International Journal of Engineering Research and General Science Volume 2, Issue 3, April-May 2014
ISSN 2091-2730

Optimization of Transmission Power in Ad Hoc Network

M.D. Boomija[1]

[1]Assistant Professor, Department of IT, Prathyusha Institute of Technology and management, Chennai, Tamil Nadu
Email: boomija.md@gmail.com

ABSTRACT - A mobile ad-hoc network is a infrastructure less, self-configuring network of mobile devices. Infrastructure less networks have no fixed router, all nodes are capable of movement and can be connected dynamically in an arbitrary manner. Nodes of these networks function as routers which discover and maintain routes to other nodes in the network. Each device in a mobile ad hoc network is free to move independently in all direction, and will therefore change its links to other devices frequently. The primary challenge in building an ad hoc is equipping each device to continuously maintain the information required to properly route traffic. The Optimization of Mobile Ad Hoc Network System Design engine works by taking a specification of network requirements and objectives and allocates resources which satisfy the input constraints and maximize the communication performance objective. The tool is used to explore networking design options and challenges, including power control, flow control, mobility, uncertainty in channel models and cross-layer design. The project covers the case study of power control analysis.

Keywords— Ad hoc network, optimization, power control, Time slot, MIMO, AMPL, Multi objective optimal

I INTRODUCTION

A mobile ad-hoc network (MANET) is a self-configuring network of mobile routers topology. The routers are free to move randomly and organize themselves at random. So, the network's wireless topology may change rapidly and unpredictably. Such a network may operate in a standalone fashion, or may be connected to the larger Internet. Minimal configuration and quick deployment make ad hoc networks suitable for emergency situations like natural or human induced disasters, military conflicts, emergency medical situations etc.

Optimization of Mobile Ad hoc network system as in Fig 1, the network design is approached as a process of optimizing variables. The optimization of network parameters is a feedback process of optimization and performance estimation through simulation. Two approaches (i) Generic Solver (ii) Specialized method. The set of control variables and objective parameters are the input to the project. If specialized method is available for the given problem, then the solution is formulated by using AMPL modeling language. It is a comprehensive and powerful algebraic modeling language for linear and nonlinear optimization problems.

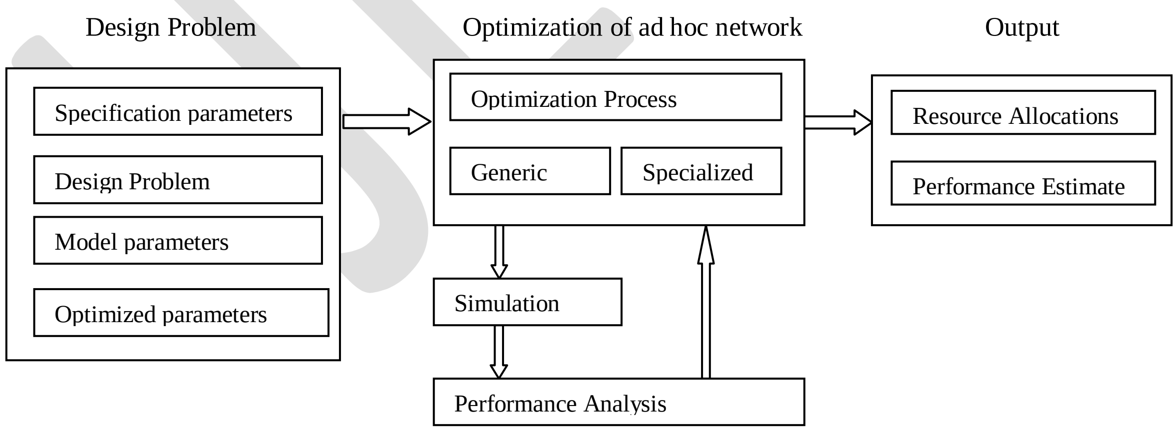

Fig 1 Mobile ad hoc network framework

II OPTIMIZATION PROBLEM

Optimization refers to the process of making a device or a collection of devices run more efficiently in terms of time and resources (e.g., energy, memory). Optimization is a necessity for MANET management decisions due to the inherent individual and collective resource limitations within the network. Mathematically, optimization entails minimizing or maximizing an objective function by choosing values for the input variables from within an allowed set. An objective function is a mathematical expression made up of one or more variables that are useful in evaluating solutions to a problem. [4]

