EE 382C

Embedded Software Systems

Adaptive Power Control in Cellular Radio System

Final Report

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Abstract

Several power control methods in cellular radio systems are reviewed. An adaptive power control scheme based on the adaptive optimization of transmitter power and receiver filter coefficients is analyzed. We implement the power control algorithm, adaptive RAKE receiver and analog RF power amplifier in HP Advanced Design System. We perform the co-simulation in HP Advanced Design System to prove the effectiveness of the adaptive RAKE receiver and the adaptive power control algorithm.

I. Introduction

Accurate power control can reduce the interference in both Global System Mobile (GSM) and Code Division Multiple Access (CDMA) systems. When the mobile is close to the base station, it can use lower power since the signal loss is smaller. For GSM, interference to other cells using the same frequency is reduced when the power control is accurate. For CDMA, accurate power control is vital because all CDMA signals interfere with each other. Lack of accurate power control reduces the capacity for CDMA systems. Moreover, power control can reduce battery drain. The major objective of power control is to alleviate the co-channel and cross-channel interference [1]. Co-channel interference is generated during the resource sharing process. Cross-channel interference results from imperfect technology, Doppler shift and multi-path propagation. The capacity maximization and fair allocation of resources among different users largely depend on the effectiveness of the power control scheme. Due to the effects of fast fading, shadowing and distance loss, an adaptive power control (APC) scheme is needed [2]. Adaptive power control algorithms are used to maintain a constant average performance among the users, minimize the required transmitter power at each mobile, and reduce the multiple-access interference effect. Adaptive power control is a difficult problem to solve. While simple power control algorithms are deployed in cellular radio systems and many quasi-analytical simulation results have been published [2-7], we review some of the important results and propose the implementation, co-simulation in HP Advanced Design System(ADS) [8]. Using the highly integrated and flexible environment in ADS, we will evaluate the system performance using adaptive power control algorithms. We also discuss the models of computation used in our design.

II. Adaptive power control

There are two types of adaptive power control: open-loop [2] and closed-loop [3]. In closed-loop implementations, the reverse link (mobile-to-base station link) channel state is estimated by the base station, and then the base station issues power control command on the forward link (base station-to-mobile link) based on the estimation. In open-loop implementations, the channel state on the forward link is estimated by the mobile itself, and this information is used by mobile as a measure of the channel state on the reverse link. The mobile adjusts its transmitter power accordingly. This scheme works well if the forward and reverse links are perfectly correlated. Closed-loop APC outperforms open-loop APC in a terrestrial environment in which the round-trip delay is small. The closed-loop APC is sensitive to round-trip delay and therefore it is not effective in a land mobile satellite system. Closed-loop APC is more complex in implementation and needs extra bandwidth for power control command. Open-loop APC can compensate for large-scale variations and provides a fast, inexpensive solution.

If the transmitter powers and receiver filters of the users are jointly optimized, the performance of a CDMA system can be greatly improved. We can use an iterative and distributed algorithm [5]. At each iteration, the receiver parameters of the mobiles are updated to suppress the interference optimally and then the transmitter powers of the mobiles are determined so that each mobile creates the minimum possible interference to other mobiles while satisfying the quality of service requirements. It is shown that the resulting power control algorithm converges to a global fixed-point power vector where all mobiles meet their SINR (signal to interference and noise ratio) based quality of service requirements and that the linear receiver converges to the MMSE multi-user detector. The block diagram of the adaptive power control scheme is shown in Figure 1. The SINR information is obtained from the adaptive RAKE receiver. Based on this information, each mobile adapts its receiver filter coefficients to suppress interference and performs iterative transmitter power level adjustment for fixed filter coefficients.

