A Cooperative Resource Allocation Strategy for Multi-Rate Transmissions in Wireless Networks.

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Abstract

In this paper, we propose a cooperative bandwidth allocation strategy for conventional multi-rate transmission in wireless networks. It efficiently assigns the available bandwidth according to the transmission rate in order to enhance the overall performance without additional power consumption. The low rate users cooperate with the high rate users by dedicating a part of their bandwidth to either relay the data or send a part of it. A thorough performance assessment is performed to evaluate the proposed strategy against the conventional management that fairly share the bandwidth regardless of the transmission rate. The cooperative strategy illustrates in terms of the probability of error and outage an enhanced performance and remarkable capability to support higher rates under different transmission conditions.

1. Introduction

The wireless networks supporting terminals with multi-rate requirements use two types of management; conventional (non-cognitive), and cognitive types. The cognitive types are aware of some transmission parameters according to which link adaptation operations, such as modulation and coding, take place for each transmitting rate [1]. While the conventional type known as Rate-Matching fairly share the available resources regardless of the user's transmission rate which is judged to be a waste of the network resources [2,3]. Most of the practical systems such as the Universal Mobile Telecommunications Systems (UMTS) utilize variable length orthogonal spreading codes like the Orthogonal Variable Spreading Factor (OVSF) codes[2,3]. According to the Rate-Matching algorithm, the terminals with high rate requirements are assigned short spreading code lengths while terminals with low rates requirements are given very long spreading code length such that the spread data fulfill the entire user's bandwidth. This result in very large spreading factors, un-necessarily, for terminals with low rates and very small spreading factor, which holds back the performance, for terminals with high rates.

The efficient use of the networks available resources is the best way to attain better quality of service especially for multi-rate transmissions; this gave the attention to the paradigm of cooperation [4-7]. This paper seeks to enhance the performance the conventional multi-rate transmission using a cooperative strategy that efficiently allocates the resources according to the transmission rate without additional power consumption at the cooperating terminal. The low rate terminals transmit their information using a part of their bandwidth size and cooperate by relaying/sending a part of the high rate terminal's information on the remaining part. The two strategies are adopted; relaying the high rate data, the Relaying strategy and sending a part of its data, the Re-Allocation strategy. A thorough performance assessment is performed to evaluate the proposed strategies against the conventional transmission under different transmission conditions. They provide better quality of service to the high rate user without affecting the quality of the low rate user, found to be more resistant to channel variation due to cooperation, and capability to support higher transmission rate with no additional cost. The paper is organized as follows; section 2 carefully discusses the proposed cooperative strategies, section 3 observes a conventional multi-rate transmission algorithm to evaluate the cooperative and conventional transmission, and section 4 is the paper conclusions.

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2. The Proposed Cooperative Multi-Rate Transmission.

This paper proposes a cooperative paradigm that efficiently re-allocates the bandwidth in a conventional multi-rate transmission framework so that the quality of service of the high rate user is enhanced with slight changes to that of the low rate user. The proposed paradigm provides, virtually, larger bandwidth to the terminals with high rate and smaller ones to those with low rate. Two strategies are employed; relaying and re-allocation strategy. In either case, the terminal with low rate requirements is assigned to cooperate with partner transmitting high rates using a part of its bandwidth and power. This operation is performed without the need of more power consumption at the cooperating terminal. We consider a CDMA based cellular system supporting multi-rate transmissions in which the users are able to cooperate in both the uplink and the downlink to forward each other data. The two proposed strategies apply different duplexing mode: the relaying strategy is based on half-duplex while the re-allocation strategy needs full-duplex for the uplink transmission and half-duplex for the downlink. In each phase of the cooperative paradigm, the base station ties-up a low rate user to cooperate with a partner with high rate requirement.

