COMP7313/8313: Network Design and Performance Analysis

Prof. Santosh Kumar

12:40pm –2:05pm, Monday, Wednesday in FIT 227

Contact Information:

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Office Hours:

Monday	Tuesday	Wednesday	Thursday	Friday
4:00 pm – 5:00 pm		4:00 pm – 5:00 pm		
Also by Appointment				

Course Description:

Mathematical modeling of networking problems; proving correctness of networking algorithms; applying optimization techniques to solving networking problems; deriving deterministic bounds on performance (approximation factors) for hard networking systems; deriving probabilistic guarantees on the performance of networking systems

Prerequisites:

- COMP 7612
- Basic knowledge of Computer Networks, Probability, and Linear Algebra
- Ability and willingness to pick up mathematical proof techniques

Why this course?

To learn basic analytical techniques that will help you become an excellent researcher.

Who should take this course?

Any graduate student who would like to improve the quality of his/her research by using analytical tools such as combinatorial optimization (LP, IP), approximation algorithms, and probabilistic methods.

Intended Outcomes:

- *Modeling*:
    1. The student will be able to identify the major issues in analyzing the performance of a computer system, protocol, or algorithm.
    2. The student will be able to list common mistakes in performance evaluation.
    3. The student will be able to choose appropriate metrics for evaluating the performance of a computer system, protocol, or algorithm.
    4. The student will be able to mathematically model a system, protocol, or an algorithm.

5. The student will be able to predict the behavior and mathematically analyze the performance of a representative computer system using one or more tools learned in this course.

- Technique 1 – *Combinatorial Optimization*:
  1. The student will be able to formulate a computer system, protocol, or algorithm design issue as an appropriate optimization problem (LP, IP, NLP, etc.)
- Technique 2 – *Approximation Algorithms*:
  1. The student will be able to define an approximation algorithm.
  2. The student will be able to present reductions to NP-Complete problems.
  3. The student will be able to apply various techniques for proving approximation guarantees to their algorithms.
  4. The student will be able to ask the right questions for any approximation algorithm that they encounter.
- Technique 3 – *Probability, Stochastic Processes, and Probabilistic Methods*:
  1. The student will be able to define a random variable.
  2. The student will be able to list the basic properties of common probability distributions.
  3. The student will be able to list the properties of stochastic processes such as Poisson process and its variations.
  4. The student will be able to use some probabilistic methods to derive probabilistic guarantees of some randomized algorithms.
- *Others:*
  1. The student will become a more effective team worker.

Required Text:

[T1] Vijay Vazirani, “Approximation Algorithms,” 2nd Edition, Academic Press, 2004.

Recommended Text:

Selected chapters and topics from the following books will be used in conjunction with the textbook.

- [R1] Raj Jain, “The Art of Computer System Performance Analysis,” Wiley, 1991.
- [R2] Wayne L. Winston, “Operations Research: Applications and Algorithms,” 4th Edition, Duxbury Press, 2004.
- [R3] Michael R. Garey and Davis S. Johnson, “Computers and Intractability: A Guide to the Theory of Incompleteness,” 1979.
- [R4] Sheldon M. Ross, “Introduction to Probability Models,” 8th Edition, Academic Press, 2003.
- [R5] Noga Alon and Joel H. Spencer, “The Probabilistic Method,” 2nd Edition, John Wiley & Sons, 2000.

Class Format

The class will involve lectures by the instructor, individual and team-based homework, paper presentations by students, and a team-based project. Basic concepts for each topic will first be introduced by the instructor in lectures. Homework will then be assigned to enhance the understanding of basic concepts. Each topic will conclude with a previously published conference or journal paper presentation from a student. The paper presented will demonstrate the application of the just concluded topic to a computer system (which will be in the domain of computer networks in most cases).

Each student is expected to form/join a team for both homework and the project. The team composition for homework may be different than for the project. The project will consist of applying one or more techniques covered in the class to a research problem. The research problem will be identified by the student(s) in consultation with the instructor. The research problem identified need not be a new one. However, the application of the selected techniques (from those covered in the course) to the chosen research problem must be new.

Class Preparation: Thorough preparation—by students *and* instructor—and active participation are essential to a successful course. Learning comes from struggling with the issues outside of class, then discussing them (and the struggle) in class. Unprepared students personally miss out on most of the learning and also cheat their classmates because they cannot contribute fully to the learning that occurs in class.

The instructor will assign readings from books and papers. Each student is expected to have read these before coming to each class. This will enhance student learning as well as enhance other students' learning because more meaningful discussion can take place in the class. Class participation assessment will be done by the instructor as well as peer students in the class.

Teams: During the first week of class, students will form teams of 2-3 unless the instructor deems a different team size is warranted. Formation of teams will be left to your discretion, but I encourage you to include some variety in terms of gender, ethnicity, nationality, work experience, etc. If you need motivation beyond the opportunity to learn from classmates with different experiences, recognize that the teams you work with on the job usually include such diversity. It is wise to have at least one team member who is a fluent in English, to help ensure that your reports are written clearly.

