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MIMO Antenna Systems and Radio Resource Management

Dr. Xu (Judy) Zhu

Department of Electrical Engineering and Electronics

The University of Liverpool

Liverpool, UK

xuzhu@liv.ac.uk

UNIVERSITY OF LIVERPOOL

Wireless Communications Group at Liverpool

- Wide research coverage: *wireless networking*, *signal processing*, *RF engineering*, etc..
- ~50 full-time academic staff, research fellows and research students
- 400+ publications (most in top IEEE journals and conference proceedings) over the last 10 years
- Active participation in EU projects, *e.g.*, *founding member of the European Antenna Centre of Excellence (ACE)*
- Excellent design software, equipment and facilities, *e.g.*, *largest reverberation chamber in the UK*.

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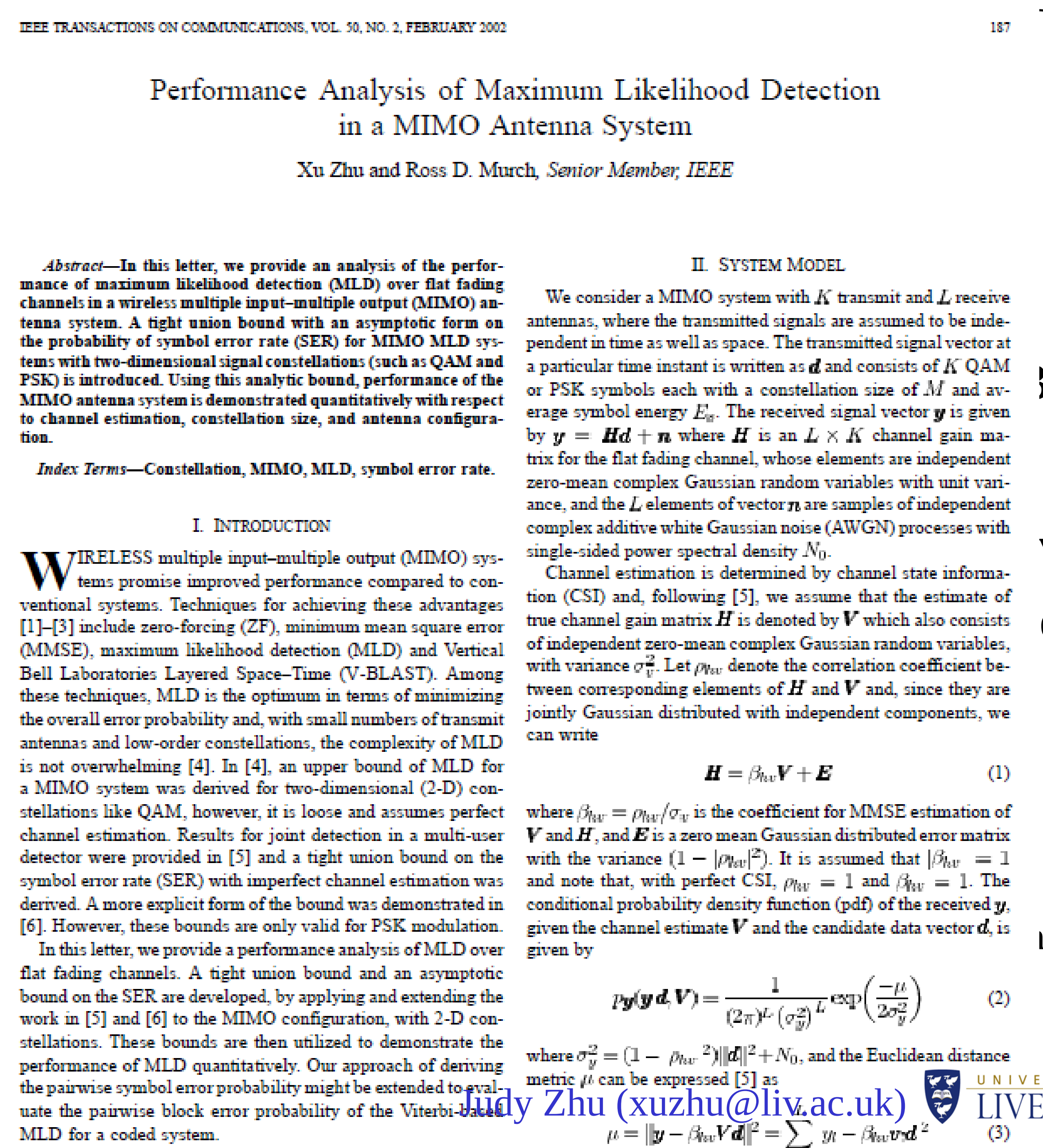


