Iterative Multiuser Receivers: Bits to System Design

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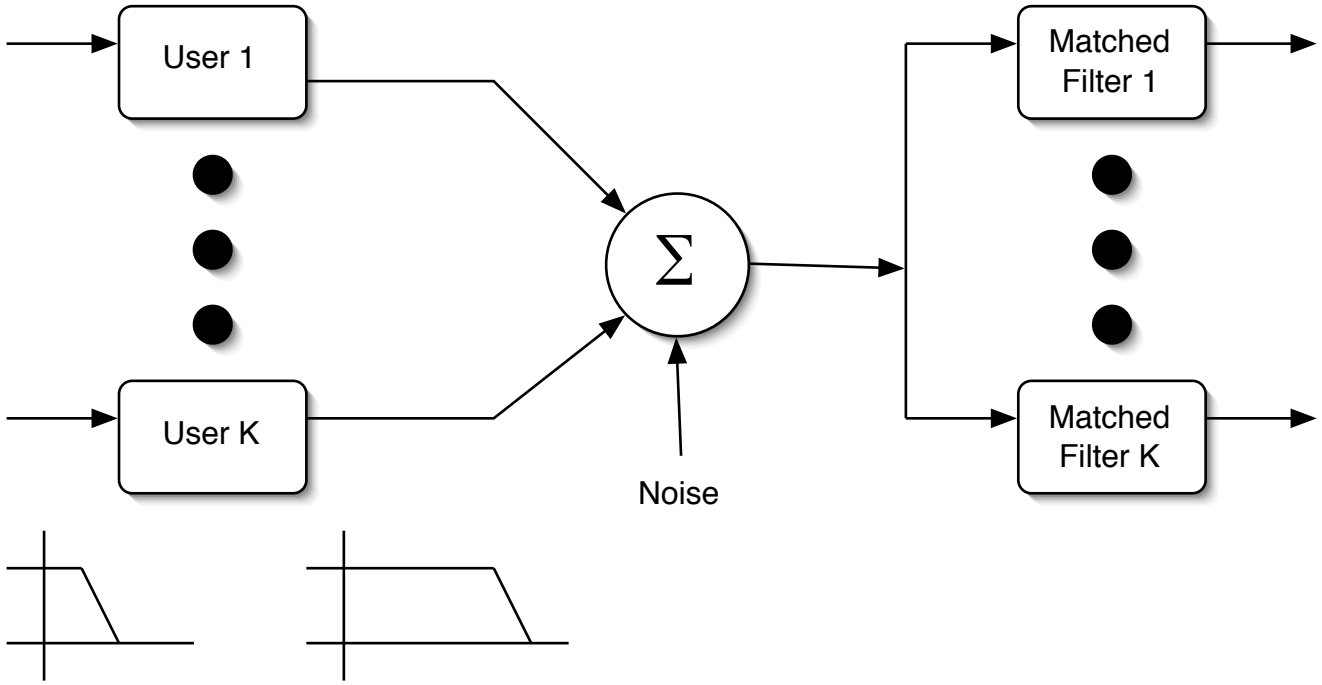
Introduction

- The DS/CDMA System/Channel Model
- The Problem
- Channel Model and Receiver Design
- Implementation Aspects
- Single Cell BER Performance Results (1 Antenna / 4 Antennas)
- System Benefits of Result
- Open Issues (Practical and Theoretical)

The Multiuser DS/CDMA System/Channel Model



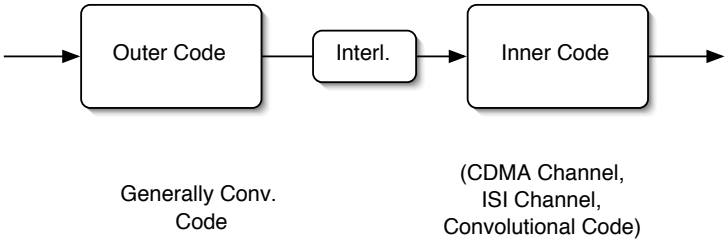
- Each User transmits with excess bandwidth (Processing Gain)
- Matched filter is optimum only when a single user is present