The Relaying strategy is a decode-and-forward based cooperative strategy; the low rate user utilizes a part of his bandwidth to relay a copy of the high rate user data using short spreading codes. The high rate data utilizes two spreading codes one for spreading on its own bandwidth and a shorter code for the relay information. The low rate data is spread using a short spreading code making the bandwidth half occupied. We will now start displaying the uplink transmission knowing that the downlink transmission is similarly applied. Each symbol is transmitted through two intervals; during the first interval the high rate user transmits its first symbol, spread by its longer code, to the base station and the low rate user (the partner). Equation (1) shows the high rate user's transmitted signal $y_{H,d}$ and that of the low rate user $y_{L,d}$, the equations here are similar to the Rate-Matching transmission.

$$y_{H,d} = \sqrt{P_H}\, h_{H,d} C_H x_H + n_{H,d} \quad , \quad y_{L,d} = \sqrt{P_L}\, h_{L,d} C_L x_L + n_{L,d} \tag{1}$$

Where P_i denotes the power transmitted from the source i, C_H is the user's spreading code, $h_{i,d}$ is the Rayleigh channel fading coefficients between the point i and d, x is the transmitted symbol with unit power, $n_{i,d}$ denotes the AWGN, H refers to the high rate user, and L represents the low rate user. While during the second interval, the partner sends its own information using its spreading code C_L on part of its bandwidth. Besides, it relays the high rate user information to the destination on the remaining part of its bandwidth using the short spreading code C_H' as shown in Equation (2).

$$y_{L,d} = \left[\sqrt{\tfrac{P_L}{2}}\, h_{L,d} C_L x_L \quad \sqrt{\tfrac{P_L}{2}}\, h_{L,d} C'_H x_H \right] + n_{L,p} \tag{2}$$

Simultaneously, the high rate user repeats the same procedure to start his second symbol. Meanwhile, the base station de-correlates the information received from both intervals. Equation (3) expresses the resulting high rate and low rate user's signals Y_H and Y_L respectively.

$$Y_H = \sqrt{P_H}\, h^*_{H,d} C_H y_{H,d} + \sqrt{\tfrac{P_L}{2}}\, h^*_{L,d} C'_H y_{L,d} \quad , \quad Y_L = \sqrt{\tfrac{P_L}{2}}\, h^*_{L,d} C_L y_{L,d} \tag{3}$$

Then, the base station coherently combines them using a maximal ratio combiner MRC. Equation (4) shows the extracted information; it is multiple access interference MAI free due to the use of orthogonal codes OVSF.

$$X_H = P_H x_H + \frac{P_L}{2} x_H \quad , \quad X_L = \frac{P_L}{2} x_L \tag{4}$$

Two factors are carefully watched the spreading code length and the transmitted power. The total transmitted power/symbol P_H=P_L=P is invariant for all users, the low rate user power equally shared during the cooperation either to send the user's data or to relay the high rate user data.

Using the Re-Allocation strategy, the base station is efficiently allocating the available bandwidth to the users according to their rate requirements. The high rate data following this cooperative framework is divided using decimation into two signals by the ratio 1/b and (b-1)/b respectively. The later part of the signal is spread and sent over the user's own bandwidth to the destination while the other part of the signal with rate 1/b is spread and send over a part of the partner's (low rate user) bandwidth as shown in equation (5).

$$y_H = \sqrt{P_H}\, h_{d,H} C_H x_H \left(\tfrac{b-1}{b}\right) + n_{d,H} \qquad , \qquad y_L = \left[\sqrt{\tfrac{P_L}{2}} h_{d,L} C_L x_L \quad \sqrt{\tfrac{P_L}{2}} h_{d,H} C'_H x_H \left(\tfrac{1}{b}\right) \right] + n_{d,L} \tag{5}$$

The spreading codes lengths used for the high rate user differ among both bandwidths according to their size. The power constraint used in the relaying strategy applies for this strategy too. Finally, the base station gathers up these signals profiting from the orthogonal spreading codes and send it as a multiple-access signal. At the receiver at each user de-correlates the received signal using its code(s), the de-correlation process of the low rate data is straightforward while the high rate user's data is expressed by equation (6).

$$Y_H = \left[\sqrt{P_H}\, h^*_{d,H} C_H y_H \quad \sqrt{\tfrac{P_L}{2}} h^*_{d,H} C'_H y_L \right] \tag{6}$$

The high rate user needs two parallel branch matched filter, one matched to C_H and the other to C_H'. The data received over its own bandwidth if first processed then followed by the data received over the partner's bandwidth. The re-allocation strategy increases the user's capability to support higher rates using the same resources compared to the Rate Matching algorithm as shown in the next section. The pre-described Re-Allocation details is a downlink half-duplex transmission, the uplink full-duplex based procedure is similar.

