ECE510: Advanced Wireless Networks

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Announcements:

- There will be a guest lecture on Tuesday, April 5.
- There will be no class on Thursday, April 7.

Course Goals:

- We will cover several areas relating to wireless communication and networking.
- Examples of systems where these areas are relevant include cellular systems, wireless LANs, *ad hoc* networks, sensor networks, satellite networks, etc.
- The emphasis of the course will primarily be on theoretical approaches and understanding - implementation details and discussion of current protocols will not be emphasized.

Background

- Lecture material will be drawn from a book draft by David Tse and Pramod Viswanath and also from conference and journal papers in this area.
- You will need adequate background to understand these.
- Some key topics you should be familiar with:
  - Stochastic processes, basic queueing models and Markov chains (ECE 422 or 454).
  - Familiarity with basic digital communication systems - e.g. coding, modulation, channel capacity (ECE 378).
  - Familiarity with basic network architecture and issues - e.g. network layers, medium access control, ARQ (ECE 333 or 454).
  - Familiarity with basic wireless communication channels - types of fading, path loss, etc (ECE 380)[1].

[1] if currently taking 380 and you have the other prerequisites -this should be okay

Network Architecture

- Networks generally have layered architecture.
  - Provides modular design, promotes standardization.
- Lowest layer is typically "physical layer" - responsible for transmitting "bits over physical medium.
- Traditionally higher layers treat physical layer as providing "fixed rate bit pipe".
- In modern wireless networks, this is often not the case
  - Tighter interaction between layers leads to improved performance.
  - Motivated by characteristics of wireless channels as well as energy/power concerns.

Course overview

We will mainly focus on physical layer issues here, but model/results are useful to provide models for higher layer issues as well.
At the physical layer two main impairments of a wireless channel are:

1. the channel is time-varying (fading),
2. the channel must be shared by many users.

First we will consider single user, time-varying channels.
We then consider multi-user channels.
Along the way, we will point out how understanding these impacts higher layer decisions.

Information Theory

Our main approach for understanding physical layer trade-offs/performance is through information theoretic arguments (i.e. channel capacity)
Reasons:

1. These provide fundamental limits on what is achievable.
2. In some cases, the performance of practical systems is approaching these limits.
3. Often provides a useful high-level abstraction for upper layer resource allocation.
4. Indicates right qualitative trade-offs for practical systems.

Today

The main goal of today's lecture is to review some basic results from information theory.
In particular we will be interested in studying the channel capacity for various wireless channels.
Our goal is to understand these results - but not to delve into the details of proving coding theorems - for this take ECE 428.

Information theory review

- Basic problem is reliably sending information over a communication channel.
- Information theory tells us there is no essential loss in assuming that the information is binary data (source/channel separation).
- Communication channels are modeled probabilistically.
- Common channel models:
  - Discrete memoryless channel
  - Band-limited white Gaussian Noise channel

Channel Capacity

- Maximum rate that can be reliably transmitted over a channel is given by the *channel's capacity*.
  - Here *reliable* means with arbitrary small probability of error, provided sophisticated enough coding is used.
- For most channel's, the capacity is given by the maximum mutual information rate.
  - Showing this requires a coding theorem and converse - which are often non-trivial to prove.
  - Though we are not proving coding theorems here - an important point is that these results rely on considering long enough codewords
  - "average over" the randomness in the channel.

Rest of lecture

Focus on some main ideas related to channel capacity: mutual information, entropy, degrees of freedom.

References:

- *Elements of Information Theory,* by Thomas Cover and Joy Thomas, Wiley 1991.
- Sect. 5.1 and Appendix B in Tse and Viswanath.