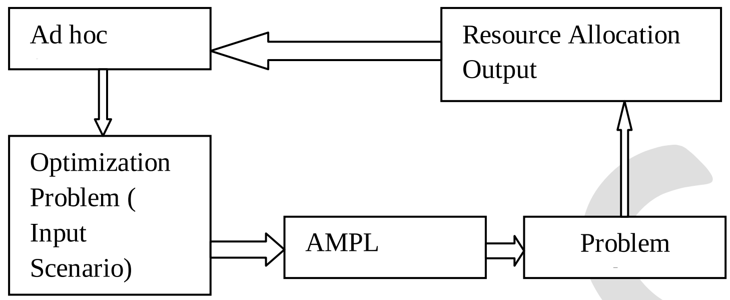

Fig 2 Optimization problem in AMPL

Mathematical explanation of optimization

Set : A = a set of feasible solutions to the objective function, f

Variable : x = an element (a vector of input variables) in the set of feasible solutions, A

Objective Function: f = a given function

If the optimization problem calls for minimizing the results of the function, then we find an element, x_0, of the set A such that: $f(x_0) \leq f(x)\ \forall x \in A$

If the problem calls for maximizing the results, then we find an element, x_0, of the set A such that: $f(x_0) \geq f(x)\ \forall x \in A$

The elements of the *allowed set*, *x*, are combinations of variable assignments that result in a *feasible solution* (a solution that satisfies all of the constraints in the optimization problem). A feasible solution that minimizes or maximizes the value of the objective function is called an *optimal solution*. [6]

The first step is to find an optimization method most appropriate to the set of control variables and objectives provided as input. If no specialized algorithm is available in the framework for the specified problem, then the problem is formulated as a mathematical program in the AMPL modeling language as shown in Fig. 2.

An appropriate generic solver is then used to solve the program, depending on whether objectives and constraints are linear or nonlinear, and whether the variables are discrete or continuous. [12] The power control problem of minimizing power under a signal-to-noise-interference constraint is an example of a linear program which is optimized using this generic solver approach. If a specialized method is available for the problem, the framework automatically uses it to find a solution. An example of a specialized method is a heuristic packing procedure. It schedules a set of concurrent transmissions and ensures a chance for every node to transmit at least once. [3]

III RELATED WORK

The generally accepted network design cycle consists of three steps: 1) developing a network model 2) estimating the performance of the proposed network through simulation 3) manually adjusting the model parameters until an acceptable performance is achieved for the target set of scenarios. The complexity of networks and the large number of design parameters, changes in the design of a model may have unintended effects. This project allows the designer to control high-level objectives instead of controlling low-level decision variables. It applies optimization theory to generalized networking models. The existing optimization techniques combined with the simulation capabilities of existing tools for the task of performance estimation.

IV SOFTWARE DESIGN

The ad hoc framework has two distinct forms: 1) an application with a graphical user interface and 2) a library with an application programming interface. The former is an interface for human users while the latter is an interface for other programs that link against it. One of the goals of the proposed framework as a network design tool is to provide a mechanism for comparing network technologies. Each such model or algorithm is implemented in this framework in a modular way such that it can be swapped out for any number of alternatives. The GUI provides a streamlined way of configuring multiple alternatives, and compare and test them through concurrent simulation and optimization. Without the need of any modification, the API supports such an extension. A set of control parameters only added with the new extension. These parameters are then automatically added to the GUI through active generative programming

V NETWORK DESIGN

The resources which are to be efficiently allocated on an ad hoc wireless network are naturally distributed, residing either on the nodes or the edges of the graphs that represent the network state. The algorithms in this framework are separated into two categories: 1) centralized and 2) distributed. The former operates on single snapshots or on a time-averaged model of the global network state. The latter operates as a control mechanism on the node.

