SPACE-TIME TRANSMIT DIVERSITY AIDED ACQUISITION AND DETECTION IN CDMA NETWORKS

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Summary

The tasks of signal acquisition and detection in a code division multiaccess (CDMA) network are considered. Identifying a base site's code sequence and acquiring its timing information are especially challenging problems in fading propagation media. Neighbouring base sites are not synchronised in the W-CDMA standard, in contrast with IS-95 and cdma2000 downlink cellular networks. Therefore distinct code sequences (rather than merely phase-shifted versions of a common sequence) are necessary to identify them. A comprehensive study of these issues appears in [1]. In the present work, we propose a simple 2-sensor transmit diversity scheme to enhance acquisition performance in the presence of time-dispersive fading, and imperfect (initial) frequency guesses. It consists of transmitting two mutually orthogonal (chip-rate) synchronisation sequences (one from each sensor) every other signalling interval; consecutive transmissions are separated by a black-out interval to avoid interference arising from frequency-selective fading. These synchronisation sequences are common to all base sites, and the timing of multiple signal paths is determined by a sliding correlator. To identify a base site's scrambling signature, again two mutually orthogonal sequences are transmitted, and the outputs of multiple correlations compared. This doubles the number of signature sequences required to identify base sites; however, this requirement is acceptable since two orthogonal pilot channels are needed for channel estimation if a 2-sensor transmit diversity scheme is sought to be used for detection. The proposed acquisition scheme yields attractive gains over conventional approaches and is robust to frequency uncertainties in the initial stages of acquisition. (The subsequent frequency acquisition task itself, is reported elsewhere.) We also study the important issue of detecting the signal of interest at a mobile. Since in-cell users are mutually orthogonal in additive white Gaussian noise downlink channels, it only remains to restore this orthogonality at the receiver in a dispersive downlink channel, via chip-rate equalisation [2,3]. Iterative MMSE equalisation is considered; in iterations subsequent to the first, the receiver uses estimates derived from the desired user's decoded signal to aid in multipath combining with the benefit of partial priors, i.e., only for the desired user. The feasibility of blind detection in such a scenario, and its implications for downlink receivers are also studied. (Iterative multistream decision feedback equalisation has been reported in [2].) Both independently of, and in conjunction with a form [4], of space-time transmit diversity [5], for dispersive media, this approach is observed to yield significant improvement in the packet error rate and the signal to interference ratio performance metrics, and consequently in the sustainable user capacity.

References

1. Y.-P. E. Wang and T. Ottosson, ``Cell-search in W-CDMA,'' *IEEE J. Select. Areas Commun.*, 18(8), 2000
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4. J. Thomas, ``Efficient algorithms for space-time coded wireless communications,'' Proc. Int. Soc. Optical Eng., 4529(17), 2001 (also: J. Thomas, ``On the properties and construction of multivariate block codes for broadband signalling,'' Research Report, ISR, College Park, MD, Jan. 1999
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Outline and Scope

- Timing and base-signature identification
- Multisensor transmit diversity in acquisition
- Detection and decoding: iterative chip-rate MMSE equalisation in synchronous downlink
- Space-Time transmit diversity in detection
- Feasibility of blind detection in downlink
- Analogues in ad-hoc wireless networks

