

EE 599 — Course Syllabus

Stochastic Network Optimization

USC, Spring 2007

I. COURSE INFORMATION

Instructor:

Michael J. Neely (EEB 520, mjneely@usc.edu, 213-740-3505)
Office Hours (EEB 520): Monday 11:05am-1:05pm, Tuesday 10:00am-12:00pm

Class Location and Time:

VHE 206, Monday/Wednesday 3:30-4:50pm

One Sentence 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 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.

Note that a free electronic copy of the text is available for download on the instructor’s homepage or on the NOW Publishers webpage:

Instructor Homepage: <http://www-rcf.usc.edu/~mjneely/>
NOW Publishers Webpage: <http://www.nowpublishers.com/>

Supplemental Reading

Additional reading in the form of instructor handouts and a list of journal articles will be provided. 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 (8th 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 quizzes, and a course project. There may also be some 10 minute questions given in class once or twice a month worth a small amount of extra credit points. There is no final exam. These will be weighted in an overall score as follows:

Homework: 25%, Quiz 1: 20%, Quiz 2: 20%, Project: 35%

The following minimum letter grades are guaranteed to students scoring within the specified intervals:

80-100 A, 60-80 B, 40-60 C

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.

II. COURSE SUMMARY AND LIST OF TOPICS

This course presents a theory of stochastic network optimization for modern data networks with time varying channels, mobility, and randomly arriving traffic. Emphasis will be on wireless networks, with applications also to computer networks and mixed wireless/wireline systems. Modern networks are modeled as queueing systems with general transmission rate capabilities determined by the physical properties of each network element. Explicitly including queues in the model not only provides a more complete cross-layer perspective, but facilitates the design of opportunistic resource allocation, routing, and flow control decisions. Mathematical techniques of *Lyapunov Drift*, *Lyapunov Optimization*, and *Virtual Cost Queues* will be introduced and used as important tools in the design of optimal dynamic control algorithms. This theory unifies notions of static convex programming and stochastic network control, and complements existing courses on linear and convex programming for networks as well as existing courses on data networks and queueing theory.

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.

Tentative Course Outline:

- Jan. 8, 10 — Discrete Time Queues, Channel and Traffic Variation, Stability and Delay, B/B/1 Queue
- Jan. 17 — “Designing Gravity” into the network via Lyapunov Drift (Note: no class Jan. 15, Martin Luther King Day)
- Jan. 22, 24 — Multi-User Uplinks/Downlinks, Capacity Regions, Opportunistic Scheduling for Stability and Max Throughput
- Jan. 29, 31 — Multi-Hop Routing. Mobile Networks. Throughput Optimality and Backpressure
- Feb. 5, 7 — Robustness, Imperfect Scheduling, Distributed Implementations for ad-hoc and mobile networks
- Feb. 12, 14 — Distributed Implementations for ad-hoc and mobile networks (continued)
- Feb. 21 — Quiz 1 (Note: no class on Feb. 19, President’s Day)
- Feb. 26, 28 — Performance Optimal Lyapunov Networking, Energy Optimality, Energy-Delay Tradeoffs
- March 5, 7 — Virtual Cost Queues, Average Power Constraints, Flow Control with Infinite Demand
- March 12, 14 — Spring Break
- March 19, 21 — Auxiliary Variables, Flow Control with Finite Demand, General Utility Optimization
- March 26 — Relation to Static Convex Programming: Solving Convex Programs with Queues
- March 28 — Quiz 2
- April 2, 4 — Alternative Lyapunov Functions, Queue Grouping and Binning, Complexity and Delay
- April 9, 11 — Mechanism Design and Network Pricing
- April 16, 18 — Special Topics (eg., Networking with Errors, Multi-Receiver Diversity, Cooperative Communication)
- April 23, 25 — Project Presentations