MEASUREMENT AND LOCATION PREDICTION IN AN INDOOR WLAN USING OPTIMIZATION AND SIMULATION

A THESIS

Submitted in partial fulfilment of the requirements for the award of the degree of

DOCTOR OF PHILOSOPHY

by

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled **"MEASUREMENT AND LOCATION PREDICTION IN AN INDOOR WLAN USING OPTIMIZATION AND SIMULATION"** in partial fulfilment of the requirements for the award of the degree of Doctor of Philosophy and submitted in the Department of Paper Technology, Indian Institute of Technology Roorkee, Roorkee is an authentic record of my own work carried out during a period from **Jan, 2008 to April, 2012** under the supervision of Dr. S. C. Sharma, Associate Professor, Electronics & Computer Discipline and Dr. Millie Pant, Assistant Professor, Mathematics Discipline, Department of Paper Technology, Indian Institute of Technology Roorkee,Roorkee.

The matter presented in this thesis has not been submitted by me for the award of any other degree of this or any other institute.

(LEENA ARYA)

This is to certify that above statement made by the candidate is correct to the best of our knowledge.

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ABSTRACT

In the new era of wireless communication, Wireless Local Area Network (WLAN) has emerged as one of the key players in the wireless communication family. The prohibitive cost of building wired network infrastructures has paved the way for wireless networking on a global scale. WLANs are being used as an alternative to the high installation and maintenance costs incurred by traditional additions, deletions and changes experienced in wired LAN infrastructures. Physical and environmental necessity is another driving factor in favour of WLANs. It is now a trend to develop the WLAN in various colleges and office campuses for increasing productivity and quality of goods.

WLAN hold the promise of increasing employee productivity by providing them ubiquitous connectivity and mobility across enterprise. In the WLAN category the products based on the IEEE 802.11g technology are dominating which offers speeds of up to 54Mbps and covers a range of up to 100 meters. Prediction of the signal strength for indoor propagation environments can be faced with many obstacles and the effects of multipath propagation such as signal attenuation, reflection and diffraction. Depending on the building construction and layout, the signal usually propagates along corridors and into other open areas. In some cases, transmitted signals may have a direct path (Line-of-Site, LOS) to the receiver. LOS examples of indoor spaces are warehouses, factory floors, auditoriums, and enclosed stadiums.

OBJECTIVE OF THE PRESENT WORK

The objective of the present work is to analyze the measured data in terms of signal strength in the indoor WLAN 802.11g at Malviya Bhavan, Boys hostel Building, Indian Institute of Technology, Roorkee, Saharanpur Campus coverage using optimization technique and simulation.

The outline of the present work is as follows:

- Collection of data for received signal strength at frequency of 2.4 GHz using Spectrum Analyzer for different scenarios at Malviya Bhavan, Boys hostel Building, Indian Institute of Technology, Roorkee, Saharanpur Campus.
- The assessment of coverage of access points using QUALNET 5.0 simulation design tool in Indoor WLAN using above data.
- The assessment of coverage of access points using Particle Swarm Optimization to find the coordinates of APs for their locations based on above measurements.

- Analyzed the effect of interference due to obstacles such as walls, tables, chairs and other elements in the indoor environment.
- The optimized results have been compared with the observed results.

Methodology

The measurements have been conducted in the Malviya Bhawan, Boys Hostel Building, IIT Roorkee, Saharanpur Campus to collect data for simulation & optimization. Using Spectrum Analyzer, the received signal strength of the access points has been calculated using omnidirectional antenna. The experiment has been conducted in building considering free space and line of sight in the design area which has dimensions of 64m x 60m and have 400 users on four floors. The facility is a four floor (Ground floor to third floor) building and nineteen access points are distributed around the building in different block points installed by the network administrator in the corridors of the building. None at the ground level, ten on the first floor, nine on the second floor and none on the third floor.

Set up for experimental data:

Domain Area: Malviya Bhawan, Boys Hostel, IIT Roorkee, Saharanpur Campus
Area: 64m X 60m
Type: Four floor Building
Device: MSA338 3.3 GHz Spectrum Analyser, Omnidirectional Antenna, Access Point AP (LINK DWL-3200AP)
MAS 300 PC software for Spectrum Analyzer
Optimization Technique: Particle Swarm Optimization

PROPAGATION COVERAGE IN INDOOR WLAN USING SIMULATION SOFTWARE

Researchers generally use simulation to analyze system performance prior to physical design or to compare multiple alternatives over a wide range of conditions in the wireless local area network. In the past few years much of the work has been done using simulation software to improve the performance of Wireless local area network.

Contribution:

The QUALNET 5.0 simulation design tool is used for the performance coverage of the WLAN access points installed at Malviya Bhawan, Boys Hostel Building, IIT Roorkee, Saharanpur Campus. In the simulation, Random Waypoint Model and Bellman Ford Algorithm have been used for free space in case of line of sight. Two Ray model has been used in case of the interferences and obstructions present in the building. The optimum coverage of the users has been estimated using simulation software for the coverage area of the site.

PLACEMENT OF ACCESS POINTS OF INDOOR WLAN USING PARTICLE SWARM OPTIMIZATION TECHNIQUE

The mathematical model of the placement of AP can be formulated as a non-linear optimization problem, for which a suitable technique is needed for obtaining the solution. Determining an optimal location for the placement of AP is a crucial task while dealing with WLAN. Owing to its non linear nature, a suitable technique is needed for its solution. In the past few years much focus has been laid on nontraditional nature inspired optimization algorithms. Some of the popular methods include Genetic Algorithms (GA), Differential Evolution (DE) and Particle Swarm Optimization (PSO).

Contribution:

PSO is used for determining the optimal location of AP installed at Malviya Bhawan. The objective function is based on minimizing the average path loss received over the entire design area and maximum path loss received by any receiver. Numerical results obtained by PSO are compared with the actual placement of AP. It is observed that PSO can be an attractive alternative for dealing with such type of problems.

COVERAGE AND ANALYSIS OF OBSTRUCTED ENVIRONMENT IN INDOOR WLAN

In real life scenario, the performance of WLAN is often affected by obstructions like wood (furniture, doors, windows etc), brick (walls), steel (almirahs) and many other such things. Consequently, the placement of AP is to be done accordingly. The formulation of the objective function, nonlinear in nature, changes according to the type of obstruction being considered.

Contribution:

Simulation software and Optimization technique is used for analysing the path losses obtained by the effects of multipath propagation such as reflection, diffraction and scattering and the interferences caused by the obstacles such as soft partitions like tables, chairs, desk, human being and by the hard partitions like wooden door, brick wall, almirah and other elements in the indoor environment as there are many variables in building construction that affect 2.4GHz transmission because the building used has its own characteristics depending on the materials and the physical structure.

Finally the optimized results have been compared with the observed results.

CONTENTS

CHAPTER 5 COVERAGE AND ANALYSIS OF OBSTRUCTED ENVIRONMENT IN INDOOR WLAN

LIST OF ACRONYMS

ACK	Acknowledgment
AP	Access point
BS	Base station
BSS	Basic Service Set
CBR	Constant bit rate
DB	Decibels
DSSS	Direct sequence spread spectrum
EM	Electro Magnetic
ESS	Extended service set
FHSS	Frequency hopping spread spectrum
GHz	Giga hertz
g max	Maximum tolerable path loss
G_t	Receiver antenna gain
G_r	Transmitter antenna gain
IBSS	Independent Basic Service Set
IEEE	Institute of Electrical and Electronic Engineering
IF	Intermediate frequency
IP	Internet Protocol
IR	Infra Red
ISM	Industrial, scientific, medical
LAN	Local Area Network
LPP	Linear Programming Problem
LOS	Line of sight
MAC	Medium Access Control
Mbps	Mega bit per second
MHz	Mega hertz
MIPP	Mixed Integer Programming Problem
NLPP	Non Linear Programming Problem
OFDM	Orthogonal frequency division multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
OPNET	Optimized Network Engineering Tools
OSI	Open system interconnection

PDA	Personal digital assistant
PHY	Physical layer
PSO	Particle Swarm Optimization
P_r	Receiving power
P_t	Transmitting power
RF	Radio Frequency
R_{th}	Receive threshold
TCP	Transfer Control Protocol
TDMA	Time Division Multiple Access
Wi-Fi	Wireless Fidelity
WiMAX	Worldwide interoperability for microwave access
WLAN	Wireless local area networks

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GLOSSARY

Throughput: This is average rate of successful message delivery over a communication channel. This data may be delivered over a physical or logical link, or pass through a certain network node. The throughput is usually measured in bits per seconds (bit/s or bps), and sometimes in data packets per second or data packets per time slot.

Reflection: It occurs when a propagating electromagnetic wave impinges upon an object which has very large dimensions when compared to the wavelength of the propagating wave. Reflections occur from the surface of the earth and from buildings and walls. The reflected waves may interfere constructively or destructively at the receiver.

Diffraction: It occurs when the radio path between the transmitter and receiver is obstructed by a surface that is large compared to the wavelength of the radio wave. The secondary waves resulting from the obstructing surface are present throughout the space and even behind the obstacle, giving rise to a bending of waves around the obstacle, even when a line-of-sight path does not exist between transmitter and receiver.

Scattering: It occurs when the medium through which the wave travels consists of objects with dimensions that are small compared to the wavelength, and where the number of obstacles per unit volume is large. Scattered waves are produced by rough surfaces, small objects, or by other irregularities in the channel.

Refraction: It is defined as a change in direction of an electromagnetic wave resulting from changes in the velocity of propagation of the medium through which it passes. This may result in a situation in which only a fraction or no part of the line of sight wave reaches the receiving antenna.

Particle swarm optimization (PSO): It is an artificial intelligence (AI) technique that can be used to find approximate solutions to extremely difficult or impossible numeric maximization and minimization problems. It provides a population-based search procedure in which individuals called **particles** change their **position** (state) with time. In a PSO system, particles **fly** around in a multidimensional search space.

AUTHOR'S PUBLICATIONS

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HONOURS AND AWARD

1) **2008: [Best Paper Award]** 3rd International Conference on Advance Computing & Communication Technology, November 2008, APIIT, pp.373-377, Panipat, India.
2) **2010: [Best Paper Award]** National Conference on Contemporary and Futuristic Trends in Computer Science and Engineering, Nov.2010.

CHAPTER 1
INTRODUCTION

Wireless communications is the fastest growing segment of the communications industry and the over the recent years it has rapidly emerged in the market providing users with network mobility, scalability and connectivity [49]. There are millions of people around the globe, who are using wireless technology [20]. Wireless technology now reaches virtually every location on the face of the earth.Wireless technology has helped to simplify networking by enabling multiple computer users to simultaneously share resources in a home, college or business without additional or intrusive wiring. More and more people are using wireless technology not only for work, but also for the convenience. Hundreds of millions of people exchange information every day using pagers, cellular telephones and other wireless communication products [87]. The technology includes the radio and infrared spectrum and is employed by both terrestrial and satellite networks. Wireless Local Area Network (WLAN) is currently among the most important technologies for wireless broadband access and the main advantages are maturity, low cost, network expansion, convenience, mobility support and the ease of deployment [27]. The flexibility offered by WLANs has been a major factor in their widespread deployment. WLAN provides an excellent way to extend the reach of local area networks, through a wireless connection. Wide area networks provide the largest coverage and which requires infrastructure investment in terms of wired base stations [44]. In the past few decades emphasis has been laid in the development of wireless and network security [62], [84], [65], [26] and indoor propagation measurement in IEEE 802.11 wireless systems.

