The Impact of Maximum Data Rate and Imperfect Channel Estimation on Adaptive Power and Rate DS/CDMA Communications

Ye Hoon Lee and Dong Ho Kim*

Department of Electronic and IT Media Engineering, Seoul National University of Science and Technology, Seoul 139-743, Korea. {y.lee, dongho.kim}@snut.ac.kr

Abstract. We consider a combined power and rate adaptation scheme in direct-sequence code division multiple access (DS/CDMA) communications over Nakagami fading channels, where the transmission power and the data rate are jointly adapted relative to channel variations. The transmission power proportional to $G_i^p$ is allocated to the data transmission of user $i$, where $G_i$ is the channel power gain for user $i$, and $p$ is a real number, and the data rate is simultaneously adapted so that a desired transmission quality is maintained. We analyze the effect of maximum data rate limit caused by a fixed bandwidth and imperfect channel estimation on the average data rate of the joint adaptation scheme.

Keywords: DS/CDMA, adaptive power and rate, estimation error, Nakagami.

Extended Summary

The radio link for either a portable or a vehicular unit can be characterized by a time-varying multipath fading, which causes the link quality to vary with time. When the transmitter is provided with channel state information (CSI), the transmission schemes can be adapted to this information, enabling more efficient use of the channel. For code-division multiple-access (CDMA) cellular systems, a power adaptation is employed to maintain the received power of each mobile at a desired level [1][2]. The power adaptation, however, requires a large amount of transmission power to compensate for deep fades. It was shown in [3] that the rate adaptation with a fixed transmission power provides a higher average data rate than the power adaptation with a fixed data rate, when the average transmission power and quality-of-service (QoS) requirements are identical. An optimal rate adaptation scheme with perfect power control was considered in [4] to maximize the throughput performance. In [5], combined rate and power adaptation schemes were considered which reduce the average transmission power by limiting the transmission power when channel gain is low. A joint rate and power allocation strategy for mixed real-time and nonreal-time traffics was considered in [6].

* Dong Ho Kim is the corresponding author (E-mail: dongho.kim@snut.ac.kr).
In this paper, we consider a joint power and rate adaptation scheme in uplink DS/CDMA communications over fading channels. The transmission power proportional to $G_i^p$ is allocated to the data transmission of user $i$, where $G_i$ is the channel gain for user $i$, and $p$ is a real number. The data rate is simultaneously adapted such that a desired QoS can be attained. Power allocation having positive value of $p$ can be interpreted as the same context of water-filling, while negative value of $p$ indicates the transmission power is allocated inversely proportional to the channel gain. We note that the proposed joint power and rate adaptation scheme reduces to rate only adaptation when $p = 0$ and power only adaptation when $p = -1$. We analyze the average data rate that the joint adaptation scheme provides, subject to an average transmission power constraint and a maximum transmission power limit. We also discuss the effect of maximum data rate limit caused by a fixed bandwidth and imperfect channel estimation on the average data rate.

Fig. 1 shows the average data rate $\bar{R}_i$ versus $N_{\min}$ for several values of $S_T/N_0$. We note that as $N_{\min}$ increases, the average data rate decreases, especially for higher $S_T/N_0$. For lower $S_T/N_0$, the effect of $R_{\max}$ on the average data rate $\bar{R}_i$ is trivial. This results from the fact that the instantaneous data rate rarely exceeds $R_{\max}$ under the constraint of maximum transmission power limit $S_{\max}$, which is much smaller than $\infty$. Figure 1 indicates that the effect of $R_{\max}$ is negligible for practical ranges of $N_{\min}$. Therefore, the effect of the maximum data rate can be ignored not only for low $S_T/N_0$ but also for high $S_T/N_0$. 

Fig. 1. Average data rate $\bar{R}_i$ versus $N_{\min}$; $K = 30$, $S_{\max}/S_T = 10$, $(E_b/N_0)_o = 7$[dB], $L = 3$, $m = 1$, $\delta = 0.5$, $\Omega_g = 1$, $R_c = 5M$. 

Proceedings, The 2nd International Conference on Information Science and Technology
Fig. 2. Average data rate $\bar{R}_o$ versus $\rho$; $K = 30$, $p = 5$, $L = 1$, $m = 1$, $(E_b/N_0)_{tx} = 7$[dB], $S_T/N_0 = 50$[dB] $\Omega_g = 1$, $R_c = 5M$.

In Fig. 2, we plot the average data rate versus the correlation coefficient $\rho$ for several values of $S_{max}/S_T$. We note that the imperfect channel estimation degrades the attainable average data rate more significantly as $S_{max}/S_T$ increases. For higher $S_{max}/S_T$, the dynamic range of transmission powers becomes larger, yielding a mis-allocation of the transmission power even for a small deviation of channel estimation. Fig. 2 indicates that more accurate channel estimation is required for systems with higher peak-to-average power ratios.

References