CT111 Introduction to Communication Systems Lecture 2: Communication Systems: 5G Roadmap and Models

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Overview of Today's Talk

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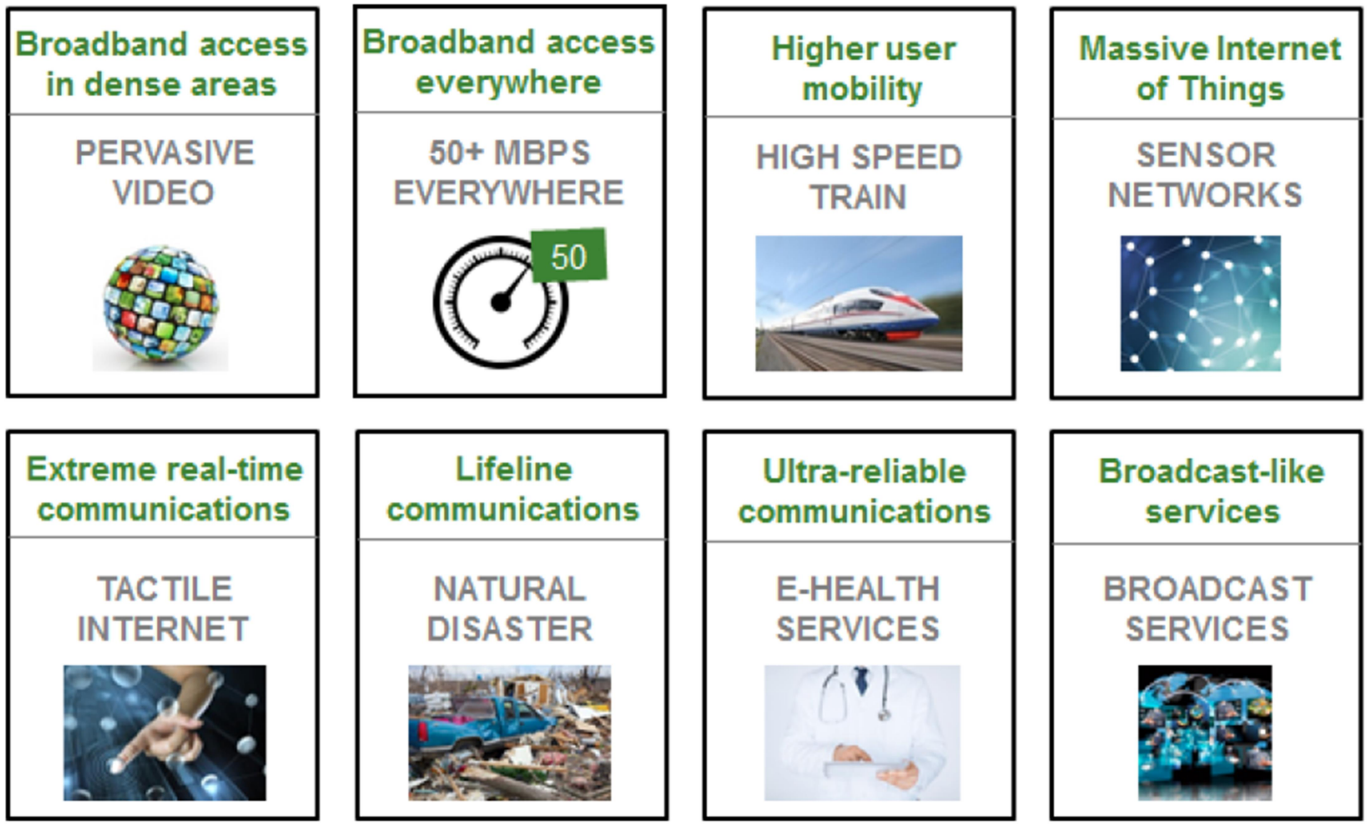
Why to Study CT111?
(4G and 5G are the reasons)