Performance Analysis of Maximum Likelihood Detection in a MIMO Antenna System

Xu Zhu and Ross D. Murch, *Senior Member, IEEE*

***Abstract*—In this letter, we provide an analysis of the performance of maximum likelihood detection (MLD) over flat fading channels in a wireless multiple input–multiple output (MIMO) antenna system. A tight union bound with an asymptotic form on the probability of symbol error rate (SER) for MIMO MLD systems with two-dimensional signal constellations (such as QAM and PSK) is introduced. Using this analytic bound, performance of the MIMO antenna system is demonstrated quantitatively with respect to channel estimation, constellation size, and antenna configuration.**

***Index Terms*—Constellation, MIMO, MLD, symbol error rate.**

I. INTRODUCTION

WIRELESS multiple input–multiple output (MIMO) systems promise improved performance compared to conventional systems. Techniques for achieving these advantages [1]–[3] include zero-forcing (ZF), minimum mean square error (MMSE), maximum likelihood detection (MLD) and Vertical Bell Laboratories Layered Space–Time (V-BLAST). Among these techniques, MLD is the optimum in terms of minimizing the overall error probability and, with small numbers of transmit antennas and low-order constellations, the complexity of MLD is not overwhelming [4]. In [4], an upper bound of MLD for a MIMO system was derived for two-dimensional (2-D) constellations like QAM, however, it is loose and assumes perfect channel estimation. Results for joint detection in a multi-user detector were provided in [5] and a tight union bound on the symbol error rate (SER) with imperfect channel estimation was derived. A more explicit form of the bound was demonstrated in [6]. However, these bounds are only valid for PSK modulation.

In this letter, we provide a performance analysis of MLD over flat fading channels. A tight union bound and an asymptotic bound on the SER are developed, by applying and extending the work in [5] and [6] to the MIMO configuration, with 2-D constellations. These bounds are then utilized to demonstrate the performance of MLD quantitatively. Our approach of deriving the pairwise symbol error probability might be extended to evaluate the pairwise block error probability of the Viterbi-based MLD for a coded system.

II. SYSTEM MODEL

We consider a MIMO system with K transmit and L receive antennas, where the transmitted signals are assumed to be independent in time as well as space. The transmitted signal vector at a particular time instant is written as $\boldsymbol{d}$ and consists of K QAM or PSK symbols each with a constellation size of M and average symbol energy E_s. The received signal vector $\boldsymbol{y}$ is given by $\boldsymbol{y} = \boldsymbol{Hd} + \boldsymbol{n}$ where $\boldsymbol{H}$ is an $L \times K$ channel gain matrix for the flat fading channel, whose elements are independent zero-mean complex Gaussian random variables with unit variance, and the L elements of vector $\boldsymbol{n}$ are samples of independent complex additive white Gaussian noise (AWGN) processes with single-sided power spectral density N_0.

Channel estimation is determined by channel state information (CSI) and, following [5], we assume that the estimate of true channel gain matrix $\boldsymbol{H}$ is denoted by $\boldsymbol{V}$ which also consists of independent zero-mean complex Gaussian random variables, with variance σ_v^2. Let ρ_{hv} denote the correlation coefficient between corresponding elements of $\boldsymbol{H}$ and $\boldsymbol{V}$ and, since they are jointly Gaussian distributed with independent components, we can write

$$\boldsymbol{H} = \beta_{hv}\boldsymbol{V} + \boldsymbol{E} \tag{1}$$

where $\beta_{hv} = \rho_{hv}/\sigma_v$ is the coefficient for MMSE estimation of $\boldsymbol{V}$ and $\boldsymbol{H}$, and $\boldsymbol{E}$ is a zero mean Gaussian distributed error matrix with the variance $(1 - |\rho_{hv}|^2)$. It is assumed that $|\beta_{hv} = 1$ and note that, with perfect CSI, $\rho_{hv} = 1$ and $\beta_{hv} = 1$. The conditional probability density function (pdf) of the received $\boldsymbol{y}$, given the channel estimate $\boldsymbol{V}$ and the candidate data vector $\boldsymbol{d}$, is given by

$$p_{\boldsymbol{y}}(\boldsymbol{y}\, \boldsymbol{d}, \boldsymbol{V}) = \frac{1}{(2\pi)^L \left(\sigma_y^2\right)^L} \exp\left(\frac{-\mu}{2\sigma_y^2}\right) \tag{2}$$