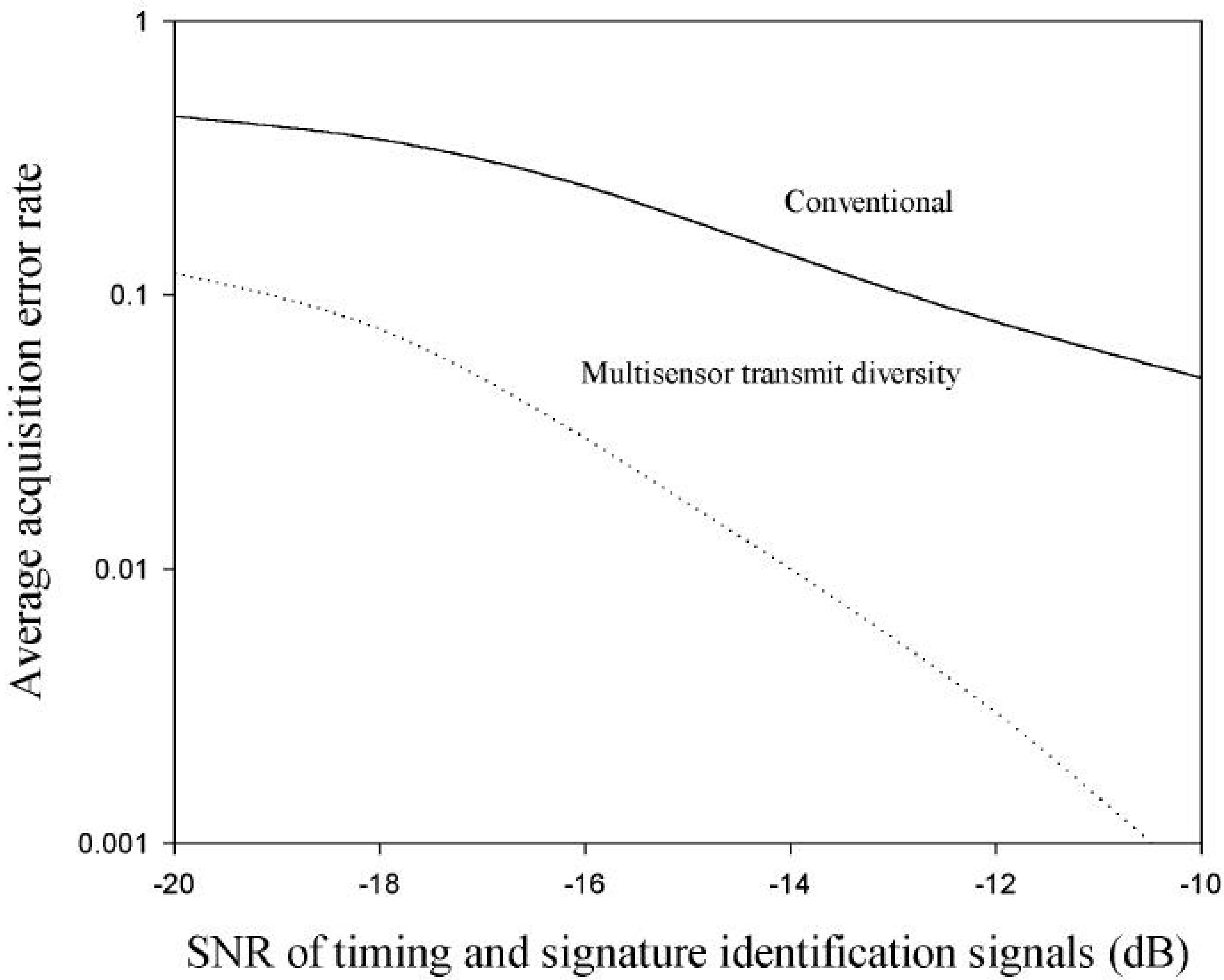
Timing and Signature Identification

- Pilot sequences for time-signature acquisition
  - Packet multipath boundary identification: synchronisation pilot, common to all base sites
  - Candidate base site identification: signature pilot, specific to each base
- Sliding-correlator for path timing acquisition
- Multiple correlators for base site identification
- Simple 2-sensor transmit diversity
  - 2 orthogonal sets of pilot sequences

Multisensor Transmit Diversity Aided Acquisition

- Independent fading across paths from 2 sensors
- Robustness to initial frequency estimate errors
- Doubling of pilot signatures required
  - Necessary (regardless of acquisition scheme) for channel estimation, in transmit diversity based detection
- Simulation Parameters:
  - 32 cell downlink, spreading factor 31, carrier 2 GHz
  - Multipath delays up to 30 chips, Doppler 200 Hz
  - Initial frequency error 20 kHz

Average acquisition error rate performance with multisensor transmit diversity



Signal Detection in Synchronous CDMA Downlink

- Walsh spreading signatures for downlink users
  - Hence only out-of-cell interference in AWGN
- Frequency selectivity destroys orthogonality
  - Restore in-cell user orthogonality: Equalisation
- Iterative chip-rate MMSE equalisation
  - Exploit decoder-derived soft estimates
  - Dramatic gains over MF-Rake, MMSE-Rake
  - Augmented by space-time transmit diversity

Iterative MMSE Equalisation

- Input Model

$$x_n = H^{(0)}s_n^{(0)} + \Sigma_j H^{(j)}s_n^{(j)} + v_n$$

- Desired user's estimate in iteration i

$$s_n^{(0,0,i)} = a_n(H^{(0)}C_n^{(0,i-1)}H^{(0)H} + \Sigma_j H^{(j)} C_n^{(j)} H^{(j)H} + \boldsymbol{s}_v^2 I)^{-H} x_n$$

- Generation of priors from decoder iterations
  - Evolution of covariance matrix across iterations

