Prediction-Based Minimum Rate Maximization Link Adaptation Strategy Revisited

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Abstract

Minimum Rate Maximization (MRM) is a link adaptation strategy for CDMA-based systems such as UMTS. It offers to all users on the uplink a minimum QoS, in terms of a target Signal-to-Interference-plus-Noise Ratio (SINR), regardless of their respective fadings. This is achieved by appropriate power and rate allocation that maximizes the minimum user information rate.

Auto-Regressive channel prediction was proposed to improve MRM robustness to imperfect channel knowledge. The prediction yields better average minimum SINR. However, this enhancement is limited by the channel estimation errors. This paper proposes a new channel gain estimator and shows that the prediction error variance is minimized for a given AR order.

1. Introduction

Minimum Rate Maximization (MRM) [1] is a link adaptation strategy for CDMA-based systems such as UMTS. It offers to all users on the uplink a minimum QoS, in terms of a target *Signal-to-Interference-plus-Noise Ratio* (SINR), regardless of their respective fadings. This is achieved by appropriate power and rate allocation that maximizes the minimum user information rate.

The original MRM strategy assumes that the channel is static and perfectly known to the base station. In practice, the channel is unknown and time-varying due to mobility and its gain needs to be estimated. Due to estimation errors and time variations of the channel gain, the MRM performance suffers from some degradation. This has been studied in [2] where we showed that the actual SINR's for the different users are no longer the same (fairness is altered) and their averaged minimum falls below the target value. In [3] we proposed the use of *Auto-Regressive* (AR) channel prediction to improve MRM robustness to imperfect channel knowledge. So, instead of using the channel gain previous estimate, the base station can forecast the future value of this gain. The prediction yields better average minimum SINR. However, this performance enhancement is limited by the channel estimation errors. This paper proposes a new channel gain estimator and shows that the prediction error variance is minimized for a given AR order. Simulations prove that the enhanced estimator results in better average performance.

2. System Model

Consider an uplink with N_u users inside a single cell. The fading channel is frequency-selective with L resolvable paths. Each path l is characterized by its slowly-varying (with respect to the frame duration T_f) complex gain g_l^k (k=user index), modeled as a complex gaussian process $N(0,2\sigma^2)$. At the base station, an L-finger Rake Receiver for each user is assumed. The *Multiple-Access Interference* is modeled as an additive white gaussian noise (independent of the thermal gaussian noise of PSD N_0). If r_k and P_k are the allocated rates and transmission powers respectively, the SINR's during the nth frame are given by

$$\gamma_k(n) = (r_k(n))^{-1} \frac{a_k(n)P_k(n)}{N_0 + \beta \sum_{j \neq k} a_j(n)P_j(n)},$$

where, $\beta = 2/3$ and $a_k(n)$ is the channel power gain, defined by $a_k(n) = \sum_{l=1}^{L} \left|g_l^k\right|^2$.

3. MRM Strategy Basics

The goal of MRM strategy is to find (r_k, P_k) that maximize the minimum user rate $r_{\min}(n) = \min_k r_k(n)$, assuming that a target SINR γ_t is guaranteed to all users. The solution requires the knowledge of the channel gains $a_k(n)$. In the case of dynamic and unknown channel, we can avoid the drawback of using the previous estimates $\hat{a}_k(n-1)$ by the use of the predicted values $\tilde{a}_k(n)$. Because of the prediction errors, the achieved SINR's $\tilde{\gamma}_k(n)$ become different from the target value γ_t as follows

$$\tilde{\gamma}_k(n)=\gamma_t\frac{a_k(n)}{\tilde{a}_k(n)}\left(N_0+\beta(N_u-1)\tilde{a}_{\min}(n)P_{\max}\right)\left(N_0+\beta\,\tilde{a}_{\min}(n)P_{\max}\sum_{j\neq k}\left(a_j(n)/\tilde{a}_j(n)\right)\right)^{-1}$$

Since the prediction accuracy depends on the properties of the channel estimator, the next section proposes a better estimator than the one considered in [3].

4. New Channel Gain Estimator

The Rake receiver delivers estimates $\hat{g}_l^k$ of the channel taps g_l^k with $\hat{g}_l^k(n)=g_l^k(n)+e_l^k(n)$ where e_l^k is the estimation error, modeled as a complex white gaussian noise $N(0,2\sigma_e^2)$ which is independent of g_l^k. In [2], the following estimator of the channel gain was used

$$\hat{a}_k(n)=\sum_{l=1}^{L}\left|\hat{g}_l^k(n)\right|^2 .$$

Since $E[\hat{a}_k]=(1+e)E[a_k]$ where $e=\sigma_e^2/\sigma^2$, this estimator is biased. Thus, we propose a new unbiased estimator

$$\hat{a}_k^u(n)=(1+e)^{-1}\sum_{l=1}^{L}\left|\hat{g}_l^k(n)\right|^2 .$$

Compared to $\hat{a}_k$, the new estimator also has a reduced variance because $(1+e)>1$.

