Joint Scheduling and Power Control for Multiclass Users in CDMA Wireless Ad Hoc Networks

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Abstract: - In this paper, we develop a cross-layer based joint algorithm for power control and scheduling. We applied the algorithm in CDMA wireless adhoc networks to determine the optimum set of admissible users with optimum transmitting power level, so as to minimize the interference level and call rejection rate. The multiple access problem is solved via two alternating phases, namely scheduling and power control. We introduce the notion of power control as part of a contention-based multiple access protocol that characterizes successful transmissions depending on a set of signal-to-interference-and-noise ratio (SINR) constraints (which directly translates to quality of service (QoS) constraints on the bit-error rate (BER) at individual receivers). The scheduling algorithm is essential to admit the transmissions of static as well as mobile users of multi service classes, in order to eliminate strong levels of interference that cannot be overcome by power control. By simulation experiments, we evaluate the performance of our algorithm in a set of admissible and non-admissible users and show that power control algorithm converges for a set of admissible users.

Key-Words: - Adhoc networks, CDMA, SINR (signal-to-interference-and-noise ratio), QoS (Quality of service), BER (bit-error rate)

1 Introduction

1.1 CDMA Wireless Ad Hoc Networks

On top of the TDMA scheme, each node has a unique preassigned signature sequence that it can use to encode the transmitted symbols. Again, our main objective is to show the applicability of our algorithm introduced for cellular CDMA systems, to contention-based wireless ad hoc networks.

First, we introduce the physical layer assumptions underlying the system. We adopt a simple signaling structure with BPSK modulation. The symbol stream is assumed to be i.i.d. and the 1 symbols are assumed to be equally probable.

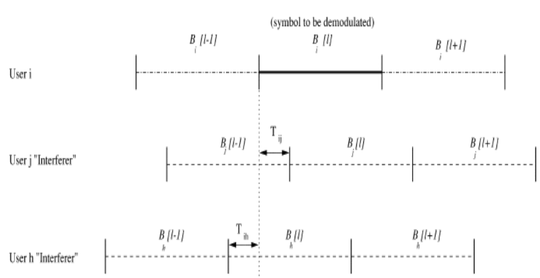


Fig.1. Asynchronous CDMA system.

The noise is assumed to be independent of the symbols and has variance σ^2 Users are assumed to have preassigned unique signature sequences which they use to modulate their information bits. The signature sequence of user is denoted $s_i(t)$ which is nonzero only in the bit interval $[0, T_b]$ and is normalized to unit energy, i.e., $\int_0^{T_b} s_i^2(t)\, dt = 1$. The receiver is assumed to be a conventional single-user detector, namely a bank of filters matched to the signature waveforms of various users [36]. For each user, we assume that all other users create interference asynchronously. The relative delays of the users, which can have any value not exceeding the bit duration T_b, do not change with time and are assumed to have a uniform distribution. For the th bit of a given user, an interfering user creates interference by either bits $(l-1)$ and l or bits l and $(l+1)$ depending on whether the interfering user has a positive or negative delay relative to the user of interest. In Fig. 3, two possible cases are depicted. The delay of user relative to the matched filter of user i is denoted T_{ji}. In Fig. 3, user has a positive delay relative to user and creates interference to the th bit of user i with bits $(l-1)$ and l. On the other hand, user has a negative relative delay with respect to user and creates interference to the th bit of user i with bits l and $(l+1)$. Accordingly, three types of cross correlations between the signature sequences of any two users and can be defined. They are denoted as $\bar{\rho_{ij}}, \rho_{ij}, \text{and } \tilde{\rho_{ij}}$, and and represent the cross correlations between the symbol of interest in one hand and the previous symbol, current symbol, and next symbol of an interferer, respectively.

1.2 Power Control And Scheduling In CDMA Networks

Power control (PC) has been extensively investigated for cellular networks (both open loop and closed loop). The primary aim of power control in cellular networks is to mitigate the near-far effect, and hence reduce the performance degradation caused by multiple access interference (MAI). While power control for ad hoc networks helps accomplish a similar objective, it assumes additional importance because finite battery life is a key issue for mobile nodes in such networks (sensor networks in particular). Thus, PC aims to appropriately utilize the limited energy resources of each node to enhance network throughput/lifetime or some other network metric. Scheduling aims to allocate the wireless channel to contending nodes in an efficient manner so that MAI is reduced, however at the same time each node is guaranteed a minimum acceptable level of performance in terms of metrics such as data rate, delay, probability of error etc.

