A Cross-Layer Based Joint Algorithm for Power Control and Scheduling in CDMA Wireless Ad-Hoc Networks

[1]REKHA PATIL, [2]A. DAMODARAM
[1]Assistant Professor, Computer Science and Engineering Department
P D A College of Engineering, Gulbarga,
INDIA
[2]Professor, Computer Science and Engineering Department,
JNTU College of Engg., JNT University, Hyderabad,
INDIA
E-mail: [1]rekha.patilcse@gmail.com, [2]damodarama@gmail.com

Abstract: - In CDMA wireless ad-hoc networks; an important goal is, permitting the requested calls of different users maintaining the quality of service. Because of interference and power, the CDMA capacity is restricted in general. The interference will increase as soon as the number of users rises by the reason of non-orthogonal factor. Consequently, there is a limit to the maximum number of users. In this paper, a cross-layer based joint scheduling and power control algorithm has been proposed with the objective of minimizing the interference level and call rejection rate. For achieving this, the algorithm determines the optimum set of admissible users with suitable transmitting power level. 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 performance of our algorithm in a set of admissible and non-admissible users has been assessed using simulation results. Moreover, it is exposed that power control algorithm converges for a set of admissible users.

Key-Words: - Ad-hoc networks, CDMA, SINR (signal-to-interference-and-noise ratio), QoS (Quality of service), BER (bit-error rate), Cross layer design.

1 Introduction

1.1 CDMA Wireless Ad Hoc Networks

The world is demanding more from wireless communication technologies than ever before as more people around the world are subscribing to wireless. Add in exciting Third-Generation (3G) wireless data services and applications - such as wireless email, web, digital picture taking/sending, assisted-GPS position location applications, video and audio streaming and TV broadcasting - and wireless networks are doing much more than just a few years ago. This is where CDMA technology fits in. CDMA consistently provides better capacity for voice and data communications than other commercial mobile technologies, allowing more subscribers to connect at any given time, and it is the common platform on which 3G technologies are built.

Spread spectrum technology is used in CDMA. It allows many users to utilize the same time and frequency allocations within a given band. Each communication is assigned unique codes by CDMA, to distinguish it from other users in the same spectrum. CDMA provides the facility to share the airwaves by many people at the same time than do alternative technologies.

Both 2G and 3G networks uses the CDMA air interface. The two main IMT-2000 standards CDMA-2000 and WCDMA are based on CDMA.

A distinctive pre-assigned signature sequence is present in every node ahead of the TDMA scheme. It can be utilized to encode the broadcasted symbols. Our main aim is apply our algorithm introduced for cellular CDMA systems, to contention-based wireless ad hoc networks.

The physical layer assumptions underlying the system are initially introduced. We take a simple signaling structure with BPSK modulation.

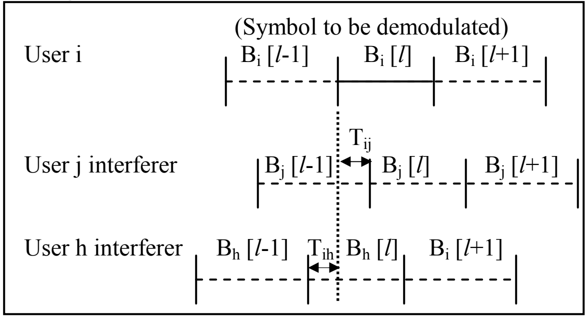

Fig. 1: Asynchronous CDMA system.

The noise is considered to be independent of the symbols and has variance σ^2. To modulate their information bits, users are supposed to include pre-assigned unique signature sequences. 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. We assume that all other users induce interference asynchronously. For each user the relative delays of the users can have any value less than the bit duration T_b. They do not change with time and are assumed to have a uniform distribution. For the l^{th} bit of a given user, an interfering user creates interference by 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. 1, two possible cases are depicted. The delay of user relative to the matched filter of user i is denoted T_{ij}. In Fig. 1, user has a positive delay relative to user and creates interference to the l^{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 l^{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 $\bar{\rho}_{ij}$, ρ_{ij}, and $\tilde{\rho}_{ij}$ 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

In Cellular wireless communication systems the aim of power control is to assign each user a transmitter power level such that all users satisfy their quality-of-service (QoS) requirements. The power control algorithms that have been developed to date may be classified as centralized or distributed, synchronous or asynchronous, iterative or non-iterative, constrained or unconstrained. The optimal power vector was found by inversion of a matrix which was composed of channel gains of all users. Those algorithms were non-iterative, synchronous, and centralized in the sense that all the power vector components were found by a matrix inversion.