VI POWER CONTROL ANALYSIS

A. Introduction

Allocation of physical resources (e.g., transmission power) based on knowledge of the network state is often complicated by the presence of uncertainty in the available information. Therefore, when the characteristics of the wireless propagation channel are highly dynamic or only noisy measurements are available, the framework represents the uncertainty as a collection of S samples of each channel state Hij in which represent a range of values that each channel between a transmitter and a receiver can take on. The problem of optimally allocating resources under such a statistical representation of the channels can be solved in the proposed model by assuming the distribution mean for each channel state or by using a optimization method which seeks to quantify the dependability of the resource allocation solution. [1]

A fundamental problem in this optimization method is the tradeoff between feasibility and optimality. It may be interpreted to be a multi objective optimization problem with two objectives: maintain feasibility and seek optimality. With this view in mind, a Pareto front can be constructed to demonstrate the tradeoff between the two objectives. A network designer then only provides this framework with 1) the requirement of sufficiently high feasibility or 2) a ceiling for the transmission power on the network.

B. Multi Objective Optimal

Multi objective optimization (known as multi objective programming, vector optimization, multi criteria optimization multi attribute optimization or Pareto optimization) is an area of multiple criteria decision making, that is concerned with mathematical optimization problems involving more than one objective function to be optimized simultaneously. Multi objective optimization has been applied in many fields of science, including engineering, economics and logistics where optimal decisions need to be taken in the presence of trade-offs between two or more conflicting objectives. [7]

In practical problems, there can be more than three objectives. For a nontrivial multi objective optimization problem, there is not a single solution that simultaneously optimizes each objective. In that case, the objective functions are said to be conflicting, and there exists a (possibly infinite number of) Pareto optimal solutions. A solution is called non dominated, Pareto optimal, Pareto efficient or non inferior, if none of the objective functions can be improved in value without impairment in some of the other objective values. Without additional preference information, all Pareto optimal solutions can be considered mathematically equally good (as vectors cannot be ordered completely). Researchers study multi objective optimization problems from different viewpoints and, thus, there exist different solution philosophies and goals when setting and solving them. The goal may be finding a representative set of Pareto optimal solutions, and/or quantifying the trade-offs in satisfying the different objectives, and/or finding a single solution that satisfies the preferences of a human decision maker. [2]

A multi objective optimization problem is an optimization problem that involves multiple objective functions. In mathematical terms, a multi objective optimization problem can be formulated [5]

$$\begin{aligned} &\min \left(f_1(x), f_2(x), \ldots, f_k(x)\right)^T \\ &\text{s.t. } x \in X, \end{aligned}$$

where the integer $k \geq 2$ is the number of objectives and the set X is the feasible set of decision vectors defined by constraint functions. In addition, the vector-valued objective function is often defined as [8]

$$f : X \to \mathbb{R}^k,\ f(x) = (f_1(x), \ldots, f_k(x))^T.$$

If some objective function is to be maximized, it is equivalent to minimize its negative. The image of X is denoted by $Y \in \mathbb{R}^k$ An element $x^* \in X$ is called a feasible solution or a feasible decision. A vector $z^* := f(x^*) \in \mathbb{R}^k$ for a feasible solution x^* is called an objective vector or an outcome. In multi objective optimization, there does not typically exist a feasible solution that minimizes all objective functions simultaneously.[9] Therefore, attention is paid to Pareto optimal solutions, i.e., solutions that cannot be improved in any of the objectives without impairment in at least one of the other objectives. In mathematical terms, a feasible solution $x^1 \in X$ is said to (Pareto) dominate another solution $x^2 \in X$, if