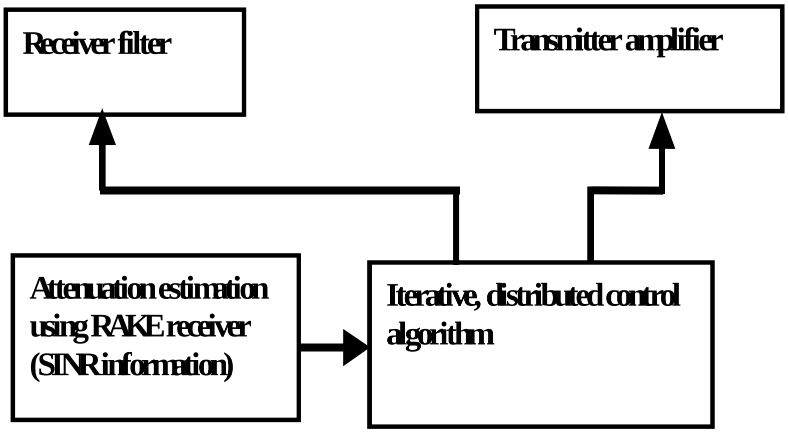

Figure 1. Block diagram of the adaptive power control scheme

III. Models of computation

In order to evaluate the adaptive power control algorithm, we need model the entire communication signal path. The cellular mobile communication path consists of synchronous DSP (digital signal processing) components and analog RF (radio frequency) circuits. Timed synchronous dataflow (TSDF) model in HP ADS is well suited for the modeling of mixed analog RF and digital systems [9]. HP Ptolemy SDF (synchronous dataflow) is extended to TSDF by adding the notion of time. Circuit envelope and high frequency SPICE are used to model analog RF circuitry [8]. With these models in ADS, we can describe functional models of analog RF components and perform the co-simulation.

IV. Implementation of adaptive power control in ADS

We implement the design hierarchy in ADS as shown in Figure 2. The cellular radio system is composed of mobiles, base stations and propagation channels. Each

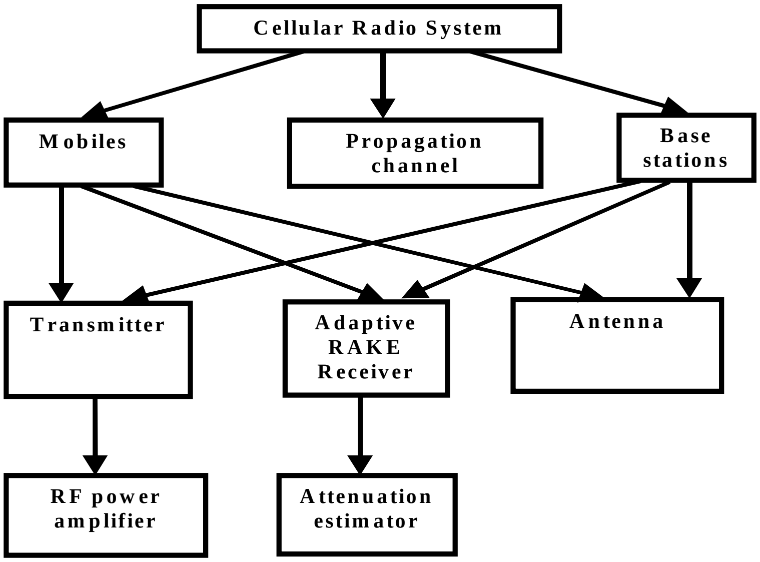

Figure 2. The design hierarchy implemented in ADS

mobile or base station consists of transmitter, receiver and antenna. In the CDMA system, there are digital modulator (spreading), FIR filter, RF modulator (not shown) and power amplifier in the transmitter. There are RF demodulator (not shown), RAKE receiver (de-spreading) and attenuation estimator in the receiver.

In order to get a better estimation of the attenuation in the communication channel at the receiver, we use adaptive RAKE receiver [2] as shown in Figure 3. After RF demodulation, signal $r(n)$ is fed to a series of tapped delay line. D represents the delay time. The outputs of the RAKE receiver taps are correlated with the de-spreading sequence $s(n)$. With a good choice of de-spreading codes, i.e. ones with impulse-like auto-correlation characteristics, each delay path is essentially spatially orthogonal and can be independently demodulated. Following correlation with $s[n]$, each $r[n-k]$ is multiplied by the appropriate attenuation factor and then fed to an accumulator. Because of the constructive and destructive interference caused by the multiple-paths, delayed accumulation of the tap outputs results in strong peaks in correlation which correspond to the originally transmitted bits. The polarity of each transmitted bit may be determined by regularly sampling the correlation at the proper time followed by clearing the accumulator. In particular, a strong negative correlation indicates that $-s[n]$ was transmitted while a strong positive correlation indicates that $+s[n]$ was transmitted. The bit polarity is detected by the decision device DEC. The output of the decision device is $b[n]$. In our implementation, the bit rate of $b[n]$ is 19.2 kps. One bit duration is 52.083 μs. The length of the de-spreading code during one bit duration is 64. The chip rate (the rate after spreading) is 1.2288 M chip/s. Chip is the nomenclature for a binary signal element in a digital spread spectrum carrier.