Power control has been studied extensively in the context of channelized cellular systems [2], [4], code-division multiple-access (CDMA)-based systems [7], and in a general framework [8]. Distributed iterative power control algorithms have been introduced for cellular systems and convergence results have been established [2], [4], [8]. More recently, there has been some focus on formulating the distributed power control problem as a non cooperative game [9]–[12]. In [12], the authors modified the power control problem formulation to incorporate the notions of utility and cost which are shown to improve the convergence characteristics of the algorithm.

It is the rule to admit requested calls of various users maintaining the quality of service. So we have to basically make a decision about whether a user should be admitted into the system according to the users' quality of service requirements and the current traffic load. Generally, the CDMA capacity is limited due to interference and power. That is as the number of users increases due to non-orthogonality factor, the interference will increase too. Hence there is a limit to the maximum number of users.

Our main objective in this paper is to develop a joint algorithm for power control and scheduling to determine the optimum set of admissible users with optimum transmitting power level, so as to minimize the interference level and call rejection rate. We introduce the notion of power control as part of a contention-based multiple access protocol that characterizes successful transmissions depending on a set of signal-to-interference-and-noise ratio (SINR) constraints (which directly translates to quality of service (QoS) constraints on the bit-error rate (BER) at individual receivers).

We propose to introduce a cross-layer design framework to the multiple access problem in contention-based wireless ad hoc networks. We mainly consider the problems of distributed power control (DPC) and Scheduling in multiple access for admitting non-conflict transmission for multiple class of users with mobility.

The paper is organized as follows. Section 2 presents the related work. Section 3 gives our scheduling and power control algorithm along with the system model. Section 4 presents the experimental results and Section 5 concludes the paper.

2. Related Work

Jens Zander [1] Distributed power control algorithms that use only the signal-to-interference (C/I) ratios in those links actually in use, are investigated. An Algorithm, successfully approximates the behavior of the best known algorithms is proposed. The algorithm involves a novel distributed C/I- balancing scheme.

David Goodman et al. [2] the Quality of Service of a telephone call is referred to as the "utility" and the distributed power control problem for a CDMA telephone is a "noncooperative game". The algorithm includes a price function, proportional to transmitter power. When terminals adjust their power levels to maximize the net utility (utility - price), they arrive at lower power levels and higher utility than they achieve when they individually strive to maximize utility.

Cem U. Saraydar et al. [3] primarily concerned with the impact of pricing the usage of wireless services on QoS. Pricing of services in wireless networks emerges as an effective tool for radio resource management because of its ability to guide user behavior towards a more effiient operating point. Then introduce a model for power control in wireless data networks using concepts from microeconomics.

Sennur Ulukus et al. [4] distributed iterative power control algorithms that use readily available measurements. Two classes of power control algorithms are proposed. Since the measurements are random, the proposed algorithms evolve stochastically and it define the convergence in terms of the mean-squared error (MSE) of the power vector from the optimal power vector that is the solution of a feasible deterministic power control problem.

Tamer A. ElBatt et al. [5] investigates the benefits, and possibly the tradeoffs, of deploying different transmit powers in the wireless ad-hoc environment. It proposes a power management scheme which can be used in conjunction with traditional table-driven routing protocols, with possibly minor modifications. The performance measures are taken to be the end-to-end network throughput and the average power consumption.

It distributed dynamic channel assignment algorithms for a multihop packet radio network are introduced. It ensure conflict-free transmissions by the nodes of the network. This algorithm is to split the shared channel into a control segment and a transmission segment. The control segment is used to avoid conflicts among nodes and to increase the utilization of the transmission segment.

Ting-Chao Hou et al. [7] presents a model for analyzing the performance of transmission strategies in a multihop packet radio network where each station has adjustable transmission radius. A larger transmission radius will increase the probability of finding a receiver in the desired direction and contribute bigger progress if the transmission is successful, hut it also has a higher probability of collision with other transmissions. The converse is true for shorter transmission range. We illustrate our model by comparing three transmission strategies.

Ram Ramanathan et al. [8] unique contributions to multihop wireless networking. We formulate topology control as a constrained optimization problem of practical importance; in particular as minimizing transmit power subject to the network being connected or biconnected. It introduces a new analytical representation of multihop wireless networks that is more general and realistic than the conventional one. These heuristics involve techniques for global coordination with local information that might be of help in other distributed control problems.