The power control algorithms that have been developed to date are deterministic in the sense that they require the exact knowledge or perfect estimates of some deterministic quantities such as:

1) Signal-to-Interference Ratio (SIR),

2) Received Interference Power, or

3) Bit-Error rate.

Unfortunately, none of those quantities is easy to estimate perfectly, and deterministic convergence results are no longer valid when these deterministic variables are replaced with their random estimates. This observation highlights the need for the study of new power control algorithms that make use of available measurements, evolve stochastically, and converge in a stochastic sense.

For cellular networks (both open loop and closed loop), Power control (PC) has been examined comprehensively. Justifying the near-far effect, and therefore lessening the performance degradation originated by multiple access interference (MAI) is the most important intend of power control in cellular networks. It presumes added significance whereas power control for ad hoc networks assists to complete a related objective, since restricted battery life is a main issue for mobile nodes in such networks (sensor networks in particular). Accordingly, to improve network throughput/lifetime or a few other network metrics, the proper consumption of the inadequate energy resources of each node has been intended by PC. To competing nodes in a proficient way, assigning the wireless channel is aspired by scheduling. MAI is condensed in that order. On the other hand, each node guarantees a least tolerable level of performance in conditions of metrics for instance data rate, delay, probability of error etc simultaneously.

In the perspective of channelized cellular systems [2], [4], code-division multiple-access (CDMA)-based systems [7], and in a common structure [8], power control has been learnt comprehensively. For cellular systems, dispersed iterative power control algorithms have been introduced. Moreover, convergence results have been recognized [2], [4], [8]. Inventing the dispersed power control problem has been paid attention in recent times as a non-cooperative game [9]–[12]. To integrate the ideas of utility and cost, the authors customized the power control problem formulation in [12]. These are made known to progress the convergence personalities of the algorithm.

Permitting the requested calls of different users maintaining the quality of service is a rule.

Consistent with the users' quality of service necessities and the existing transfer load, the necessary verdict has to be made to allow the user into the system. Because of interference and power, the CDMA capacity is restricted in general. The interference will increase as soon as the number of users rises by the reason of non-orthogonal factor. Consequently, 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 problems 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 presents the assumptions and definitions of our system. Section 4 gives our scheduling and power control algorithm along with the system model. Section 5 presents the experimental results and Section 6 concludes the paper.

2 Related Work

Distributed power control algorithms, using just the signal-to-interference (C/I) ratios in those links essentially in use are examined by Jens Zander [1]. To approximate the conducts of the best-known algorithms effectively, a new algorithm is recommended. A novel distributed C/I- balancing scheme, is engrossed by the algorithm.

David Goodman et al. [2] "utility" is referred to be the Quality of Service of a telephone call and "non-cooperative game" is known as the distributed power control problem for a CDMA telephone. A price function, proportional to transmitter power, is included in the algorithm. The terminals reach at lesser power levels and higher utility, whilst they regulate their power levels to make the most of the net utility (utility - price). This value is higher than they attain while they independently attempt to maximize utility.

With the impact of costing the handling of wireless services on QoS has principally worried by Cem U. Saraydar et al. [3]. On account of its capability to lead user behavior in the direction of a more competent operating point, Pricing of services in wireless networks appears as an efficient tool for radio resource management. In wireless data networks, a model for power control has been introduced subsequently using concepts from microeconomics.

Distributed iterative power control algorithms to utilize readily existing measurements have been proposed by Sennur Ulukus et al. [4]. Two classes of power control algorithms are recommended. The proposed algorithms progress stochastically, in view of the fact that the measurements are arbitrary. Moreover, in terms of the mean-squared error (MSE) of the power vector from the optimal power vector, the junction is defined, i.e. the solution of a feasible deterministic power control problem.

The benefits, and probably the tradeoffs of deploying dissimilar transmit powers in the wireless ad-hoc environment are examined by Tamer A. ElBatt et al. [5]. With perhaps slight adjustments, a power management scheme is proposed that could be utilized in conjunction through established table-driven routing protocols. The chosen uninterrupted network throughput takes the performance measures and the common power utilization.

