Transmit Power Management Technique for Wireless Communication Networks

*Isabona Joseph, Bede Asuquo
Department of Physics, University of Uyo, Nigeria
(*E-mail: josabone@yahoo.com)

**Moses E. Ekpenyong
Department of Mathematics, Statistics and Computer science, University of Uyo, Nigeria
(E-mail: ekpenyong_moses@yahoo.com)
(**Corresponding Author)

Abstract

For fixed Quality of Service (QoS) constraints and varying mutual channel interference, how should a mobile node in a wireless network adjust its transmitter power to maintain an acceptable link quality? This paper simulates a dynamic power management algorithm based on interference controlled approach to establish a relationship between QoS requirements and the transmit power. Our interference controlled transmit power relies on pilot tone transmissions and adjusts the power based on the interference levels measured from the pilot tones. Simulation results show improved system performance.

***Keywords**: QoS, CDMA, Wireless Systems, SNR, Transmit Power Optimization*

1. Introduction

The idea of using multi-hop transmission to enhance cellular networks dates back to the use of repeaters that performed analogue retransmission and were applied mainly in hot spots or hard-to-reach areas. Mobile multi-hop enabled wireless terminals can dynamically form a network, where the network infrastructure is mission incomplete, or inadequate. Due to the potential cost of deployment, there are many interesting deployment scenarios where a group of people wish to communicate with each other [1]. In multi-hop networks, communication is possible in a point-to-point fashion between wireless terminals. If the coverage of two terminals is too small to reach each other, the terminals could communicate by hopping over neighbouring terminals. Multi-hoping enables two distant terminals to communicate with each other and also has the potential to save energy. Multi-hop cellular can also help balance the load among cells making use of available bandwidth [2]. These advantages cannot easily be achieved. Adding multi-hopping on top of cellular architecture increases the complexity of these networks.

Generally, the performance of CDMA is interference limited. Therefore, for muli-hop, CDMA cellular networks concept is to gain all its advantages. We therefore advocate the use of power control which is typically employed to reduce the inference and thus increase the performance. Power control in multi-hop networks, however, poses unique and novel challenges, which is discussed in the next section.

In our previous work [3], we derived a system model and present a computer simulation to optimize the transmit power for each user and thus maintain the required signal-to-noise ratio (SNR) for satisfactory call quality by achieving a minimal SNR for every user with an acceptable channel performance.

2. Problem Description

In a CDMA system, multiple transmitters use the same bandwidth at the same time to send their information to one or multiple receivers. Due to the attenuation, a given terminal receives high or power levels from transmitting terminals that are close by than from transmitting terminals that are far away, a situation known as near-far effect. The near-fear effect plays a crucial role in multiuser CDMA systems, which is interference limited. To overcome the changing signal strength, power control entities are implemented in the transmitter. These entities are commonly referred to as Transmitter Power Control (TPC). For cellular CDMA mobile communication systems the TPC adjusts the transmission power S_t at the sender-side to ensure that all signals arrive at the receiving end with the same power level S_r. Generally, the lower the power level of a given signal, the larger the number of supported terminals in a CDMA cell. Thus, the main goal of TPC in cellular systems is to correct, adjust and manage the power of each transmitting node such that the received signals are equal in power, which is achieved by measuring the *SIR* of the incoming signals and adjusting the transmission power to meet the desired *SIR*.

The design of the TPC for multi-hop CDMA systems is significantly more complex than the design for cellular CDMA systems [4]. This is because adhoc networks are lacking the structure of cellular networks. In cellular networks all communication is organized in forward link (base station to mobile terminal) and reverse link (mobile terminal to base station) communication. There is no direct communication between two mobile terminals, i.e., if two mobile terminals wish to communicate with each other, the communication is relayed by the base station. This structuring of the communication wish to communicate with a central entity (base station) provides for central coordination and inherent fairness in the power allocation. On the other hand, in adhoc networks, two mobile terminals communicate directly with each other, without relaying, by a central entity. In this unstructured scenario each receiver tells the sender it is communicating with, to transmit power level that ensures proper reception. Each user thus controls its corresponding sender in a selfish manner, without any central co-ordination. The absence of a central coordination (without overall knowledge), however, may lead to an unstable situation in an adhoc cluster if multiple receivers want to control the transmitting power of the related node. This paper addresses these problems outlined above using dynamic interference power control approach.