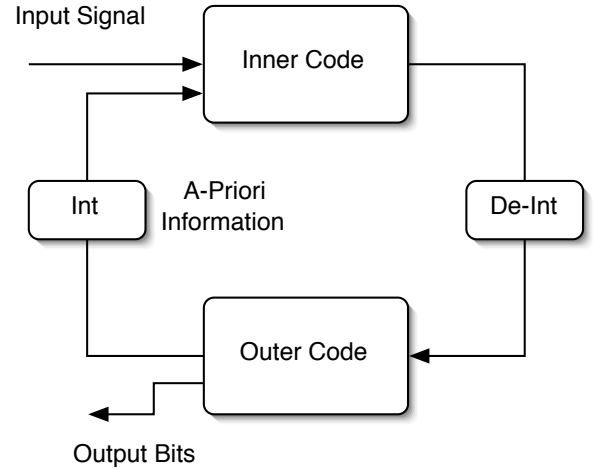
The Problem

"To Achieve Capacity for a Multiple Access Channel"

- The Optimal Solution is exponentially complex in the number of users (Verdú) (need to search every combination (000,001,010,011,100,101,110,111))
- The Traditional Solutions use :
  - Linear/Non-Linear (Decorrelator, etc.)
  - Uncoded Techniques (MMSE, etc.)
- These Solutions are suboptimal or very complex
- Ideally we need a solution that is:
  - Linear in Complexity and approaches Optimum Performance

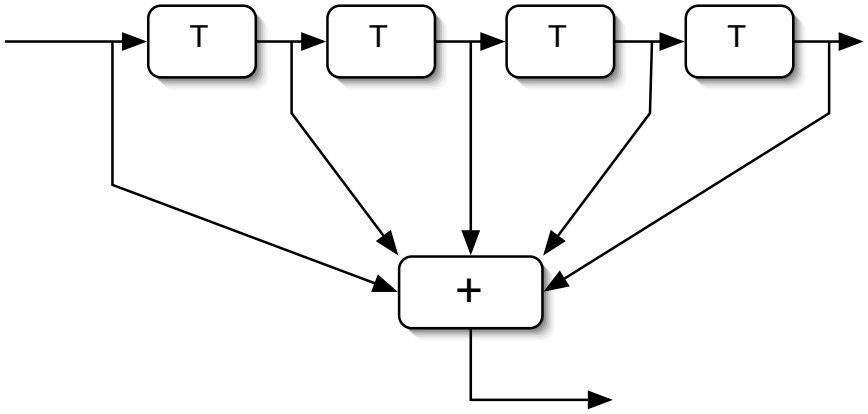
Channel Model and Receiver Diagram





- Model consists of inner and outer code
- Important is that each code is seperated by an interleaver

Generalised Code Construction



- Consists of a delay line with multiple taps
- Normally Single Input
- Single/Multiple Outputs
- Generalised Channel Description $y = Hd + n$

Interference Cancellation

Inner Decoder is still very computationally complex

We rearrange the MF-DS/CDMA channel model by writing it as

$$y = d + Md + z$$

We then cancel the off-diagonals with our data estimate $\tilde{d}$

$$\begin{aligned} x &= y - M\tilde{d} \\ &= Id + Md - M\tilde{d} + z \\ &= d + M(d - \tilde{d}) + z. \end{aligned}$$