- The world is currently migrating from 3G to 4G
- However, the research and the advanced development in the industry is currently migrating from 4G to 5G
  - → Perfect time to get on the board.
  - → CT-111 would be the first step
- Let us see next what the research and the industry are targeting for

Why to Study CT111?
5G Targets (by NGMN)

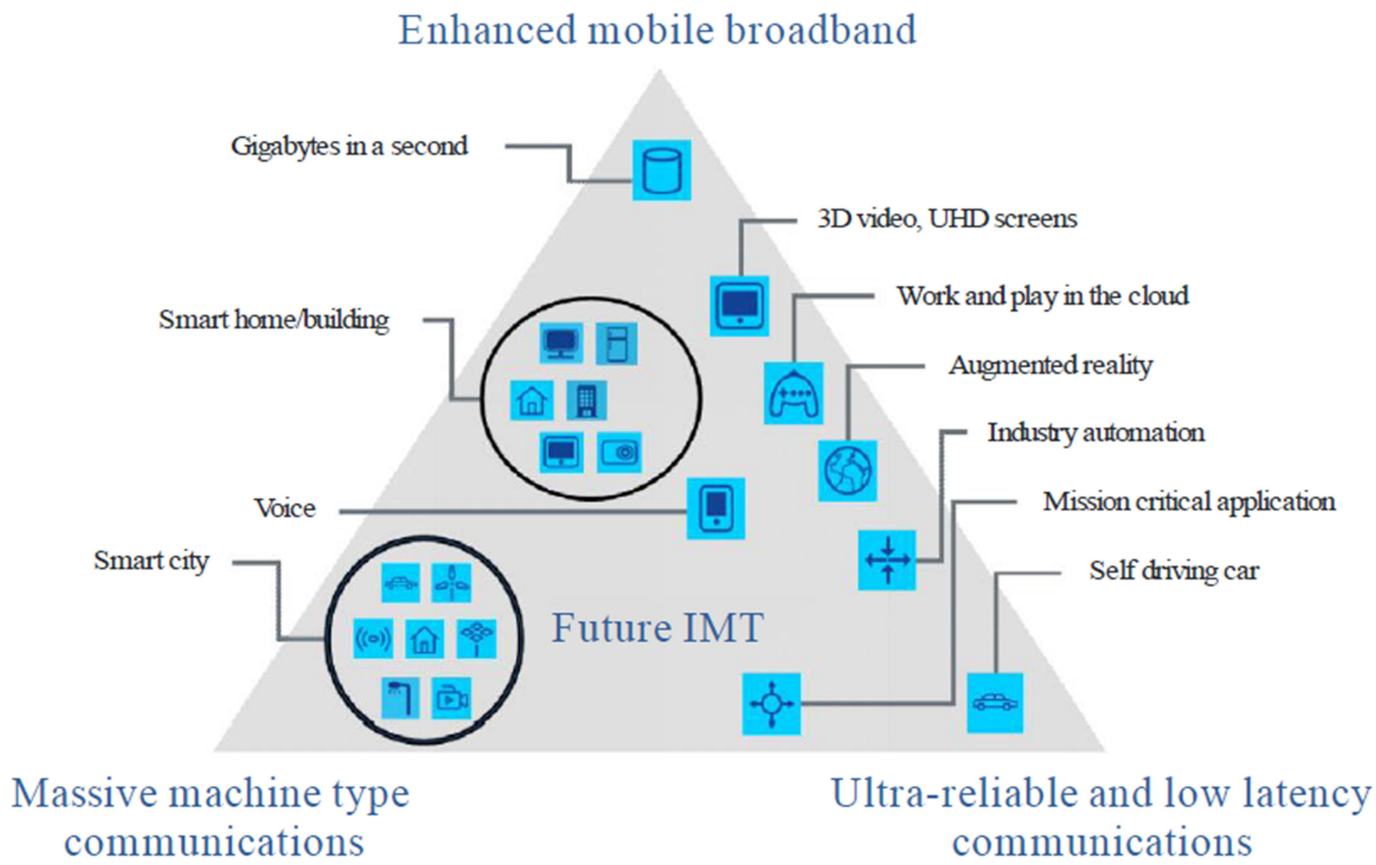


→ Reference: 5G White Paper, NGMN Alliance, Feb 2015

Why to Study CT111?
5G Targets (by NGMN)