1. $f_i(x^2) \leq f_i(x^1)$ for all indices $i \in \{1, 2, \ldots, k\}$ and
2. $f_j(x^2) < f_j(x^1)$ for at least one index $j \in \{1, 2, \ldots, k\}$. [7]

A solution $x^1 \in X$ (and the corresponding outcome $f(x^*)$) is called Pareto optimal, if there does not exist another solution that dominates it. The set of Pareto optimal outcomes is often called the Pareto front. [11]

VII IMPLEMENTATION

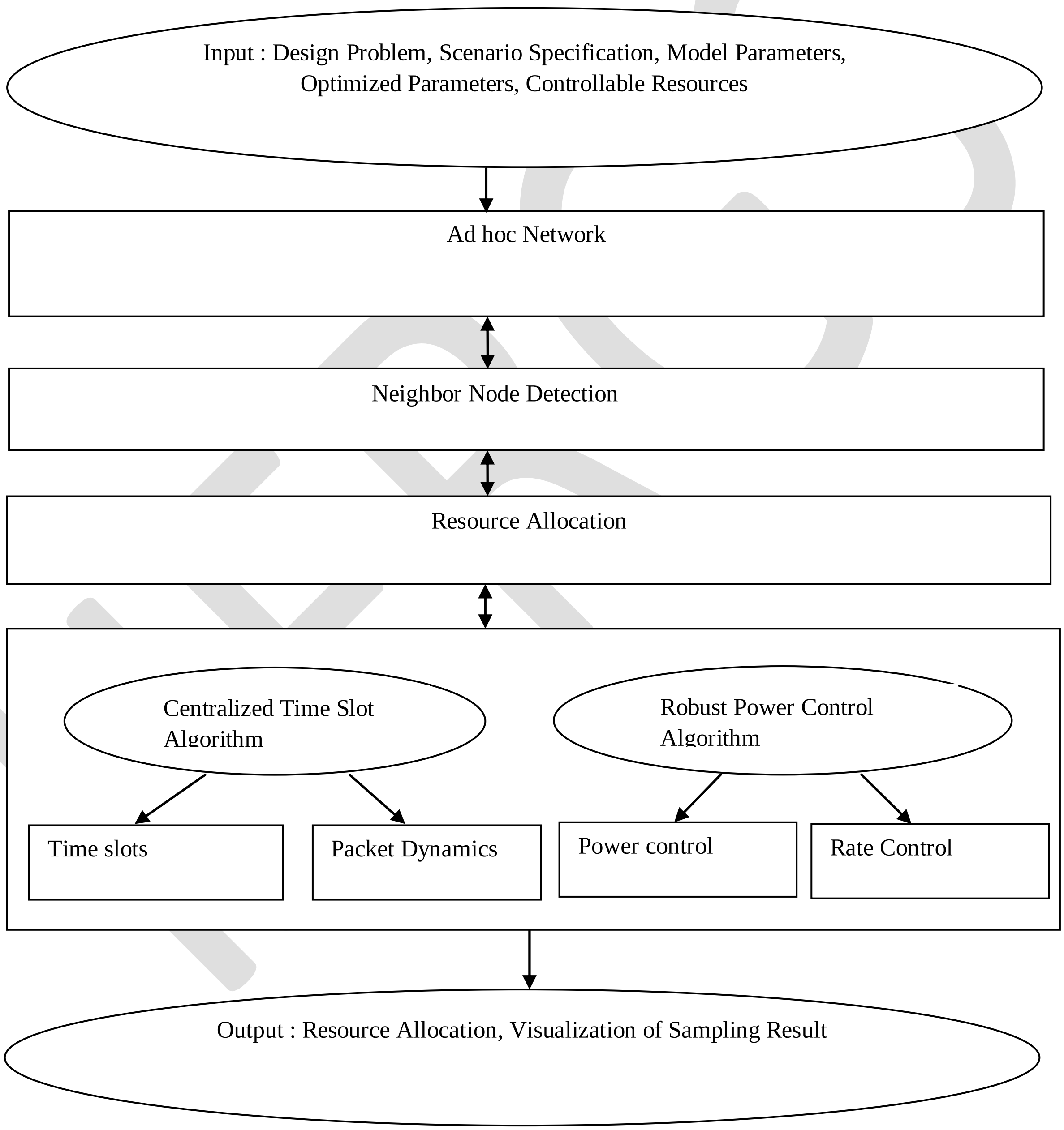

Fig 3 Framework Architecture

The framework in Fig. 3 takes model parameters, optimized parameters and controllable resources as power and time as input. The nodes are created with initialized parameters as distance and bandwidth. Each node detects its neighboring node automatically within its range. Multiple nodes are created. Select any two nodes as source and destination. N nodes are deployed randomly in a surface uniformly. In a conventional multi-hop transmission, each source communicates to its intended destination through multiple intermediate nodes (hops). It guarantees each node at least once chance to transmit and guarantee concurrent transmitters and succeed. The majority of the works involving transmitting data through different clusters we propose an adaptive cluster size dynamically throughout the network. In the first stage, a source node of a MIMO link performs a local transmission at a rate to a subset of its neighbors. This is followed by the simultaneous transmission of encoded versions of the same message by the cooperating neighbors including the source to the destination of the MIMO link Strategies for routing. It presents a joint power and rate control adaptive algorithm to optimize the trade-off between power consumption and throughput in ad hoc networks. Each node chooses its own transmission power and rate based on limited environment information in order to achieve optimal transmission efficiency. Fig 4 – 7 shows the node creation and optimal path findings process to send packets form source node to destination node.

