Syllabus -- EE 649
Stochastic Network Optimization and Adaptive Learning
for Discrete Time Systems

Units: 4
Time: Fall 2023, Mon/Wed 8-9:50am
Location: GFS 113
Prerequisites: EE 503 or MATH 407 or ISE 538

Instructor: Michael J. Neely
Office hours: Mon 10am-11:55am (EEB 520)
Contact info: **mikejneely@gmail.com**
[Please put "EE 649" or "649" in subject of emails. Instructor can also be contacted via Piazza.]
Piazza signup: Please sign up for class discussion page by visiting this link:
https://piazza.com/usc/fall2023/ee649

Course Description
This course presents a mathematical theory of stochastic optimization, control, and adaptive learning for dynamic networks with time variation and uncertainty. The focus is on computer and wireless networks, including networks with random traffic, time varying channels, and mobility. Applications to operations research and economics are also considered. The general theory of Lyapunov optimization is developed for constrained optimization of time averages and online convex programming. This is applied to problems such as queue stability, utility maximization, distributed scheduling, energy allocation, profit maximization, inventory control, smart grid, energy harvesting, and stock market trading. Students use the theory in simulation projects and in a final project on a topic of their choice. Additional topics include:

- Multi-objective optimization, Zinkevich online learning, stochastic Frank-Wolfe
- Enhanced Lyapunov optimization for fast $O(1/t)$ convex programming
- Backpressure routing
- Utility, delay, convergence time tradeoffs
- Constrained and time-varying Markov decision systems

Learning Objectives
Students learn the Lyapunov drift and drift-plus-penalty technique for queue stability and optimization of time-varying discrete time systems. Students learn to map problems into stochastic versions of convex programs, the system assumptions and limitations of this method, and extensions to state-based systems with Markov chain dynamics and control. Students apply these methods to a variety of problem types, including problems of their own choosing.

Important dates
Midterm exam: Wed Sept. 27 (class time, in class room)
Final exam: Wed Dec 6, 8-10am (*final exam might be changed to a take home exam, TBA)
Project due: Mon. Nov. 27
Last day of class: Wed. Nov. 29 (*an additional class may be scheduled for presentations, TBA)

Sept. 4: Labor day (no class)
Oct. 12-13: Fall recess (no class)
Nov. 10: Veterans day (no class)
Nov. 22-26: Thanksgiving break (no class)

Course Notes
All materials (such as handouts, problem sets, notes, and slides) are posted on Piazza.

Technological Proficiency and Hardware/Software Required
Students are expected to have access to computers (such as laptops) for basic simulation in the program language of their choice (such as Python, C, C++, Matlab).

Required Readings and Supplementary Materials
Textbook:
M. J. Neely. Stochastic Network Optimization with Application to Communication and Queueing Systems. Morgan & Claypool 2010. http://dx.doi.org/10.2200/S00271ED1V01Y201006CNT007

Supplementary notes and papers shall also be posted, including:
i) M. Zinkevich, "Online convex programming and generalized infinitesimal gradient ascent," Proc ICML 2003.
ii) E. Hazan, A. Agarwal, and S. Kale, "Logarithmic Regret Algorithms for Online Convex Optimization," Machine Learning, Dec. 2007.
iii) H. Yu and M. J. Neely, "A Simple Parallel Algorithm with an $O(1/t)$ Convergence Rate for General Convex Programs, SIAM Journal on Optimization, 2017.
iv) M. J. Neely, "Convergence and adaptation for utility optimal opportunistic scheduling," IEEE Trans. Networking, June 2019.

Description and Assessment of Assignments
- Problem sets: Approximately four problem sets shall be given for students to learn the theory (some problem sets include small simulations).

- Simulation project: One extended simulation project shall be given.

- Final project: Students will apply the theory developed in class to study their own problem formulation. The genre of the problem can be chosen by the student. Potential areas include wireless and computer networks, operations research, road traffic engineering, stock market trading, etc. Students are encouraged to incorporate both analysis and simulation into their projects. Students can work either individually or with one other teammate. Teams are encouraged to meet with the professor in advance to discuss progress, auspicious directions of investigation, expectations, and any other issues related to their specific project. A final project report (5-10 pages) and a final presentation will be required of each team. Final projects are due on the first scheduled class period of the last week of class. If needed, an additional class time will be scheduled to enable presentations during the last week of class (possibly on the Thursday or Friday of that week, whichever is most agreeable to those presenting).

Grading Breakdown

Assessment Tool (assignments)		% of Grade
Homeworks		25%
Midterm		20%
Simulation project		5%
Final Exam		20%
Final Project		30%
TOTAL		100%

Assignment policies

Assignments are given roughly every 2 weeks, with due dates written at the top of the assignment. Grading will be completed before the next round of homework is assigned. The simulation project will be announced after problem set 2 is given and may be given extra time as needed.

