Performance Optimization of WLAN Networks

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Abstract: Wireless LANs hold the promise of increasing employee productivity by providing ubiquitous connectivity and mobility across enterprise. It is now a trend to develop the WLAN in various colleges and office campuses for increasing productivity and quality of goods. There are many obstacles when deploying WLAN, which demands seamless indoor handover. The objective of the work reported here is to develop modeling tools for performance optimization of WLAN networks and WLAN access points. To solve the problem, we use the Particle Swarm optimization.

Keywords: Wireless LAN, access point, path loss model, Particle Swarm Optimization.

I. INTRODUCTION

The WLAN technology has won growing interest in the last years. Access points can nowadays be found in our daily environment, e.g. in many office buildings, public spaces and in urban areas [1]. A wireless LAN is a data transmission system designed to provide location-independent network access between computing devices by using radio waves rather than a wired infrastructure. In the corporate enterprise, wireless LANs are usually employed as the final link between the existing wired network and a group of client computers, giving these users wireless access to the full resources and services of the corporate network across a building or campus [8].

WLAN networks have become very popular means for providing a wireless networking facility for home users, educational institutions, companies etc. due to their ease of installation and their high data rate provision, apart from providing, although limited, mobility to users. [2].

If the APs are placed too far apart, they will generate a coverage gap, but if they are too close to each other, this will lead to excessive co-channel interferences and increases the cost unnecessary. In this paper, we present methods to determine location in such a WLAN. For the indoor environment, there are two types of elements; namely static and dynamic elements. The static elements such as natural and manmade materials. The dynamic element comprises of moving objects [3]. The basic structure of a WLAN is called a Basic Service Set (BSS) which comes in two categories: Infrastructure BSSs and Independent BSSs. In infrastructure mode, the wireless network consists of at least one access point connected to the wired network infrastructure and a set of wireless end stations. This configuration is called a Basic Service Set (BSS)[8]. An Extended Service Set (ESS) is a set of two or more BSSs forming a single subnetwork as shown in figure-1. In an independent BSSs (IBSS) stations communicate directly with each other and are usually composed of a small number of stations set up for a short period of time. IBSSs are often referred to as ad hoc networks as shown in figure-2.

Particle swarm optimization (PSO) is a kind of evolvement-computation technology based on the movement and intelligence of swarms was developed in 1995 by James Kennedy (social-psychologist) and Russell Eberhart (electrical engineer). It uses a number of agents (particles) that constitute a swarm moving around in the search space looking for the best solution. This paper is organized as follows: Section II presents
the indoor path loss. Notations are given in section III. Section IV provides the mathematical model description and path loss model. Section V shows the algorithm of the access point’s calculation. Section VI shows the solution of the model and operation of PSO. Section VII describes the method of testing. The measurement results are presented in Section VIII. Finally, section IX concludes the paper.

II. INDOOR PATH LOSS

The radio wave propagation is a complex phenomenon and is affected by various factors, such as distance, propagation environments, signal interference, reflections, and attenuation [9]. The amount of attenuation varies with the frequency of the RF signal and the obstructing materials type and density [6]. Generally speaking, the lower the frequency of transmission the better the signal will travel through the air and through objects as shown in figure-3. Indoor propagation mechanism needs to overcome three specific main electromagnetic wave phenomena, namely the reflection, diffraction and scattering. These phenomena may occur and degrade the signal strength quality of the WLAN network. The distance between transmitter and receiver is shorter due to high attenuation caused by the internal walls & furniture and often also because of the lower transmitter power. The short distance implies shorter delay of echoes and consequently a lower delay spread.

III. GENERAL NOTATIONS

Throughout this paper the following notations are used:

- \( a_j \) \( j = 1 \ldots N \) Access point (AP)
- \( r_i \) \( i = 1 \ldots M \) Receiver/user
- \( d(a_j, r) \) Distance between AP and receiver
- \( g(a_j, r) \) Path loss from \( \text{user} \) to access point \( j \)
- \( g_{\text{max}} \) Maximum tolerable path loss
- \( P_t \) Transmit power
- \( P_r \) Received power
- \( R_{th} \) Receive threshold
- \( A_p \) Position of AP

It should be noted that \( a_j \) represents the unknown coordinates of APs. Their number \( N \) is not known either. The coordinates of users \( r_i \) are assumed to be known and these users can be distributed in design area according to the design specifications.