Marianna Carrera et al. [9] present Cross-layer Unicast Transmission Time (X-UTT), a MAC-aware load-independent link cost metric for 802.11based wireless mesh networks. X-UTT utilizes information acquired from a network-layer unicast probing system and a MAC-layer monitoring system. It is designed to capture the wireless link capacity and be independent of the load induced by self-interference and cross-interference in a mesh network.

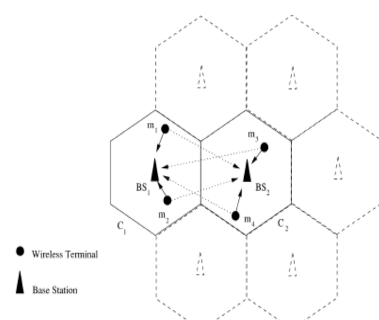
Yih-Hao Lin et al. [10] developed a locally centralized algorithm which minimizes the average power consumption of the system, while maintaining the end-to-end throughput, if feasible. Using the same methodology, one could replace the MIMO broadcast subsystem by some other multi-user subsystem structure, such as a MIMO multi-access network.

S. Malarkkan et al. [11] presents performance of call admission control and resource reservation schemes based on the mobility of the users in WCDMA cellular systems. In order to guarantee the handoff dropping probability, the mobility of the user is predicted based on a realistic mobility model. The admission threshold is adaptively controlled to achieve a better balance between guaranteeing handoff-dropping probability and maximizing resource utilization.

Mikael Skoglund et al. [12] addresses issues related to several of the traditional layers. At the core of the project we have challenged the separated layers paradigm by investigating several different aspects of cross-layer optimization. Our results address the gains achievable using cross-layer techniques, versus the cost of implementing them.

3. Our Scheduling Algorithm for Admissible And Non-Admissible Users

3.1. System Model



Consider a CDMA system with N active users in each Cell and there are M user classes. In DMA wireless *ad hoc* networks, a transmission cenario is **valid** iff it satisfies the following condition. A node is not allowed to transmit and receive simultaneously. We can take the following system parameters

- Users of class M have maximum received power limitation L_m.
- P_n: Received power of nth user ∈ $(0, L_m]$
- U:Z+ ® {1…M} , maps each user to a class.
- W: Chip Rate
- $D_{U(n)}$: Data rate of class U(n)
- I_n: Total interference to nth user

Then, signal-to-noise-interference ratio (SINR) is given by

$$SINR_n = \frac{WP_n}{D_{U(n)} I_n} \quad (1)$$

$$I_n = \sum_{i=1, i<>n}^{N} V_{U(i)} P_i + I_{other} + \eta \quad (2)$$

where,

$V_{U(i)}$	:	Activity Factor of class U(i)
I_{other}	:	Inter-cell Interference
H	:	Background noise

3.2. Our Scheduling Algorithm for Admissible Users

Given N active users. There is a request for a communications link (i.e. new call or hand-off).
By (1) and (2), we get the power of 0th user

$$P_0(1+1) = \frac{SINR_{U(0)} D_{U(0)}}{W} \sum_{i=1, i<>n}^{N} V_{U(i)} P_i(1) + I_{other}(1) + \eta \quad (3)$$

and wait until converges to decide admittance.

By using one-step matrix inversion,

$$P^* = [P_0^*, P_1^*, \ldots\ldots P_N^*] = X^{-1} y$$

$$X = \begin{Bmatrix} \dfrac{W}{SIR_{U(i)} D_{U(i)}}, & i = j \\ -V_{U(i)} & , \ i <> j \end{Bmatrix} \quad (4)$$

$$y_i = I_{other}(1) + \eta \quad , i = 1,2,\ldots..N \quad (5)$$

If X is non-singular, then solution is feasible and there is no need to wait for convergence. When a new call arrives, Priority is first given for Hand-off Calls than new call. Let Tk be the Upper threshold value to a new call.