For a multihop packet radio network, distributed dynamic channel assignment algorithms are initiated. Through the nodes of the network, it guarantees conflict-free broadcasts. The shared channel is cracked into a control segment and a transmission segment using this algorithm. Conflicts between nodes are evaded through the control segment. In addition, the control segment increases the utilization of the transmission segment.

For examining the performance of transmission strategies in a multihop packet radio network, having adaptable transmission radius for each station, a model has been offered by Ting-Chao Hou et al. [7]. The probability of discovering a receiver in the preferred direction would be improved by means of a larger transmission radius. Also it will contribute better advancement if the transmission is triumphant. But it also has a higher probability of impact with other transmissions. For smaller broadcast range, the communication is true. With evaluating three transmission strategies, the model is exemplified.

To multihop wireless networking, Ram Ramanathan et al. [8] has given distinctive contributions. As a constrained optimization trouble of practical significance, the topology control has been devised; specifically as reducing transmit power subject to the network being connected or bi-connected. A latest investigative demonstration, more common and realistic than the conservative one, of multihop wireless networks has been commenced by it. With local information for assisting in further distributed control problems, these heuristics engross methods for global harmonization.

Cross-layer Unicast Transmission Time (X-UTT), a MAC-aware load-independent link cost metric for 802.11 rooted wireless mesh networks have been offered by Marianna Carrera et al. [9]. Information obtained from a network-layer unicast inquisitive system along with a MAC-layer monitoring system has been exploited by X-UTT. For detaining the wireless link capability and for being autonomous of the self-interference and cross-interference stimulated load in a mesh network, this is been planned.

To lessen the standard power consumption of the system whereas upholding the uninterrupted throughput if reasonable, a locally centralized algorithm has been built by Yih-Hao Lin et al. [10]. One may possibly reinstate the MIMO broadcast subsystem through a few added multi-user subsystem structures, for instance a MIMO multi-access network with the similar method.

Derived from the mobility of the users in WCDMA cellular systems, concert of call permission control and resource reservation schemes have been presented by S. Malarkkan et al. [11]. The mobility of the user is forecasted based on a reasonable mobility model with the aim of assuring the handoff reducing probability. To accomplish an improved equilibrium between promising handoff-dropping probabilities and make the most of resource consumption, the admission threshold is adaptively controlled.

Associated topics have been addressed by Mikael Skoglund et al. [12] to several of the traditional layers. The alienated layers paradigm by examining numerous dissimilar features of cross-layer optimization has been defied at the central part of the project. By means of cross-layer techniques, the benefits attainable against the cost of executing them are addressed.

Peter Marbach et al. [13] developed a new approach which allows us to avoid the use of a reduced model, explicitly decomposing the network process into independent link processes. They have used the methods of neuro-dynamic programming (NDP) [reinforcement learning (RL)], together with a decomposition approach, to construct dynamic (state-dependent) call admission control and routing policies. These policies are based on state-dependent link costs, and a simulation-based learning method is employed to tune the parameters that define these link costs.

Gavin Holl et al. [14] proposed a rate adaptive MAC protocol called the Receiver-Based AutoRate (RBAR) protocol. The novelty of RBAR is that its rate adaptation mechanism is in the receiver instead of in the sender. They have showed that RBAR is better because it results in a more efficient channel quality estimation which is then reflected in a higher overall throughput. This protocol is based on the RTS/CTS mechanism and consequently it can be incorporated into many medium access control protocols including the widely popular IEEE 802.11 protocol.

Young-Long Chen et al. [15] proposed centralized call admission control (CCAC) scheme is to combine the two mechanisms and to treat the call admission decision as an eigen-decomposition problem. In the proposed approach, a new call is accepted only if the quality-of-service (QoS) requirements of all the active links in the network can still be maintained. In order to reduce the computational complexity of the eigen-decomposition problem, they have proposes an additional scheme which uses a norm operation rather than direct computation.

A call admission control (CAC) scheme and a resource reservation estimation (RRE) method suitable for the wideband code division multiple access (W-CDMA) systems are proposed in H. Chen et al. [16]. The proposed CAC scheme gives preferential treatment to high priority calls, such as handoff calls, by pre-reserving a certain amount of channel margin against the interference effect. It is called the interference guard margin (IGM) scheme. The amount of guard margin is determined by the measurement performed by the RRE module in base stations. Each RRE module dynamically adjusts the level of guard margin by referencing traffic conditions in neighboring cells based upon users' requests.

