Management Science and Engineering 336
Competition and Cooperation in Communication Networks

(Previously: Market Models for Networked Systems)

Mondays and Wednesdays, 1:15 PM–2:30 PM
Terman Engineering Center, Room 453
3 units

Instructor:

Ramesh Johari
Assistant Professor
Management Science and Engineering
Electrical Engineering (by courtesy)
Terman Engineering Center, Room 319
E-mail: ramesh.johari@stanford.edu
Office hours: Mondays, 3:30 PM–5:00 PM, Terman 319
Additional office hours by appointment

Course webpage:

The course webpage will be accessible through `http://eeclass.stanford.edu/msande336`.

Course description:

Research in communication networks over the last decade has increasingly focused attention on the *incentives* of agents in the system, both providers and end users. Recent efforts to rethink the basic design of the Internet have followed this trend as well, typically asking at a fundamental level whether *the deregulated Internet can be self-sustaining*. This high level problem requires understanding network details from protocols to provider contracts. Ultimately, we aim for a network architecture that allows service providers to operate profitably, yet ensures efficient and fair resource allocation for end users.

This course will survey recent research using game theoretic methods to study cooperation and competition in communication networks. The course will have three primary units: (1) mathematical preliminaries and introduction to game theoretic methods; (2) models of service provider competition, including contract formation, pricing, and network effects; and (3) resource allocation in communication networks. Section (2) will comprise a majority of the course: we will emphasize making connections between various disparate threads of research studying competition between network service providers. While the course will primarily be taught in lecture format, the focus will be on encouraging discussion of open questions and modeling issues. For this reason, it is emphasized that the course should be viewed as a *research seminar* by prospective students.

Outline of topics:

A list of research papers to be covered will be available at the first lecture. The following is a representative set of topics to be covered, but not exhaustive:

1. Introduction to competition and cooperation in communication networks: service provider competition, interdomain routing, resource contention among end users.

2. Basic elements of economic modeling: utility, fairness, efficiency.

3. Notions of equilibrium: competitive equilibrium, dominant strategy equilibrium, Nash equilibrium, Bayesian equilibrium, subgame perfect equilibrium.

4. Interdomain routing: models, instability, and the case for source routing.

5. Traffic routing models: selfish routing without pricing; selfish routing with pricing; selfish routing with pricing and investment. Implications for source routing in the Internet. Interaction between selfish routing and traffic engineering.

6. Network effects and externalities: economic studies of peering relationships in the Internet. Alternative contracting models. Network formation games.

7. Resource contention in networks: economic models of congestion control; dynamic models of congestion control algorithms; interaction of congestion control with provider incentives.

Prospective students should consult the slides for Lecture 1 on the website for an introduction to the course.

Grading

The grade will be based on the following:

- 30% 2 problem sets
- 70% final project

The choice of topics for the final project will be quite broad: students can choose to either discuss and present recent research results in the field, or develop their own problem statement and analysis.

Prerequisites

The listed prerequisite is a basic course in optimization, such as MS&E 211 or equivalent; a doctoral course in convex optimization is also recommended, such as MS&E 311 or EE 364. Because the course will have significant mathematical depth, real analysis at the level of Mathematics 115 is strongly recommended (see below).

Since this is a doctoral course, students should bear the following in mind:

- While no prior exposure to game theory will be explicitly assumed, the basic elements will be covered rather quickly. In particular, although MS&E 246 or Econ 203 are not listed as prerequisites, students without such background should be prepared to devote significant time outside of class to master the basics.
- A significant amount of the course material will require advanced mathematical maturity. Basic real analysis concepts will be assumed, such as continuity, limits, convergence, open and closed sets, compactness, convexity, etc.

The topics of the course are likely to be of interest to a broad spectrum of students. Intending students who are not comfortable with the prerequisites listed above should expect to audit the course; any questions or concerns can be directed to Prof. Johari at the e-mail address above.

Textbooks

There will be no required textbook for this course. However, you may find some of the following books helpful. The first two books that are listed are highly recommended; the remaining two are books that I have found useful.

Highly Recommended

1. *A Course in Game Theory*, Osborne and Rubinstein. This is a good introductory level text in game theory, that still is quite rigorous. Although many game theory books are out there, I have found that this one is a good introduction for engineers.
2. *Microeconomic Theory*, Mas-Colell, Whinston, and Green. This very large textbook is an encyclopedic reference on the subject, and likely very useful for many parts of this course.

Other Useful Reading

1. *Game Theory for Applied Economists*, Gibbons. This is a basic undergraduate level text in game theory, appropriate if you have never seen the subject before; it provides an elementary treatment of most of the major topics.
2. *Game Theory*, Fudenberg and Tirole. This encyclopedic reference should be on the shelf of every game theorist, but it is not necessarily the easiest book to learn from.