- Broadband Access in Dense Areas
  - → Competitor to Cable TV
- Broadband Access Everywhere
  - → Internet and phone calls in rural areas
- High Speed Mobility
  - → Internet and phone calls in bullet trains and planes
- Massive Internet Of Things (IOT)
  - → Connected devices that interact with each other
- Extreme Real Time Communications
  - → Very fast, low latency, for autonomous vehicles, industrial automation, augmented reality
- Lifeline Communications
  - → Mission critical applications, public safety
- Ultra Reliable Communications
  - → Robotic surgery, surgeon located thousands of miles away, etc.

Why to Study CT111?
5G Targets (by ITU)



→ Reference: ITU-R M.2083-0

Why to Study CT111?
5G Targets (by ITU)

- Enhanced Mobile Broadband (hologram)
- Critical Communications (drones and robots)
- Massive MTC (inventory control, flexible manufacturing)
- Network Operation that save energy
- Enhancement of Vehicle to Everything (autonomous driving)

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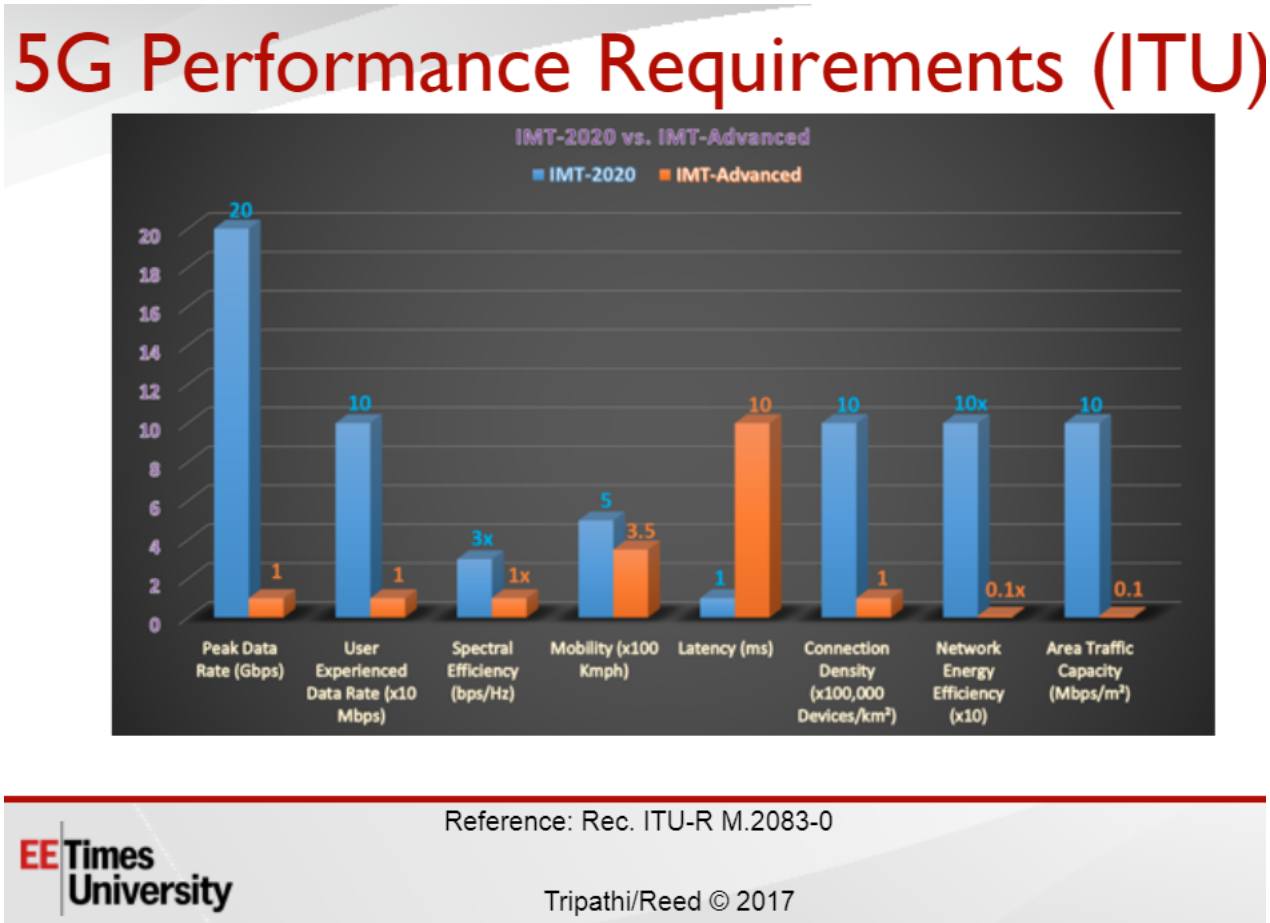
5G Targets (by ITU)