Jyoti Laxmi Mishra [17] analyzed the different types of call admission control algorithm is done. The aim of this research is to enhance the same algorithm with multiclass users and multiservice using fuzzy logic. They have improved and enhanced the QoS by generating efficient CAC algorithm for multiclass users. The fuzzy based CAC scheme for wideband CDMA cellular system, to meet the challenges in CAC due to user mobility, limited radio spectrum, heterogeneous and dynamic nature of multimedia traffic, and QoS constraints has been studied and its performance is analysed in S.Malarkkan and V.C.Ravichandran [18].

Zouhair El-Bazzal et al. [19] proposed an Efficient Clustering Algorithm (ECA) in Mobile Ad hoc Networks based on the quality of service's (QoS) parameters (cluster throughput/delay, packet loss rate). The goals are yielding low number of clusters, maintaining stable clusters, and minimizing the number of invocations for the algorithm. They have implemented a new admission control algorithm that provides the desired throughput and access delay performance in order to determine the number of members inside an ECA cluster that can be accommodated while satisfying the constraints imposed by the current applications.

Osamah Badarneh et al. [20] presented the multilayered multicast routing in ad hoc wireless network. Two algorithms for constructing multiple trees to meet the requirements (number of video layers requested) of destination nodes were proposed and their complexities were analyzed. In addition, simple video layers assignment was proposed. Simulation results demonstrate that the multiple trees algorithms achieve higher USR as compared with the single trees algorithms with some increase in number of forwarding nodes.

Tzay-Farn Shih and Hsu-Chun Yen [21] proposed a routing algorithm that uses Dijkstra algorithm to calculate route in a cluster-by-cluster basis. This cluster-based protocol reduces the number of nodes participate in routing. Calculating route by Dijkstra algorithm also reduces a lot of routing traffic and route setup time. In CLACR, the routing packets and data packets are transmitted by unicast, which reduces the probability of collision and diminishes broadcast storm problem. The simulation results showed that CLACR has much better performance than LAR1.

Bazil Taha Ahmed et. al [22] calculated the uplink capacity and interference statistics of air-ground W-CDMA system.

3 Assumptions And Definitions

In this section, we provide the assumptions underlying this study and introduce appropriate notation:

1) Consider a wireless *ad hoc* network consisting of n nodes. There is no wireline infrastructure to interconnect the nodes, i.e., they can communicate only via the wireless medium.
2) Each node is supported by an omni-directional antenna.
3) Each node knows the geographical location of all other nodes via *location discovery* schemes. This information is necessary for the receivers to feedback their SINR measurements to their respective transmitters.
4) Assume that all nodes share the same frequency band, and time is divided into equal size slots that are grouped into frames.
5) The slot duration is assumed to be larger than the packet duration by an interval called a "guard band." These bands are necessary to compensate for arbitrary delays incurred by transmitted packets due to signal propagation delays and/or clock drifts
6) We assume that the frame length is fixed throughout system operation. It is chosen, heuristically, depending on the number of nodes, network load, and quality-of-service constraints.
7) Each node generates data packets of fixed length, destined to all other nodes, according to a Poisson distribution with aggregate rate packets/second.
8) We assume that each generated packet is intended for a single neighbor only, i.e., the cases of broadcasting and multicasting are out of the scope of this work.
9) We assume a maximum power level, denoted, that a node can use for transmission. This is enforced by the limited weight and size of the wireless terminal.
10) The interference model adopted assumes that each node in the area could potentially cause interference at any receiving node, even if it is too far.
11) The power decay law is assumed to be inversely proportional to the fourth order of the distance between the transmitter and the receiver. Accordingly, the link gain matrix is assumed to be constant throughout this study.
12) We assume the existence of a separate feedback channel that enables receivers to send their SINR measurements to their respective transmitters in a *contention-free* manner. This can be justified based on the fact that feedback messages are typically smaller than data packets and, hence, the scarce wireless bandwidth will not be wasted.
13) Define the average slot throughout as the long-run average of the percentage of packets successfully received by single-hop neighbors in each time slot