Determining an optimal location for the placement of AP is a crucial task while dealing with WLAN. Owing to its non-linear nature, a suitable technique is needed for its solution. In the past few years much focus has been laid on nontraditional nature inspired optimization algorithms. Some of the popular methods include Genetic Algorithms (GA), Differential Evolution (DE) and Particle Swarm Optimization (PSO) [74], [61] etc. These algorithms, due to their flexible nature have been applied successfully to a wide range of real life [38], [41] and benchmark problems [1] [63] [41].

1.1 WLAN (Wireless Local Area Network)

Wireless local area networks (WLANs) are becoming a mainstream connectivity solution for a broad range of business customers. WLANs provide network services where it is difficult or too expensive to deploy a fixed infrastructure. A WLAN is a flexible data communication system minimizing the need for wired LAN within a campus or building. WLANs can coexist with fixed infrastructure to provide mobility and flexibility to users [24]. The wireless market is expanding rapidly as the benefits of going wire-free, increases productivity and popularity of IEEE 802.11. WLAN has increased to a great extent in recent years. Using electromagnetic waves, WLANs transmit and receive data over the air and combine data connectivity with user mobility and through simplified configuration, enable movable LANs.

With wireless LANs, users can access shared information and network managers can set up networks without installing or moving wires. WLAN networks are in demand for providing a wireless networking facility for educational institutions, home users, companies etc. due to their high data rate provision and ease of installation. [50]. WLAN has fastly become the method of choice for wireless access in indoor and public areas. The general idea of WLAN is basically just to provide a wireless network infrastructure comparable to the wired LAN.

The architecture of the IEEE 802.11 WLAN is designed to support a network, where most decision-making is distributed across the mobile stations. The basic structure of an IEEE 802.11 WLAN is called a Basic Service Set (BSS), which is a set of stations that communicate with each another. When a BSS includes an access point (AP) and several wireless devices it is called an infrastructure BSS. Multiple access points can provide wireless coverage for an entire building or campus. These devices communicate with each other through the AP as shown in Fig.1.1. When all of the stations communicate directly with each other and are usually composed of a small number of stations set up for a short period of time and there is no connection to a wired network, the BSS is called an independent BSS (IBSS) [28]. IBSSs are often referred to as ad hoc networks as shown in Fig. 1.2.

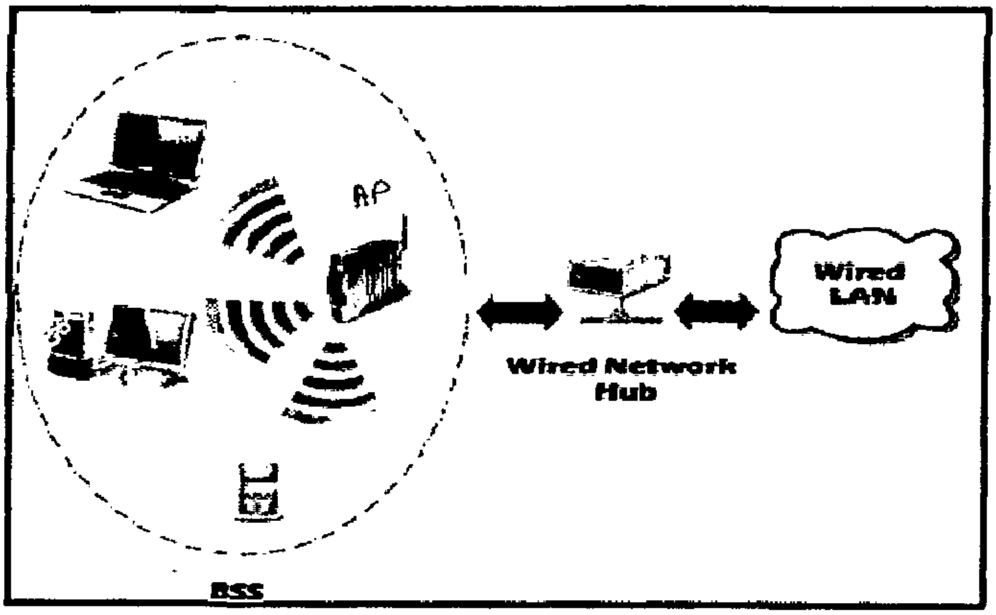


Fig. 1.1 Infrastructure Basic Service Set (Reproduced from[28])

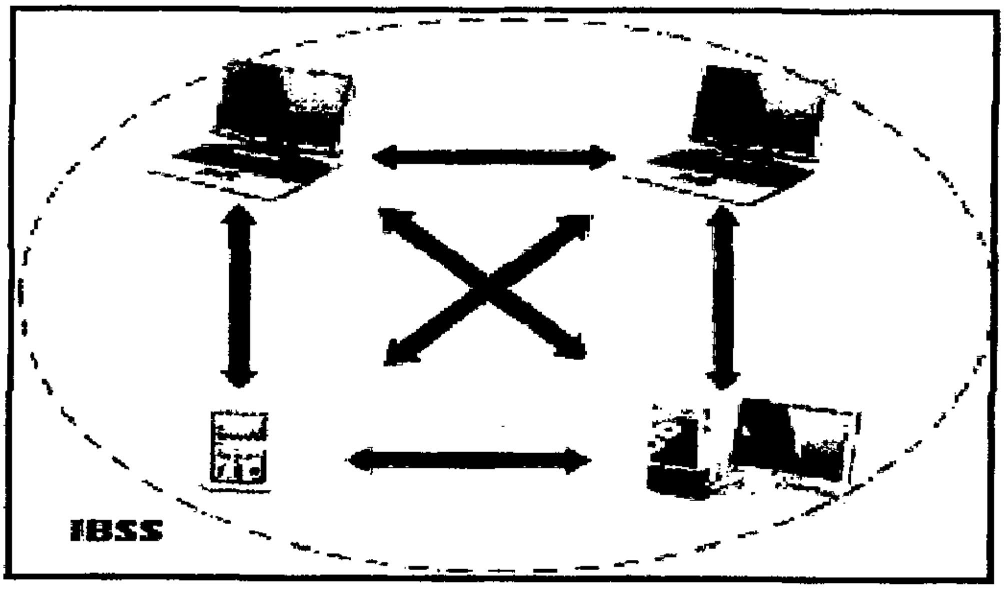


Fig. 1.2 Independent Basic Service Set

IEEE 802.11g standard improves the performance of WLANs, while providing compatibility with the existing installed base of 802.11b networks [29]. IEEE 802.11g combines the best of both IEEE 802.11a and IEEE 802.11b. 802.11g supports bandwidth up to 54 Mbps and it uses the 2.4 GHz ISM band frequency for greater range [93].

1.2 Challenges in WLANs

Many different and sometimes competing design goals have to be taken into account for WLANs to ensure their commercial success.

• Global operation:

WLAN *products should sell in all countries, therefore, many national and international* frequency regulations have to be considered.

• Low Power:

Devices communicating through WLAN are typically also wireless devices running on battery power. Hence, WLAN must implement special power saving modes and power management functions.

• License-free operation:

LAN operators do not want to apply for a special license in order to be able to use the product. Thus, the equipment must operate in a license-free band, such as the 2.4 GHz ISM band.

• Bandwidth:

Bandwidth is the one of the scarcest resource in wireless networks. The available bandwidth in wireless networks is far less than the wired links.

• Link Errors:

Channel fading and interference cause link errors and they may sometimes be very severe.

• Robust transmission technology:

Compared to wired counterparts, WLANs operate under difficult conditions. If they use radio transmission many other electrical devices may interfere.

• Simplified spontaneous co-operation:

To be useful in practice, WLANs should not require complicated setup routines but should operate spontaneously after power up. Otherwise these LANs would not be useful for supporting e.g., ad hoc meetings, etc.

• Easy to use:

LANs should not require complex management but rather work on a plug-and-play basis.

• Protection of investment:

A lot of money has already been invested into wired LANs. Hence new WLANs must protect this investment by being inter operable with the existing networks.

• **Safety and security:**

Most important concern is of safety and security. WLANs should be safe to operate, especially regarding low radiation. Furthermore, no users should be able to read personal data during transmission i.e., encryption mechanism should be integrated. The network should also take into account user privacy.

• **Transparency for application:**

Existing applications should continue to run over WLANs. The fact of wireless access and mobility should be hidden if not relevant.

• **Range**

In indoor environment, building structures like metal framework, walls, doors and even people, can affect the manner in which the energy propagates, and thus interfere with the range and coverage a particular system achieves. The current range for typical wireless LAN systems varies from under 100 feet to more than 300 feet because most WLAN systems use RF waves and these radio waves can penetrate most indoor walls and obstacles [6].

1.3 Why to use WLAN

Reduced Cost:

In contrast with the wired LAN, WLANs are considered to be cheapest network, because whenever network administrator wants a device to connect there is no need for any more wires or cables and as many devices can connect with the help of access points [10].

Mobility:

WLAN systems can provide LAN users with access to shared information anywhere in their organization and mobility increases productivity and those service opportunities are not possible with wired networks [87].

Installation Flexibility:

Wireless technology allows the network to go beyond the area where wire cannot go.

Installation Speed and Simplicity:

Installation of WLAN system is fast and easy and can eliminate the need of cable through walls and ceilings.

Scalability:

To meet up the requirements of a particular applications and installations WLAN system can be configured in a variety of topologies and configurations can easily be changed in the infrastructure mode, where thousands of users can accommodate in a single environment and allow roaming over a broad area by adding access points to boost or extend coverage.

1.4 Indoor Propagation

The radio wave propagation is a complex phenomenon and is required in order to predict the performance of a wireless system in its working environment and is affected by various factors such as distance, propagation environments, signal interference, reflections, diffraction and attenuation.

The main complexity of the indoor propagation channel is its low probability of line of sight (LOS) path between transmitter and receiver and its sensitiveness to site-specific. These phenomena may degrade the signal strength quality of the WLAN network. The indoor propagation characteristics should be considered fully in an order to obtain the maximum signal quality without modifying the indoor facilities such as walls, tables, chairs, and other elements.

1.5 What is Optimization

Optimization is the search for the best solution among alternatives, or the extreme value of a variable or a function. The process of finding the largest or the smallest possible value, which is a given function can attain in its domain of definitions, is known as optimization. The function to be optimized could be linear, non-linear, fractional or geometric. Sometimes even the explicit mathematical formulation of the function may not be available often the function has to be optimized in a prescribed domain, which is specified by a number of constraints in the form of inequalities and equalities. The process of optimization addresses the problem of determining those values of the independent variables which do not violate the constraints and at the same time give an optimal value of the function being optimized. Thus, the mathematical techniques for finding the optimal value (the greatest possible value or the least possible value) of a function are called Optimization Techniques.

