# Course Introduction

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Machine Learning For Wireless Communications (EE798L)

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# Introduction

- How machine learning can be applied to wireless systems
- Will teach machine learning fundamentals and pick-up wireless examples to show their applications

If you're comfortable, I'm not teaching and you're not learning. It's going to get uncomfortable in here, and that's ok. It's normal and it's part of the process.

Prof. Brene Brown, University of Houston, and author of the book "Daring Greatly"

# Making the learning process convenient

- Will share the slides and other relevant study material
- Will give take home tutorials – not graded, will be discussed in class to clarify doubts
- Will hold special tutorials for MATLAB programming if students need
- Contact hours for doubts – 7 pm onwards

# Course evaluation and logistics

- Mini-quiz-1 – 10%
- Mini-quiz-2 – 10%
- Mid-sem – 20%
- End-sem – 40%
- MATLAB simulation assignments based on class material - 10%
- Reading assignments - 10%
- Books/slides/tutorial/assignments will be uploaded in Google class-room - link is shared
- Attendance policy – will not take attendance
- Strongly encourage to attend classes – slides do not contain everything
- Cheating: award zero in the quiz/assignment

# Books

- Text book - A First Course In Machine Learning Second Edition [FCML]
  - Simon Rogers, Mark Girolami, CRC Press, 2017.
- Reference book-1 - Pattern Recognition and Machine Learning by Christopher Bishop [PRML]
  - Christopher Bishop, Springer, 2010.
- Reference book-2 - Probabilistic Machine Learning: An Introduction [PML]
  - Kevin P. Murphy, MIT Press 2021.

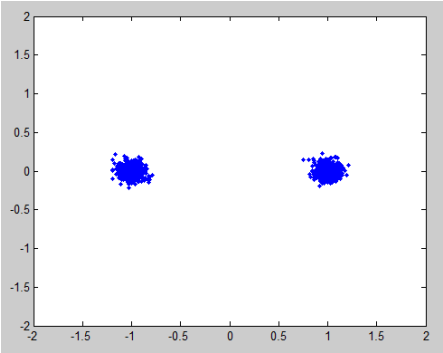
# Single-antenna Wireless systems

- Begin with single-antenna digital communication system which operate in AWGN channel


  - System is mathematically modeled as $y = x + n$
  - Example - satellite communications systems
- Single-antenna digital communication system which operate in wireless AWGN channel
  - Mathematically modeled as $y = hx + n$
  - Example - cellular communications

# Machine learning and wireless – classification and detection (1)

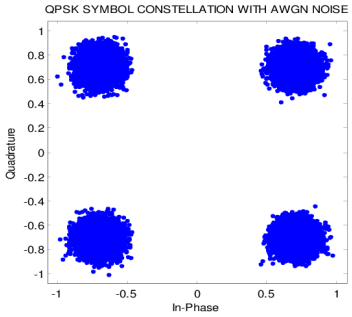
- Consider single-antenna AWGN channel $y = x + n$
  - $x$ can be BPSK/4-QAM/16-QAM/64-QAM/256-QAM/1024-QAM
- If $x$ is a BPSK signal then it can either take value $+1$ or $-1$ with let's say equal probability
- Received noisy signal will look like:




- ML parlance - we need to classify receive signal either as $+1$ or $-1$
- Wireless parlance - we need to detect the receive signal and declare it either as $+1$ or $-1$

# Machine learning and wireless – classification and detection (2)

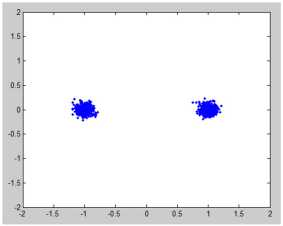
- If $x$ is a 4-QAM signal then it can take following values with let's say equal probability
  - $\frac{1}{\sqrt{2}} + \frac{j}{\sqrt{2}}$, $\frac{1}{\sqrt{2}} - \frac{j}{\sqrt{2}}$, $-\frac{1}{\sqrt{2}} + \frac{j}{\sqrt{2}}$, $-\frac{1}{\sqrt{2}} - \frac{j}{\sqrt{2}}$
- Receive noisy signal for AWGN channel $y = x + n$ will look like:

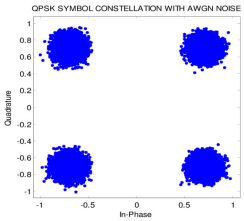



- ML/Wirelss parlance - we need to classify/detect receive signal

# Machine learning/wireless – clustering/modulation detection

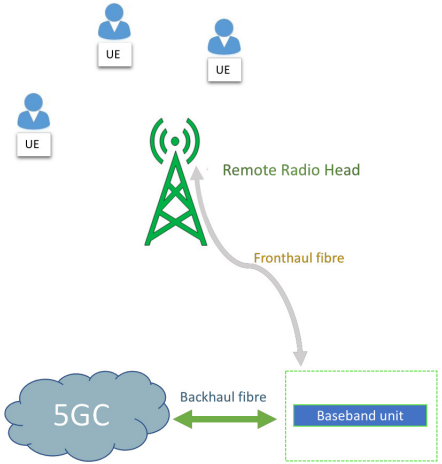
- We do not even know whether $x$ is a BPSK or QPSK modulation
  - Blind modulation detection
  - Example: Stealth communication systems
- Receive noisy signal will be either of these constellations