Tentative course schedule

	Topics/Daily Activities	Readings/Preparation	Deliverables
Week 1	Rates, Queues, Stock Price Problem	**Chapter 1**	**HW 1 assigned**
Week 2	Capacity region, stability, Lyapunov drift	Chapters 1-2	
Week 3	Interference networks, NxN switches	Chapter 3	HW 1 due, HW 2 assigned
Week 4	Adaptivity performance and learning times	Chapter 3	
Week 5	Energy optimization and drift-plus-penalty	Chapter 4	HW 2 due, HW 3 assigned, Simulation project assigned
Week 6	Examples: Video quality maximization	Chapter 4	
Week 7	Examples: Smart grid energy optimization	Chapter 4	HW 3 due, HW 4 assigned
Week 8	Online convex optimization	Notes, Zinkevich paper	
Week 9	Multi-objectives and stochastic Frank-Wolfe	Chapter 5, Notes, Neely Frank-Wolfe paper	HW 4 due
Week 10	Converses	Notes, Hazan paper	
Week 11	Multi-hop and Backpressure	Chapter 4 and 5	Project proposal due
Week 12	Markov chains for discrete time queues	Chapter 1 and notes	Simulation project due
Week 13	State based scheduling	Chapter 7 and notes	
Week 14	Markov decision problem and DPP	Chapter 7 and notes	
Week 15	Project presentations		Project due
FINAL			Refer to the final exam schedule in the USC *Schedule of Classes* at classes.usc.edu.

Statement on Academic Conduct and Support Systems

Academic Conduct:

Plagiarism – presenting someone else's ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in SCampus in Part B, Section 11, "Behavior Violating University Standards" policy.usc.edu/scampus-part-b. Other forms of academic dishonesty are equally unacceptable. See additional information in SCampus and university policies on Research and Scholarship Misconduct.

Students and Disability Accommodations:

USC welcomes students with disabilities into all of the University's educational programs. The Office of Student Accessibility Services (OSAS) is responsible for the determination of appropriate accommodations for students who encounter disability-related barriers. Once a student has completed the OSAS process (registration, initial appointment, and submitted documentation) and accommodations are determined to be reasonable and appropriate, a Letter of Accommodation (LOA) will be available to generate for each course. The LOA must be given to each course instructor by the student and followed up with a discussion. This should be done as early in the semester as possible as accommodations are not retroactive. More information can be found at osas.usc.edu. You may contact OSAS at (213) 740-0776 or via email at osasfrontdesk@usc.edu.

Support Systems:

Counseling and Mental Health - (213) 740-9355 – 24/7 on call
studenthealth.usc.edu/counseling
Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

National Suicide Prevention Lifeline - 1 (800) 273-8255 – 24/7 on call
suicidepreventionlifeline.org
Free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week.

Relationship and Sexual Violence Prevention Services (RSVP) - (213) 740-9355(WELL), press "0" after hours – 24/7 on call
studenthealth.usc.edu/sexual-assault
Free and confidential therapy services, workshops, and training for situations related to gender-based harm.

Office for Equity, Equal Opportunity, and Title IX (EEO-TIX) - (213) 740-5086
eeotix.usc.edu
Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants.

Reporting Incidents of Bias or Harassment - (213) 740-5086 or (213) 821-8298
usc-advocate.symplicity.com/care_report
Avenue to report incidents of bias, hate crimes, and microaggressions to the Office for Equity, Equal Opportunity, and Title for appropriate investigation, supportive measures, and response.

The Office of Student Accessibility Services (OSAS) - (213) 740-0776
osas.usc.edu
OSAS ensures equal access for students with disabilities through providing academic accommodations and auxiliary aids in accordance with federal laws and university policy.

USC Campus Support and Intervention - (213) 821-4710
campussupport.usc.edu
Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

Diversity, Equity and Inclusion - (213) 740-2101
diversity.usc.edu
Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

USC Emergency - UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call
dps.usc.edu, emergency.usc.edu
Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

USC Department of Public Safety - UPC: (213) 740-6000, HSC: (323) 442-120 – 24/7 on call
dps.usc.edu
Non-emergency assistance or information.

Office of the Ombuds - (213) 821-9556 (UPC) / (323-442-0382 (HSC)
ombuds.usc.edu
A safe and confidential place to share your USC-related issues with a University Ombuds who will work with you to explore options or paths to manage your concern.

*Occupational Therapy Faculty Practice - (323) 442-33*40 or otfp@med.usc.edu
chan.usc.edu/otfp
Confidential Lifestyle Redesign services for USC students to support health promoting habits and routines that enhance quality of life and academic performance.