Optimization is a mathematical discipline that concerns the finding of minima and maxima of functions, subject to so-called constraints. Optimization is an interdisciplinary subject cutting through the boundaries of art, science, mathematics, economics, engineering, natural sciences, and many other fields of human endeavour [86]. Optimization comprises a wide variety of techniques from operations research, artificial intelligence and computer science, and is used to improve business processes in practically all industries. The interaction between computer science and optimization has yielded new practical solvers for global optimization problems, called meta-heuristics. Some of the population-based methods are: Genetic Algorithm, Evolutionary Programming, Evolution Strategies, Ant Colony Optimization, Particle Swarm Optimization (PSO) and Differential Evolution (DE). The present study is concentrated on meta-heuristic namely PSO (Particle swarm optimization).

1.5.1 Why Particle Swarm Optimization (PSO)

In the past several years, PSO has been successfully applied in many research and application areas. It has been demonstrated that PSO gets better results in a faster, cheaper way in comparison to other methods like Genetic algorithms, Simulated Annealing etc. PSO is a population-based search algorithm inspired by the behaviour of biological communities that exhibit both individual and social behaviour; examples of these communities are flocks of birds, schools of fishes and swarms of bees. The PSO system consists of a population (swarm) of potential solutions called particles. Particle Swarm Optimization technique, a new evolutionary soft computational technique, has been used to eliminate the random noise present in the bio-medical images.

1.6 Simulation Software Qualnet 5.0 for Wireless Network

Simulation is the imitation of the operation of a real-world process or system over time. Simulation involves the generation of an artificial history of the system, and the observation of that artificial history to draw inferences concerning the operating characteristics of the real system that is represented. Simulation is an indispensable problem-solving methodology for the solution of many real-world problems [31]. Nowadays different simulation softwares are available to understand the behavior of WLAN network like OPNET, NS-2, GLOMOSIM and Qualnet etc. QualNet Developer is a tool created by Scalable Network Technologies (SNT) to improve the design, operation, and management of networks. It is a commercial ad hoc network simulator based on the GloMoSim. QualNet Developer5 is ultra high-fidelity network simulation software for modelling wireless, wired and mixed-platform network and networking device performance. QualNet Developer is the only modeling and simulation tool that can explore and analyze early-stage alternative device designs and application code in closed, synthetic networks at real time speed, at a scale of up to thousands of network nodes. It uses simulation and emulation to predict the behavior and performance of networks with thousands of nodes [60]. QualNet Developer enables users to:

•Design new protocol models
•Optimize new and existing models
•Design large wired and wireless networks using SNT-provided or user-designed models
•Analyze the performance of networks and perform "what-if" analyses to optimize them
• Real time speed or faster
• Real network fidelity and network results at a simulation price

1.7 Background of the problem

This section summarizes the research plan of the author to perform in order to complete the work. Details of the techniques, as well as plan of action are detailed later in this thesis. Planning and implementing Indoor WLAN is a time consuming and can be a tedious work, because if the access points (APs) are placed too close to each other, this will lead to excessive co-channel interferences and increases the unnecessary cost. But if they are placed far apart, they will generate a coverage gap. Indoor scenarios are usually very complicated and due to moving people rapidly changing environment.

For the indoor environment, the obstruction is due to the two types of elements and they are static and dynamic elements. The static elements are such as natural and manmade material and the dynamic element comprises of moving objects. The wireless performance could be hampered due to the change in location and the number of increased users. These disadvantages can be overcome by using a good optimization technique and simulation tools and providing maximum coverage and location of the users.

1.8 Goals and Objective

The objective of the present work is to analyze the measured data in terms of signal strength in the indoor WLAN 802.11g at Malviya Bhavan, Boys hostel Building, Indian Institute of

Technology, Roorkee, Saharanpur Campus coverage using optimization technique and simulation software.

The outline of the present work is as follows:

- Collection of data for received signal strength at frequency of 2.4 GHz using MSA338 Spectrum Analyzer for different scenarios at Malviya Bhavan, Boys hostel Building, Indian Institute of Technology, Roorkee, Saharanpur Campus.
- The assessment of coverage of access points using QUALNET 5.0 simulation design tool in Indoor WLAN using above data.
- The assessment of coverage of access points using Particle Swarm Optimization to find the coordinates of APs for their locations in free space and line of sight based on above measurements.
- Analyzed the effect of interference due to obstacles, such as hard partitions like walls, ceiling tiles, wooden doors etc. and soft partitions such as tables, chairs, furniture, human being etc. and other elements in the indoor environment.
- Analysis of optimized results with observed results.

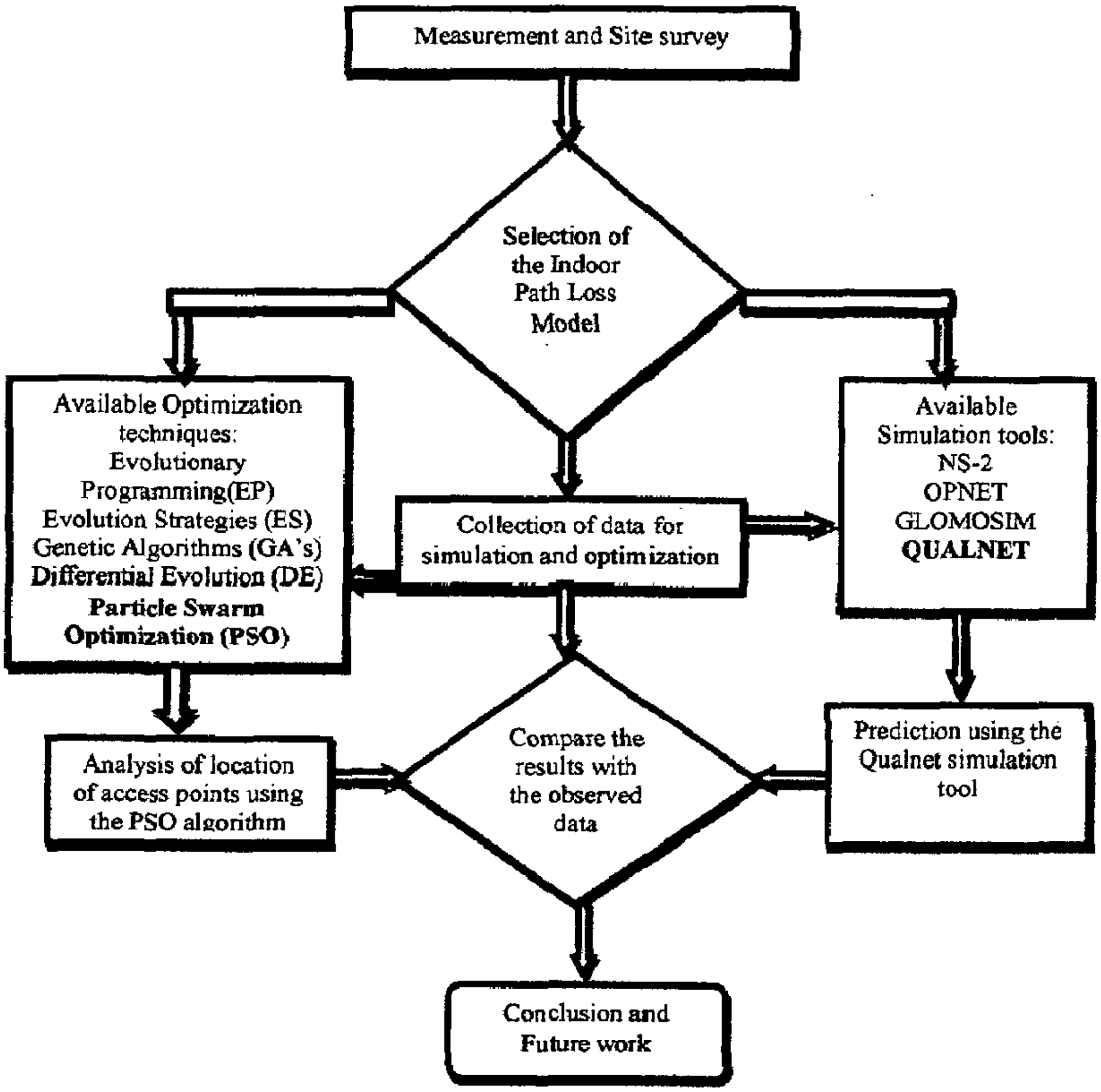
1.9 Layout of Thesis

Thesis methodology is divided into different steps in order to simplify the work. The steps are shown in terms of Flowsheet1.1. This section outlines the structure of the thesis. The thesis is divided into six chapters.

- In Chapter two, the fundamentals of indoor propagation mechanism, IEEE 802.11 standards and optimization techniques have been discussed.
- Chapter three shows the measurements taken using MSA338 spectrum analyzer and analysis by using the simulation software Qualnet 5.0 for performance coverage of access points in indoor WLAN.
- Chapter four explains the results and analysis of the measurement using the particle swarm optimization technique and the analysis for location of access points and maximum coverage for the users.
- Chapter five shows the measurement and the predication made by comparing optimized and simulated results with observed data and analyzed the effect of signal losses

obtained by the obstacles and interferences such as walls, tables, chairs, human beings and the other elements in the indoor environment.

Finally, we provide the concluding remarks and scope for future work in chapter 6.



Flowsheet1.1 Work plan of the thesis

CHAPTER 2

FUNDAMENTALS OF INDOOR PROPAGATION MECHANISM, IEEE 802.11 STANDARD AND OPTIMIZATION TECHNIQUES

This chapter presents an overview of aspects and concept of the systems and techniques used in the present work such as indoor propagation mechanism, IEEE 802.11 standards, measurements using spectrum analyzer, Qualnet5.0 simulation software for the performance coverage of the users and particle swarm optimization technique.

In the section 2.1, brief description of the indoor propagation mechanism has been given. Section 2.2 presents the line of sight propagation and section 2.3 describes the concept of free space loss. Section 2.4 describes the indoor path loss. In section 2.5 IEEE 802.11 Standards has been given. Section 2.6 presents the measurement tools. Section 2.7 describes the optimization technique and particle swarm optimization. In Section 2.8 the Qualnet simulation software is given. Brief summary of this chapter is shown in section 2.9.

2.1 Indoor Propagation Mechanisms

The performance of the wireless system depends heavily on the characteristics of the indoor propagation. The information is transmitted through an antenna and then it converts the radio frequency signal into an electromagnetic wave. The electromagnetic wave is intercepted by the receiving antenna at the receiver, which converts it back to an RF signal. Ideally, this RF signal is the same as that originally generated by the transmitter. The original information is then demodulated back to its original form. Indoor radio propagation is not influenced by weather conditions, such as rain, snow, foliage or clouds, as is outdoor propagation, but it can be affected by the layout of rooms, building structure and the type of different construction building materials.

In the indoor environment the propagated electromagnetic signal can undergo necessary three mechanisms of electromagnetic wave propagation i.e. reflection, diffraction and scattering. These three phenomenon cause signal distortions, making the signal either become stronger and additional signal propagation losses. These phenomena can also create additional propagation paths, beyond the direct line of sight path between the radio transmitter and receiver, resulting in multiple signals getting to the receiver with different delays. This leads to shadowing and multi-path fading, affecting the performance of wireless communication systems as it depends on the transmission path between the transmitter and the receiver [37].

