Coverage Extension Using Power-Controlled Relaying in CDMA

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Abstract. In this paper, the advantages of a power-control-based relay system for a code division multiple access (CDMA) network are explored. Relay nodes are placed in the form of a ring (not necessarily circular) based on system requirements, whereby a mobile user and base station can communicate directly or through relay nodes, depending on the received signal strength. Power control through the relays will provide an added advantage to the mobile stations, because they will use less power to transmit in reverse link. An optimal route is determined using the fundamental concept of the CDMA network, which is encouraging for implementing this system in practical circumstances. Through the proper allocation of relay nodes, coverage of the overall area (cell) can be extended. Area extension results for using relay nodes in the cell area are proven analytically. Finally, this paper shows that power-controlled relaying in a CDMA network will increase the number of active users per given cell at a given time.

1. Introduction

In a code division multiple access (CDMA) system, the near-far problem can affect system performance. To counter this problem, power control is used [1]. The goal of this paper is to model a CDMA system to extend the coverage area and improve capacity. A new approach is presented based on the power-controlled relaying in CDMA systems. Cell-size expansion directly contributes to a reduction in the number of base stations [2]. Fewer larger cells covering a given geographical area provide the benefits like large frequency-reuse distance (which decreases inter-cell interference), cost reduction, effective frequency planning and effective capacity planning. Relays are positioned in a ring around a base station (B.S.) at distance "r." When the end user moves out of the ring, he/she will require assistance of relays to communicate with the base station. Perfect power control is assumed within the relay ring. Distances between the base station and the relay, between the relay and the end user, and between the base station and the end user are "r," "d," and "l," respectively [3]. Figure 1 shows how the base station, the relay, and the end user are placed.

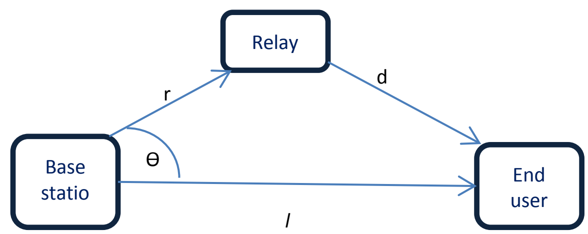

Figure 1. Simple Relay Network.

Relays are selected based on hand off mechanism in conventional CDMA system. The relay with best path will be chosen to communicate.

2. Experiment, Results, Discussion, and Significance

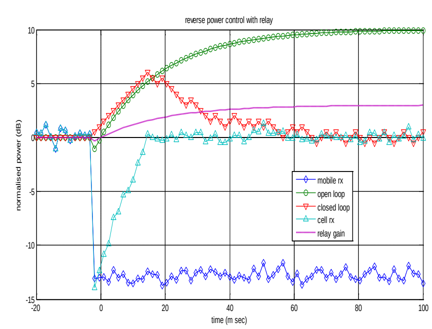

Figure 2. Reverse power control for relay-based cdma system.

A scenario can be analyzed for a relay-based system. The relay gain is defined as

$$R_{gain}=P_{reg}-P_{w/rel} \quad (1)$$

Where, P_{reg} is the power required to transmit a signal to a unit distance in a regular CDMA system, and $P_{w/rel}$ is the power required to transmit a signal to a unit distance in a power-control-based relay system.
In a relay based CDMA system, because of this relay gain (3 dB), an acceptable degradation can be extended to 13 dB. This additional degradation does not compromise quality because the time to rise to an acceptable quality in both a regular CDMA system

and in a relay-based system is the same, i.e., 10 ms, as observed in Figure 2. Based on these results, it can be claimed that due to the use of relays, a mobile user can travel farther away from the base station.

In a CDMA system, normal approximation for outage probability is given by Akl et al. [2] as

$$P_{out} \approx Q\left[\frac{K_0^1-\rho(\lambda/\mu)(1+f)e^{(\beta\,\sigma_C)^2/2}}{\sqrt[2]{\rho(\lambda/\mu)(1+f)e^{(\beta\,\sigma_C)^2}}}\right] \quad (2)$$

where ρ is the activity factor, λ is the call arrival rate, $1/\mu$ is the call duration, K_0^1 is number of users, and f is the frequency-reuse factor, which is equal to 0 for a single cell. The standard deviation σ_C ranges from 1.5 to 2.5 db. This fluctuation of E_b is caused by interference due to imperfect power control. The greater the distance, the greater will be the variance. For a power-control-based relay communication system, path loss can be reduced in an efficient manner, hence reducing σ_C.

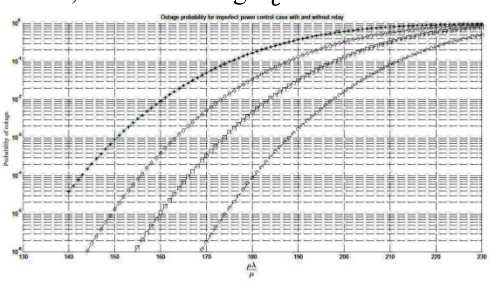

Figure 3. Outage probability with relaying.

In Figure 3, it can be seen that σ_C = 2.5 is for a regular CDMA system without relay, and σ_C = 1.5 and σ_C = 2.0 are for the power-control-based relay-system cases. When power-controlled relaying is employed, σ_C can be reduced, which means that the performance can be moved towards the perfect power-control case (which is desirable), achieving coverage extension.

The effective height of the relay antenna depends on the relay gain; therefore, relay gain is added in the form of h_r as

$$L = 119.95 + (44.9 - 6.55log_{10}(h_{bs} + h_r))log_{10}d_{km} - 13.82log_{10}(h_{bs} + h_r) - 2.52h_M + 25log_{10}(\%) \quad (15) \quad (3)$$

Here, $h_r = \mu h_{relay}$, where h_{relay} is the true height of the relay, and μ is bounded as 0 ≤ μ ≤1. A constraint $h_{relay} \le \left(\frac{1}{2}\right) h_{bs}$ is assumed, and μ mainly depends on σ_C, so that as σ_C is reduced, μ increases, i.e., $\mu \propto 1/\sigma_C$. This implies that the effective height will depend on σ_C.

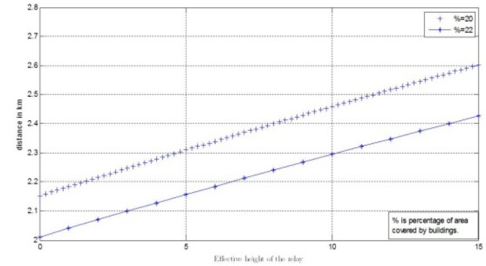

Figure 4. Distance in Kilometers Given Effective Height of Relay.

As shown, in Figure 4, the effective height of the relay increases, and a significant increase in the link distance is achieved. At a height equal to zero, the link distance is 2.15 km. And at h_r = 13 m, the link distance is almost 2.55 km. This is an improvement of about 0.4 km over the regular system, i.e., close to 20% improvement in the coverage area. With this, it can be claimed that the coverage extension is possible in a real-time CDMA system by implementing power-controlled relays.

3. Conclusions

In this paper, a new approach for relaying in CDMA systems is discussed. A possible way to implement the power-control-based relay system is provided. It is observed that cell coverage can be extended up to 20% when the effective height of relay h_r is 13 m. With the analysis provided in the thesis, it can be claimed that the coverage extension can be obtained by applying power-controlled relaying in a CDMA system.

4. Acknowledgements

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References

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