3. Solution Approach: An optimal interference controlled TPC

Power control is generally used to increase the capacity in a network. When the complete knowledge of all transmitting powers is missing, some signaling among the node is necessary to exchange at least a local knowledge. However, an overwhelming among signaling would decrease the already scarce bandwidth of wireless multi-hop networks. Therefore we designed an interference controlled TPC. This TCP approach is designed for low cost terminals, which can run low complexity algorithms and mechanisms, for instance, nodes in sensor networks. The interference controlled TCP works as follows: Each wireless terminal listen to pilot tones of the neighbouring terminals. The pilot tones are transmitted with transmit power target, S_{target}. The pilot tones contains information about the wireless terminal such as the power update step size, Power Control Command (PCC) and the probability to send within the next period. The user's transmitted power P_t (dB_m), at each node is updated by fixed step size of Δ(dB). For fairness, terminals with low interference, terminals are asked to transmit with low transmission power. Simultaneously terminals with high interference have to use higher transmission powers, depending on their locations. Thus, the higher the interference level, the higher the transmitting power. Each node adjust its transmission power by calculating:

$$S_{transmit} = S_{t\arg et} - PCC(\Delta)$$

where

$$PCC = \pm 1 \text{ with a probability of } \varepsilon_+ + \varepsilon_- = 1$$

Here, the target power is kept at $S_{target} = S_r$

Advantages of optimal interference power control

The advantages of optimal interference power control include

(i) *Heterogeneity of users considered:* In optimal interference control approach, different types of classes for different types of users are considered. Also the resources unused by the how-end users are distributed to high-end users. This supports the users to the unused resources taken by the low-end users.

(ii) *Increased number of users:* Power control is achieved by implementing the optimal interference based power control method, hence the overall interference and noise in the system gets reduced. This method gives room for some more number of users to enter the system even at different locations and aims at optimizing the power but not compromising the QoS parameter. So by optimizing power for a user the Bit Error Rate (BER) is reduced.

3.1 Link equations/Calculation

CDMA Link Capacity

Throughout this paper, we are concerned with the reverse link because the link CDMA link capacity is limited by the reverse link. Supposing there are *N* users in a cell and the signal is denoted by *S*, then in *S* the interference can be calculated as $I = (N\text{-}I)S + N_0$, where N_0 is the background thermal noise. Hence the *SIR* is given by

$$SIR = \frac{S}{(N-1)S + N_0} \qquad (1)$$

Suppose the digital demodulator for each users can operate against the noise at an energy per bit-to noise power density level is given by ε_B / N_0, whose numerator is obtained by dividing the desired signal power by the information bit rate, R, and dividing the noise (or interference) by the total bandwidth, *W*. This result in

$$\varepsilon_b / N_0 = \frac{S / (R.\alpha)}{N_0 + (N-1).S/W} \qquad (2)$$

where α is a turning parameter that can be optimized. Rearranging the terms in (1), we can express the signal power *S* when *N* channels are occupied in the cell, as

$$S = \frac{N_t.W}{\dfrac{W / (R.\alpha)}{\varepsilon_b / N_0} - (N-1)} \qquad (3)$$

According to *IS-95* standards [5], the bit energy to interference density ratio, ε_B / N_0, is the important parameter here, to guarantee a bit error rate of 10^{-3}.

4. Wireless Link Model

For our simulation, we use the free space propagation model to determine the received signal strength at the receiving terminal under the assumption that there is only one line of sight path between the sending terming and the receiving terminal. Then, the strength of the received signal strength S_r depends on the transmitted power S_t. The distance *d* between the sender and receiver, the antenna gain [6], [7], [8] of sender and receiver, G_s and $_{Gr}$, the wave length λ, and the pathloss *L*, is given by

$$S_r = \frac{P_t G_t G_r \lambda^2}{(4\pi d)^2 d} \qquad (4)$$

Note that in this free space equation, the received power declines with the square of the distance. In the following calculations we set

$$\frac{G_t G_r \lambda^2}{(4\pi)^2 L} = -30dB \ [5]$$

4.1 Implementation

The simulation algorithms were developed to provide solution to problem of: interference, near-far-effect and system's equation. It was develop and then coded into a computer program using

Visual Basic (VB) 6.0 as the programming language. Visual Basic 6.0 is an object oriented programming language suitable for scientific simulations/applications. This means that it makes use of objects which are a combination data and codes. Data represent the relevant information that is used to program the systems dynamics, while the codes are the series of programming instructions written to process the system data needed.