Following de-interleaving we assume the noise is again white, therefore

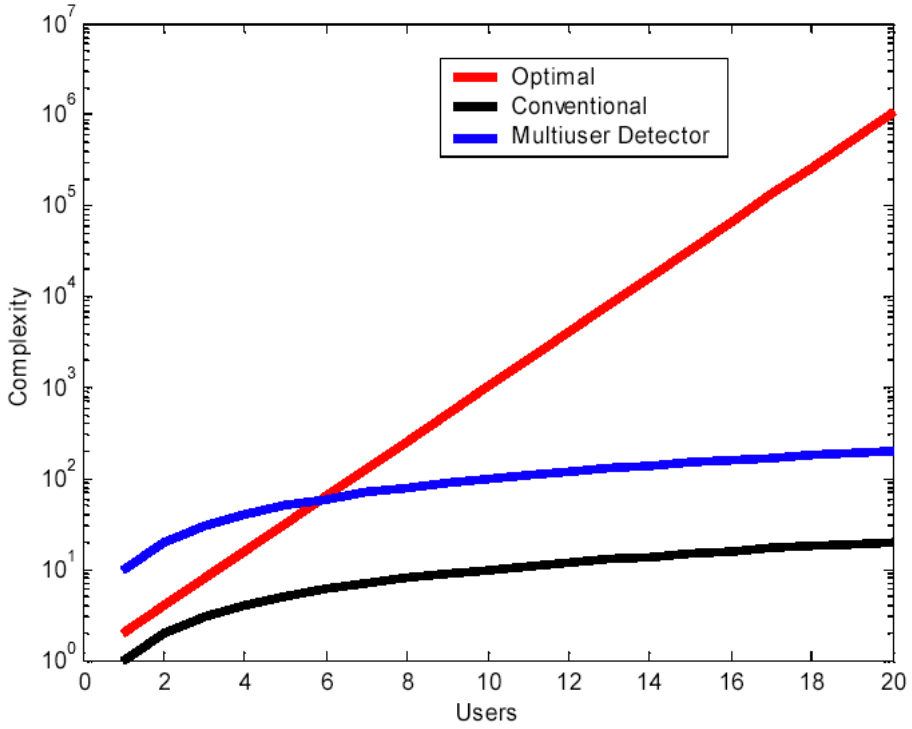
$$x = d + M(d - \tilde{d}) + n.$$

Other Known Applications

"Applications are not just for multi-user channels"

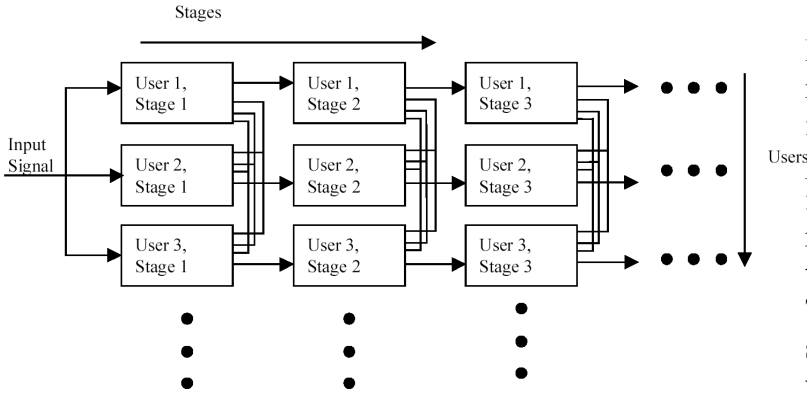
- Multi-Carrier CDMA
- ISI Channels
- E^2PR4 channels etc (Magnetic Recording)
- OFDM Channels (likely)
- Multiuser Trellis coded (QAM) systems

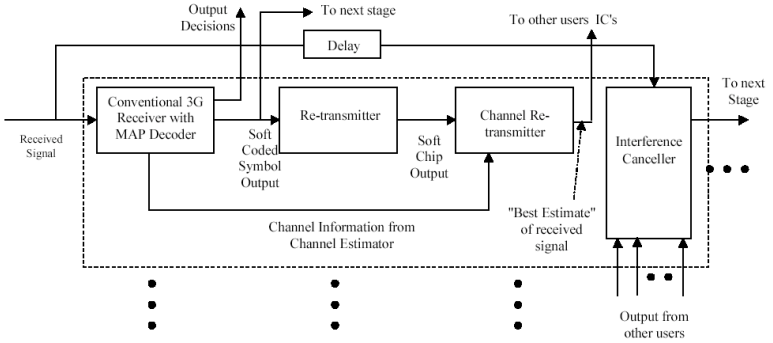
Computational Complexity



- Complexity vs. Number of users
- Complexity of MUD is aproximately 10 times MF
- Complexity of “Optimum” (Verdú) Receiver is O(2^K)