4 Our Scheduling Algorithm for Admissible And Non-Admissible Users

4.1 System Model

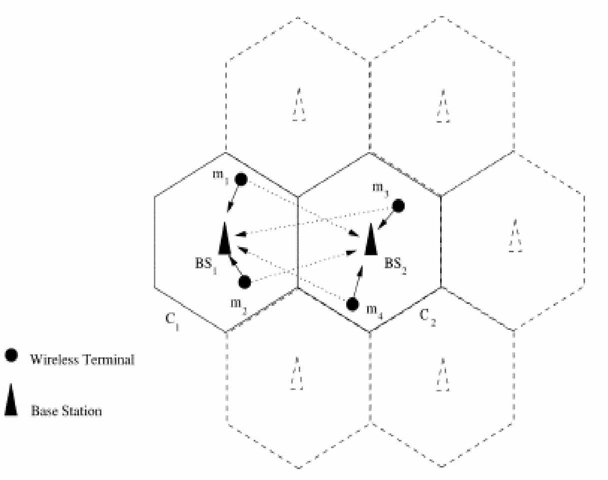

Fig. 2: CDMA System with N users

Consider a CDMA system with N active users in each Cell and there are M user classes (refer Fig. 2). In CDMA wireless *ad hoc* networks, a transmission scenario 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 $\in (0, L_m]$
- 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

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

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

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

4.2 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

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

and wait until converges to decide admittance.