In the present analysis the distance function assumed to be Euclidean, hence on the plane, the distance \( (d') \) between an AP \( a_j \) and a receiver \( r_i \) is given by [4]:

\[
d(a_j, r) = \sqrt{(r_i^1 - a_j^1)^2 + (r_i^2 - a_j^2)^2}
\]

where \( a_j = (a_j^1, a_j^2) \), and \( r_i = (r_i^1, r_i^2) \)

IV. MODEL DESCRIPTION

The aforementioned problem can be modeled as an optimization problem for which the objective function is to minimize the path loss. Mathematically it may be given as:

\[
\min g(a_j, r_i) \leq g_{\text{max}} \quad \forall i = 1, \ldots, M \quad (1)
\]

Constraint (1) states that path loss is evaluated against the maximum tolerable path loss \( g_{\text{max}} \). This ensures that the quality of coverage at each receiver location is above the given threshold. This given value, \( g_{\text{max}} \) can be calculated by subtracting receiver threshold \( (R_{th}) \) from transmitter power \( (P_t) \).

\[
g_{\text{max}} = P_t - R_{th} \quad (2)
\]

The above inequality (1) can be expressed in the equality form as:

\[
(min, g(a_j, r_i) - g_{\text{max}})^2 = 0,
\]

where \( (\alpha)^2 = \max (\alpha, 0) \)

A. Path Loss Model

In general the power received by an antenna that is separated from the transmitting antenna by the distance \( d \) in free space is given by [4-5]:

![Figure 3: Indoor path loss](image-url)
\[ P_r(a_i, r_i) = \frac{P_t G_t G_r \lambda^2}{(4\pi d(a_i, r_i)^2) \lambda} \]  

(4)

where \( P_t \) is the transmitted power, \( G_t \) and \( G_r \) are the transmitter and receiver antenna gain, \( d \) is the distance between transmitter and receiver, and \( \lambda = c/f \) is the wavelength of the carrier frequency, \( c \) is the speed of light (\( 3 \times 10^8 \) meter per second) and \( f \) is the frequency of the carrier in hertz. The path loss, which represents signal attenuation between the transmitted and the received power and is measured in dB (decibels), in free space environments, is given by [4-5]:

\[ g(a_i, r_i)[dB] = -10 \log \left( \frac{G_t G_r \lambda^2}{d(a_i, r_i)^2} \right) \]

(5)

The above equation does not hold when points \( a_i \) and \( r_i \) are very close to each other. Therefore, large scale propagation models use a close-in distance, \( d_0 \) which is known as the received power reference distance point. Therefore, path losses at reference distance assuming transmit and receive antenna with unity gain as described in [4-5] can be calculated from:

\[ g(a_i, r_i)[dB] = 20 \log \left( \frac{4\pi d_0 f}{c} \right) \]

(6)

V. COMPUTATIONAL STEPS FOR ACCESS POINT’S CALCULATION

Initially set the number of APs to 1: \( N = 1 \); then the necessary number of APs is found through the following steps.

1) Solve the constraint condition of path loss for each receiver using equation (3);
2) Solve the power received by an antenna in free space using equation (4);
3) If the solution exists, then \( N \) is the desired number;
4) Otherwise, \( N \) is increased by 1: \( N = N + 1 \);
5) Go to step 1.

Flowchart of the above computational steps is given in figure- 4.