2.1.1 Reflection:

When a propagating electromagnetic wave impinges upon an object, which is having larger dimensions than the wavelength, reflection occurs. During reflection, part of the wave may be transmitted into the object with which the wave has collided. Reflections occur from the surface of the earth and from walls and buildings. The reflected waves may interfere constructively or destructively at the receiver [24]. The propagated signal striking a surface will either be reflected, absorbed, or the combination of both and this reaction depends on the physical and signal properties. The physical properties are the surfaces geometry, texture and material composition and the signal properties are the arriving incident angle, orientation and wavelength. Perfect conductors will reflect the entire signal. Smooth metal surfaces of good electrical conductivity are efficient reflectors of radio waves. All other materials will reflect part of the incident energy and transmit the rest. The amount of transmission and reflection depends on the reflecting material and on the material thickness, angle of incidence and dielectric properties. In an indoor environment, objects such as walls, ceilings, floors, and furniture are the major contributors of reflection [24]. Fig. 2.1 shows the reflected signal.

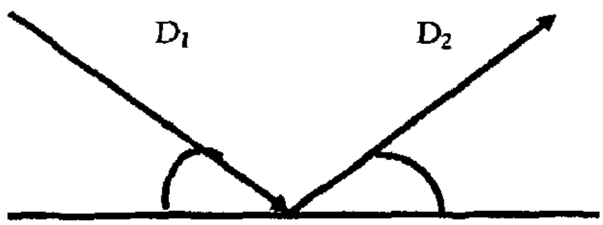


Fig. 2.1 Reflected Signals

2.1.2 Diffraction:

Diffraction is the name given to the mechanism by which waves enter into the shadow of an obstacle. When the radio path between the transmitter and receiver is obstructed by the surface with sharp irregularities, which is large compared to the wavelength of the radio wave, diffraction occurs and when there is no line-of-sight (LOS) between the transmitter and receiver. Diffraction allows waves to bend around the obstacle and this change makes it possible to receive energy around the edges of an obstacle as shown in Fig. 2.2

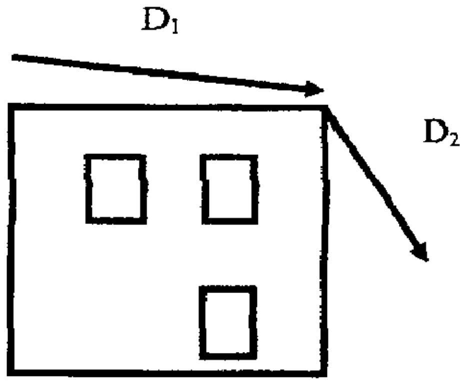


Fig. 2.2 Diffraction of a Signal

In the Indoor environment, there are many types of edges and openings and both orientated in the horizontal and vertical planes. The resultant diffracted signal depends on the geometry of the edge, impinging signal properties and on the spatial orientation such as amplitude, phase and polarization. The diffraction of a wave at an obstacle edge results that the wave front bends around the obstacle edge and diffraction is found close to the inside walls around corners and hallways.

2.1.3 Scattering:

When the medium through which the wave travels consists of objects with dimensions smaller than the wavelength and where the number of obstacles per unit volume is large, scattering occurs. Scattering is the process in which small particles of different index of refraction suspended in a medium diffuse a portion of the incident radiation in all the directions.If there are many small objects relative to the signal wavelength in the signal path then the propagated wave front will break into many directions. In the indoor environment scattered waves are produced by rough surfaces, small objects or by other irregularities [24]. The resulted signal will scatter in all directions and adding to the constructive and destructive interference of the signal as shown in Fig. 2.3. The construction materials such as for electrical and plumbing service produce the scattering effect [24].

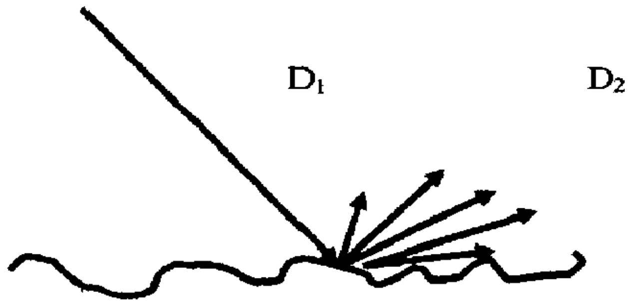


Fig. 2.3 Scattered Wave front

2.1.4 Multipath:

Multipath is caused by the combined effects of reflection, diffraction and scattering. Multipath is defined as a propagation phenomenon in which the transmitted signal arrives at the receiver by more than one path and the multipath signal components combine at the receiver to form a distorted version of the transmitted waveform.The direct and reflected signals are often opposite in phase, which can result in a significant signal loss due to mutual cancelation in some circumstances [14]. The multipath components can combine constructively or destructively depending on phase variations of the component signals as shown in Fig. 2.4. Depending on the differences in the path lengths of direct and reflected waves, the composite signal can be either larger or smaller than the direct signal. The destructive combination of the multipath components results in a severely attenuated received signal. In indoor multipath occurs in areas, where many metallic surfaces are present.

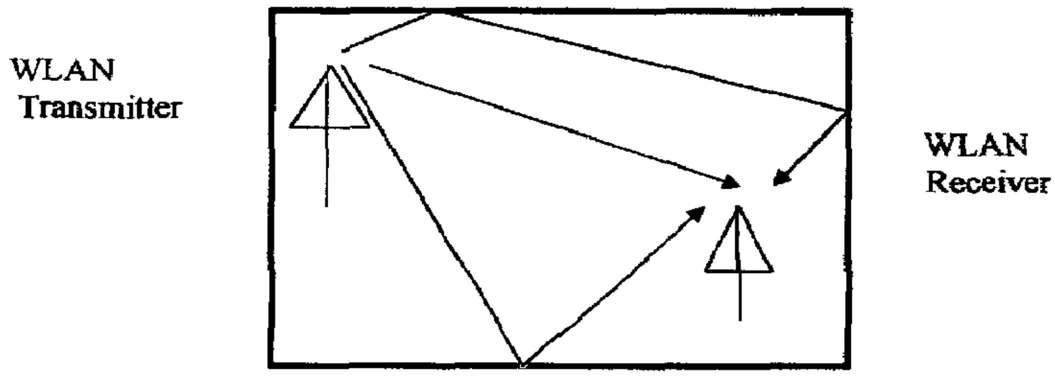


Fig. 2.4 Radio Signals Travelling over Multiple Paths

2.1.5 Refraction:

Refraction is defined as the bending of the waves as they move from one medium into another medium in which the velocity of propagation differs. This bending or change of direction is towards the medium that has the lower velocity of propagation. This results in a situation in which only a fraction or no part of the line of sight wave reaches the receiving antenna as shown in Fig. 2.5.

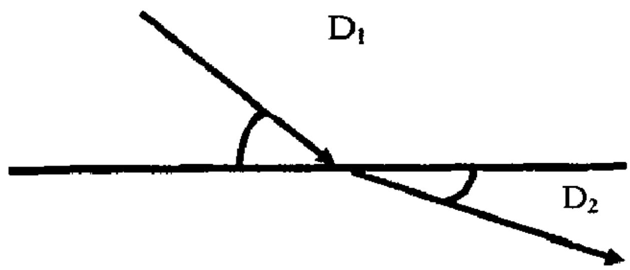


Fig. 2.5 Refracted wave

2.2 Line of Sight Propagation

At frequencies higher than 30 MHz, line of sight (LOS) is the dominant propagation mode. A signal can thus be transmitted either to a receiving antenna or to a satellite, which is in the line of sight of the transmitting antenna. In a communication system for the line of sight, a received signal will differ from the transmitted signal due to various transmission impairments [50]. Examples of LOS indoor spaces are; warehouses, auditoriums, factory floors enclosed stadiums etc. [24].

2.3 Free space loss

In any wireless communication, the receiving antenna will receive less signal power the farther it is from the transmitting antenna and assuming all the sources of impairments are nullified the transmitted signal attenuates over distance, because the signal is being spread over a larger and larger area. This form of attenuation is known as free space loss, which means that the loss in signal strength. Free space loss assumes that the receiver and transmitter are both in free space [24]. The free space loss occurs when the signal travels through space without any other effects attenuating the signal it will diminish as it spreads out.

2.4 Indoor Path Loss

Path loss (PL) is defined as the ratio of the effective transmitted power to the received power, calibrating out all system losses, amplifier gains and antenna gains.

Over any transmission medium, the strength of a signal drops with distance. This reduction in strength is called path loss as shown in Fig. 2.6. Path loss is the loss of power of an RF signal travelling or propagating through space. For effective communication received signal may not have sufficient strength and therefore system performance degrades significantly. The amount of absorption in path loss will depend on the size and structure of an object. Thickness of an object can also losses the signal [23]. It is expressed in dB. Path Loss of RF signals occurs naturally with distance and the path between receiver and transmitter is usually blocked by ceilings, walls and other obstacles [50].

In the indoor structure there are variety of physical barriers and materials and the amount of attenuation varies with the frequency of the RF signal, building construction and layout, obstructing materials type and density.

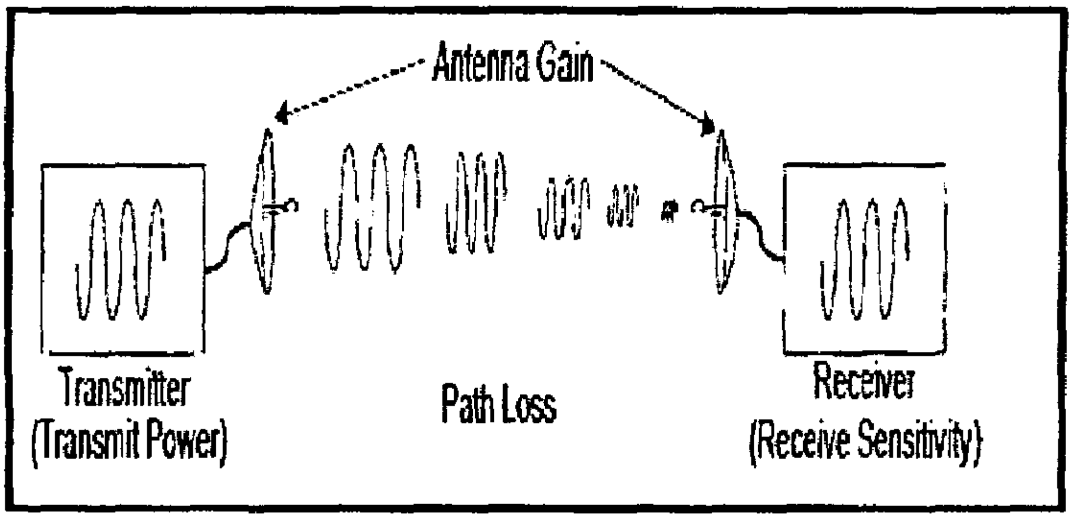


Fig. 2.6 Indoor path loss

Path loss depends on:

- The distance between transmitting and receiving antennas.
- Line of sight clearance between the receiving and transmitting antennas.
- Antenna height.

2.4.1 Obstacles to the signal strength

The objects absorb or reflect signal strength and degrade or block the signal [57]. The obstacles or the interferences in the indoor area are given below. For example:

Walls –If the wall is composed of heavier construction materials, such as concrete or brick walls for both exterior and interior space.