By using one-step matrix inversion,

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

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

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

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 Request
If $(0 < P_0^* < T_{U(0)})$ and $(0 < \mathrm{P_n}^* < L_{U(0)})$
  then
      admit call
    else
      reject. call
If Hand - off request
    If $(0 < P_n^* < L_{U(n)})$
      then
        admit call
      else
        reject. call
```

4.3 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

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

Here,

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

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

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).

5 Experimental Results

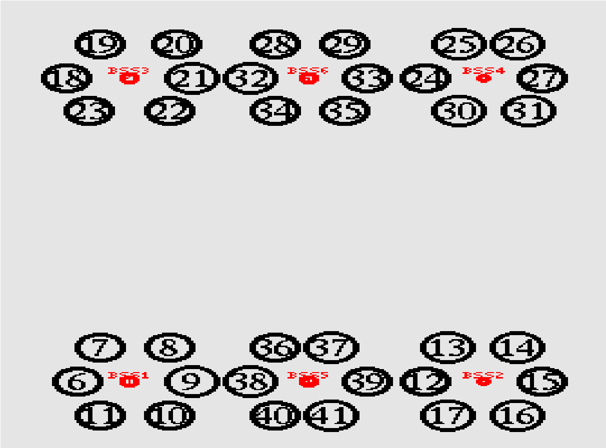

Fig. 3: CDMA system with 6 users in each cell.

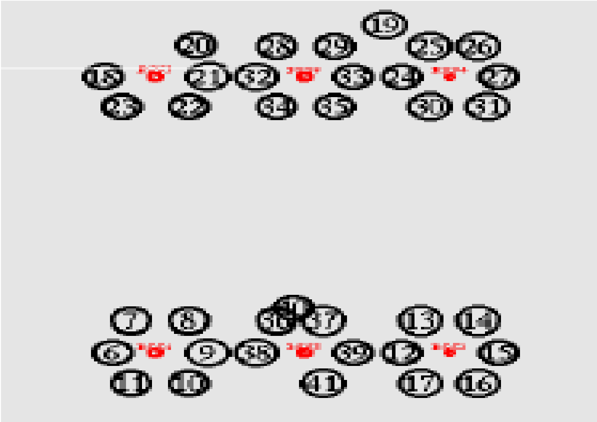

Fig. 4: CDMA system with user mobility

5.1 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 tool used is NS2. The NS2 simulation software [12] is a general-purpose simulation tool that provides discrete event simulation of user defined networks.

In our simulation, the channel capacity of mobile hosts is set to the same value: 2 Mbps. The distributed coordination function (DCF) of IEEE 802.11 for wireless LANs as the MAC layer protocol is used. It has the functionality to notify the network layer about link breakage. In the simulation, mobile nodes move in a 600 meter x 600 meter rectangular region for 50 seconds simulation time. Initial locations and movements of the nodes are obtained using the random waypoint (RWP) model of NS2. All nodes have the same transmission range of 250 meters. We have the simulation setup is as per Fig. 3. We divided the area into 6 cells. Each cell consists of 6 users. The CDMA system with user mobility is depicted in Fig. 4.

The simulation parameters are summarized in Table 1.

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

5.2 Simulation Results

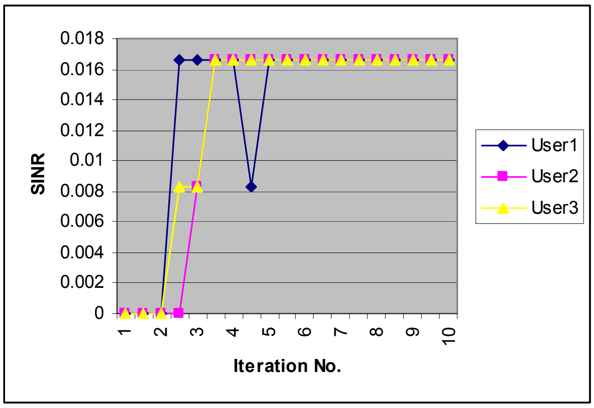

Fig. 5: Admissible scenario with 3 users

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 Fig. 5. We can see that the algorithm converges well for this admissible scenario.

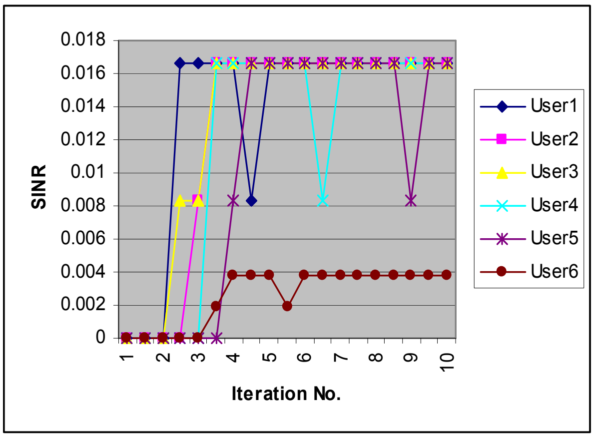

Fig. 6: Inadmissible scenario with 6 users

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. 6 shows that it is a non-admissible scenario since the algorithm fails to converge.

Next, we show the average slot throughput and packet loss for the optimum valid and admissible scenarios under various load conditions. Fig.7 and Fig.8 show the average slot throughput and packet loss for CDMA wireless *ad hoc* network, respectively.

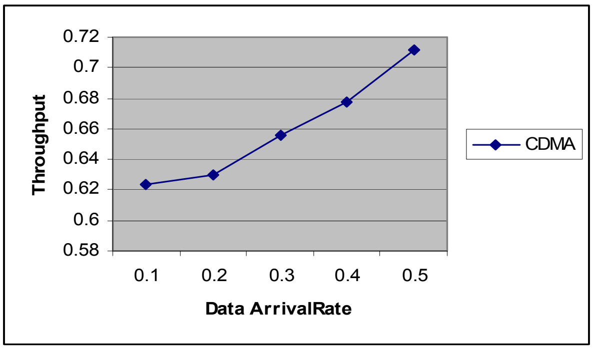

Fig. 7: Avg. Throughput of an admissible scenario

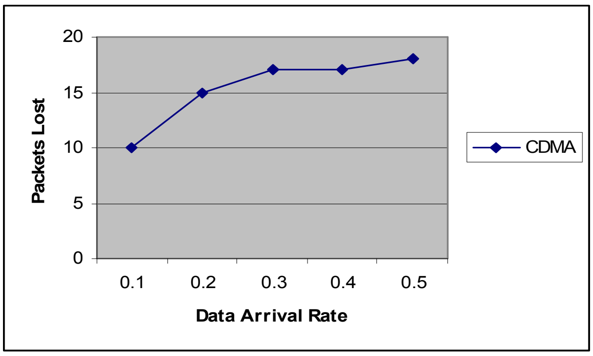

Fig. 8: Average Packet Loss of an admissible scenario

Next, we show the average power consumption for the optimum valid and admissible scenarios under various load conditions. Fig.9 shows the average power consumption for CDMA wireless *ad hoc* network.

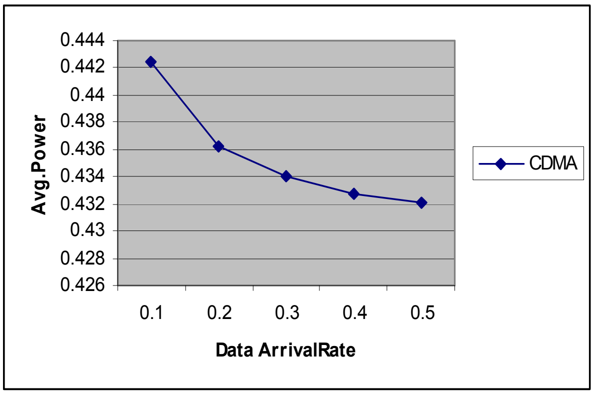

Fig. 9: Average Power of an admissible scenario

6 Conclusion