Teams are to work *independently*. Reports, programs, or solutions from students who took the class in the past are strictly off limits.

Evaluation:

Grading Plan: An individual's grade will be composed of his/her team's score as well as his/her individual score as described in the following table.

Homework& Quizzes	45%	Paper Review & Presentation	25%
Class Participation	5%	Project Report & Presentation	25%

Assignment of letter grade will be determined based on performance of the entire class.

Difference Between 7313 and 8313 Evaluation: Students registering for 8313 will be required to submit an extra task such as making a presentation.

Course Topics in Chronological Order (subject to change):

Week	Course Topics

1	Course Overview and Introduction *Reading: Chapter 1 from Reference book R1*
2,3	Mathematical modeling of networking problems *Reading: Chapter 2 and 3 from Reference book R1*
4	Review of Linear Algebra and Linear Programming (LP) *Reading: Chapter 2 from Reference R2*
5	Modeling Networking Problems as LP *Reading: Chapter 4 from Reference R2; Selected research papers*
5	Reviewing Duality Theory *Reading: Chapter 6 from Reference R2*
6	Modeling networking problems as Integer Programs (IP) *Reading: Chapter 9 from Reference R2; Selected research papers*
7	Reducing networking problems to known Mathematical Problems *Reading: Chapter 3 from Reference R3; Selected research papers*
8	Introduction to Approximation Algorithms *Reading: Chapter 1 from the Textbook*
9	Applying Greedy algorithms to derive performance guarantee for NP-Complete networking problems (NPCNP) *Reading: Chapter 2 from the Textbook; Selected research papers*
10	Designing Polynomial Time Approximation Schemes for NPCNP *Reading: Chapters 8 and 9 from the Textbook; Selected research papers*
11	Applying Dual Fitting to derive performance guarantee for NPCNP *Reading: Chapter 13 from the Textbook; Selected research papers*
12	Applying LP Rounding to derive performance guarantee for NPCNP *Reading: Chapter 14 from the Textbook; Selected research papers*
13	Review of Probability Theory *Reading: Sections 2.1-2.3 from Reference R4*
14,15	Deriving probabilistic guarantees on the performance of networking systems using probabilistic methods *Reading: Sections 4.3 and 4.4 from Reference R5; Selected research papers*

Course Policies:

Attendance: Students are expected to **attend class** and to **arrive on time**. To a significant extent, the value you get from the course depends on your presence in class, and your classmates' opportunities to learn from your insights depend on your presence in class.

Late Policy: For every day that an assignment is late, 10% of the total maximum credit will be deducted. For example, if an assignment is worth a maximum of 10 points, it will be worth only a maximum of 9 points if the assignment is late by one day

Plagiarism/Cheating Policy: (These paragraphs are mandatory.)

Plagiarism or cheating behavior in any form is unethical and detrimental to proper education and ***will not be tolerated.*** All work submitted by a student (projects, programming assignments, lab assignments, quizzes, tests, etc.) is expected to be a student's own work. The plagiarism is incurred when any part of anybody else's work is passed as your own (no proper credit is listed to the sources in your own work) so the reader is led to believe it is therefore your own effort. Students are allowed and encouraged to discuss with each other and look up resources in the literature (including the internet) on their assignments, but ***appropriate references must be***

included for the materials consulted, and appropriate citations made when the material is taken verbatim.

If plagiarism or cheating occurs, the student will receive a failing grade on the assignment and (at the instructor's discretion) a failing grade in the course. The course instructor may also decide to forward the incident to the University Judicial Affairs Office for further disciplinary action. For further information on U of M code of student conduct and academic discipline procedures, please refer to: http://www.people.memphis.edu/~jaffairs/

Online Resources:

1. Dr. Raj Jain's slides for book R1: http://www.cse.wustl.edu/~jain/books/perf_sli.htm
2. Companion Site for book R2
http://www.brookscole.com/cgi-wadsworth/course_products_wp.pl?fid=M20b&product_isbn_issn=0534380581&discipline_number=17
3. Linear Programming: http://www2.isye.gatech.edu/~spyros/LP/LP.html
4. The Simplex Algorithm:
http://people.hofstra.edu/faculty/Stefan_Waner/RealWorld/tutorialsf4/frames4_3.html
5. Integer Programming: http://people.brunel.ac.uk/~mastjjb/jeb/or/ip.html
6. Course homepage of Computer System Performance Evaluation at the Chinese University of Hong Kong: http://www.cse.cuhk.edu.hk/~cslui/csc5420.html
7. Lecture Notes for a Performance Evaluation Techniques course offered in the Technical University of Berlin:
http://www.tkn.tu-berlin.de/~awillig/user_includes/pet_ss2005/pet_ss2005.html
8. Course Notes for a Computer System Performance Evaluation Course at the George Mason University: http://cs.gmu.edu/~menasce/cs672/slides/
9. Course Notes for a System Performance Evaluation Course at the University of Waterloo: http://bbcr.uwaterloo.ca/~pinhan/CS457/CS457.html