4.2 Performance Evaluation & Discussion of Results

This section presents plots showing the results obtained for the system performance. A spread spectrum bandwidth of 1.25 MHz, a user data rate of 8kb/s, a voice activity factor of $^{2}/_{5}$, carrier frequency of 2 GHz, speed of light of 3 x 10^8m/sec and a path-loss exponent of 2 are considered. The channel bit error rate (BER) depends on the $^{\varepsilon_b}/_{N_0}$. This is kept constant at 8dB by the power control mechanism [8].

Here the parameters used for the performance evaluation are transmitted power, the numbers of users in the system and mobile distance locations. Figure 1 shows the transmit power of users at different locations. We observe that the transmit power increases steadily as the distance between the transmitting and receiving nodes increases. This increase in power allows the system to accommodate more users, thus increasing the capacity and network coverage area. The reason for such performance is due to the compensation for signal fluctuation between the receiver and the transmitting nodes as the transmit power increases.

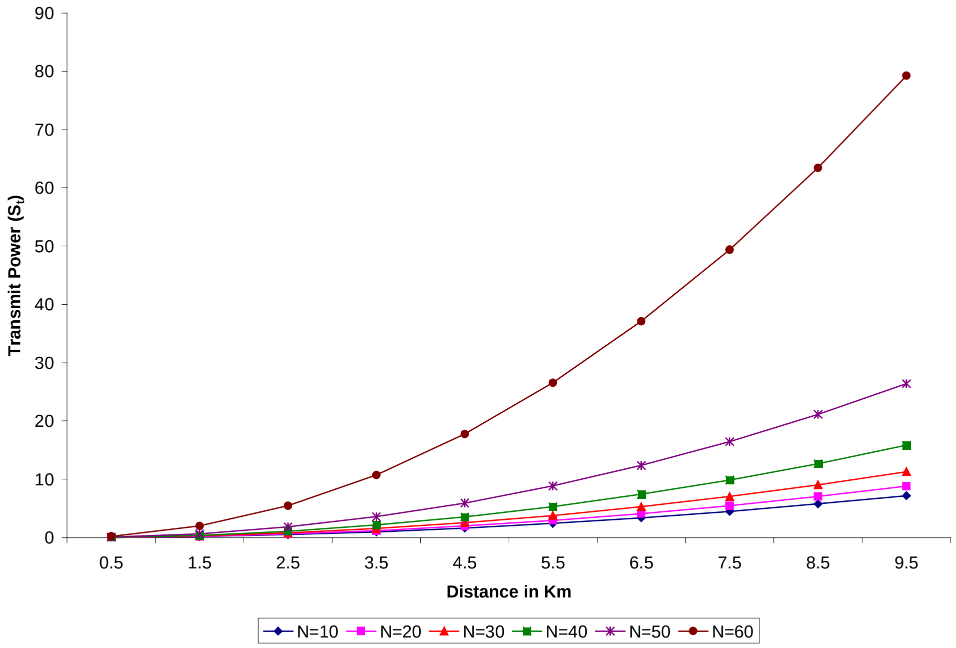

Figure 1. Transmit Power (S_t) vs Distance in Km

In Figure 2, the transmit power is plotted against number of users. We observed from this figure that the transmit power increases with the users. This increment in power helps the system to meet and maintain the minimum link target qualities required by users at different locations. This is because, our interference controlled approach gets the unused resources from low-end users and these resources can be used by high and users or some new users.