Space-Time Transmit Diversity

- Idea: Enforce orthogonality between doublets transmitted from 2 sensors
  - ML receiver simplifies to cross-coupled MF
  - Achieves full diversity (with no increase in transmission power or interference levels)
  - Achieves Shannon capacity for (2,1) configuration
  - But … applies only to flat fading!
- Extension to frequency-selective media
  - Use mutually isolated vector symbols
  - Time-reversed complex conjugation

Transmit Diversity in Downlink Iterative Equalisation

Output signal to interference ratio for desired user in iteration i, is proportional to

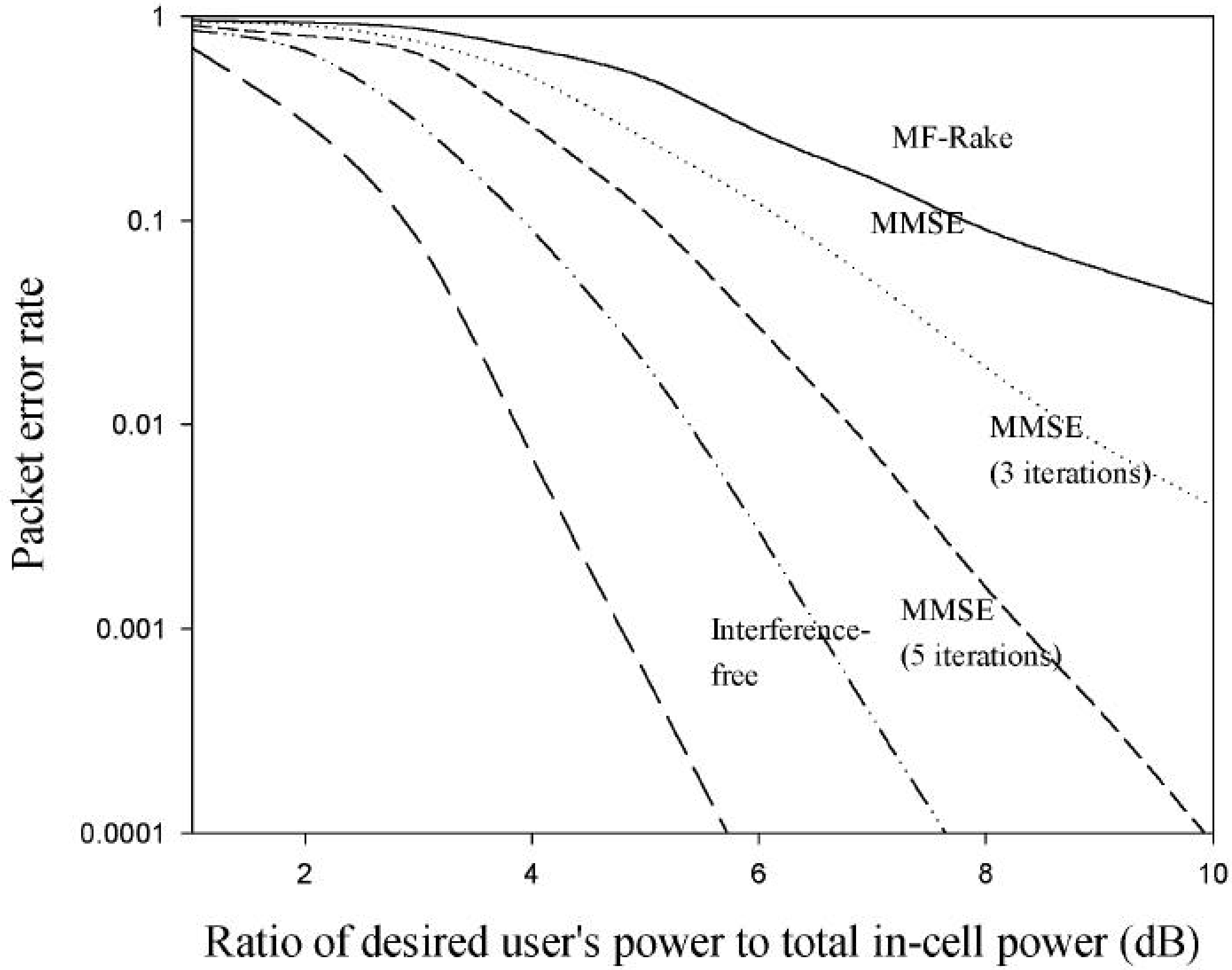
$$\sum_q h^{(0,q)H} C_n^{(i-1)\ -1} h^{(0,q)}$$