Algorithm

If New Call Re*quest*
If $(0 < P_0^* < T_{U(0)})$ and $(0 < P_n^* < L_{U(0)})$
then
admit call
else
reject. call
If Hand - off request
If $(0 < P_n^* < L_{U(n)})$
then
admit call
else
reject. call

3.3. Distributed Power Control Algorithm

The main result of this section indicates that under some transmission constraints, the structure of the power control problem at hand is similar to the problem formulated and solved earlier for channelized cellular systems. According to [4], the uplink distributed power control algorithm executed by node follows the following iteration

$$P_i(N+1) = \frac{\beta}{SINR_i(N)} P_i(N) \text{ , for all i.} \quad (6)$$

where,

P_i power transmitted by node to its base station (BS);
$SINR_i$ signal-to-interference-and-noise ratio at BS;
N iteration number

The formulation of the power control problem for a valid scenario in CDMA wireless *ad hoc* networks is given by

$$Min \sum_{m \text{ links}} P_{ij} \quad (7)$$

such that

$$SINR_{ij} >= \beta$$

where P_{ij} is the power transmitted from node i to node j.

The power control problem for a valid transmission scenario in TDMA/CDMA wireless *adhoc* networks would have a formulation similar to (7).

4.Experimental Results

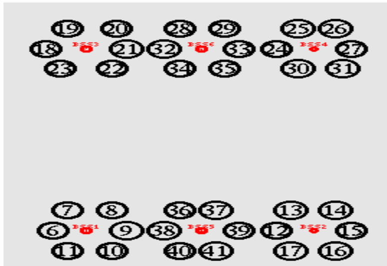


Fig. 2. CDMA system with 6 users in each cell.

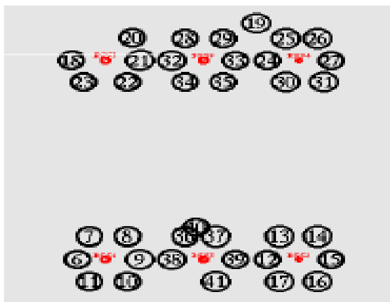


Fig. 3. CDMA system with user mobility

4.1 Simulation Setup

In this section, we simulate our proposed joint scheduling and power control algorithm in CDMA cellular networks for admissible and non-admissible transmission scenarios. The simulation parameters are given in Table 1. The simulation tool used s NS2. The NS2 simulation software [12] is a general-purpose simulation tool that provides discrete event simulation of user defined networks.

Number Of Nodes	36
No. of Cells	6
Users per Cell	6
Slot Duration	2 msec
SINR threshold	5
Frame Length	3 slots
Txpower	0.66 w
RxPower	0.395 w
Routing Protocol	AODV
Speed of mobile	25 m/s
Traffic Model	CBR

Table 1 Simulation Parameters

4.2. Simulation Results

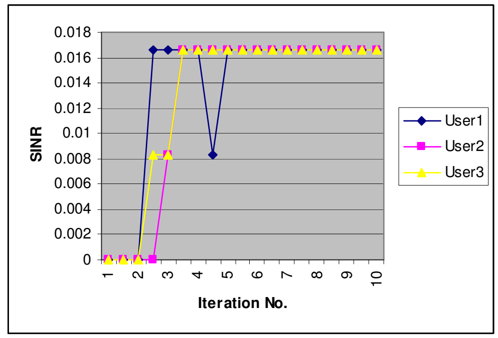


Fig4. Admissible scenario with 3 users

Let us consider a valid scenario that involves 3 links 19-22,28-35 and 25-31 from cell1, cell2 and cell3 respectively. First we will apply the power control algorithm to this valid scenario and the results are given in Fig4. We can see that the algorithm converges well for this admissible scenario.

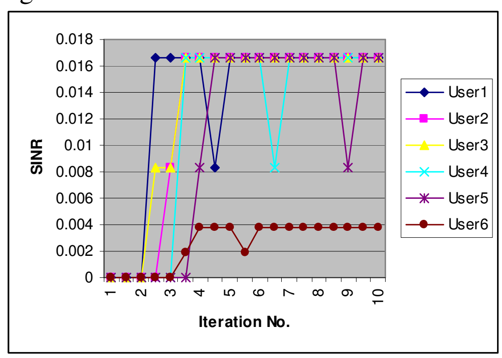


Fig5. Inadmissible scenario with 6 users

Now Let us consider the scenario that involves 6 links 19-22,28-35,25-31,7-10,13-16 and 36-41 from each of the six cells. At 3.0 seconds, the user starts moving from cell1 to cell 2. Fig.5 shows that it is an non-admissible scenario since the algorithm fails to converge.

Next, we show the average slot throughput and average power consumption for the optimum valid and admissible scenarios under various load conditions. Fig.6 and Fig.7 show the average slot throughput and power he for CDMA wireless *ad hoc* network.

