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

Department of Electrical and Computer Engineering
University of Massachusetts Amherst

FALL 2022

Course Description:

With 5G networks being deployed worldwide, academia and industry are already shifting their attention towards 6G. This course focuses on the evolution, fundamentals, and challenges of 5G/6G wireless network design. It starts with an overview of the evolution from 4G to 5G networks 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 modeling and analyzing these networks, including network optimization, game theory, and machine learning. Applications of the latest enabling technologies and real networking problems will be covered in the lectures, analyzed in detail at seminars, and implemented through the project assignment. These problems include virtualization, wireless networks intelligence at the edge, spectrum allocation, caching, and virtual networks, among others.

Course credits: 3 credits

Course website: Class materials will be available on Moodle.

Prerequisites: Preliminary knowledge on networking (ECE 325) and machine learning is encouraged.

Course meetings: Tuesdays and Thursdays 1:00-2:15pm at Marston Hall, room 220. The lectures will be recorded using Echo360, and the recordings can be access through Moodle. The lectures can also be attended live in Zoom (UWW students).

Instructor: Dr. Lorenzo (blorenzo@umass.edu).

Office hours: Tuesdays 2:15-4:15 pm at 309G Knowles Engineering Building or by Zoom.

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.

Objectives:

Students completing this course will be able to:

- Explain the evolution of wireless networks and identify the technologies involved
- 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 analyze real networking problems by using the above analytical tools

Textbook:

The class materials are self-contained.

- The following textbook is recommended (*not mandatory*):

S. Glisic and B. Lorenzo, Artificial Intelligence and Quantum Computing for Advanced Wireless Networks, Wiley, Feb. 2022.

- Additional required resources for the seminars discussions:

Recent papers on advanced wireless networks–provided in Moodle.

- Recommended reading:

Sun, Y., Peng, M. Zhou, Y., Huang, Y., & Mao, S. (2019). Application of machine learning in wireless networks: Key techniques and open issues. IEEE Communications Surveys & Tutorials, 21(4), 3072–3108. https://ieeexplore.ieee.org/document/8743390

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.
- 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	20%
6 seminars	30%
Project assignment	25%
Midterm Exam	25%

Schedule lectures:

Lecture	Section	Topic/Activity During Class	Day
1	Introduction	Wireless networks today, future trends and challenges	Sept. 6
2		5G/6G Network Evolution	Sept. 8
3	Evolution of Mobile Communication Systems	LTE and Small Cells	Sept. 13
4		Multi-hop Cellular Networks	Sept. 15
5		Cognitive Networks	Sept. 20
6		Review Machine Learning I	Sept. 22
7		Seminar 1	Sept. 27
8	5G/6G Enabling Technologies	SDN	Sept. 29
9		Virtualization	Oct. 4
10		Fog, Mobile Edge and Cloud Computing	Oct. 6
11		Seminar 2	Oct. 11
12		Exam 1 (Lectures 1-11)	Oct. 13
13	Wireless Networks Intelligence at the Edge	Adaptive Resource Allocation in Fog RAN	Oct. 18
14		Review Machine Learning II	Oct. 20
15		Seminar 3	Oct. 25
16	Network Optimization	Network Utility Function Decomposition	Oct. 27
17		Convex Optimization Theory	Nov. 1
18		Cross-layer Optimization	Nov. 3
19		Cross-layer Optimization (cont.)	Nov. 8
20		Seminar 4	Nov. 10
21	Game theory	Non-cooperative Games	Nov. 15
22		Bayesian Games	Nov. 17
23		Seminar 5	Nov. 29
24		Cooperative Games (cont.)	Dec. 1
25	Matching Theory	Matching Theory	Dec. 6
26		Seminar 6	Dec. 8

Schedule Midterm Exam: the midterm exam will be on Thru, Oct. 13, 7:00 pm - 8:30 pm in Marston room 132. It will cover lectures 1 to 11 (topics described above). Close book.

UWW can join in Zoom (link available on Moodle)

Schedule homework assignments:

	Posted	**Deadline**
Homework 1	Tue., Sept. 13	Sun., Sept. 25
Homework 2	Tue., Oct. 4	Sun., Oct. 16
Homework 3	Tue., Nov. 1	Sun., Nov. 13
Homework 4	Thurs., Nov. 17	Sun., Dec. 6

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

Schedule seminars as in page 3

In the seminars, students will work in groups to prepare a 30-minute seminar presentation based on an assigned paper that utilizes the analytical tools presented in the lectures to solve different networking problems. The presentation should include a summary of the problem addressed in the paper, an explanation of the modeling and analysis of the problem, performance evaluation, and suggestions for improvement. After the presentation there will be a discussion. All students are expected to participate in the discussions of their own papers and the other papers that other groups will present. 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 2 weeks before the seminar presentation.**

Schedule project assignment:

	Posted	Deadline
Project	Thurs., Sept. 22	Wed., Dec. 14

The project assignment will be posted on Moodle. Students will work in groups of 2 or 3 to program several machine learning algorithms applied to solve a networking problem using Python and TensorFlow, analyze the results, and make a report. For more details, please see the description of the project assignment on Moodle.

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.

Late Policy:

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

Academic Honesty Statement:

Maintaining the integrity of scholarship and research within institutions of higher education requires a cultural commitment. All members of the UMass Amherst community are expected to be knowledgeable of and uphold our academic honesty policies (https://www.umass.edu/honesty/). Academic dishonesty includes but is not limited to cheating, fabrication, plagiarism, and *abetting or facilitating* dishonesty. Instructors are requested to take reasonable steps to address academic misconduct, and appropriate sanctions may be imposed on any student who has committed an act of academic dishonesty. Any person who has reason to believe that a fellow student has committed academic dishonesty should bring such information to the attention of the appropriate course instructor or an alternate, trusted member of the faculty or College administration 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. Community members may fill out the College’s classroom experience form (https://tinyurl.com/UMassEngineerClassroom) to report academic dishonesty anonymously. 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.