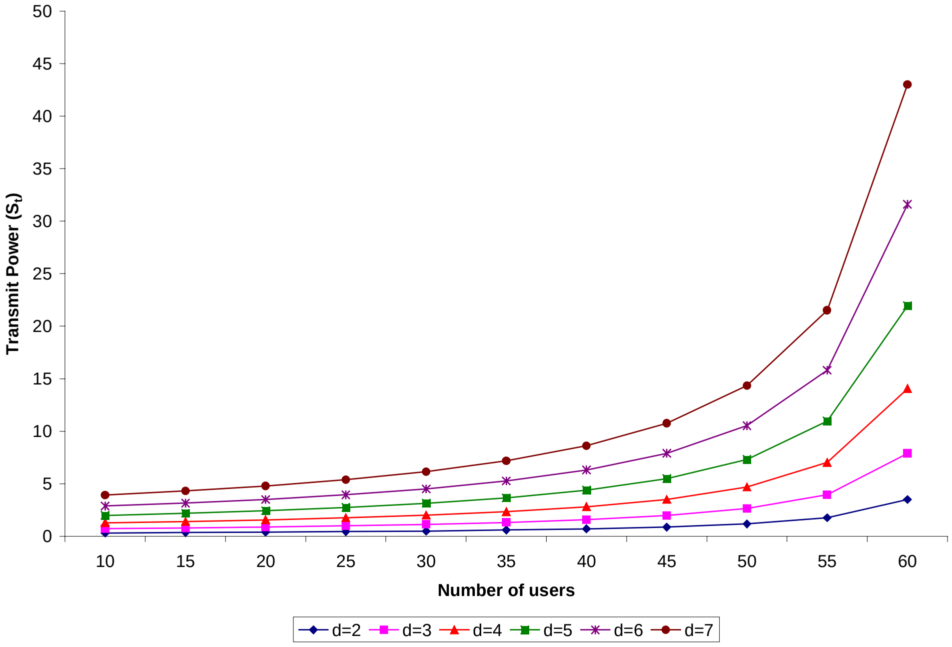

Figure 2. Transmit Power (S_t) vs Number of Users

5. Conclusion

Through simulation, we have demonstrated that our low complexity for power control gives favourable results in terms of power consumption and capacity for the CDMA system, thus yielding the performance requirements for the system. Additive white Gaussian noise added to the system model was assumed to be, -102dB. This could be further modified in the future to accurately reflect the existing noise in a CDMA cell, if profiles of such noise metrics are available. Thus the performance of the power control algorithm in real time situations could be accurately modeled. The effect of this on the reverse link channel needs to be explored for performance enhancement.

6. References

1. Broch, D, A., Johnson, D. B., Hu, Y. C. and Jet Cheva, J., 1998, A performance comparison of multi-hop wireless adhok network routing protocols. In Mobile computing & networking, pp. 85-97.

2. Tam, Y. H., Safwat, A. M. and Hassanein, H. S., 2003, “Load Balancing and Relaying Framework. In TDD W–CDMA Multi-hop Cellular networks”, In Proc. IEEE Vehicular Tech Conference. Vol. 5:2931-2935.

3. Joseph, I., Asuquo, B. and Ekpenyong, M. E., 2007, Capacity and Coverage of Power Controlled CDMA Cellular Systems. Journal of the Nigerian Associaton of Mathematical Physics, Vol II, pp. 605-612.

4. Fitzek, F., Seeling, P. and Reisslein, M., 2002, Link Level Design Issues for IP based Multi-hop Communication Systems.

5. Mobile Station-base Station Compatibility Standard for Dual-mode Wideband Spread Spectrum Cellular System, 1993, TIA/EIA interim Standard (IS- 95).

6. Akl, R. J., Hedge, M, V., Naraghi-pour, M. and Min, P. S., 2001, “Multicell CDMA Network Design. IEEE Trans. Vehicular Tech, Vol. 50, No. 3, pp. 711-722.

7. Rappaport, T., Seidel, S. and Takamizawa, K., 1991, Statistical Channel Impulse Response Models for Factory and Open Plan Building Radio Communication Systems Design. IEEE Transactions on Comm.

8. Gulhousen, K. S., Jacobs, I. M., Padovain, R., Viterbi, A. J., Weaver, L. A., and Wheatley, C. E., 1991, ‘On the Capacity of A Cellular CDMA System’, ‘IEEE Trans. Veh. Technol., Vol. 40, No. 2, pp. 303 – 312.

Article received: 2008-02-10