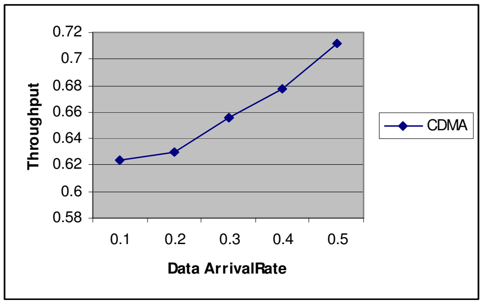


Fig6. Avg.Throughput of an admissible scenario links.

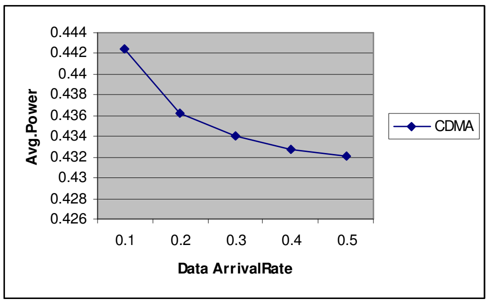


Fig7. Average Power of an admissible scenario

5. Conclusion

In this paper, we presented a cross-layer based joint algorithm for power control and scheduling in CDMA wireless adhoc networks to determine the optimum set of admissible users with optimum transmitting power level so as to minimize the interference level and call rejection rate. We solved the multiple access problem via two alternating phases until an admissible set of users, along with their transmission powers, is reached. We have tested the joint algorithm in a scenario of multi class users with mobility. In the first phase, a scheduling algorithm effectively admits the transmissions of static as well as mobile users of multi service classes, in order to eliminate strong levels of interference that cannot be overcome by power control. We give priority for the mobile users when determining the admissible set of users. In the second phase, a distributed power control algorithm determines the set of powers that could be used by the scheduled users to satisfy their transmissions. By simulation experiments, we evaluated the performance of our algorithm in a set of admissible and non-admissible users and show that power control algorithm converges for a set of admissible users.

References

[1] Jens Zander "Distributed Cochannel Interference Control in Cellular Radio Systems" IEEE Transactions on Vehicular Technology, Vol. 41, No. 3, August 1992.

[2] Goodman, D.J., N. Mandayam, "Power Control for Wireless Data", IEEE Pers. Comm., Vol. 7, No. 2, pp. 48 -54, Apr 2000.

[3] Cem U. Saraydar et al. "Efficient power control via pricing in wireless data networks" Communications, IEEE Transactions on Volume 50, Issue 2, Feb 2002 Page(s): 291 - 303

[4] Sennur Ulukus et al. "Stochastic Power Control for Cellular Radio Systems" Ieee Transactions On Communications, VOL. 46, NO. 6, JUNE 1998.

[5] T. ElBatt, S. Krishnamurthy, D. Connors, and S. Dao, "Power management for throughput enhancement in wireless ad hoc networks," Proc. IEEE ICC, 2000.

[6] I. Cidon and M. Sidi, "Distributed assignment algorithms for multihop packet radio networks," IEEE Trans. Comput., vol. 38, pp. 1353–1361, Oct. 1989.

[7] Ting-Chao Hou et al. "Transmission Range Control in Multihop Packet Radio Networks" Ieee Transactions On Communications. Vol. Com-34. No. I. January 1986

[8] R. Ramanathan et al. "Topology control of multihop wireless networks using transmit power adjustment," Proc. IEEE INFOCOM, 2000.

[9] Marianna Carrera et al. "A Cross-Layer Load-Independent Link Cost Metric for Wireless Mesh Networks" Proceedings of the ACM CoNEXT conference, December 2007.

[10] Yih-Hao Lin et al. "Distributed Link Scheduling, Power Control and Routing for Multi-hop Wireless MIMO Networks" Signals, Systems and Computers, 2006. ACSSC '06. Fortieth Asilomar Conference on Publication Date: Oct.-Nov. 2006

[11] S. Malarkkan et al. "Performance Analysis of Call Admission Control in WCDMA Systems with Mobility based Interference Margin Reservation" Science Publications *Journal:* Journal of Computer Science *Volume:* 2 *Issue:* 10 (2006-01).

[12] Mikael Skoglund et al. "Cross-Layer Issues in Wireless Multimedia Internetworking" Final Project Report, Sept. 2005