Diversity advantage from $h^{(0,0)}$ and $h^{(0,1)}$

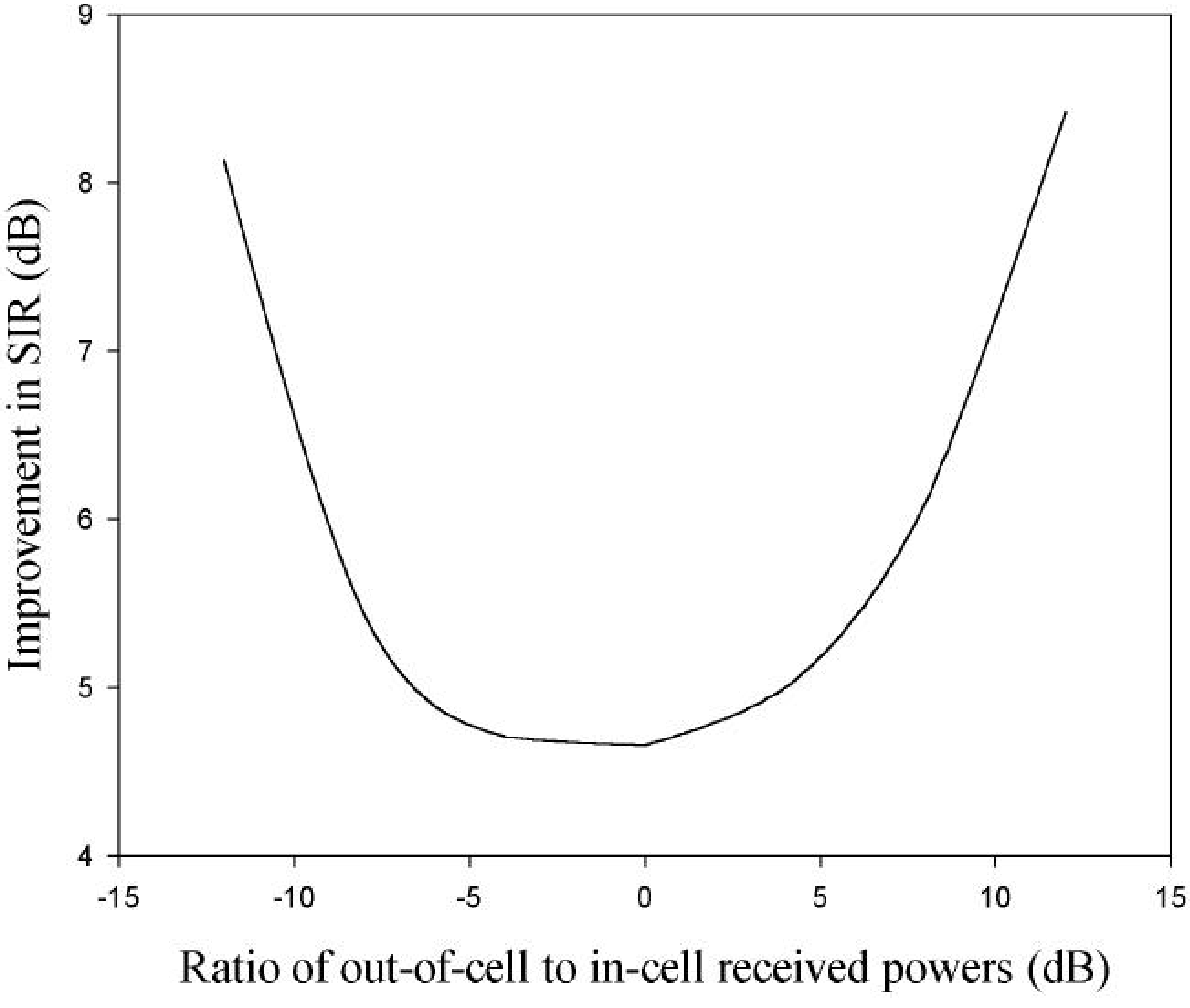
Simulation parameters:

- 32 cell downlink, spreading factor 31, carrier 2 GHz
- Multipath delays up to 30 chips, Doppler 200 Hz
- Perfect timing, signature, and frequency acquisition

Packet error rate performance with iterative chip-rate MMSE equalisation



Improvement in SIR with iterative chip-rate MMSE equalisation
(5 iterations compared against conventional MMSE equalisation)



Blind Downlink Equalisation

- Necessary and sufficient condition:

Rank of composite block Toeplitz channel matrix
= Rank of desired block Toeplitz component
  + Rank of interferers' block Toeplitz component
(assuming iid inputs)

- Implications for downlink scenario

Related Work

- Role of multisensor transmit diversity in frequency acquisition
- Iterative MMSE chip-rate decision feedback downlink equalisation
- Rank-reduced and frequency domain schemes
- Semi-blind approaches to downlink receivers
- Adaptation for use in OFDM systems