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Why to Study CT111?
An Experiment of Communications

- We're here to study communication systems: what makes them work, how do they operate, what benefits they bring
- Let's do a small lab experiement, will make use of multiple communication devices
  - → How many? about 300 or so!
- Yes, all of us, if we're anything, are amazing communication instruments
  - better than the best of the current tech
  - our skill, that we end up trivializing only because it comes easily to us, is, in fact, a true wonder, an act of miracle
- Ours is a remarkable ability to shape events in each other brains with an exquisite precision
  - → By filling up air in my lungs and releasing it so that it makes some sounds, I am able to cause some precise new combinations of ideas to form in your brains, due to which you will be forever changed [REF: Language Instinct by Steven Pinker]
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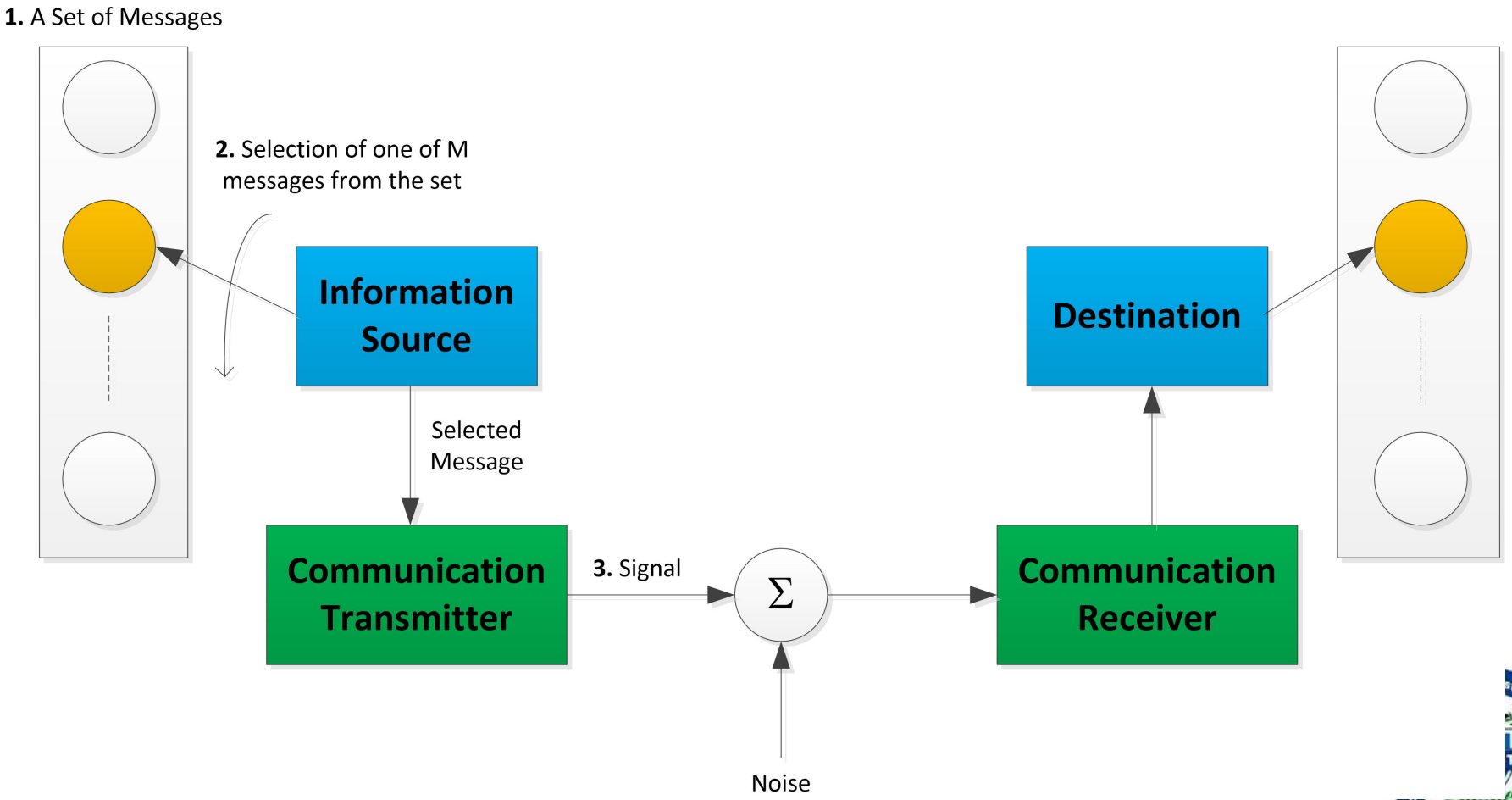
A Model of Digital Communication Systems

