Fall 2008 EECS 290S: Network Information Flow

Instructors:

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Course Webpage: http://inst.eecs.berkeley.edu/∼ee290s/fa08

Description:

Claude Shannon invented information theory in 1948 and it forms the basis for the design of all modern day communication systems. His original theory was primarily point-to-point, quantifying information and studying how fast it can flow across an isolated noisy communication channel. Until recently, there had been only limited success in extending the theory to a network of interacting nodes. Progress has been made in the past decade, driven both by engineering interest in wireless networks as well as conceptual advances such as network coding, which shows the surprising result that even in noiseless wireline networks, coding across packets can improve throughput beyond pure store-and-forward routing.

This course is a fresh perspective on the state-of-the-art of the field. Our strategy is to use analytically simpler discrete deterministic network models to capture the interaction between nodes and as an approximation to more complex noisy network models. Starting with the classical wireline network and progressing to more complex models for wireless networks, we hope to answer questions such as:

- What is the optimal way for relay nodes to cooperate and send information?
- How can information flow over a network be quantified and visualized?
- What is the optimal way to deal with interference between two or more competing flows of information?

Because of our emphasis on the use of deterministic models, we hope to make this course accessible to computer science and electrical engineering students alike.

Prerequisites:

The first part, focusing on network coding, requires only a low level of understanding of information theory. As we move to noisy channel models, the level of understanding needed increases. So students who have not taken EECS 229A or equivalent can try to catch up by reading *Elements of Information Theory* by Cover and Thomas. Talk to the instructors if you haven't taken a course in information theory.

Evaluation:

There will be two problem sets covering the first two parts of the class (10% of the grade), a take-home midterm also covering those parts (15%), class participation including an in-class paper presentation (25%) and a final paper/project (50%).

Students are *strongly* encouraged to take the class for credit. Auditors need the approval of the instructors.

Text:

For the first part of the course, we will follow Chapters 17-21 of Raymond Yeung's new book: Information Theory and Network Coding. A preprint is available at http://iest2.ie.cuhk.edu.hk/∼whyeung/post/main2.pdf.

For the rest of the course, we will use papers. Cover and Thomas is good background.

Course Outline:

1) Wireline Networks

- single unicast flow: Ford Fulkerson, max-flow min-cut theorem
- network coding for multicast: examples, max-flow min-cut theorem, linear network coding, algorithmic construction, random coding and random linear coding, convolutional network codes over cyclic networks
- multiple unicast flows: broadcasting to two sinks, sub-optimality of linear codes.

2) Deterministic Networks

- deterministic models
- single unicast and multicast flows : generalized Ford-Fulkerson theorem for linear finite-field deterministic models; general deterministic networks.
- multiple unicast flows: two-user interference channels, interference alignment in $K \geq 3$-user interference channel, general deterministic broadcast channels.

3) Noisy-channel Networks (Gaussian and General Discrete-Memoryless)

- multiple access channels
- relay networks: achievable schemes. Approximately optimal schemes close to the cutset bound. Examples with capacity strictly less than the cutset bound.
- interference channels: the 2-user Gaussian interference channel, structured codes and interference alignment in $K \geq 3$-user Gaussian interference channels.
- broadcast channels: degraded channels, scalar Gaussian broadcast channel, parallel broadcast channels with degraded components, writing on dirty paper, vector Gaussian broadcast channel, Gelfand-Pinsker coding with transmitter side information, Marton's scheme for general broadcast channels.

4) Distributed Source Coding and Joint Source-Channel Coding

5) Feedback and Complexity