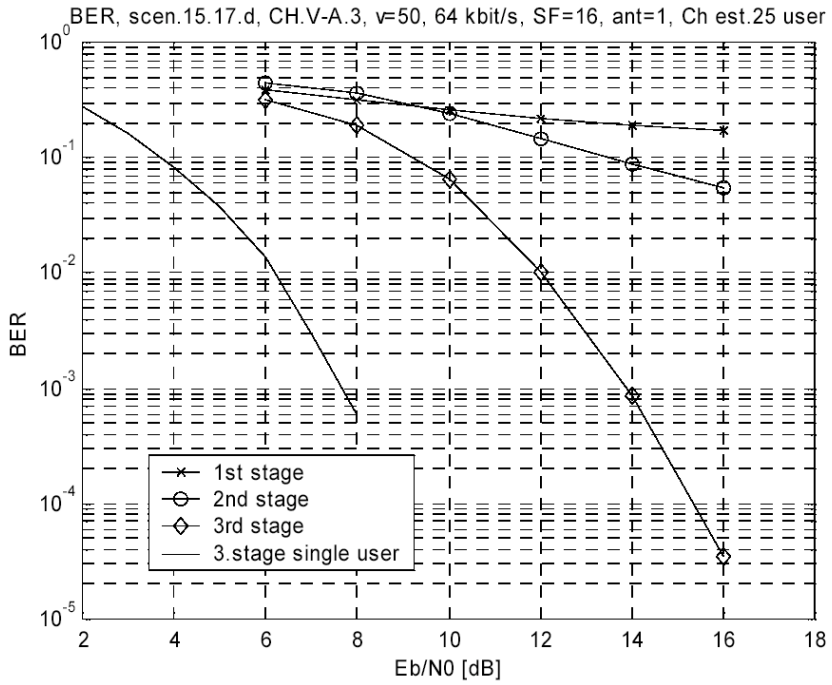
Implementation Aspects





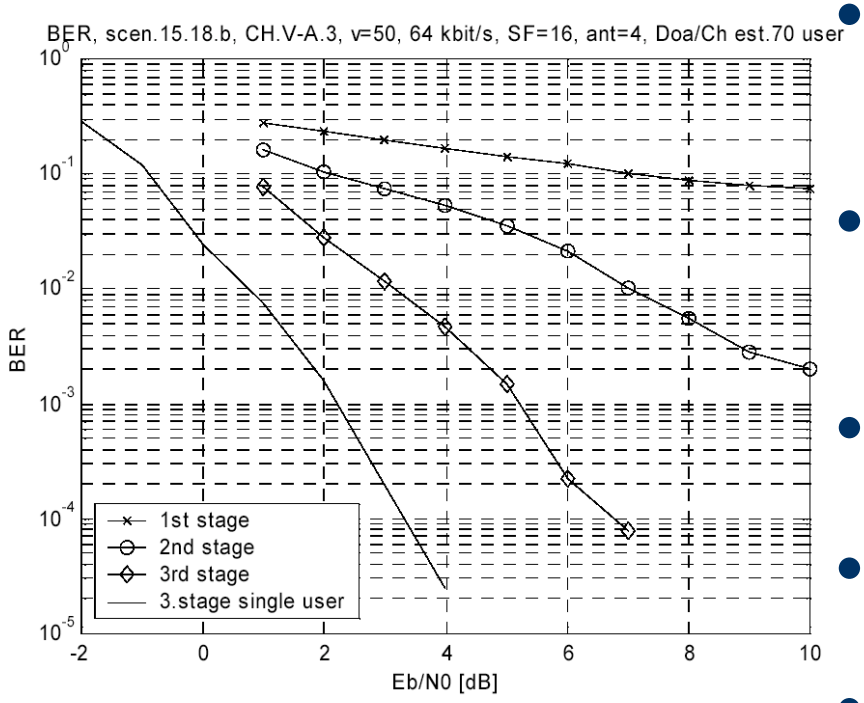
- Modular Implementation, Possible to Translate to DSP/VHDL Implementation
- Possible to increase stages and Users as needed

Single Cell BER Performance Results



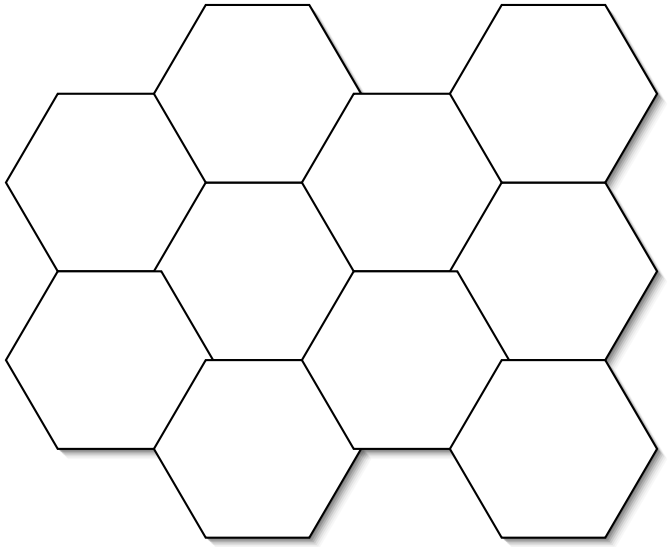
- 25 Users, Processing Gain 16
- Veh. A Channel, 50km/hr (Freq. Selective Fading, Fading on each Tap)
- 3GPP Release '99 Compliant
- Single User Performance = Solid line
- Performance over iterations shown

Single Cell BER Performance Results - 4 Antennas



- 70 Users, Processing Gain 16, 4 Antennas (ULA)
- Veh. A Channel, 50km/hr (Frequency Selective Fading, Fading on each Tap)
- 3GPP Release '99 Compliant
- Single User Performance = Solid line
- Performance over iterations shown

What do these results mean?