- We need to first classify which modulation was transmitted
- Wireless system uses clustering technique from machine learning to count the number of clusters
  - Two-widely popular technique - K-means and Gaussian mixture modeling
- We built a stealth communication system where we had to classify such modulation schemes

# Motivation - indigenous 5G network designed at IITK



# Indigenous 5G network installation in IITK campus

Remote Radio Head

Baseband Unit


Core network

# Technology transferred to Tata-Tejas network

**EDUCATION TECHNOLOGY: IIT Madras, IIT Kanpur license 5G tech to Tata Group company**

Tejas Networks will be paying a ToT non-exclusive, licence fee of Rs 12 crore in multiple instalments based on technical milestones

Share

TNN | Posted December 12, 2023 12:17 PM


In a move towards indigenisation of telecommunications equipment, IIT Madras, IIT Kanpur and the Society for Applied Microwave Electronics Engineering and Research (SAMEER) jointly developed a '5G RAN sub-system' at the 5G Test Bed. The three institutions are jointly licensing the 5G radio access network (RAN) technology to Tejas Networks, a Tata Group company, that

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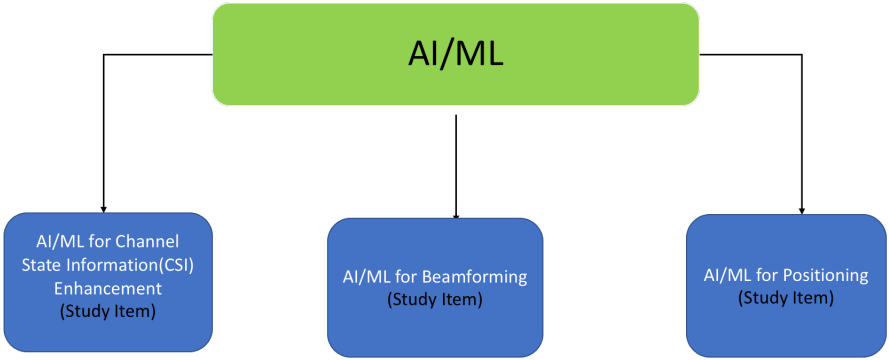
# 5G is evolving to 6G




38.843 - Study on Artificial Intelligence (AI)/Machine Learning (ML) for NR air interface

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# Machine learning based research for 6G (1)

# Machine learning based research for 6G (2)

interdigital.

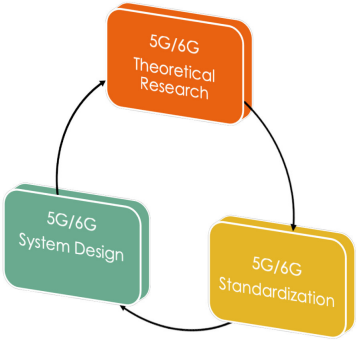
## InterDigital and the Indian Institute of Technology Kanpur (IIT-K) Formalize Wireless Research Partnership

October 02, 2023 04:00 ET| Source: InterDigital, Inc. Follow

WILMINGTON, Del., Oct. 02, 2023 (GLOBE NEWSWIRE) -- InterDigital, Inc. (Nasdaq: IDCC), a mobile and video technology research and development company, and the Indian Institute of Technology at Kanpur (IIT-K) have announced a bilateral research partnership to develop enabling technologies that impact future wireless standards. Specifically, InterDigital will sponsor research and innovation at IIT-K that advances MIMO (Multiple-Input, Multiple-Output) systems to achieve the improved spectrum efficiency and network coverage required for 5G Advanced and 6G network deployments. The research will support critical advancements enabling networks to scale and meet growing bandwidth and coverage demands of advanced applications like metaverse experiences, holographic communications, and digital twins.

The InterDigital and IIT-K partnership is aligned with the growing collaboration between India and the United States around 6G research and standardization. The partnership follows a *joint statement* from the two countries at the recent G20 Summit highlighting the importance of joint research and development in 6G technologies while acknowledging IIT-K as a key collaborator.

# Brief Introduction




- 5G/6G research, standardization are extensively using machine learning
- Practicing engineer – Designed 3G, 4G and 5G systems – nine years in the industry
- Work with companies such as Interdigital, Qualcomm, Nokia, Intel, BEL
- Recognition by honorable PM for 5G standard work
- Recognition by honorable PM for 5G Testbed work