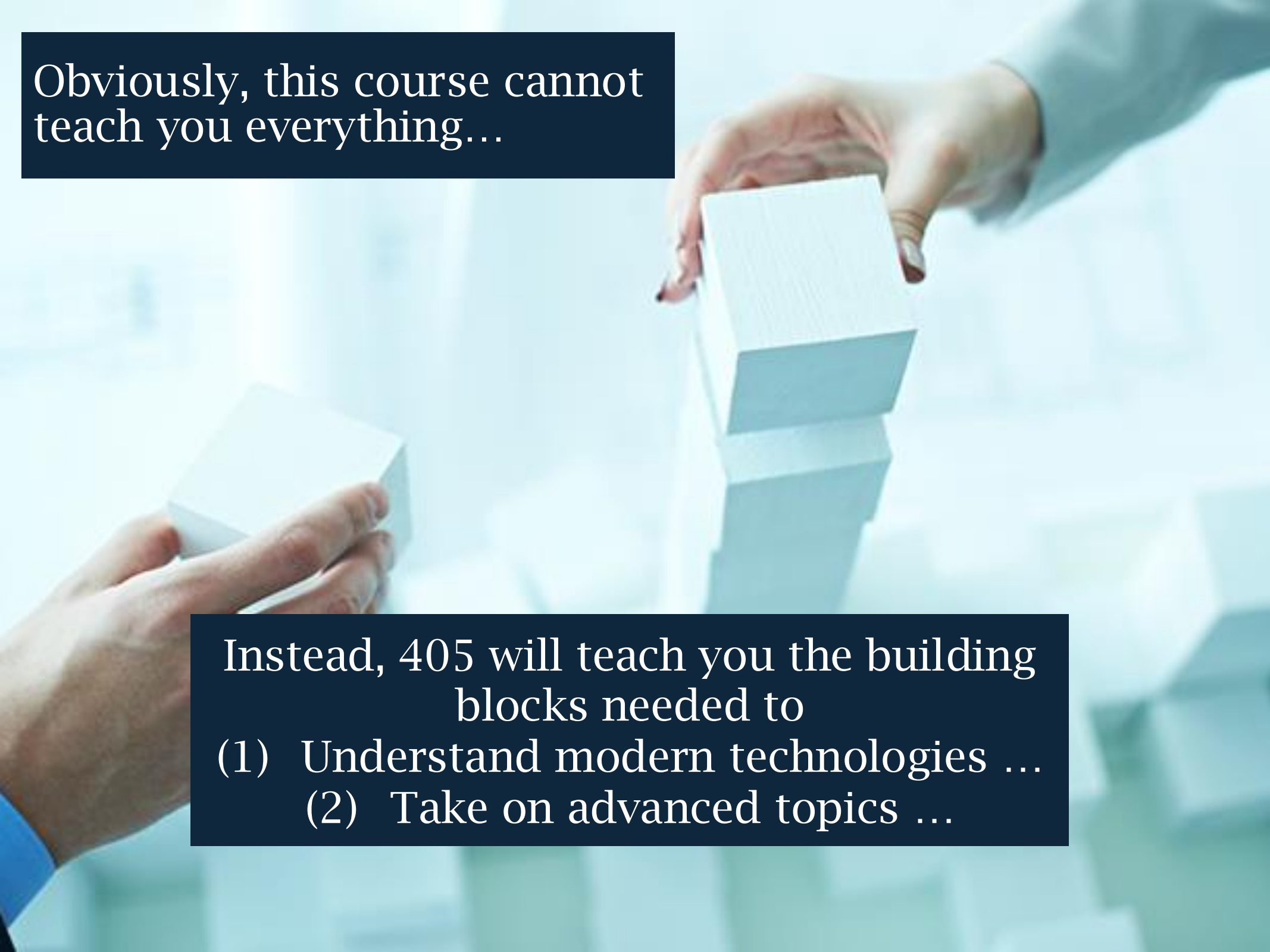


Image inside a box




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:

Hailan Shanbhag

Arman Maghsoudnia

  - A/Es: Eugen Bosnjak, Efe Tarhan, Alexandre Huou

Course Information

- Language: English
- Lectures: Tuesday 13:15 – 16:00 in OO123
  - 45 ~ 50 min lecture
  - 10 min break
  - 45 ~ 50 min lecture
  - 10 min break
  - 45 ~ 50 min lecture
- Exercise Sessions: Thursday 16:15 – 18:00 in CM 1100
- Lab Sessions: Friday 9:15 – 11:00 in BC 02
- Recordings
  - CO123 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 2025 playlist and not, FALL 2024 or SPRING 2023

Course Information

- Quizzes:
  - 3 to 4 multiple choice or true or false questions.
  - Questions are about previous lecture.
  - Supposed to be somewhat easy.
  - Quiz is on Moodle
  - We will release it on Tuesday after class and it will be due next Monday (1 week later)
  - We will have 10 quizzes
  - Quizzes are meant to keep you up to date on the lectures. They are not meant to test you knowledge.

- Surveys:
  - 3 surveys: beginning, middle, end of the class
  - Get feedback from you.
  - Similar to quizzes: released Tuesday after class and due next Monday.

Course Information

- Hands on Tutorials:
  - 2 Tutorials during lecture time
    - **Build your own private 5G base station and network.**
    - Use wireless signals for sensing and imaging in non-line-of-sight.
  - Meant to teach you practical experience working with real hardware.
  - Tutorials done in groups or 4-5.
  - Must attend in person to get the grade.
  - **Each tutorial has multiple tasks and you will get fill grade as long as you complete all tasks.**

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
  - 5% on 10 Quizzes
  - 2% on 3 Surveys
  - 10% on 2 Tutorials
  - 21% on 3 Homeworks
  - 28% on 4 Labs
  - 34% Final Exam

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

- Tentative Schedule

Week	Date	Lecture	HW & Lab	Quiz & Survey
Week 1	Tue. 9 Sep	Introduction + Wireless Channel		
	Fri. 12 Sep			
Week 2	Tue. 16 Sep	OFDM	LAB 1 OUT	Survey 1
	Fri. 19 Sep			
Week 3	Tue. 23 Sep	Tutorial 1 : Build your own 5G base station & network	HW 1 OUT	Quiz 1
	Fri. 26 Sep			
Week 4	Tue. 30 Sep	Modulation & Data Rates + MIMO		Quiz 2
	Fri. 3 Oct		**LAB 1 DUE**	
Week 5	Tue. 7 Oct	MAC + Scheduling	LAB 2 OUT	Quiz 3
	Fri. 10 Oct			
Week 6	Tue. 14 Oct	Cellular 1: 3G/4G/5G + Millimeter Wave Networks		Quiz 4
	Fri. 17 Oct		**HW 1 DUE**	
Break				
Week 7	Tue. 28 Oct	Cellular 2: Planning + Handover + Slicing + ORAN + AI	HW 2 OUT	Survey 2
	Fri. 31 Oct		**LAB 2 DUE**	
Week 8	Tue. 4 Nov	IoT + Wireless Localization 1		Quiz 5
	Fri. 7 Nov			
Week 9	Tue. 11 Nov	Wireless Localization 2	LAB 3 OUT	Quiz 6
	Fri. 14 Nov		**HW 2 DUE**	
Week 10	Tue. 18 Nov	Wireless Sensing + Imaging		Quiz 7
	Fri. 21 Nov			
Week 11	Tue. 25 Nov	Tutorial 2: Use wireless signals for sensing and imaging in non-line-of-sight.	HW 3 OUT & LAB 4 OU	Quiz 8
	Fri. 28 Nov		**LAB 3 DUE**	
Week 12	Tue. 2 Dec	Adhoc Networks + Routing + Network Coding		Quiz 9
	Fri. 5 Dec			
Week 13	Tue. 9 Dec	Wireless Security & Privacy		Quiz 10
	Fri. 12 Dec		**HW 3 DUE**	
Week 14	Tue. 16 Dec	Advanced Topics: Full Duplex, Medical Implants, Intellegent Reflective Surfaces, Underwater Networks, Acoustics, Satellite Networks, …		Survey 3
	Fri. 19 Dec		**LAB 4 DUE**	