ECE 597AA/ ECE 697AA – Artificial Intelligence Based Wireless Network Design

Department of Electrical and Computer Engineering
University of Massachusetts Amherst

FALL 2020

Course Description:

This course focuses on wireless networks design and analysis. It starts with an overview of the evolution from 4G to 5G and the technical specifications for 5G. It revises the latest challenges in 5G/6G wireless networks design, which motivates the need for AI-based solutions. Specific examples of network functionalities using AI will be discussed. The technology enablers are based on software defined networks and virtualization, edge computing, and dynamic networking to support services that require high data rates, low latency, high reliability and massive connectivity. The course will also provide the analytical tools for the modelling and analysis of these networks including network optimization, queueing theory, game theory and machine learning. Examples of resource allocation problems in ultra-reliable low-latency networks, virtual networks, multi-access edge networks, and 5G/6G networks will be discussed by using these tools.

Course credits: 3 credits

Prerequisites: An introductory course on networking (ECE 325). A basic understanding of probability and random processes (ECE 214).

Course meetings: Tuesday and Thursday 4:00-5:15pm on Zoom. A link to each Zoom session can be found on Moodle. Lectures will be recorded and the recordings will be posted on Moodle.

Instructor: Beatriz Lorenzo, Dr. (blorenzo@umass.edu). Office hours: Tuesday 5:15-6:15 pm, Thursday 5:15-6:15 pm, or another time by appointment.

Teaching Assistant: Fubao Wu (fubaowu@umass.edu). Office hours: Monday 5:00-6:00 pm, and Wednesday 10:00-11:00 am.

Office hours will not be recorded. Links to Zoom sessions for office hours can be found on Moodle.

Communication:

The course materials, assignments and announcements will be available on Moodle. If you have any general question about the course or a specific question about any topic covered in the course, please post it in the Student Q&A Forum on Moodle. For questions that require more detailed explanations, please attend the office hours or ask any time during the lectures. For questions related to the homework and project assignments, please contact the TA. For personal questions that only pertain to you or your grades, please email the instructor or the TA.

Objectives:

Students completing this course will be able to:

- Understand the theoretical background of the analytical tools presented in this course
- Assess the suitability of the different analytical tools to model a given networking problem
- Model and analyse real networking problems by using the above analytical tools
- Define metrics of interest to study the performance of the network using the previous analytical tools

Textbooks:

The following textbook is recommended (not mandatory). The class materials are self-contained.

Advanced Wireless Networks: 4G Cognitive Opportunistic and Cooperative Technology by S. Glisic, B. Lorenzo. 2nd edition, John Wiley and Sons.

Recent papers on advanced wireless networks

Topics covered:

- Introduction to wireless networks architecture, technology and standards. Introduction to LTE. Architecture of the LTE Air Interface. Evolution from 4G to 5G. Enabling technologies for 5G. Artificial Intelligence-based wireless network design for 5G and beyond.
- Network optimization: Convex vs. non-convex problems, duality theory, decomposition methods for network utility maximization, multi-objective problems, and Pareto optimality. Applications to cross-layer optimization.
- Queueing theory: birth-death process, single server queues, M/M/c, priorities and scheduling. Applications to resource allocation in multi-access edge networks.
- Game theory: Cooperative, non-cooperative, and evolutionary games. Applications to cognitive networks.
- Matching theory: stability, deferred-acceptance, and strategy proof. Applications to heterogeneous networks.
- Machine learning: supervised and unsupervised learning. Reinforcement learning and deep reinforcement learning. Applications to dynamic resource allocation.

Grading:

4 homework assignments	30%
5 seminars	30% (15% presentation and 15% seminar sheet)
Project assignment	40%

No exams.

Schedule homework assignments:

	Posted	Deadline
Homework 1	Tuesday, September 8	Friday, September 18
Homework 2	Tuesday, September 29	Friday, October 9
Homework 3	Tuesday, October 20	Friday, October 30
Homework 4	Tuesday, November 10	Friday, November 20

The homework assignments will be posted on Moodle and should be submitted on Moodle before the deadline.