In this paper, a cross-layer based joint scheduling and power control algorithm has been proposed with the objective of minimizing the interference level and call rejection rate. For achieving this, the algorithm determines the optimum set of admissible users with suitable transmitting power level. We solved the multiple access problem via two alternating phases until an admissible set of users, along with their transmission powers, is reached. We give priority for the mobile users when determining the admissible set of users. We have tested the joint algorithm in a scenario of multi class users with mobility. In the scheduling algorithm, the transmissions of static as well as mobile users of multi service classes are admitted effectively, in order to eliminate strong levels of interference that cannot be overcome by power control. In the distributed power control algorithm, the set of powers that could be used by the scheduled users to satisfy their transmissions are determined. 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", *IEEE Transactions on Communications* 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" *Fortieth Asilomar Conference on Signals, Systems and Computers, 2006. ACSSC '06.* 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.

[13] Peter Marbach, Oliver Mihatsch, and John N. Tsitsiklis "Call Admission Control and Routing in Integrated Services Networks Using Neuro-Dynamic Programming" *IEEE Journal On Selected Areas In Communications*, Vol. 18, No. 2, February 2000

[14] Gavin Holl, Nitin Vaidya and Paramvir Bahl "A Rate-Adaptive MAC Protocol for Multi-Hop Wireless Networks" International Conference on Mobile Computing and Networking, *Proceedings of the 7th annual international conference on Mobile computing and networking 2001.*

[15] Young-Long Chen, Jyu-Wei Wang, Jyh-Liang Chen and Jyh-Horng Wen "Performance of Call Admission Control with Power Control in Multimedia Cellular Systems" *International Journal of Applied Science and Engineering* 2007. 5, 1: 65-74.

[16] H. Chen, S. Kumar and C.-C. Jay Kuo, "Interference-based Guard Margin Call Admission Control for CDMA Multimedia Wireless Systems", *Proc. SPIE Visual Communications and Image Processing Conf.*, Jan. 20-25, 2002, San Jose, CA, Vol. 4671, pp. 344-355.

[17] Jyoti Laxmi Mishra, Keshav. P. Dahal and M.A. Hossain "Multiclass Call Admission Control for Performance Evaluation of Wideband CDMA" *IWS 2006.*

[18] S.Malarkkan, and V.C.Ravichandran "Performance Analysis of Call Admission Control in WCDMA System with Adaptive Multi Class Traffic based on Fuzzy Logic" *IJCSNS International Journal of Computer Science and Network Security,* VOL.6 No.11, November 2006

[19] Zouhair El-Bazzal, Michel Kadoch, Basile Agba And Francois Gagnon "Performance Improvement of Clustered Mobile Ad hoc Networks using a CDMA Single Channel and Based on Admission Control Approach" *WSEAS Transactions On Communications*, Feb. 26, 2008.

[20] Osamah Badarneh, Michel Kadoch, Ahmed Elhakeem "Multilayered Multicast Algorithms for Ad Hoc Wireless Networks" *7th WSEAS Int. Conf. on Applied Computer & Applied Computational Science (ACACOS '08),* Hangzhou, China, April 6-8, 2008

[21] Tzay-Farn Shih And Hsu-Chun Yen "Core Location-Aided Cluster-Based Routing Protocol for Mobile Ad Hoc Networks" *Proceedings of the 10th WSEAS International Conference on Communications, Vouliagmeni, Athens, Greece,* July 10-12, 2006 (pp223-228).

[22] Bazil Taha Ahmed, Miguel Calvo Ramon, and Ramon Martinez Rodriguez-Osorio "Uplink (Reverse Link) Capacity of an Air-Ground W-CDMA System" *12th WSEAS International Conference on Communications, Heraklion, Greece,* July 23-25, 2008.