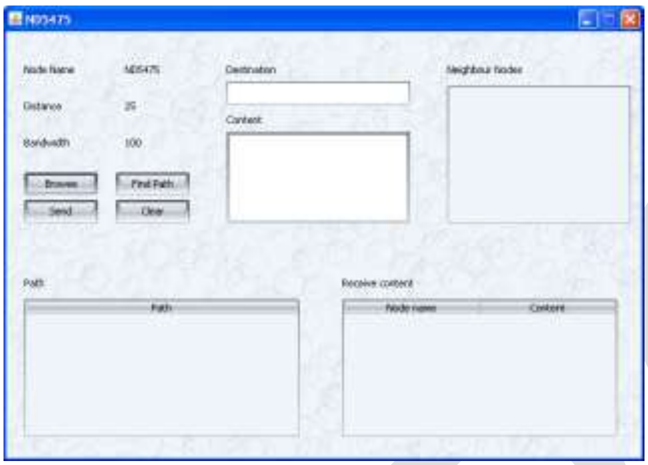

Fig 4 Node 1 Creation

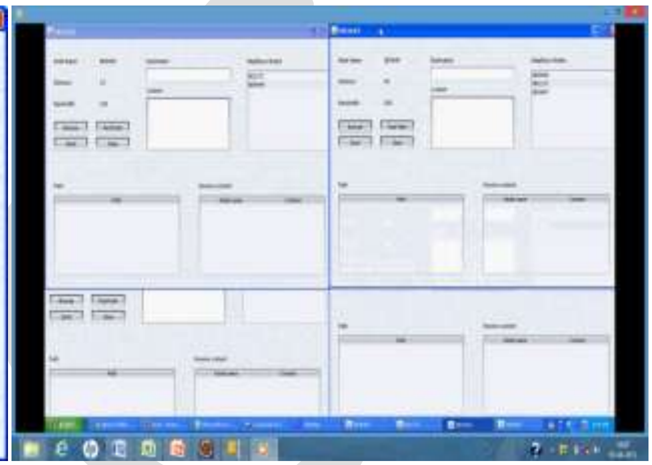

Fig 5 Multiple Node Creation

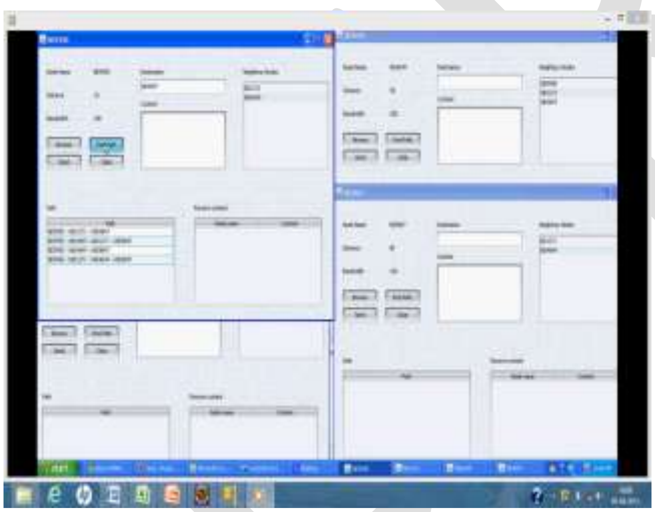

Fig 6 Path Creation

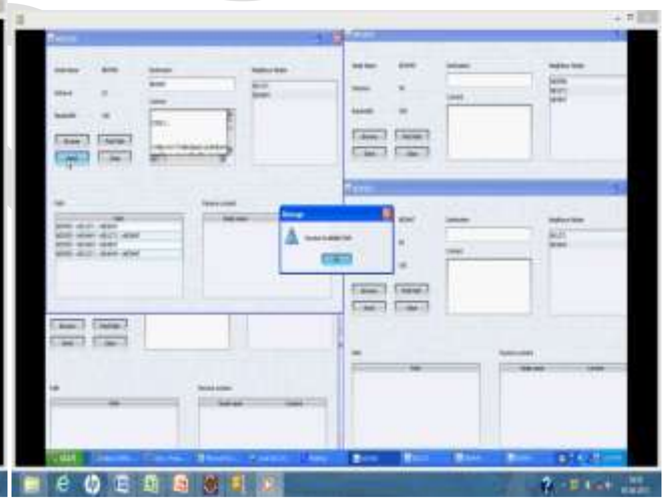

Fig 7 Send Content

A Simulation and Results

A trade-off (or tradeoff) is a situation that involves losing one quality or aspect of something in return for gaining another quality or aspect. Pareto efficiency, or Pareto optimality, is a state of allocation of resources in which it is impossible to make any one individual better off without making at least one individual worse off.The Pareto front formed from solving the power control problem allows the network designer to choose an operating point based on the prioritization of the two objectives, transmit power and channel feasibility. We first look at a single mobile network where the uncertainty in the