OPTIMIZATION ALGORITHMS FOR ACCESS POINT DEPLOYMENT IN WIRELESS NETWORKS

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Abstract

Wireless Local Area Networks (WLANs) have become very popular as they provide mobility for the nodes and the convenience with which such networks can be setup. However, there are important design considerations while setting up such networks. This paper focuses on the issues in the design of wireless networks and discusses several proposed techniques. The important issues are node coverage, co-channel interference, signal strength and the desired bandwidth at the nodes. Several solutions have been proposed to address these issues and these solutions are based on Discrete gradient optimization algorithm[1], Genetic Algorithmic approach[8] and Global Optimization technique[4]. In this paper we review these three techniques and propose a new search technique based on Heuristic approach.

Keywords

Access Points, Global Optimization, Signal Coverage, Heuristic.

1. Introduction

Wireless Local Area Networks have become common place at home and office environments as they provide mobility to the users and also they can be setup with very little effort. Mobile Adhoc Networks do not even require any additional infrastructure for forming a network. To setup a WLAN all that is required are a few Access Points(APs) that are strategically located. These Access Points have an Omni-directional antenna that sends wireless signals uniformly in all directions. However, it is no easy task to decide on the number and locations where these APs have to be fixed in an indoor environment so as to provide not only coverage but ensure minimum signal strength at all node points, requisite bandwidth, in the presence of obstructions, reflections and signal interference. Design of this nature is very complex and needs proper modeling and formulating the problem as an optimization problem with several constraints.

The indoor environment may consist of several compartments, nodes spread across the entire floor area. The nodes are assumed to be fixed in their position and the access points when they radiate energy, the energy loss as a function of distance, loss due to obstruction and signal interference from reflected energy is to be considered while modeling the network. The amount of signal attenuation as a result of obstruction depends on the material used in the obstruction. If the node is place inside a partition made of aluminum or glass material, the typical value of absorption coefficient is 0.7. On the other hand if a wall made of bricks and coated with cement then the absorption coefficient depends on the thickness of the wall. The walls and ceilings acting as reflecting surfaces, the effective signal strength at the nodes depends on the reflection coefficient and the phase with which the direct and reflected signals meet the receiver.

This paper is organized as follows. In section 2, we present the basic mathematical model, followed by that a refined model that accounts for attenuation due to obstruction and interference due to reflection. Section 3 describes the three different algorithms to solve this optimization problem. In section 4 we describe the new Heuristic Search Technique(HST). In section 5 we discuss the results of simulation and compare with respect to signal strength, coverage and bandwidth. Finally, the conclusions are given in section 5.

2. Mathematical Model

The mean path loss Pth as a function of distance is given by

$$Pth(d) = Pth(d0) + 10n\log10 (d/d0) \quad \text{---} \quad 2.1$$

Where d is the distance from the access point and the first term Pth(d0) the constant loss at a reference distance. The distance d0 is typically 1 meter. The multiplication factor n has a value equal to 2 in free space. The first term can be computed using the following formula

$$Pth(d0) = 20 \log 10 (4 \pi \, d0/ \lambda) \quad \text{---} \quad 2.2$$

Where λ is the wavelength of the radiated RF energy. The path loss at a distance d in the presence of soft and hard partitions can be written as

$$Pth(d) = Pth(d0) + 20 \log10 (d/d0) + A\_SP[db] + A\_HP[db] + A\_OR\_GDREF \quad \text{---} \quad 2.3$$

where, A_SP and A_HP are the attenuation due to soft and hard part itions. A__OR_GDREF is the factor that accounts for Attenuation or Gain due to reflections from the surrounding walls and ceiling. In the design of a WLAN with N nodes and M Access Points the Objective function is to minimize the loss at the nodes, so as to obtain a signal strength slightly greater than the required minimum. This can be formulated as under. Let us designate the path loss at node i due to access point j as PL_ni_aj. Therefore the total path loss due to all the access points at a given access point must satisfy the following constraints.

3. Solutions of the Model

3.1 Descent Gradient Method

Let $y=f(x)$ have a maximum at x_{max}. Pick an arbitrary value for x, say x_1. Compute $f'(x_1)$. If the slope of y is positive at x_1, i.e. $f'(x_1) > 0$, then $x_{max} > x_1$ lies to the right of x_1. Likewise if $f'(x_1) < 0$, then $x_{max} < x_1$ lies to its left. Thus we know the direction in which x_1 should be updated in order to approach x_{max}. In fact this direction is given by $f'(x_1)$. So we can use the update rule:

$$x1 = x1 + \eta f'(x1) \qquad \text{---} \quad 2.6$$

where $\eta$is a positive constant. If η is sufficiently small, and there is indeed a maximum for f, the above update rule will converge to it after a finite number of iterations. As applied to the current problem of deploying APs, the next AP position to be selected would be in a direction where the objective function has the steepest gradient.