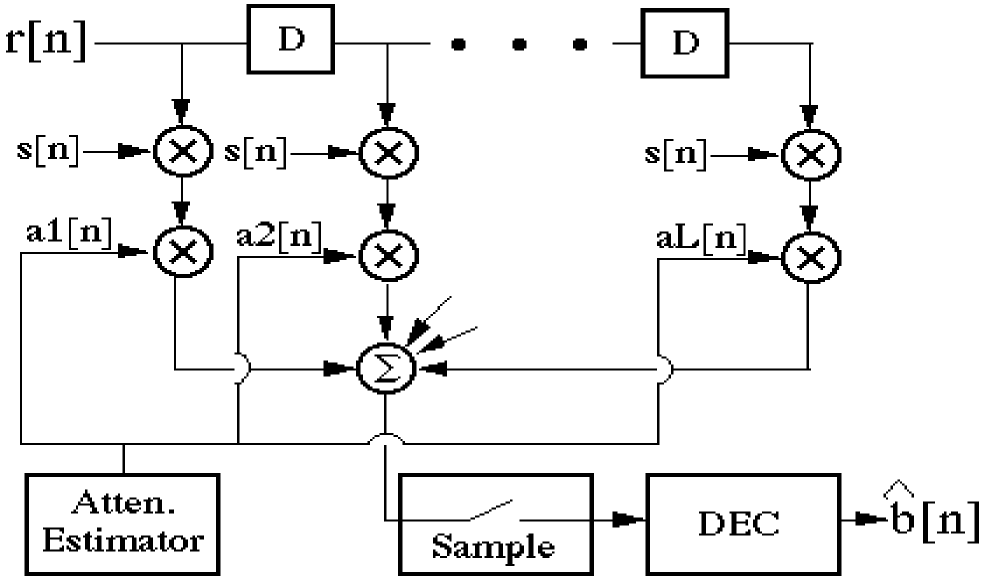

Figure 3. Adaptive RAKE receiver with attenuation estimator [2]

We implement the attenuation estimator for one path as in Figure 4. It is assumed that the transmitted information bit consists of ±1, as does the de-spreading code *s*[*n*]. *M* represents the length of the spreading code. The rationale behind this approach is that a receiver employing a length-M de-spreading code would produce a maximum correlation of ±*M* over one bit duration, given a noiseless channel with no attenuation. The attenuation factor *ak*[*n*] would simply reduce the correlation by a factor of *ak*[*n*]. Assuming a slowly-changing channel (usually a good assumption), the *ak*[*n*] measured for the previous bit may be used to estimate the current *ak*[*n*] value. The circuit of Figure 4 could be implemented as a sliding correlator. While the sliding correlator can only measure *ak*[*n*] for one path per bit, it has the advantage of lower complexity and may be suitable for the more slowly changing channels. Using two or more parallel estimators would be more complex but would provide more up-to-date attenuation estimates.

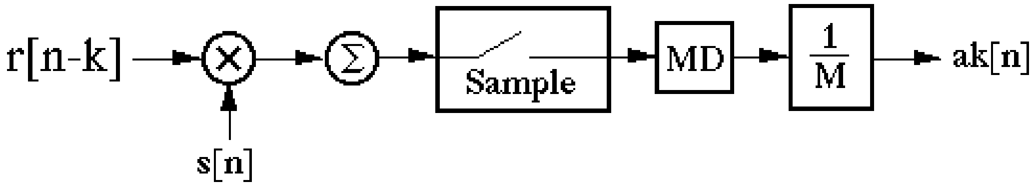

Figure 4: Attenuation estimator

V. Co-simulation and results

We implement the adaptive power control algorithm and adaptive RAKE receiver and put them into a cellular radio system in ADS. We perform the co-simulation of the whole system to evaluate the performance. The results show the RAKE receiver can adaptively adjust its parameter $ak[n]$ to pick up the strong correlation signal and suppress interference and noise with the help of attenuation estimator. By adaptively adjust the gain of the transmitter power amplifier, we can minimize the interference that users create to each other while maintaining the desired SINR or bit error rate (BER) and increasing the throughput of cellular radio systems. Compared to the quasi-analytical simulation, the implementation in ADS has its advantages: it can be more accurately simulated and then synthesized. It also makes a good demo for ADS.

VI. Future work

We will perform the synthesis of the adaptive power control module in ADS.

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