channel state (represented by the set of samples of each channel) comes from the changing topology due to the movement of the nodes. We then look at the effect of considering only a fraction of nearest interferers at each active receiver.

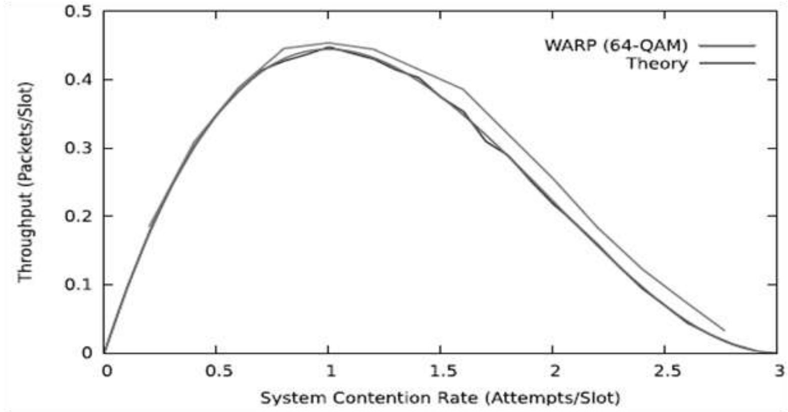

Fig 8 Optimization of Mobile Ad Hoc Network Simulation for 3 topology

Fig 8 shows the throughput in packets per time slot under slotted Aloha for three transmitters as a function of the system contention rate (defined as Np for N = 3 users and p the per-user contention probability). The figure shows the theoretical throughput under the channel collision model (error free reception iff a transmitter is the sole transmitter in the slot), the measured throughput using the WARP testbed when the nodes employ 64-QAM, and the simulated throughput under the framework when the nodes operate in the collision channel model.