The next section shows that, using this new estimator, the prediction order can be optimized.

5. Optimizing the AR Prediction Order

Considering $\hat{a}_k^u$ as the observation for the channel gain prediction, simulations show that there is an optimum AR order P^* that minimizes the prediction error variance. Figure 1 shows that, for channel estimation error relative variance of e = 0.1 and different values of the Normalized Doppler Spread f_dT_f, $P^*=3$ is a good choice since no significant improvement can be achieved with a higher order.

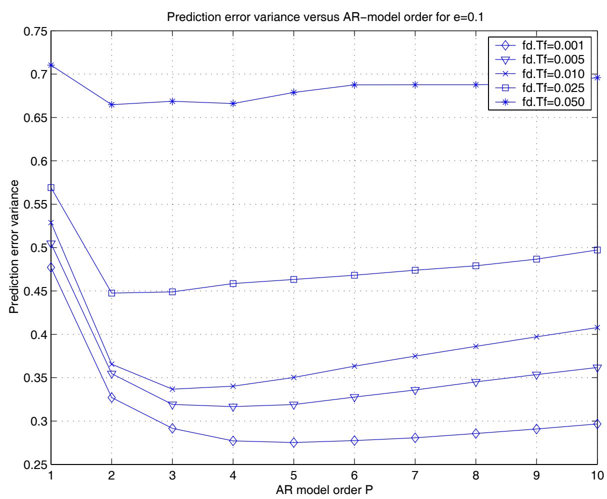

Figure 1. Prediction order choice.

6. Simulation Results

In Figure 2, we plot the average minimum SINR for the biased and unbiased estimator with and without prediction, i.e. when the previous (delayed) estimate of the channel gain replaces its actual value. These curves show that, thanks to the new estimator proposed in section 4, the average performance is improved, and that the prediction can achieve better minimum SINR even with a reduced AR order.

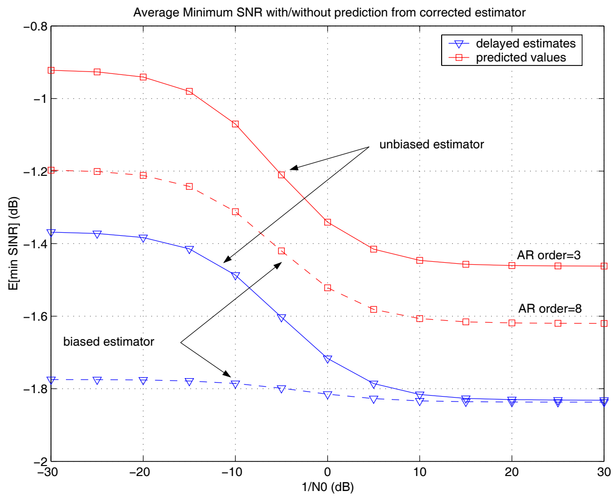

Figure 2. Average minimum SINR.

7. Conclusion

In this paper, we presented a new channel power gain estimator to be used in the context of Minimum Rate Maximization link adaptation strategy. This estimator takes into account the model of the channel estimation errors, making it an unbiased estimator of a reduced variance. We also showed that when the channel estimation errors are taken into account in the choice of the AR prediction order, an optimum order does exist. This order corresponds to the minimum prediction error variance. Finally, simulations showed how the proposed estimator improves the MRM performance, in terms of the average minimum SINR. Furthermore, using the optimized-order prediction of the channel gain, a better performance can be achieved with a reduced AR order.

8. References

[1] C. Poulliat, I. Fijalkow and D. Declercq, "Average performance analysis of a link adaptation strategy based on the minimum user rate maximization", *ICC,* June 2004.

[2] A. Alsawah, I. Fijalkow and C. R. Johnson, Jr., "Robustness study of minimum rate maximization link adaptation strategy", *submitted to ICC-06,* September 2005.

[3] A. Alsawah, I. Fijalkow and C. R. Johnson, Jr., "Improving minimum rate maximization link adaptation strategy using channel prediction*", submitted to ICASSP-06,* October 2005.