CDMA AND NARROWBAND MULTIUSER DETECTION WITH ANTENNA ARRAYS

Version 1.1

by

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1 MOTIVATION

1.1 Multiuser Detection and the Claims

- Most radio systems support a large number of users. Their transmissions can interfere with each other at a given receiver, jeopardizing reliable communications.

- Traditional remedies keep the signals more or less orthogonal, allowing the receiver to attenuate undesired signals:

  - FDMA
  - TDMA
  - CDMA
  - sectorization
  - separation of cochannel cells

Effectively, this treats interference as noise, and ignores its structure and modulation format.

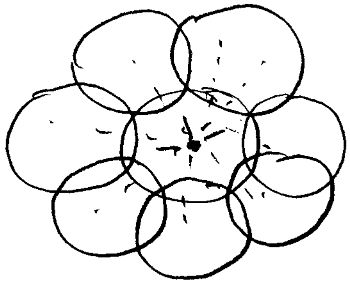
- Multiuser dection:
  - Take explicit account of the structure of the interferers (spreading code, finite alphabet, instantaneous channel state)
  - and thereby reduce the damage to detection of the desired signal.

- Claims for MUD:
  - All users enjoy single-user performance, as though the interferers were not there.
  - The mutual orthogonalization can be greatly relaxed, or even eliminated.
  - Power control to ensure similar power levels on reception can be greatly relaxed.
  - Large increases in system capacity are possible.

- Is this true? How do we do it?

1.2 MUD and the Capacity of Simple CDMA

- Consider the uplink of a CDMA system



The base station receives interference power

I_d from own cell

I_i from other cells

both proportional to N_s, users per sector.

$$I_t = I_d + I_i$$

Typically $I_i \approx 0.6\, I_d = 0.38\, I_t$

- Now introduce perfect MUD for own cell users (not realistic to include other cell users). This makes the new value $I_d' = 0$, regardless of number of users. The capacity seems to be unbounded.

- The catch? All the other cells are also using MUD and have increased their population, so $I_i' > I_i$.
  - If I_t is the max tolerable interference level, then

$$I_t = \frac{I_i}{0.38} = I_i'$$

  - So $\frac{I_i'}{I_i} = \frac{1}{0.38} \approx 2.7 = \frac{N_s'}{N_s}$

    and MUD has allowed us to increase the capacity by a factor of just over 2.5.
  - A more detailed analysis (Appendix A) gives the same result.

- This was a uniform system — all users the same. WCDMA allows a more heterogeneous approach. Higher rate users with lower processing gain, higher power. Mixed detection methods.

- The need for antenna arrays with MUD:
  - Arrays provide diversity, greater tolerance of other cell interference, to break the "2 $\frac{1}{2}$ barrier."
  - Most useful MUD methods rely on accurate knowledge of all users' CSI (channel state info). Increasing numbers of diversity antennas make accuracy requirements less stringent [Gran98, Gran00, Cave00b, Ho01] – at least for narrowband systems.

    This makes the 2 $\frac{1}{2}$ barrier more approachable.

1.3 Structure and Objectives of the Course

- This course is a survey of the leading techniques for MUD. For each one:
  - How does it work?
  - How well does it work?
  - What is the computational load?

- The treatment will be mathematical – there's no credible alternative. To keep it tolerable:
  - main lecture notes contain models, key concepts and arguments, performance results
  - detailed derivations and additional resource material in appendices

- MUD is an active, rapidly evolving research area and much remains unknown. There is no single best solution, and there will probably be mixed solutions to handle heterogeneous traffic.

Implications for this course:

- We can't cover every variation, and even some important topics are missing (downlink, coding, macrodiversity, etc)
- You'll have to be able to read the literature and to develop your own solutions.
- So the course will deal with many of the principles, so you know more or less what to expect from a method.