VI. SOLUTION OF THE MODEL

The standard powerful optimization techniques (Newton based, quasi-Newton methods, conjugate gradient search method, steepest descent method cannot be applied to the problem at hand because the function in the left hand side of (3) is nondifferentiable and nonconvex. Direct search methods are seem to be the best option but suitable for continuous functions only and the problem at hand is discontinuous. The discontinuity is because of a tiny change in the position of users or APs that can happen. Also genetic algorithms could be an option for smaller area; they would not be applicable to real situations since a large number of function evaluations are required. We use the new Particle Swarm Optimization Algorithm (PSO). PSO is the only algorithm that does not implement the survival of the fittest and no crossover operation in PSO.
A. Operation of PSO
All particles in PSO are kept as members of the population through the course of the run. The modification in the particle’s position can be mathematically modeled according to the following equation:

\[
V_{i}^{t+1} = wV_{i}^{t} + c_{1}\text{rand}(\ldots)\times(p_{best} - s_{i}^{t}) + \\
c_{2}\text{rand}(\ldots)\times(g_{best} - s_{i}^{t})
\] (1)

Where

- \(V_{i}^{t}\): velocity of agent \(i\) at iteration \(k\),
- \(c_{i}\): weighting factor,
- \(\text{rand}\): uniformly distributed random number between 0 and 1,
- \(s_{i}^{t}\): current position of agent \(i\) at iteration \(k\),
- \(p_{best}\): \(p_{best}\) of agent \(i\),
- \(g_{best}\): \(g_{best}\) of the group.

The following weighting function is usually utilized in eq (1):

\[
w = w_{\text{Max}} - [(w_{\text{Max}} - w_{\text{Min}})\times \text{max iter}] \times (\text{iter} - 1) / (\text{max iter}) \quad (2)
\]

where

- \(w_{\text{Max}}\): initial weight,
- \(w_{\text{Min}}\): final weight,
- \(\text{iter}\): current iteration number,
- \(\text{max iter}\): maximum iteration number,
- \(s_{i}^{t} + V_{i}^{t+1}\) \quad (3)

VII. METHOD OF TESTING

A. Setup
A simple case without obstacles was considered for conducting the test in order to examine the model. The design area has 40 users. The specification of the model of Access point is LINK (DWL-3200AP) and IEEE 802.11b standard are used to test the model.

B. Methodology
Once the priority areas have been identified, look for places nearby where it will be easy to install an access point. Access point will require a connection to the wired LAN and also a source of power. The signal strength, noise level and signal/noise ratio should then be measured, using 3.3GHz Spectrum analyzer with Omnidirectional dipole antennas has been chosen, at a number of points around the access point. The coverage should be checked in those priority areas that are within range. While in other places the aim should be to identify the points where the available bandwidth is likely to drop below the theoretical maximum: typically where the signal strength falls below -70dBm or where the signal/noise ratio is less than about 15dB [7].

VIII. RESULTS

A. Case I
In order to examine the behavior of our model, with some values of \(P_{t}\) and \(R_{th}\). It should be noted that in the developed model, the aim is to provide only the coverage for the users. figure.5 shows a part of the Boy’s Hostel Map.

figure.5 shows a part of the Boy’s Hostel Map

figure.6 Measured Path Loss

figure.6 shows the receive threshold and measured path loss so that we can assure the coverage of all users.

B. Case II

figure.7 shows a part of the Boy’s Hostel Map
Heberling, “Performance and Accuracy Test of the WLAN Indoor


Acknowledgment

I would like to thank the Ministry of Science, department of Science and Technology, New Delhi for sponsoring this work under Women Scientist Scheme WOS-A, Grant No: DST-498-DPT.

References


IX. Conclusion

We have addressed the problem of coverage planning in WLANs, which is starting to attract the attention of both industry and research community. This paper investigates allocation problems with objective functions based on minimizing the average path loss received over the entire design area and maximum path loss received by any receiver. The algorithm described above used for finding the optimal placement of APs. WLAN planner will be able to setup the access point for the optimum propagation coverage. Further work will be extended to include obstacles in the mathematical model presented in this paper and test will be conducted and also it will involve the comparison of results taken by the optimization technique and by the simulation software. This stresses the need for appropriate planning models and procedures that are specific to WLANs.

ACKNOWLEDGMENT

I would like to thanks the Ministry of Science, department of Science and Technology, New Delhi for sponsoring this work under Women Scientist Scheme WOS-A, Grant No: DST-498-DPT.

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