Schedule seminars:

	Posted	**Live Presentation**
Paper 1	Thursday, August 27	Thursday, September 10
Paper 2	Thursday, September 17	Thursday, October 1
Paper 3	Thursday, October 8	Thursday, October 22
Paper 4	Thursday, October 29	Thursday, November 12
Paper 5	Thursday, November 5	Thursday, November 19

Each student will be assigned 5 papers which utilize the analytical tools presented in the lectures to solve different networking problems. Students will work in groups to prepare a thirty-minute seminar presentation on **one** of the assigned papers. The presentation should include a summary of the problem addressed in the paper, explanation of the modelling and analysis of the problem, performance and suggestions for improvement and extension.

After the presentation there will be a discussion. All students are expected to participate in the discussions of their own paper and the other 4 papers that will be presented by other groups. In addition, a seminar sheet should be returned after attending the presentation answering a set of questions. The seminar sheet and the papers will be available on Moodle.

Schedule project assignment:

	Posted	Deadline
Project	Monday, September 21	Friday, November 20

The project assignment will be posted on Moodle. Students will work in pairs to program several machine learning algorithms for resource virtualization using Python and TensorFlow, analyse the results and make a report.

Attendance policies:

It is mandatory to attend the seminar presentations. If you have a problem to attend the seminars in the slotted times let me know as soon as possible. It is advisable, but not mandatory, to attend the lectures. The recordings of the lectures will be available on Moodle.

Late Policy:

Deadlines are strict. A submission after the deadline will receive zero credit.

Academic Honesty Policy Statement:

Since the integrity of the academic enterprise of any institution of higher education requires honesty in scholarship and research, academic honesty is required of all students at the University of Massachusetts Amherst. Academic dishonesty is prohibited in all programs of the University. Academic dishonesty includes but is not limited to: cheating, fabrication, plagiarism, and facilitating dishonesty. Appropriate sanctions may be imposed on any student who has committed an act of academic dishonesty. Instructors should take reasonable steps to address academic misconduct. Any person who has reason to believe that a student has committed academic dishonesty should bring such information to the attention of the appropriate course instructor as soon as possible. Instances of academic dishonesty not related to a specific course should be brought to the attention of the appropriate department Head or Chair. The procedures outlined below are intended to provide an efficient and orderly process by which action may be taken if it appears that academic dishonesty has occurred and by which students may appeal such actions. Since students are expected to be familiar with this policy and the commonly accepted standards of academic integrity, ignorance of such standards is not normally sufficient evidence of lack of intent. For more information about what constitutes academic dishonesty, please see the Dean of Students website: http://umass.edu/dean_ students/codeofconduct/acadhonesty/

Disability Statement:

The University of Massachusetts Amherst is committed to providing an equal educational opportunity for all students. If you have a documented physical, psychological, or learning disability on file with Disability Services (DS), Learning Disabilities Support Services (LDSS), or Psychological Disabilities Services (PDS), you may be eligible for reasonable academic accommodations to help you succeed in this course. If you have a documented disability that requires an accommodation, please notify me within the first two weeks of the semester so that we may make appropriate arrangements.

Inclusivity and Diversity:

The diversity of the participants in this course is a valuable source of ideas, problem solving strategies, and engineering creativity. If you feel that your contribution is not being valued for any reason, please speak with the instructor privately. If you wish to communicate anonymously, you may do so in writing or speak with Dr. Paula Rees, Director of Engineering Diversity Programs (rees@umass.edu, 413.545.6324, Marston 128). We are all members of an academic community where it is our shared responsibility to cultivate a climate where all students/individuals are valued and where both they and their ideas are treated with respect.

Health and Wellbeing:

You are not alone at UMass. If you are experiencing new stresses related to the COVID-19 pandemic in addition to other pressures such as health, money, family, and academic concerns or stress and trauma from societal inequities and violence, reach out CEI 128 Marcus or Dr. Paula Rees (rees@umass.edu).