EE 599/649 — Course Syllabus
Stochastic Network Optimization
USC, Fall 2008

I. Course Information

Instructor:

Michael J. Neely (EEB 520, mjneely@usc.edu, 213-740-3505)
Office Hours (EEB 520): Monday/Wednesday 3:30-5:30pm

Class Location and Time:

KAP 158, Monday/Wednesday 2:00-3:20pm

Brief Course Description:

Stochastic Network Optimization: Network layer capacity; optimal control of wireless and ad-hoc mobile networks; opportunistic resource allocation, routing, and flow control; minimum energy networking; general utilities and constraints; queue stability; energy-delay and utility-delay tradeoffs.

Prerequisites:

Prerequisites are EE 465 or EE 562a, or permission of instructor. Familiarity with queueing systems and Markov chains is expected. Advanced networking courses such as EE 549 and/or EE 550 are strongly recommended pre- or co- requisites, but not required.

Textbook:

This course will use the following required text:

- "Resource Allocation and Cross-Layer Control in Wireless Networks," by L. Georgiadis, M. J. Neely, and L. Tassiulas, Foundations and Trends in Networking, vol. 1. no. 1, pp. 1-144, 2006.

The text can be purchased from the NOW Publishers webpage via a link from the instructor webpage (see below). A free electronic copy (PDF format) is also available on those pages.

Web Resources

- Instructor Webpage: http://www-rcf.usc.edu/∼mjneely/
- NOW Publisher Webpage: http://www.nowpublishers.com/
- Stochastic Network Optimization Homepage: http://www-rcf.usc.edu/∼mjneely/stochastic/

Supplemental Reading

Additional reading in the form of instructor handouts and a list of journal articles will be provided. A current list of papers in the area can be found on the Stochastic Network Optimization Homepage (listed above). For students interested in background reading on queueing theory, Markov chains, and convexity, the following texts are recommended (but not required):

1) Chapter 3 of *Data Networks* by D. Bertsekas and R. Gallager (Queueing Theory and Little's Theorem)
2) *Discrete Stochastic Processes* by R. Gallager (Renewal Theory and Markov Chains)
3) *Introduction to Probability Models* by Sheldon Ross (8^{th} edition) (Introduction to Markov chains and Discrete Probability)
4) *Convex Analysis and Optimization* by D. P. Bertsekas, A. Nedic, and A. E. Ozdaglar (Closed/Open Sets, Convexity, Duality, Subgradients)
5) *Nonlinear Programming* by D. P. Bertsekas (Linear and Convex Programming, Subgradient Algorithms)

Grading:

There will be 2-4 problem sets given during the semester, two midterms, and a course project. There may also be a few 10 minute questions given in class, worth a small amount of extra credit points. There is no final exam. These will be weighted in an overall score as follows: Homework: 20%, Midterm 1: 20%, Midterm 2: 20%, Project: 40%. The following minimum letter grades are guaranteed to students scoring within the specified intervals: 80-100 A, 70-80 A-, 60-70 B+, 50-60 B. The above thresholds may be adjusted at the end of the semester at the discretion of the instructor. Any such adjustments will be in favor of a higher letter grade.

Midterm Exam Dates:

Wednesday Oct. 8, Nov. 5(in class and at class time – 2:00-3:30pm KAP 158)

II. Course Summary and other Details

This course presents a theory of stochastic optimization and cross-layer control for modern networks with time varying channels, node mobility, and randomly arriving traffic. Emphasis will be on wireless systems, with applications also to computer networks, mixed wireless/wireline networks, and problems in operations research. Networks are modeled as queueing systems with general transmission rate capabilities determined by the physical properties of each network element. This approach provides a cross-layer perspective and facilitates the design of opportunistic resource allocation, routing, and flow control policies. Concepts of Network Capacity and mathematical techniques of Lyapunov Drift, Lyapunov Optimization, Backpressure and Max-Weight Scheduling, and Virtual Cost Queues will be introduced and used as important tools for optimization and design. This theory unifies notions of static convex programming and stochastic network control.

Homeworks will involve analytical problem sets. Some homeworks will also involve computer simulation of simple network algorithms, and will have "design your own problem" questions, where students develop their own problem and solution. The resulting problems and solutions will be printed and given to all other students. Students may also be scheduled to present their work during class.