B Pareto Optimal Tradeoff

The simulation setup is a mobile network of 100 nodes on a 1 km 2 square arena. The nodes are placed uniformly at random. The nodes then move under a random waypoint model [10] at a speed of 2 m/s for a duration of 1 second during which the channel sampling process is performed. The transmission packing procedure is performed once and results in 10 unicast transmission-receiver pairs. The interference set I1 in (1) is used for computing the SINR. In other words, in this case, every active transmitter is defined in the optimization problem as a potential source of interference. A single simulation run for 100 nodes with a full interference set takes approximately 1 second to execute on a 2.4 GHz processor.

The bottom curve in Fig. 8 shows a Pareto front of solutions produced by the framework. Given the network topology, this solution set provides the network designer a range of optimal transmission power allocations. The designer can then choose one of these solutions based on the relative value of the power objective versus the feasibility objective.

C Shrinking the Interference Set Effect

The set of channel state samples is collected and optimized over for that single network, producing a Pareto front of solutions. In this section, we consider the effect of k in the interference set Ikj . This set is the set of k closest interferers to active receiver j.

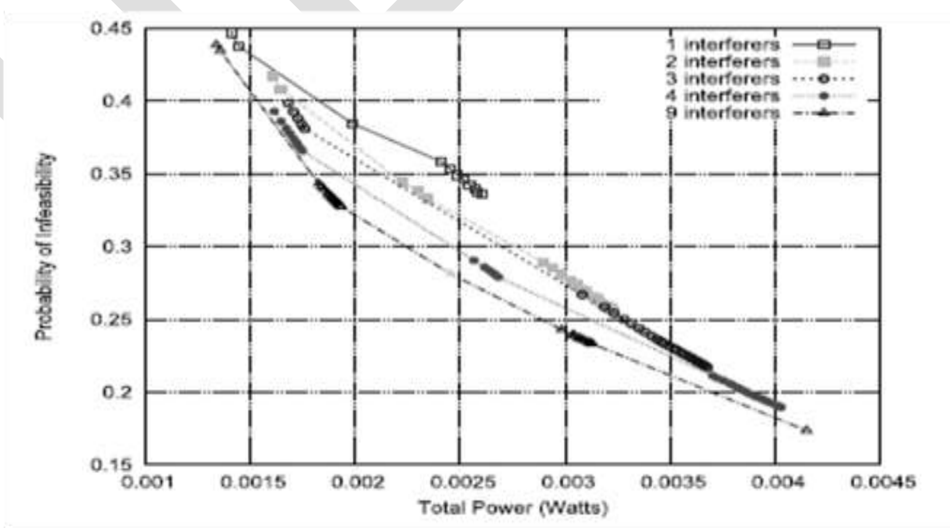

Fig 9 Tradeoff between the feasibility objective and the optimality objective (minimizing the total transmit power)

Fig. 9 shows the effect of decreasing k from the maximum of 9 to 1 for the single network described in the previous section. This plot provides an intuition that increasing k has diminishing returns. This pattern is looked at more closely in this section. However, for the objective function in the optimization problem, a more limited interference set is used. The importance of keeping k small and independent of network size is twofold. First, a small constant k significantly reduces the complexity of the optimization problem as the size of the SINR computation in (1) no longer depends on the number of active transmitters, and thus is independent of network size. Second, a constant k removes the need for every transmitter-receiver pair to have channel state information from every other interfering transmitter on the network to this pair's receiver. Therefore, the significant overhead of sharing this information between nodes is removed, allowing for distributed power control approaches to make resource allocation decisions without first gathering channel state information from the whole network.