Furniture –That are largely made of metal and wood.

Ceiling tiles –Especially if they are made up of material such as metal.

Coated glass – If the transparent glass coated with a metalized film or has a wire mesh embedded in it degrade signal strength.

Natural elements – such as water, trees, and bushes in courtyards, lobbies or other interior public spaces.

2.5 IEEE 802.11 Standards

The original IEEE 802.11 standard is a set of standards, released in 1997 is developed by the Institute of Electrical and Electronics Engineers (IEEE) and defines a common media access control (MAC) layer that supports the operation of all 802.11-based WLANs by performing core functions, such as managing communications between access points and radio network cards. The physical layer handles the transmission of data for the WLAN by using various modulation schemes. Subsequent amendments to 802.11 define specific physical (PHY) layers, such as 802.11a, 802.11b, or 802.11g etc. The 802.11 data link and physical layers is shown in Fig. 2.7. The IEEE 802.11 standard specifies parameters for both the physical and medium access control (MAC) layers of a WLAN and it defines how wireless networks communicate [28]. The MAC layer consists of protocols responsible for maintaining the use of the shared medium. These standards provide the basis for Wi-Fi wireless networks. The WLAN IEEE standards are shown in Table 2.1.

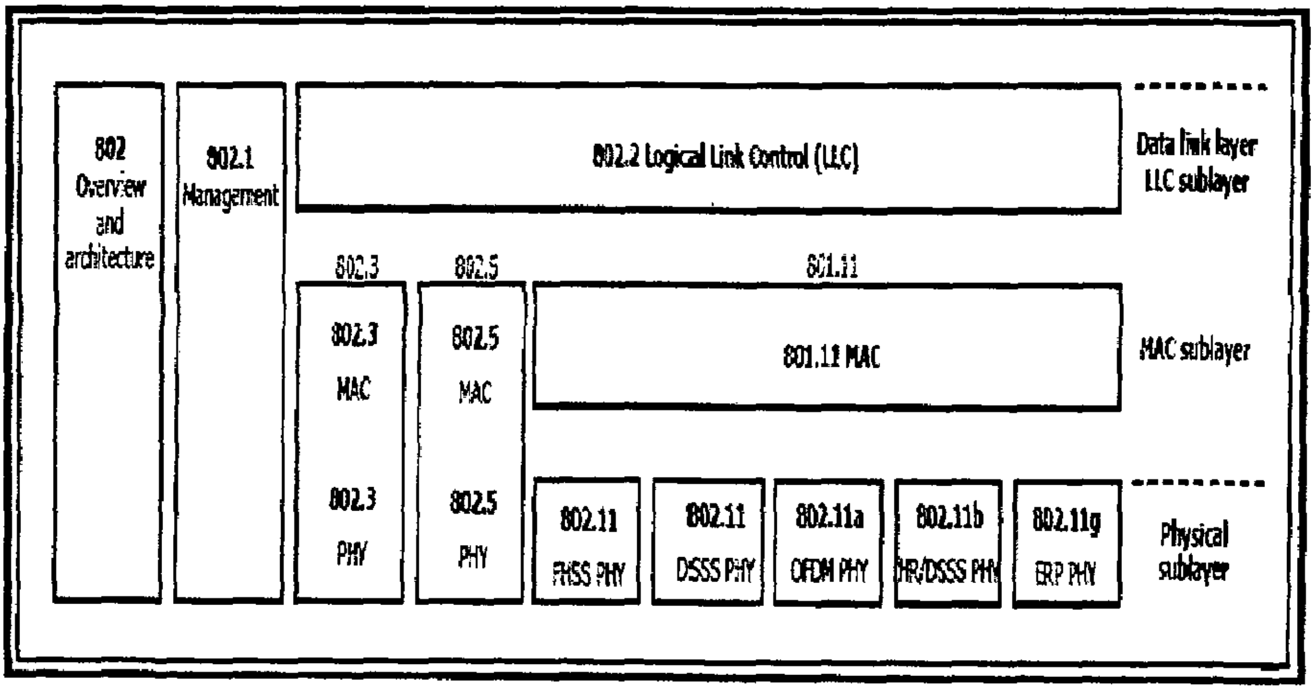


Fig. 2.7 802.11 data link and physical layers (Reproduced from [18])

Table 2.1 The WLAN IEEE standards

PARAMETERS	IEEE 802.11A	IEEE 802.11B	IEEE 802.11G
Standard Approved	September 1999	September 1999	2002
Unlicensed Frequencies of Operation(GHz)	5.15-5.35 GHz	2.4-2.4835GHz	2.4-2.4835GHz
Available Bandwidth(MHz)	300 MHz	83.5 MHz	83.5 MHz
Modulation Technique	OFDM	DSSS	DSSS, OFDM
Throughput speeds(Mbps)	54Mbps	11Mbps	54Mbps
Number of access points required	Every 50 feet	Every 150 feet in each direction	Every 150 feet in each direction
Data Rate per Channel	54, 48, 36, 24, 18, 12, 9, 6 Mbps	11, 5.5, 2, 1Mbps	54, 36, 33, 24, 22, 12, 11, 9, 6, 5.5, 2, 1 Mbps
Maturity	Less matured but progressing fast	More matured products	Under development
Cost	More expensive	Cheaper	More expensive

2.5.1 IEEE 802.11a

The Institute of Electrical and Electronics Engineers (IEEE) ratified the original 802.11 specification in 1997 as the standard for wireless LANs such as 802.11a standard operates in the 5GHz spectrum. The 802.11a standard was designed for higher bandwidth applications and includes data rates of 6, 9, 12, 18, 24, 36, 48, 54 Mbps using orthogonal frequency division multiplexing (OFDM) modulation on up to 12 discrete channels [29].Due to its higher cost, 802.11a is usually found on business networks. 802.11a supports bandwidth up to 54 Mbps and signals in a regulated frequency spectrum around 5 GHz. This higher frequency compared to 802.11b shortens the range of 802.11a networks. The higher frequency also means 802.11a signals have more difficulty penetrating walls and other obstructions. Because 802.11a and 802.11b utilize different frequencies, the two technologies are incompatible with each other [93].

2.5.2 IEEE 802.11b

The IEEE 802.11b WLAN standard, often called Wi-Fi is the most popular and widely implemented of the 802.11 family standards reasons for its easily availability and price of the supported products [57]. It implements an adaptive method that uses direct-sequence spread spectrum (DSSS) modulation technique to achieve a shorter range with higher bit rates and a long range with reduced bit rates. IEEE 802.11b is a physical layer standard operates in the 2.4 GHz industrial, scientific and medical (ISM) unlicensed frequency spectrum uses complementary code keying (CCK) modulation technology, which allows for higher data rates with less chance of multi-path propagation interference. The four data rates of 1, 2, 5.5, and 11 Mbps are specified on up to three non overlapping channels and the lowest two rates are also allowed on up to 13 overlapping channels [29]. Interference that can affect 802.11b devices that uses 2.4 GHz range include microwave ovens, bluetooth devices, cordless phones, garage door openers, wireless headsets and other appliances.

2.5.3 IEEE 802.11g

In 2002 and 2003, WLAN products supporting a newer standard called 802.11g emerged on the market. The IEEE 802.11g WLAN standard can be thought of as an intersection between the 802.11b and 802.11a standards. Like 802.11b, 802.11g operates in the same 2.4-GHz portion of the radio frequency spectrum that allows for license-free operation on a nearly worldwide basis. 802.11g achieves the high 54 Mbps data rates of 802.11a in the 2.4 GHz band, thereby maintaining compatibility with installed 802.11b equipment and the performance of 802.11g, in terms of both data transfer speeds and range, is better than any of the alternatives [89]. 802.11g is also limited to the same three non overlapping channels as 802.11b. A mandatory requirement of 802.11g is full backward compatibility with 802.11b, which both provides investment protection for the installed base of 802.11b clients [18]. 2.4-GHz 802.11g networks have the same coverage as 2.4-GHz 802.11b networks. The 802.11b standard uses CCK modulation, whereas 802.11g uses both CCK modulation for backward compatibility [29]. Like 802.11a, 802.11g uses Orthogonal Frequency Division Multiplexing (OFDM) for transmitting data to achieve better throughput at a given distance. The 802.11a standard also uses OFDM modulation, but there is more signal loss as it travels through objects because it uses a higher frequency [29]. OFDM is a more efficient means of transmission than Direct Sequence Spread Spectrum (DSSS) transmission, which is used by 802.11b. When coupled with various modulation types, 802.11g is capable of supporting much higher data rates than 802.11b. 802.11g uses a combination of OFDM and DSSS transmission to support a large set of data rates supported by both 802.11a and 802.11b [18]. The relative range of 802.11b, 802.11g and 802.11a devices is as shown in Fig. 2.8.

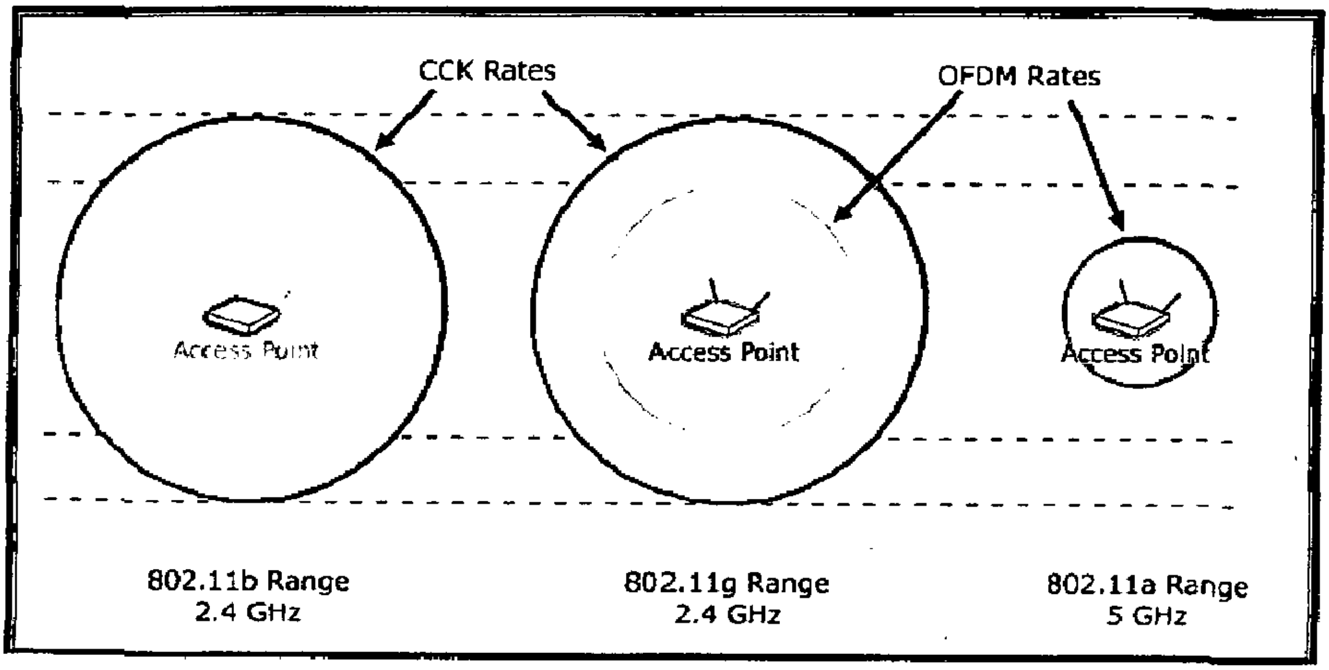


Fig. 2.8 Relative Range of 802.11b, 802.11g and 802.11a devices (Reproduced from [18])

2.6 Measurement tools

The various measurement tools used for the collection of data are access point and spectrum analyzer in the Malviya Bhavan, Boys Hostel Building, IIT Roorkee, Saharanpur Campus, Saharanpur.