3. The Simulation Results.

In this section, we consider two users' based cellular system supporting conventional multi-rate transmission; orthogonal variable length spreading codes OVSF are used and the users fairly share the bandwidth and power resources. Under the effect of Rayleigh flat fading channel and AWGN, we simulate both the Rate Matching algorithm as well as the proposed strategies to evaluate their efficiency. The selection of the spreading code length takes into consideration each strategy requirements and the bandwidth size while for the re-allocation strategy the decimation factor takes the value of ½. The probability of error is first observed for both user's under the effect of similar value of Rayleigh flat fading channel. Figure (1-a) illustrates at low values of signal-to-noise ratio (SNR) a range of 0.5 db performance degradation while for high values of SNR nearly 1 db degradation takes place using both proposed strategies. On the other hand, Figure (1-b) demonstrates a remarkable enhancement on the high rate user performance. The Relaying strategy provides 1 db enhancement compared to 0.2 db for the Re-Allocation strategy for high SNR range. Then the resistivity of the proposed strategies to channel variations is investigated, the low rate user channel is kept invariant and severe channel deterioration is assumed for the high rate user. The Relaying strategy leads to 2 db enhancement on the high rate user performance compared to 0.5 db using the Re-Allocation strategy under the effect of high values of SNR. Next, the probability of outage of both users' is investigated for different levels of Rayleigh flat fading channel under the constraint of the quality of service. The probability of error is restricted to a pre-specified threshold of 10^{-3} for the low rate user and 10^{-6} for the high rate user. Figure (2-a) illustrates an enhancement of 50% using the relaying strategy and 30% utilizing the re-allocation strategy compared to the rate matching algorithm while the low rate user outage is hold back by only 10%. Finally, the re-allocation strategy capability to support higher rates compared to the rate matching algorithm is tested using the same resources and shorter spreading codes. Figure (2-b) shows similar performance of the high rate user transmitting R-2R using the Rate Matching algorithm and R-3R using the Re-Allocation strategy at no additional cost. The analysis of these results show remarkable performance enhancements using the proposed strategies and illustrate resistivity to channel variations due to the cooperation procedure. The Relaying strategy generally leads to better performances but the Re-Allocation strategy is capable to support higher rate without additional cost.

4. Conclusions

In this paper, a resource allocation strategy applying a cooperative paradigm in wireless networks is proposed that support conventional multi-rate transmissions. Two cooperative strategies were proposed; the relaying strategy and the bandwidth re-allocation strategy. The Relaying strategy is convenient for either half-duplex downlink or uplink transmission on the contrary to the Re-Allocation strategy that requires full-duplex for the uplink and half-duplex the downlink transmission. Either strategy provided an enhanced performance for the high rate user performance compared to the Rate Matching algorithm and resulted in a reasonable performance lag for the low rate user. On the other hand, the proposed cooperative procedure both strategies were more resistant to channel degradation. Moreover, the bandwidth re-allocation strategy increased the system capability to support higher transmission rates with no additional cost.

5. References

1. Y. Fallah, H. Mansour, S. Khan, P. Nasiopoulos, and H. Alnuweiri, “A Link Adaptation Scheme for Efficient Transmission of H.264 Scalable Video Over Multi-rate WLANs,” *IEEE Transactions on Circuits and Systems for Video Technology*, Vol. 18, No. 7, pp 875- 877, july 2008.

2. M. Dell’Amico, M. Merani, and F. Maffioli, “Efficient Algorithms for assignment of OVSF Codes in Wideband CDMA,” *Proceeding IEEE International Conference on Communications ICC’02, 2000, pp3055-3060*.