A Simple Block Diagram



A Model of Digital Communication Systems

A Simple Block Diagram

Key design parameters:

1. Size M of the message set: determines number of bits N required to convey the message
   - $\rightarrow$ $N = \log_2 M$
2. How fast the messages are selected: determines the number of messages per second
   - $\rightarrow$ the larger the message set size and/or the greater the speed of the message transfer, the bit rate R = the number of bits per second, increases
   - $\rightarrow$ Greater the bit rate R, the greater the information that gets conveyed. However, greater also is the work that the communication system has to do.
3. The power P_s that the communication receiver gets (determined by the power that the transmitter can put in the transmitted signal), the spectral bandwidth W that it has and the power P_n of the noise that the communication channel introduces

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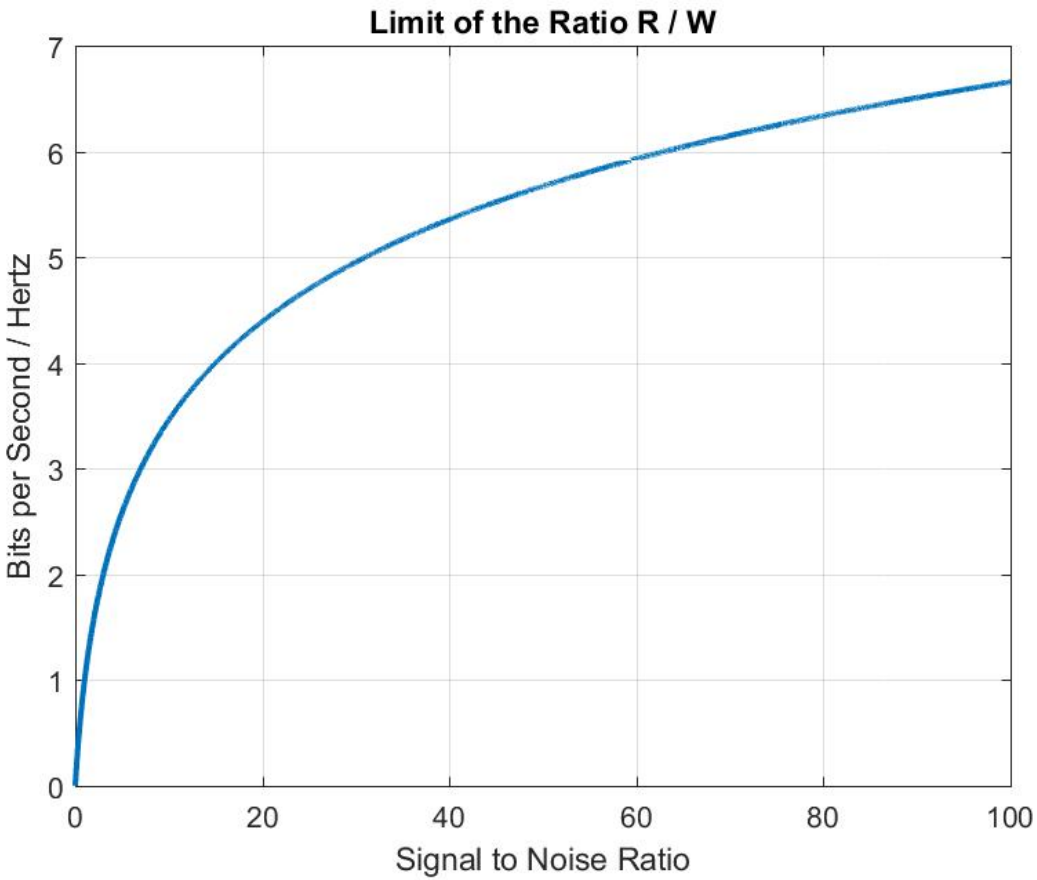
A Fundamental Limit on Communications

Shannon Information Theory

→ The celebrated relationship:

$$R \leq W \log_2 \left(1 + \frac{P_s}{P_n}\right)$$



Bandwidth Efficiency η_B

- As data rate R increases, the pulse width of transmitted signal reduces and therefore the bandwidth B, which is inversely proportional to the transmitted pulse width, increases.
- This cannot be avoided; however some schemes use the available bandwidth more efficiently than the others
- We will denote the ratio R/W as the bandwidth efficiency η_B.
- It is obviously better to have η_B as large as possible. However, there is a cost associated to making η_B large.

Energy Efficiency η_E

- Communication systems are characterized by the signal to noise ratio (SNR) P_s/P_n required to attain a certain performance