2.6.1 Access Point

Wireless access points (APs or WAPs) are specially configured WLAN nodes performs all of WLAN node functions with distribution services. The AP is a device that links a wireless network to a wired LAN by means of Ethernet cable and act as a central transmitter and receiver of WLAN radio signals useful for larger networks. They are well-suited for adding wireless capability to an existing wired network. It increases the range of a wireless network and provides security features and additional network management. Access points used in small business or home networks are generally small, dedicated hardware devices featuring a built-in network adapter, radio transmitter and antenna. The advantages of access points are easy-of-use, range, features and throughput. Fig.2.9 shows the image of access point. In the wireless network, the access point sends and receives signals to any number of wireless devices such as adapters and routers and maintains an array, which stores the address of all WLAN nodes and responds with an acknowledgement, whenever it receives a successful data frame.

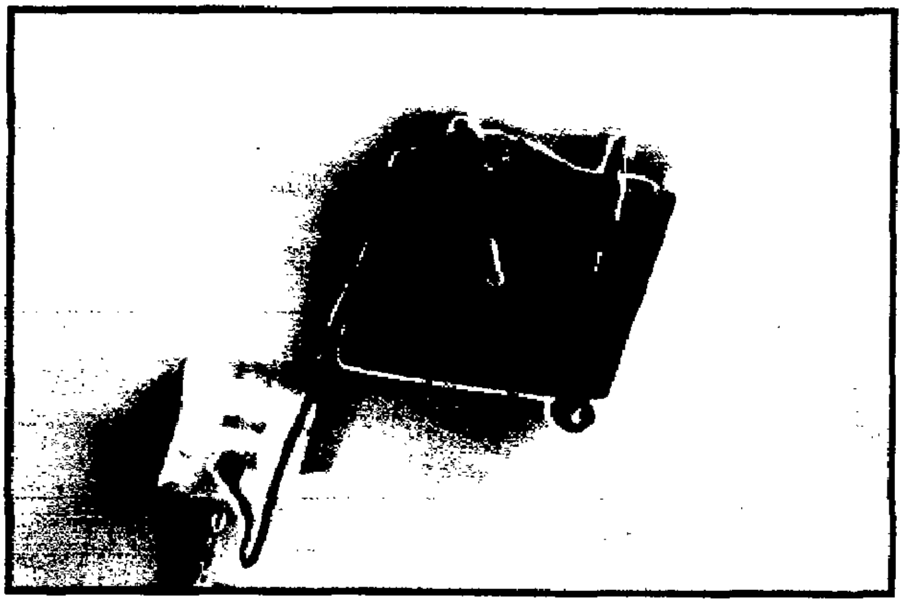


Fig.2.9 Image of Access Point

2.6.2 Spectrum Analyzer

A spectrum analyzer is a wide band, very sensitive receiver. It works on the principle of super-heterodyne receiver to convert higher frequencies ranging up to several 10s of GHz to measurable quantities [78]. The received frequency spectrum is slowly swept through a range of pre-selected frequencies, converting the selected frequency to a measurable DC level and displaying the same on a CRT. The received signal strength is normally measured in decibels (dBm). MSA338 is an authentic portable spectrum analyzer providing performance and functions that are comparable to large-size bench type in a compact, lightweight and inexpensive model as shown in Fig. 2.10.

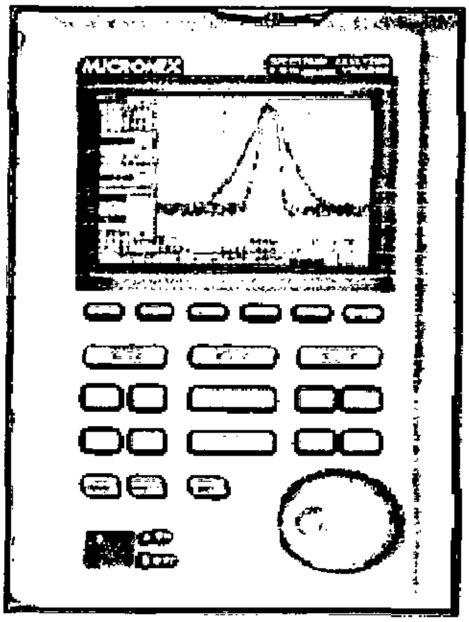


Fig. 2.10 MSA338 Spectrum Analyzer

2.7 Optimization

Optimization refers to the selection of a best alternative from a set of available alternatives or it is the process of making something more efficient or optimal.

Optimization means solving problems to minimize or maximize a real function by systematically choosing the values of real or integer variables within an allowed set. Broadly optimization techniques can be categorized as Conventional or classical and Unconventional techniques. The difference between conventional and unconventional optimization algorithms are given below [58]:

1. The conventional algorithms start from a single initial feasible solution, whereas the unconventional algorithms start with a set of initial feasible solutions.

2. The accuracy of the conventional algorithms depending on the selection of initial local solution, whereas the performance of unconventional algorithms will vary for every run and the solution may be local or global [58].

3. The conventional optimization algorithms need the function to be continuously differentiable throughout the range of search, while in unconventional algorithms the domains of the problems may be non convex and disconnected.

Some popular conventional methods are Newton-Raphson, Steepest descent, conjugate gradient search, quasi-Newton etc. and some popular unconventional optimization algorithms are

Genetic Algorithm, Evolutionary Programming, Evolution Strategies, Differential Evolution (DE), Ant Colony Optimization, Particle Swarm Optimization (PSO) etc.

2.7.1 Local and Global Optimal Solutions

For a minimization problem, a feasible solution x^* is said to global minima of the problem if $f(x^*) \le f(x)$ for all $x \in S$. If $f(x^*) \le f(x)$ for all $x \in S \cap N_\varepsilon(x^*)$, where $N_\varepsilon(x^*)$ is called a ε neighborhood of x^*, then x^* is called local minima. A point x^* is a stationary point if the derivative of the function $f(x)$ is zero at x^*.

An optimization problem may have no optimal solution, only one optimal solution or more than one optimal solution. If the problem has a unique local optimal solution, then it is also the global optimal solution. However, if the problem has no more than one local optimal solution, then one or more of these may be global optimal solutions.

In most of the Non-Linear Programming Problems (NLPP), a global optimal solution rather than a local optimal solution is desired. Determining the global optimal solution of a NLPP is much more difficult than determining the local optimal solution. However, because of the practical necessity, the search for the global optima is often necessary.

2.7.2 Particle Swarm Optimization for Global Optimization

Global Optimization refers to finding the extreme value of a given function in a certain feasible region. Such problems are classified in two classes; unconstrained and constrained problems. Particle swarm optimization (PSO) is an important unconventional optimization algorithm. It is a kind of evolvement-computation technology based on the movement and intelligence of swarms and it was developed in 1995 by Russell Eberhart (electrical engineer) and James Kennedy (social-psychologist). It optimizes a problem by having a population of candidate and uses a number of particles that constitute a swarm moving these particles around in the search space looking for the best solution. Each particle maintains a memory which helps it in keeping the track of its previous best position. The positions of the particles are distinguished as personal best and global best. PSO was first intended for simulating social behavior [58].

Another reason that PSO is attractive is that there are few parameters to adjust. One version, with slight variations, works well in a wide variety of applications. Particle Swarm

Optimization has been used for approaches that can be used across a wide range of applications, as well as for specific applications focused on a specific requirement.

PSO is an optimization tool provides a population-based search procedure in which individuals called particles change their position (state) with time. In a PSO system, particles fly around in a multidimensional search space. During flight, each particle adjusts its position according to its own experience, and according to the experience of a neighboring particle, making use of the best position encountered by itself and its neighbor. Thus, as in modern GAs and memetic algorithms, a PSO system combines local search methods with global search methods, attempting to balance exploration and exploitation.

2.7.3 Differences between PSO and other Unconventional Techniques

The most striking difference between PSO and the other unconventional is that PSO chooses the path of cooperation over competition. The other algorithms commonly use some form of decimation, survival of the fittest. In contrast, the PSO population is stable and individuals are not destroyed or created. Individuals are influenced by the best performance of their neighbors. Individuals eventually converge on optimal points in the problem domain. In addition, the PSO traditionally does not have genetic operators like crossover between individuals and mutation, and other individuals never substitute particles during the run. Instead, the PSO refines its search by attracting the particles to positions with good solutions. Moreover, compared with genetic algorithms (GAs), the information sharing mechanism in PSO is significantly different. In GAs, chromosomes share information with each other. So the whole population moves like a one group towards an optimal area. In PSO, only gbest (or Pbest) gives out the information to others. It is a one way information sharing mechanism. The evolution only looks for the best solution. In PSO, all the particles tend to converge to the best solution quickly, comparing with GA, even in the local version in most cases.

2.8 Simulation Software

In the research area of computer and communication networks, simulation is a useful technique since the behaviour of a network can be modelled by calculating the interaction between the different network components using mathematical formulas. They can also be modelled by actually or virtually capturing and playing back experimental observations from a real production networks. After we get the observation data from simulation experiments, the behaviour of the network and protocols supported can then be observed and analyzed in a series of offline test experiments. All kinds of environmental attributes can also be modified in a controlled manner to assess how the network can behave under different parameters combinations or different configuration conditions. The simulation program can be used together with different applications and services in order to observe end-to-end or other point-to-point performance in the networks [32]

Network emulation, however, means that network under planning is simulated in order to assess its performance or to predict the impact of possible changes or optimizations. The major difference lying between them is that a network emulator means that end-systems such as computers can be attached to the emulator and will act exactly as they are attached to a real network [32]. The different simulation softwares are shown in Table 2.2.

Table 2.2 Simulation Softwares

NAME	NS-2	OPNET	GLOMOSIM	QUALNET
Granularity	Finest	Fine	Fine	Finer
Metropolitan mobility	Support	Support	Support	Support
Parallelism	No	Yes	SMP/Beowulf	SMP/Beowulf
Interface	C++/OTCL	C	Parsec(C-based)	Parsec(C-based)
Popularity	88.8%	2.61%	4%	2.49%
License	Open source	Free academic License for limited use	Open source	Commercial
Graphical Support	No or very Limited visual aid	Excellent graphical support, Excellent facility for debug	Limited Visual aid	Good graphical support, Excellent for debug
Emulation	Limited	Not direct	Not direct	Yes
Scalability	Small	Medium	Large	Very large

2.8.1 QualNet

QualNet network simulation software has been developed and marketed by Scalable Network technologies. It is a commercial ad hoc network simulator based on the GloMoSim. It provides a comprehensive set of tools with many components for custom network modelling and simulation. QualNet also largely extends the set of models and protocols supported by the initial GloMoSim distribution. QualNet is the only modeling and simulation tool that can explore and analyze early-stage device designs and application code in closed, synthetic networks at real time speed or faster. Designed to take full advantage of the multi-threading capabilities of multi-core, multi-processor, cloud computing, cluster and 64-bit processor systems, QualNet supports over thousands of network nodes [60]. QualNet offers unmatched platform portability and interface flexibility. QualNet runs on sequential and parallel Windows, Linux, and Mac OS X operating systems, and is also designed to link seamlessly with other modelling and simulation applications.