3.2 Genetic Solution

In this approach, the entire floor area is divided into cells of appropriate size and the nodes and APs are placed inside these cells. In genetic approach, an initial population has to be created by randomly placing the APs across the grid structure. Genetic operations such as mutation, crossover are then applied to these initial genes to generate the next generation genes. An appropriate fitness function for this problem domain is used to decide on the fitness of the gene to get promoted to the next generation. This process is repeated until a satisfactory solution is obtained. The problem with this approach is that the convergence of the method is very slow and depends on the

$$\min \sum PL\_ni\_aj - PLmax >= 0$$

$$\min \sum_{j=1}^{M} PL\_ni\_aj - PLmax >= 0 \qquad \text{---} \quad 2.4$$

where, PL is the Maximum acceptable path loss at any node. The PLmax is calculated as under:

$$PLmax = Pt - Rth$$

Where, Pt is the transmitted power and Rth is the receiver threshold. A feasible solution (a1,a2,….aM) exists only if

$$\sum_{i=1}^{N} \left(\min \sum_{j=1}^{M} PL\_ni\_aj - PLmax \right) = 0 \quad \text{---} \quad 2.5$$

parameters like the initial population, mutation probability, crossover point etc.

3.3 A Global Optimization(AGOP) technique

Global Optimization technique is designed to solve unconstrained and continues optimization problems. The problem can be formulated as :

$f(x) : R^n \rightarrow R$ such that $x \in B$ where B is a given Box constraint.The AGOP must be given an initial set of points x say $\Omega = x1,x2,x3\ldots..xq \subset Rn$. Suppose x* be a point in Rn that has the smallest value for the objective function that is, f(x*)<= f(x) for all x $\subset \Omega$. A possible approach has been developed for finding a possible descent direction at point x*. An inexact search along this direction provides a new point xq+1. A local search around this point is then carried out. This is done using local variation method. This is an efficient local optimization method that does not directly use derivatives and can be applied to non-smooth functions. The set is augmented with this new value and the whole process is again repeated. The process is terminated when v is approximately 0 or a prescribed number of iterations are carried out The solution returned would be the value x*.

4. Heuristic Approach

The idea here is, to divide the floor area into a grid. The cell size should be large enough to occupy an access point and a receiver. The method begins with random locations of the APs. It then heuristically, estimates the signal strengths at the receivers by moving in the four diagonal directions. The cell that shows the best signal strength is chosen as the next AP position.

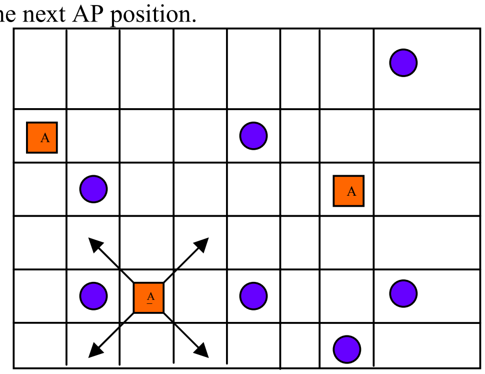

Fig 4.1 - Heuristic Search Technique : Circles→ Nodes Rectangles→Access Points

If the two diagonal positions show almost equal signal strength then the AP is moved on a horizontal line that lies between these to diagonal positions. Only one AP is moved at a time and each AP is moved in turn until the desirable signal strength and coverage is obtained. The process can be best described with the following algorithm.

4.1 Heuristic Algorithm

1. Read the floar Area.
2. Draw a grid.
3. Compute the number of Access Points(APs).
4. Lay the receivers and APs.
5. For each Access Point APi do the following :
   Estimate the Pathloss according to the eq. by moving the AP diagonally
6. Decide the direction of movement using the above described technique.
7. Check if desired results are obtained if not repeat step 5 else Goto step 8.
8. Print Solution and Stop.

5. Conclusion

In this paper we have presented a model to design a Wireless LAN of strategically deploying the Access Points so as to network the nodes in a given area taking into account signal degradation, obstructions and reflections. We have formulated the design problem as an optimization problem with the important constraints. Three techniques have been presented to solve the design problem namely, Discrete Gradient Method, Genetic Approach and Global Optimization Technique. Though all of these provide satisfactory solutions however, they either suffer from high computational complexity, slower convergence and implementation difficulties. In this paper a new technique namely, Heuristic Search Technique is also discussed which is much simpler to implement and provides faster and accurate solution.

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