VIII CONCLUSION

Power control in ad-hoc networks is a more difficult problem due to non availability of access point in network. Power control problem is defined by two ways. First, in ad-hoc networks, a node can be both a data source and a router that forwards data for other nodes .Node is involving in high-level routing and control protocols. Additionally, the roles of a particular node may change over time. Second, there is no centralized entity such as an access point to control and maintain the power control mode of each node in the network. The power control analysis of mobile ad hoc network system shows the tradeoffs and optimization approaches implemented in the framework. The method for finding an optimized power allocation solves the power control problem. This empirical result indicates that only a small number of nearest interfering transmitters have a significant effect on the feasibility of a channel.

REFERENCES:

[1] OMAN: A Mobile Ad Hoc Network Design System July 2012 (vol. 11 no. 7) pp. 1179-1191 Fridman, A. Weber. S,Graff C, Breen D.E, Dandekar.R,. Kam, M.

[2] Analyzing performance of ad hoc network mobility models in a peer-to-peer network application over mobile ad hoc network Amin, R.; Ashrafch, S.; Akhtar, M.B.; Khan, A.A. Electronics and Information Engineering (ICEIE), 2010 International Conference Volume: 2

[3] Power Aware and Signal Strength Based Routing Algorithm for Mobile Ad Hoc Networks Varaprasad,G. Communication Systems and Network Technologies (CSNT), 2011 International Conference Publication Year: 2011 , Page(s): 131 - 134

[4] Performance analysis of effect of transmission power in mobile ad hoc network Das, M.; Panda,B.K.;Sahu,B.Wireless and Optical Communications Networks (WOCN), 2012 Ninth International Conference Page(s): 1 - 5

[5] Lin, "Multiple-Objective Problems: Pareto-Optimal Solutions by Method of Proper Equality Constraints," IEEE Trans. Automatic Control, vol. AC-21, no. 5, pp. 641-650, Oct. 1976. S. Agarwal, R. Katz, S. Krishnamurthy, and S. Dao, "Distributed Power Control in Ad-Hoc Wireless Networks," Proc. 12th IEEE Int'l Symp. Personal, Indoor and Mobile Radio Comm., vol. 2, 2001

[6] Chen, Y., Yu, G., Qiu, P., & Zhang, Z. (2006). Power aware cooperative relay selection strategies in wireless ad-hoc networks. In Proceedings of IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (pp. 1–5).

[7] Yasser Kamal Hassan, Mohamed Hashim Abd El-Aziz, and Ahmed Safwat Abd El-Radi, "Performance Evaluation of Mobility Speed over MANET Routing Protocols", in International Journal of Network Security, Vol.11, No.3, PP.128 - 138, Nov. 2010.

[8] P. Gupta and P. Kumar, "Critical Power for Asymptotic Connectivity in Wireless Networks," Stochastic Analysis, Control, Optimization and Applications: A Volume in Honor of WH Fleming, pp. 547-566, Springer, 1998.

[9] T. Camp, J. Boleng, and V. Davies, "A Survey of Mobility Models for Ad Hoc Network Research," Wireless Comm. and Mobile Computing, vol. 2, no. 5, pp. 483-502, 2002.

[10] X. Jia, D. Kim, S. Makki, P. Wan, and C. Yi, "Power Assignment for k-Connectivity in Wireless Ad Hoc Networks," J. Combinatorial Optimization, vol. 9, no. 2, pp. 213-222, 2005.

[11] F. Dai and J. Wu, "On Constructing k-Connected k-Dominating Set in Wireless Networks," Proc. 19th IEEE Int'l Parallel and Distributed Processing Symp., 2005.

[12] Pradhan N, Saadawi T. Adaptive distributed power management algorithm for interference-aware topology control in mobile ad hoc networks. In: Global Telecommunications Conference 2010, IEEE GLOBECOM 2010, 2010.