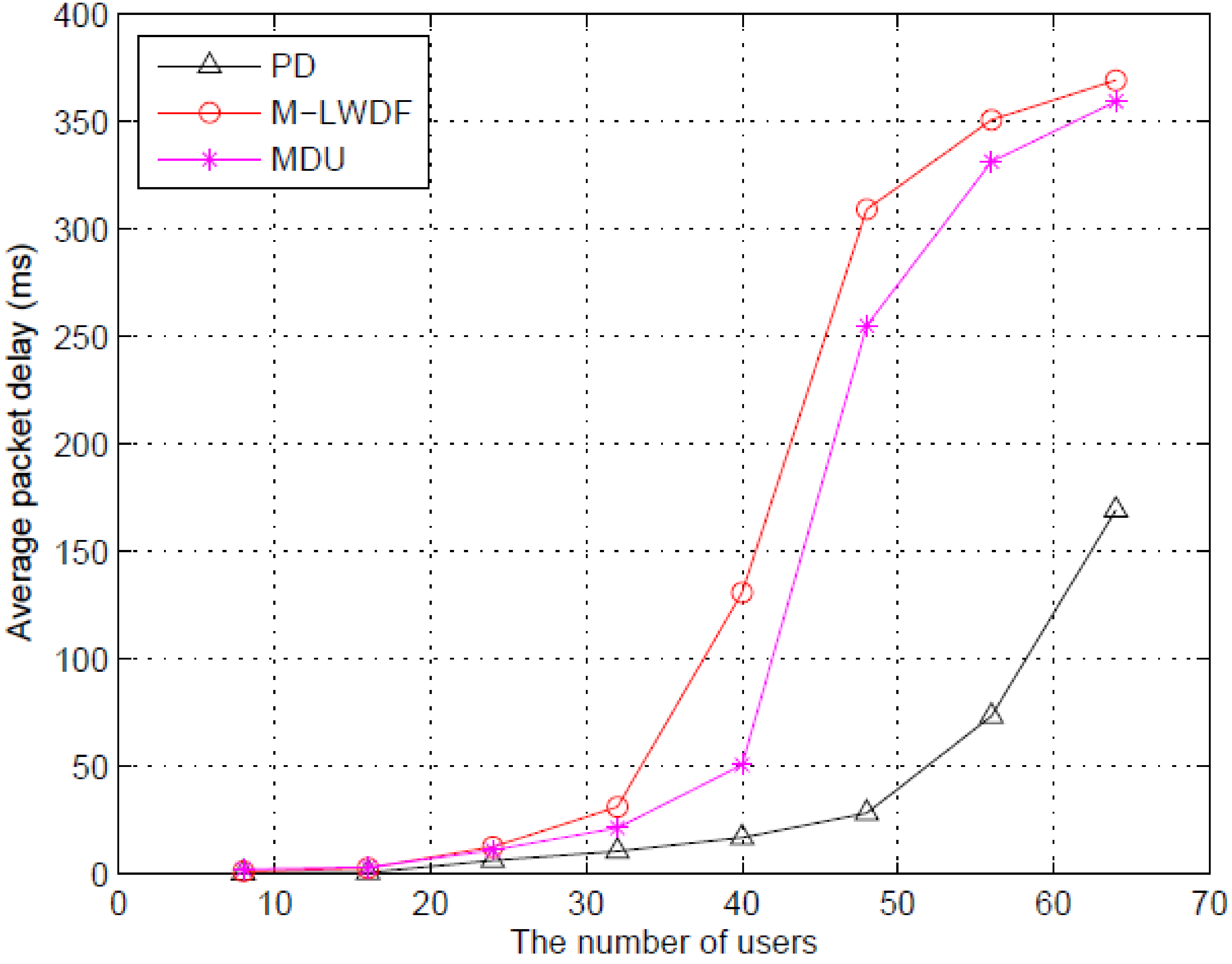
where $\sigma_y^2 = (1 - \rho_{hv}{}^2)\|\boldsymbol{d}\|^2 + N_0$, and the Euclidean distance metric μ can be expressed [5] as

$$\mu = \|\boldsymbol{y} - \beta_{hv}\boldsymbol{V}\boldsymbol{d}\|^2 = \sum y_l - \beta_{hv}\boldsymbol{v}_l\boldsymbol{d}^2 \tag{3}$$

P4: mm-Wave Air Interface

- Ideas:
  - Signal processing for massive MIMO: complexity, scalability, etc.
  - Massive antenna array development
  - Channel characterisation for various scenarios
  - Multiuser system: interference
  - Spectrum allocation

Radio Resource Management (P1)



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Relay LTE-Advanced Systems in the Downlink", in *Proc. IEEE ICC 2013*, Jun. 2013.

Judy Zhu (xuzhu@liv.ac.uk)

Software/Hardware Platforms for 5G Networks (P5)

- Test bed for systems operating from 40 MHz to 30 GHz in LOS and NLOS environments