Components of QualNet Developer:

QualNet Architect: Design Mode

QualNet Architect: Design Mode allows users to set up terrain, network connections, subnets, mobility patterns of wireless users, and other functional parameters of network nodes. Users can create network models by using intuitive, click and drag operations. They also can customize the protocol stack of any of the nodes and specify the application layer traffic and services that run on the network.

QualNet Architect: Visualize Mode

QualNet Architect: Visualize Mode gives the user opportunities to perform in-depth visualization and analysis of a network scenario designed in Design Mode. As simulations are running, users can watch packets at various layers flow through the network and view dynamic graphs of critical performance metrics. Real-time statistics are also an option, where users can view dynamic graphs while a network scenario simulation is running.

QualNet Analyzer

QualNet Analyzer is a statistical graphing tool that displays hundreds of metrics. We can customize the graph display. All statistics are exportable to spreadsheets in CSV format.

QualNet Packet Tracer

QualNet Packet Tracer provides a visual representation of packet trace files generated during the simulation of a network scenario. Trace files are text files in XML format that contain information about packets as they move up and down the protocol stack.

QualNet File Editor

QualNet File Editor is a text editing tool that displays the contents of the selected file in text format and allows the user to edit files.

2.9 Summary

This chapter provides the literature on aspects and concept of the systems such as indoor propagation mechanism, measurements using MSA338 spectrum analyzer, Qualnet5.0 simulation software for the performance coverage of the users and particle swarm optimization technique for the location of access points used in the present work. Different types of IEEE standards and regulations were reviewed in order to show how it made possible to communicate over different users.

CHAPTER 3
PROPAGATION COVERAGE IN INDOOR WLAN USING SIMULATION SOFTWARE

This chapter focuses on the propagation coverage using simulation based on measurement results. In simulation the propagation coverage is investigated using Qualnet5.0 simulation tool. In real and theoretical measurement there are plenty of factors that hamper signaling strength in an indoor environment. This chapter is organized as follows.

In the section 3.1, brief description of the related work is given. In section 3.2 the work plan for the coverage effect of users using Qualnet simulation software is given. In section 3.3 the simulation environment has been given. Propagation Environment of data collection site has been given in section 3.4. In section 3.5, methodology of the data collection has been given. In section 3.6 measurements and analysis using Qualnet simulation software for first floor and second floor has been given. Finally section 3.7, presents the brief summary of this chapter.

3.1 Related Work

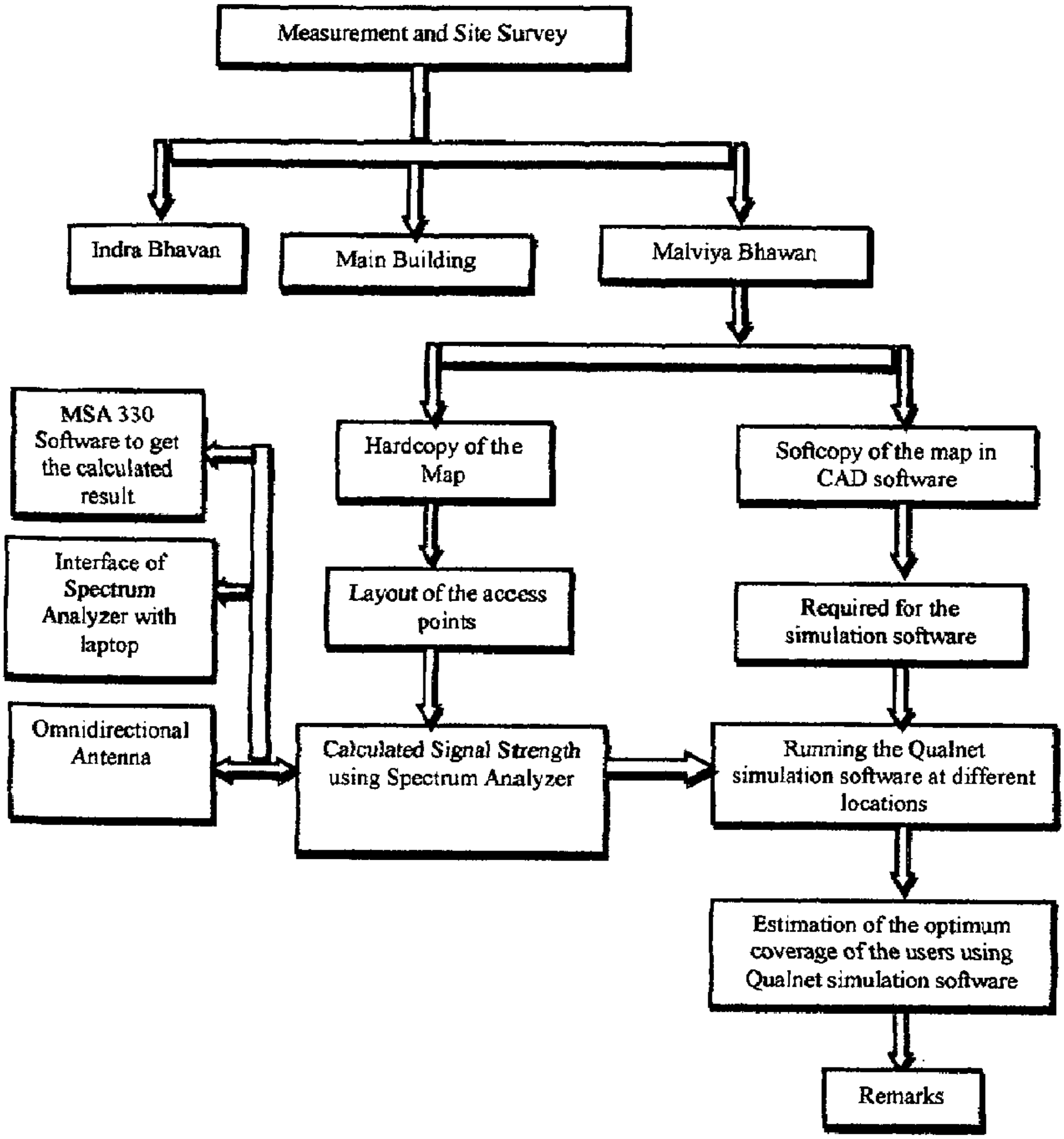
Mohd. Dani Baba, et. al [50] has developed a mathematical path loss model using OPNET simulation design tool, to evaluate the performance of indoor WLAN mobility. Agustin Zaballos, et.al [7] has used OPNET modeller in indoor and outdoor WLAN environments for the propagation loss estimation. Karthik Chandrashekar, et.al [36] has used OPNET modeler as the discrete event Simulator to estimate the performance of a indoor WLAN network. Traoré Soungalo et. al [83], has used OPNET modeller 9.1 for improving WLAN performance such as data rate, physical characteristics and fragmentation threshold. A brief summary of the related work on simulation in indoor WLAN is shown in Table 3.1.

Table 3.1 Related work using simulation technique

S.NO.	PAPER	MODEL	TECHNIQUE	AVAILABLE INFORMATION	AUTHORS	YEAR
1	Modelling new indoor and outdoor propagation models for WLAN	Linear, One Slope, Modified Free Space, Motley Keenan, COST Multi-Wall and CCIR Urban Model	OPNET Modeler	Non differentiable, Non convex	Agustin Zaballos, et.al[7]	2004
2	Performance Analysis of Indoor WLAN Mobility	Indoor Path Loss Model	OPNET 10 Simulator Software	Reflection, Diffraction, Scattering	Mohd. Dani Baba, et.al[50]	WSEAS Int. Conference on Electronics, Hardware, Wireless and Optical 2005
3	Optimal Design of Wireless Local Area Networks (WLANs) using Simulation	Indoor Path Loss Model	OPNET Modeler Direct search, Greedy, Graph based, SM and Genetic algorithms	Non differentiable	Karthik Chandrashekar, et.al[36]	IEEE 2009
4	Evaluating and Improving Wireless Local Area Networks Performance	Indoor Path Loss model	OPNET 9.1 Simulation Software	data rate, physical characteristics and fragmentation threshold	Traore Soungalo, et.al[83]	Int. Journal of Advancements in Computing Technology, March2011

3.2 Work plan

The measurements have been conducted in the Malviya Bhawan, Boys Hostel Building, IIT Roorkee, Saharanpur Campus to collect data for simulation & optimization. Using Spectrum Analyzer, the received signal strength of the access points has been calculated using omnidirectional antenna. The work plan for the coverage effect of users using simulation software is shown in Flowsheet 3.1.



Flowsheet3.1 The work plan for the coverage effect of users

3.3 Simulation Environment

The QUALNET 5.0 simulation design tool is used for performance coverage of the WLAN access points installed by the network administrator at different locations in the Malviya Bhawan, Boys Hostel Building, IIT Roorkee, Saharanpur Campus. Simulation environment parameters selection for present analysis is shown in Table 3.2.

Table 3.2 Simulation parameter

PARAMETER	VALUE
Area	64m x 60m
No. of Nodes	10
Frequency	2.4 GHz
Simulation Time	60sec
Node Placement	Random
Mobility Model	Random waypoint
Propagation Model	Free space
Channel Bandwidth	5.5 Mbps
Traffic Type	CBR
Routing Protocol	Bellman Ford
MAC Protocol	IEEE 802.11g

The above Table gives the various parameters and their corresponding values used in the present work.

3.4 Data collection at site

Experiments are conducted in the Malviya Bhawan, Boys Hostel, Saharanpur campus, IIT Roorkee to collect the data for simulation. The facility is a four floor (Ground floor to third floor) building and nineteen access points are distributed around the building in different block points installed by the network administrator in the corridors of the building. None at the ground level, ten on the first floor, nine on the second floor and none on the third floor. The access points are not evenly distributed over each floor and some access points are purposely placed so as to cover the floor above or below its location, as well as its immediate surrounding area. Front view of the building gives and data collection site is shown in Fig. 3.1(a-e).