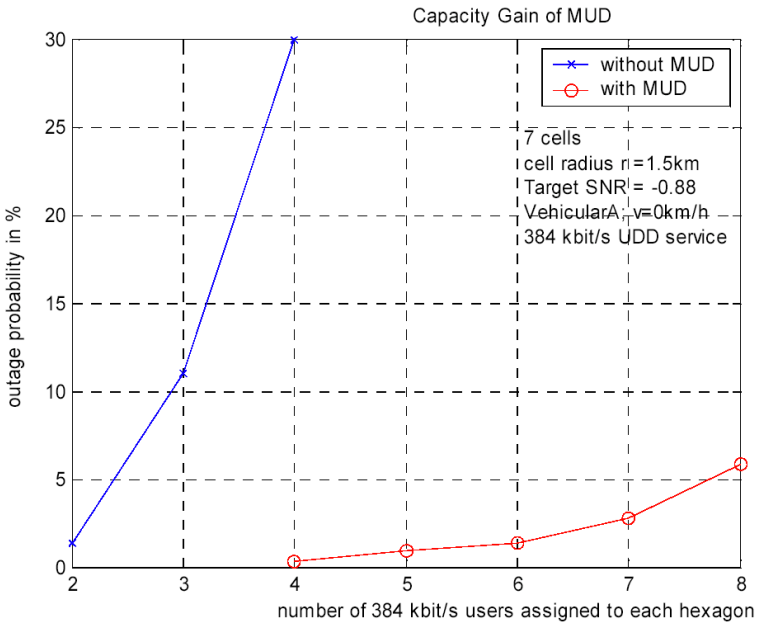


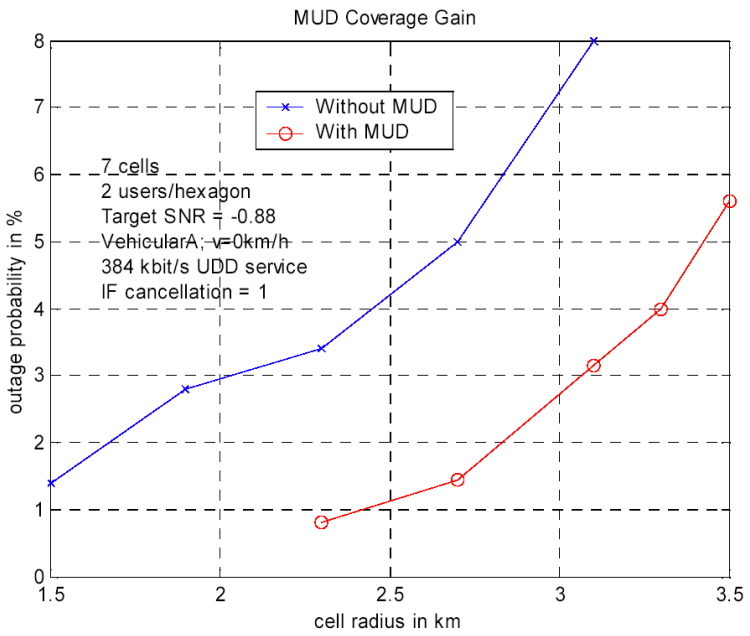
- In terms of System Benefit? (Capacity-Cell Size)
- In terms of Provider Benefit? (“$$$!!”)

For this we need to study the system aspects!

- Multi-cell Environment
- Power Control
- Intra/Inter Cell Interference

System Level Results





- Capacity Gain is from 2.5 to 7.5 users per cell (3 times increase)
- Coverage Gain is from 2.7 km to 3.4 km (increase of 1.5 times)

Practical Open Issues

- Implementation Aspects
  - Packet Data
  - Different Data Rates
  - Efficient Implementation (Still 10x more complex than MF)
- Implementation of Tracking and Acquisition
  - With high Interference System conventional approaches fail

Theoretical Open Issues

- Analytical Tools
  - Better tools to predict performance (Maybe Particle filters?)
  - Analysis that includes channel estimation/tracking/different data rates
- Performance Limits in terms of:
  - Capacity
  - Cramer Rao Bounds

Conclusions

- Discussed Multiuser Detection Problem in DS/CDMA
- Discussed iterative MUD Solution
- Highlighted model and design
- Showed Implementation Aspects
- Showed BER Performance
- Considered System (Cellular) Aspects and Results
- Open Issues (Theoretical and Practical)