- Typically improving η_B (making it large) requires SNR P_s/P_n to be increased
- We will define energy efficiency η_E as $\left(\frac{P_s}{P_n}\right)^{-1}$ required to attain some excellent communication performance (e.g., only one bit out of 10^5 bits is in error on average).
- Greater the required $\frac{P_s}{P_n}$, the smaller the energy efficiency.

Fight between η_E and η_B

- As it often is the case in the life, it is hard to get best of both the worlds.
- An increase in η_B translates to a decrease in η_E and vice versa.

Relation to Other Courses

Analog and Digital Communications: Designed to be a precursor to A&D. Several lectures may have some overlap with A&D.

Coding Theory: cover block codes, convolutional codes, Turbo and LDPC codes. Describes the performance analysis and their application in the system design.

Wireless Communications: this course provides a detailed study on the statistical description of the wireless channel. The course also covers multiple wireless (2G/3G/4G) standards. CT-111 will provide an overview of the channel models, and will allow you to understand the basics of these various wireless standards.

Relation to Other Courses

Information Theory: emphasizes the fundamental limits on the communications. In CT111, we will study the algorithms used at the transmitter and the receiver of the digital communication system that attempt to approach these limits.

Estimation and Detection Theory: provides a detailed mathematical background on the algorithms used at the receiver of a communication system. In this class, we will cover a part of this material.

Probability and Statistics for Engineers: this class serves as foundation course for all of the courses listed above. We will utilize some statistical concepts in CT111.