Course Project:

Students will be encouraged to apply the theory developed in class to study their own problem formulation. Potential areas include wireless and mobile ad-hoc networks, computer networks and switching systems, operations research and road traffic engineering, etc. Potential topics include MIMO scheduling, optimal pricing for wireless access points, low complexity and/or low delay routing, redundant packet transfers and/or network coding, ARQ strategies, networking with errors, etc. Students are encouraged to incorporate both analysis and simulation into their projects.

Students can work either individually or with one other teammate. A final project report (5-10 pages) and a final presentation will be required of each team. Projects are due April 23, and will be presented during the final week of the course.

Statement for Students with Disabilities:

Any student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to me (or to TA) as early in the semester as possible. DSP is located in STU 301 and is open 8:30 a.m.5:00 p.m., Monday through Friday. The phone number for DSP is (213) 740-0776.

Statement on Academic Integrity:

USC seeks to maintain an optimal learning environment. General principles of academic honesty include the concept of respect for the intellectual property of others, the expectation that individual work will be submitted unless otherwise allowed by an instructor, and the obligations both to protect ones own academic work from misuse by others as well as to avoid using anothers work as ones own. All students are expected to understand and abide by these principles. Scampus, the Student Guidebook, contains the Student Conduct Code in Section 11.00, while the recommended sanctions are located in Appendix A: http://www.usc.edu/dept/publications/SCAMPUS/gov/. Students will be referred to the Office of Student Judicial Affairs and Community Standards for further review, should there be any suspicion of academic dishonesty. The Review process can be found at: http://www.usc.edu/student-affairs/SJACS/.

III. Tentative Course Outline

This is a rough list of lecture topics for each date. We may deviate from this schedule as needed.

Aug. 25, 27 — Discrete Time Queues, Channel and Traffic Variation, Stability and Delay, B/B/1 Queue

Sept. 3 — "Designing Gravity" into the network via Lyapunov Drift (Note: no class Sept. 1, Labor Day Holiday)

Sept. 8, 10 — Multi-User Uplinks/Downlinks, Capacity Regions, Opportunistic Scheduling for Stability and Max Throughput

Sept. 15, 17 — Multi-Hop Routing. Mobile Networks. Throughput Optimality and Backpressure

Sept. 22, 24 — Robustness, Imperfect Scheduling, Distributed Implementations for ad-hoc and mobile networks

Sept. 29, Oct. 1 — Distributed Implementations for ad-hoc and mobile networks (continued)

Oct. 6 — Intro to Performance Optimization

Oct. 8 — Midterm 1

Oct. 13, 15 — Performance Optimization Continued. Energy Optimality, Energy-Delay Tradeoffs

Oct. 20, 22 — Virtual Cost Queues, Average Power Constraints, Flow Control with Infinite Demand

Oct. 27, 29 — Auxiliary Variables, Flow Control with Finite Demand, General Utility Optimization

Nov. 3 — Relation to Static Convex Programming: Solving Convex Programs with Queues

Nov. 5 — Midterm 2

Nov. 10, 12 — Alternative Lyapunov Functions, Queue Grouping and Binning, Complexity and Delay

Nov. 17, 19 — Mechanism Design and Network Pricing

Nov. 24, 26 — Special Topics (eg., Networking with Errors, Multi-Receiver Diversity, Cooperative Communication)

Dec. 1, 3 — Project Presentations (all projects are due on Dec. 1)

Note: Due to conference traveling, we may need to reschedule the lecture on Wednesday Sept. 11, Sept. 24, Oct. 29, to another date (Likely Friday 2-3:30pm or whenever conveneint for the class).

Note: While we will not have lectures on performance optimization until October, you may want to read up on this material early, as it may help with project ideas. The following papers may also be useful for this material (both available on the Stochastic Network Optimization Home Page):

- M. J. Neely, "Energy Optimal Control for Time Varying Wireless Networks," IEEE Transactions on Information Theory, vol. 52, no. 7, pp. 2915-2934, July 2006.
- M. J. Neely and A. Sharma, "Dynamic Data Compression with Distortion Constraints for Wireless Transmission over a Fading Channel," arXiv:0807.3768v1, July 24, 2008.