The Optimal Throughput of some Wireless Multiaccess Systems

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Abstract — **The throughput performance of some multiaccess wireless systems is compared on the basis of the average energy per successfully received information bit E_b/N_0. We prove that, for an optimal choice of the system parameters, some systems are not interference limited and have a similar behavior: at high E_b/N_0 they "self-orthogonalize", i.e., on the average only one user per degree of freedom is active, while at low E_b/N_0 they have the same throughput of conventional CDMA, achieved by infinite users per degree of freedom transmitting with vanishing rate.**

I. Introduction

We assume that an infinite uncoordinated population of users access at random a block fading channel. To cope with multiaccess interference and fading the users retransmit erroneously received packets (Hybrid- ARQ protocol) that are then combined at the receiver to improve decoding. We analize an unspread system with Single User Decoder (SUD) [1] a CDMA system with random spreading, linear filtering (SUMF and MMSE) and SUD [3], and an unspread system with joint decoding, either full Joint Multi User Decoding (JMUD), or a Successive Interference Canceling (stripping) with SUD (SIC-SUD) [2]. Three combining schemes are analized: ALOha-type scheme (ALO), where channel packets are made of the same basic codeword repeated many times and previously received chunks are discarded; Repetition Time-Diversity scheme (RTD), where channel packets are made of the same basic codeword repeated many times but previously received chunks are combined by maximal ratio combining before decoding; and INcremental Redundancy scheme (INR), where channel packets are made of different chunks of redundancy and previously received chunks are taken into account at each decoding attempt. In order to be fair, we compare the systems in terms of their optimized maximum throughput (aggregate average reliable received nat/dim) versus E_n/N_0 (average energy per successfully received information nat).

II. Results

We prove that there exists a minimum value of E_n/N_0, referred to as $(E_n/N_0)_{\min}$, above which the system has non zero throughput. This value is function only of the protocol and the fading statistics and is given by $(E_n/N_0)_{\min} = [\max(1 - \Pr[|c|^2 \leq x])]^{-1}$ for ALO and by $(E_n/N_0)_{\min} = \mathrm{E}[|c|^2]$ for RTD and INR. This shows the benefit of packet combining, RTD or INR, over discarting previous transmission in a faded environment.

We show also that there exists an interval $E_n/N_0 \in [(E_n/N_0)_{\min}, (E_n/N_0)_{\text{th}}]$ ("low E_n/N_0"), for which the throughput is maximized by an infinite number of users per degree of freedom transmitting at vanishing rate. In this regime the simplest system can be implemented without performance loss, in fact all the protocols have the same throughput, that of SUMF-CDMA given by $\eta = [(E_n/N_0)_{\min}^{-1} - (E_n/N_0)^{-1}]$. In the interval $E_n/N_0 > (E_n/N_0)_{\text{th}}$ ("large E_n/N_0"), the throughput is maximized by finite number of users per degree of freedom that, in the limit of large E_n/N_0, tends to 1 (one user per slot, in the unspread system, or one user per chip, in the CDMA system). The differences in performance among systems and protocols are visible in this regime. While SUMF-CDMA and SIC-SUD are interference limited, the other systems are not; the best performance is obtained by joint decoding even without packet combing (without fading JMUD is equivalent to the unfaded single user system and with fading it approaches this value for high E_n/N_0) and, among SUD-based systems, MMSE-CDMA outperforms the unspread system.

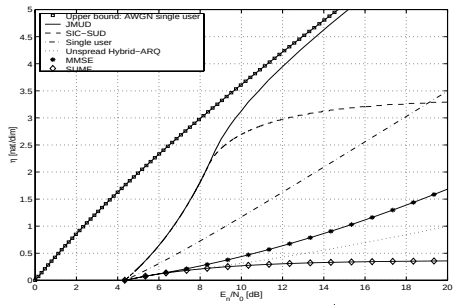

Figure 1: Throughput versus E_n/N_0 for ALO with Rayleigh fading.

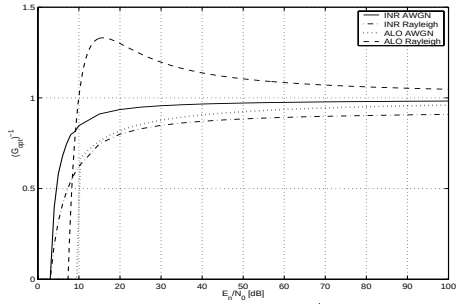

Figure 2: Throughput versus E_n/N_0 for an unspread Hybrid-ARQ system.

As an example, Fig 1 shows the throughput versus E_n/N_0 for the ALO protocols with Rayleigh fading for the different system and Fig. 2 shows the the number of degree of freedom per user of the unspread system for different protocol.

References

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