Syllabus

- **Course Info:**

  Course Number & Title: ECE9900 (5G Wireless Systems)
  Course Homepage: `http://www.princeton.edu/~mvaezi/ece9900`
  Lectures Time: Tuesday 3:00-5:30
  Location: CEER 314

  Please visit the course website for course information, special announcements, and course materials.

- **Instructor:**

  Instructor: Prof. Mojtaba Vaezi
  E-mail: mvaezi at villanova.edu
  Phone: (610) 519-5658
  Office: Tolentine 433A
  Office Hours: Tuesday 1:30-2:30 p.m., or by appointment

- **Course Description:**
  This course covers several topics on fifth generation (5G) of wireless systems with a specific focus on the physical layer and air interface technologies. 5G systems are being developed by industry for deployment starting in 2020. In comparison to 4G systems, 5G systems are to support for 10 times higher the peak data rate, 10 times lower latency, and 10 times higher number of connected devices.

  The course starts with a review of cellular standards evolution to today's state-of-the-art 4G LTE technology. Next, we move on to describe the requirement of 5G networks in terms of modulation, waveform design, and access methods. We compare the performance of different non-orthogonal multiple access methods as well as multiple variants of orthogonal frequency division multiplexing (OFDM), being considered by standardization bodies. We then look at the opportunities and challenges introduced by using mmWave frequency bands, massive MIMO, cloud-RAN, and full-duplex communications. The course involves reading fundamental current research papers and book chapters.

  - **Target Audience:**
    Anyone interested in or working within the field of wireless mobile systems will

benefit from this 5G course. The course is well-suited for graduate students in signal processing and wireless communications and design engineers who require an in-depth understanding of 5G principles, design concepts, and state-of-the-art research activities.

Prerequisite: An introductory course on digital or cellular communications is required.

- **Learning objectives:**
  Students are exposed to the cutting-edge technologies that are the main topics for research and standardization in industry and many academic research groups. Upon completing the course, students should be able to:
  - Identify major requirements deriving 5G systems
  - Explain key 5G wireless features/advantages
  - Describe major 5G enabling technologies
  - Understand new radio (NR) architecture and system considerations
  - Engage in research for cutting-edge wireless technologies
- **Topics:**
  - Overview of cellular systems (1 week)
  - Overview of 4G LTE technology (1 week)
  - Multiple access for 5G (2 weeks)
  - Waveform design for 5G (2 weeks)
  - Massive MIMO (4 weeks)
  - Cloud-RAN (1 week)
  - mmWave (2 weeks)
  - full-duplex (1 week)

- **Assessment:**

Assessment will be based on eight assignments (4 problem sets, 4 paper summaries), one midterm exam, and a final project, with the following weighting:

	Weight	Remarks
Problem Sets	20%	4 sets; each due in 1 week
Paper Summaries	20%	4 one-page summaries
Midterm Exam	20%	April 3, 2018 (tentative)
Final Project	40%	May 6, 2018 (by 6 p.m.)

Letter grade assignments will be made based on the grading policy of the university policy.

- **Assignments policy:**
  - Problem sets are due the following week of the assigned date, on Tuesdays by 3:00 p.m.
  - Assignments can be handed in class or submitted electronically.
  - There will be 20% penalty for late problem sets. No assignment is accepted more than a week later.
  - Students are allowed, even encouraged, to work on the problem sets in groups of two, but solutions must be written individually.
  - The summaries must be sent at least two hours before the beginning of the class in which the paper is discussed.
  - No credit will be given to the late summaries as the papers will be discussed in class, right after the deadlines.
- **Paper Summaries:** The purpose of paper summaries in this course is to introduce the fundamental research in 5G wireless communication systems. This requires reading deeply on a wide range of topics with the following purposes: 1) To make the students ready for the specific topic to be discussed in the class. 2) To familiarize the students with the process of writing research papers/reports in the wireless communication field.

  You are expected to carefully read the papers and submit a one-page summary describing the motivation for the work, the problem studied, key ideas/contributions, and possible ideas to extend/improve the paper. Specifically, each summary should answer these four questions
  - What is the major contribution of the paper?
  - What is the paper's strength?
  - What is the paper's weakness?
  - What would you do to extend the work?

  Each class typically has two papers. One paper is background reading. A second paper is the focus of the class discussion and requires a review. You should read and be familiar with the background paper, but do not need to know all of its details.

- **References:**

1. *Multiple Access Techniques for 5G Wireless Networks and Beyond*, by Mojtaba Vaezi, Zhiguo Ding, and H. Vincent Poor, Springer 2018, in process.

2. *Massive MIMO Networks: Spectral, Energy, and Hardware Efficiency*, by Emil Björnson, Jakob Hoydis, and Luca Sanguinetti, Foundations and Trends in Signal Processing, 2017.

3. *Cloud Mobile Networks: From RAN to EPC*, by Mojtaba Vaezi, Ying Zhang, Springer 2017.

4. *Millimeter Wave Wireless Communications* by Theodore S. Rappaport, Robert W. Heath, Robert C. Daniels, James N. Murdock, Prentice Hall, 2014.

- **Student Code of Academic Integrity:** Academic integrity is a primary value for any institution of higher education. Cheating on tests, plagiarism, and other forms of academic dishonesty and misconduct are completely unacceptable, especially at Villanova which prides itself on its commitment to the Augustinian values of truth, unity, and love. Students are expected to adhere to Villanova's Code of Academic Integrity accessible via the following link:
https://www1.villanova.edu/villanova/provost/resources/student/policies/integrity.

- **Statement on Disability:** "It is the policy of Villanova to make reasonable academic accommodations for qualified individuals with disabilities. If you are a person with a disability (non-physical) please register with the Learning Support office by contacting Learning.support.services@villanova.edu or 610-519-5176 as soon as possible. Registration is needed in order to receive accommodations. The Office of Disability Services collaborates with students, faculty, staff, and community members to create diverse learning environments that are usable, equitable, inclusive and sustainable. The ODS provides Villanova University students with physical disabilities the necessary support to successfully complete their education and participate in activities available to all students. If you have a diagnosed disability and plan to utilize academic accommodations, please contact Gregory Hannah, advisor to students with disabilities @ 610-519-3209 or visit the office on the second floor of the Connelly Center."