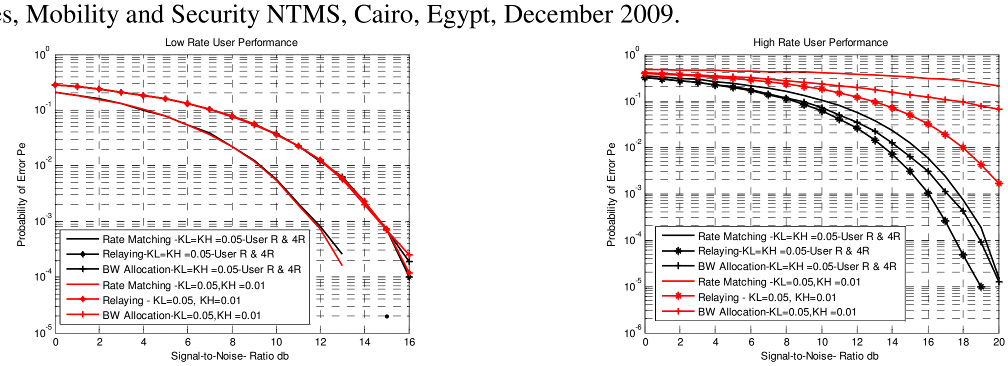
3. M-X Chen, and R-H Hwang, “Efficient OVSF Code assignment and reassignment strategies in UMTS,” *IEEE Transactions on Mobile Computing,* Vol 5, No. 7, pp.769-783, Jul. 2006.

4. A. Nostratinia, T. Hunter, and A. Hedayat,“Cooperation Communication in Wireless Networks,” *IEEE Communication Mag*azine, pp. 74–80, Oct. 2004.

5. J. Laneman, D. Tse, and G. Wornell, “Cooperative diversity in wireless networks: Efficient Protocols and Outage Behaviour,” *IEEE Trans. Inf. Theory*, vol.50, no.12, pp.3062-3080, Dec. 2004.

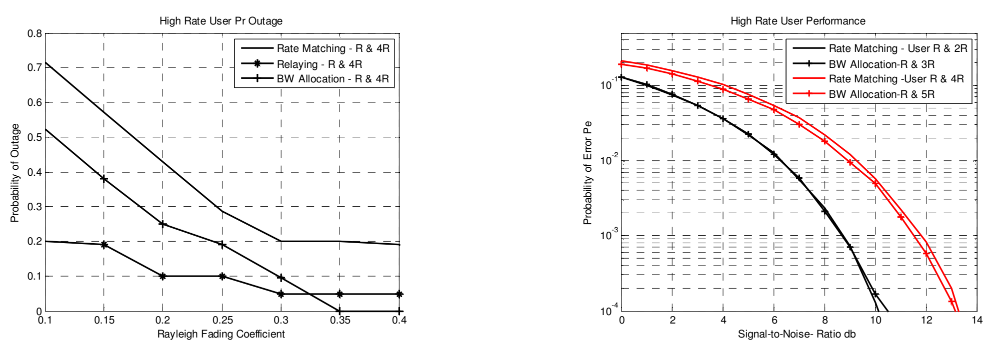
6. K. Azarian, H. El Gamal, and P. Schniter, “On the achievable diversity-multiplexing tradeoff in half duplex cooperative channels,” *IEEE Trans. Inf. Theory*, vol. 51, no. 12, pp. 4152–4172, Dec. 2005.

7. Noha El-Ganainy and Said El-Khamy,“A New Implementation of a Half-Duplex Decode-and-Forward Cooperative Algorithm using Complete Complete Complementary Codes" The 3rd International Conference on New Technologies, Mobility and Security NTMS, Cairo, Egypt, December 2009.



(a) (b)

Figure(1) The Probability of error versus the signal-to-noise SNR under the effect of a Rayleigh fading channel using the proposed and conventional transmissions. The low rate user (R) performance is displayed in (a) and The high rate user(4R) performance is displayed in (b).



(a) (b)

Figure (2) The high rate user probability of outage versus the Rayleigh channel coefficient using conventional and proposed strategies is displayed in (a). The high rate user probability of error versus the signal-to-noise SNR for different transmission conditions using the conventional and proposed strategies is shown in (b).