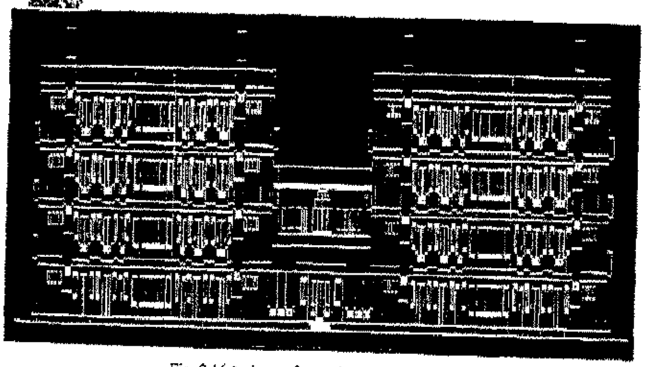


Fig. 3.1(a) gives a front view of the building

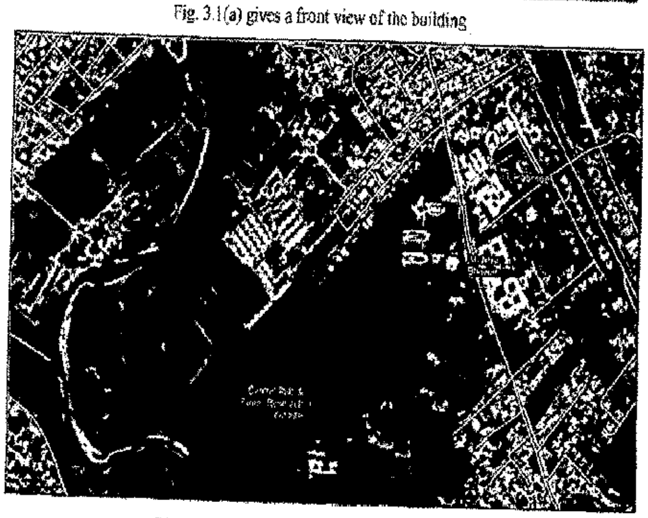


Fig. 3.1 (b) Google map of the data collection site

Fig. 3.1(c) Data collection site building

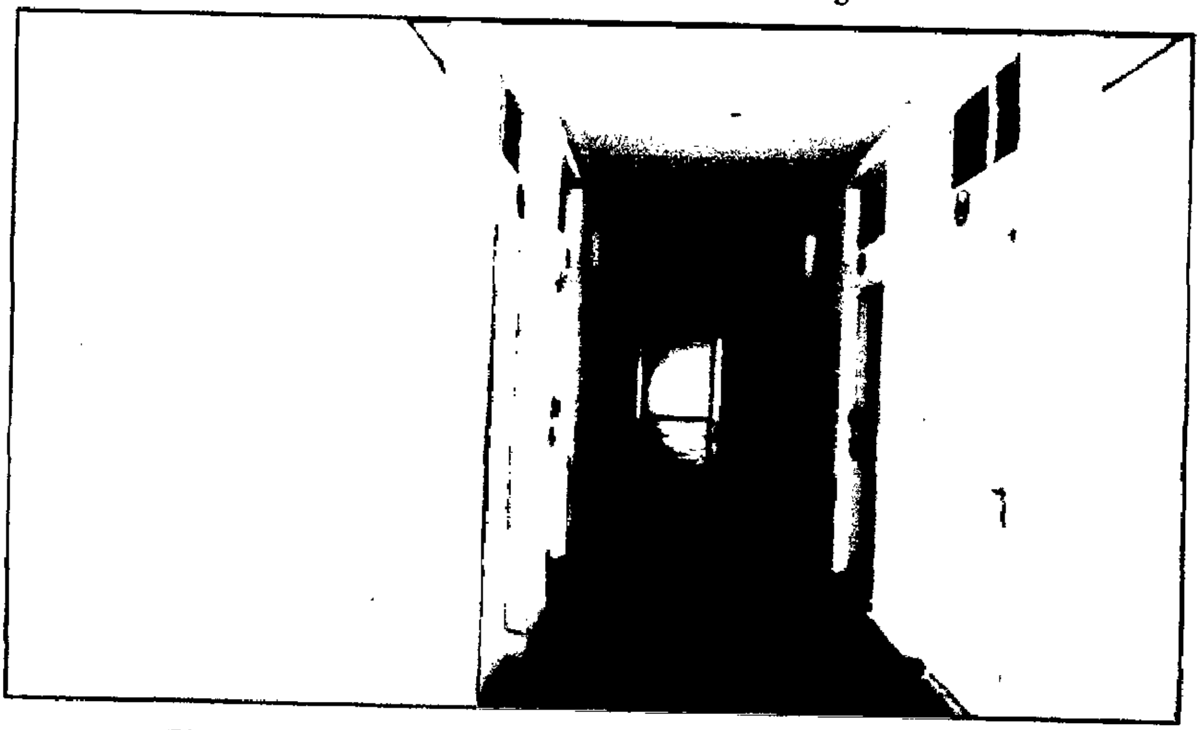


Fig. 3.1 (d) Corridor of the building where the access points installed

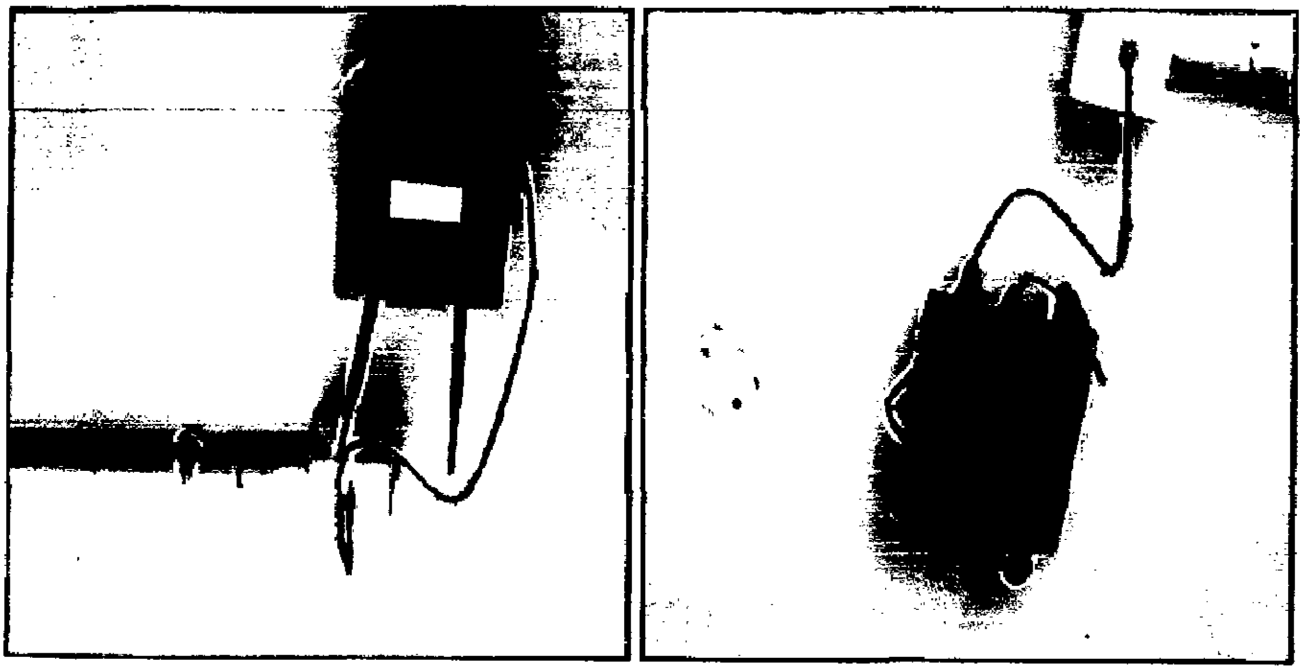


Fig. 3.1(e) Access point AP (link dwl-3200ap)

3.4.1 Data collection

We have performed our experiment in building considering free space and line of sight in the design area which has dimensions of 64m x 60m and have 400 users on four floors. Fig. 3.2 shows the layout of the building, the access points have been located at first floor and second floor. The plan of the floor where the experiments are conducted is shown in Fig. 3.3 for first floor. The first floor has 100 rooms with 100 users and part of corridors with ten access points installed in the corridors. The entire wing of the first floor is covered by ten access points installed at the locations of the corridors indicated by red symbols in Fig. 3.3. Ten locations of measurement are chosen on the first floor of the Malviya Bhavan building as shown in Fig. 3.3 denoted as A,B,C,D,E,F,G,H,I and J. The plan of the second floor where the experiments are conducted is shown in Fig. 3.4. The second floor has 100 rooms with 100 users and part of corridors with nine access points installed in the corridors. This is shown in Fig.3.4 and the access points are denoted as A, B, C, D, E, F, G, H and I.

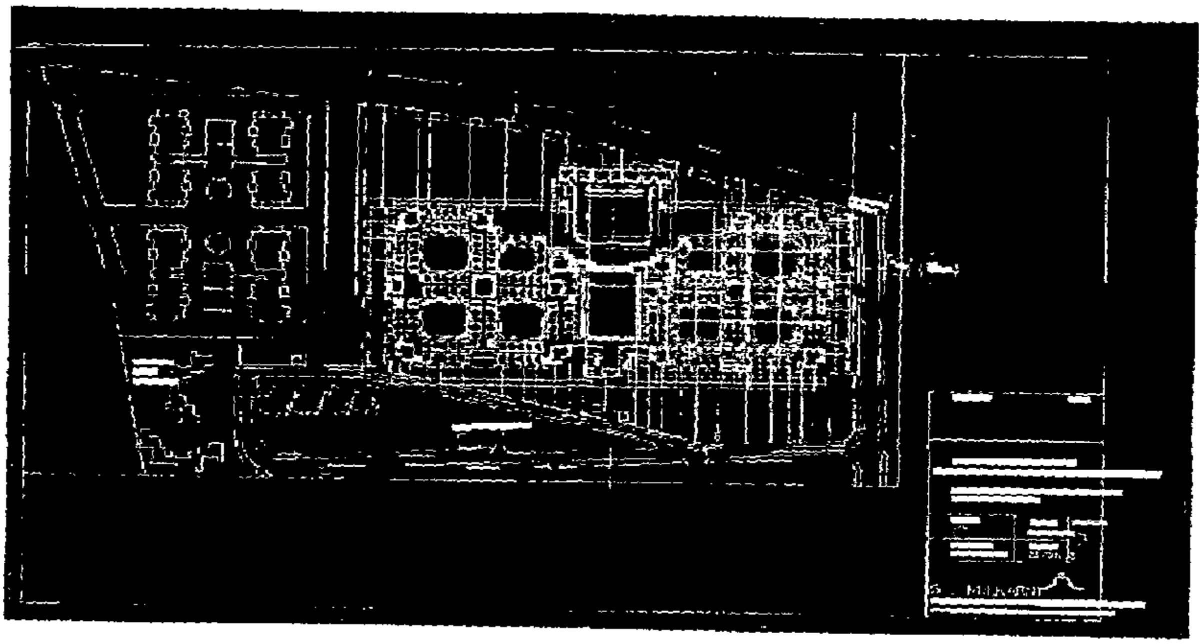


Fig. 3.2 Layout of the building

3.4.2 Set up for experimental data

The data are collected at the first and second floor of the building.

Domain Area: Malviya Bhawan, Boys Hostel, IIT Roorkee, Saharanpur Campus

Area: 64m X 60m

Type: Four floor Building

Standard: IEEE 802.11g

Device: Laptop running Windows 2007, MSA338 3.3GHz Spectrum Analyzer, M304 Omnidirectional Antenna, Access Point AP (LINK DWL-3200AP)

Tools and Software used: Qualnet 5.0 Simulation Software, Developer C++, AutoCAD software, MAS 300 PC software for Spectrum Analyzer.

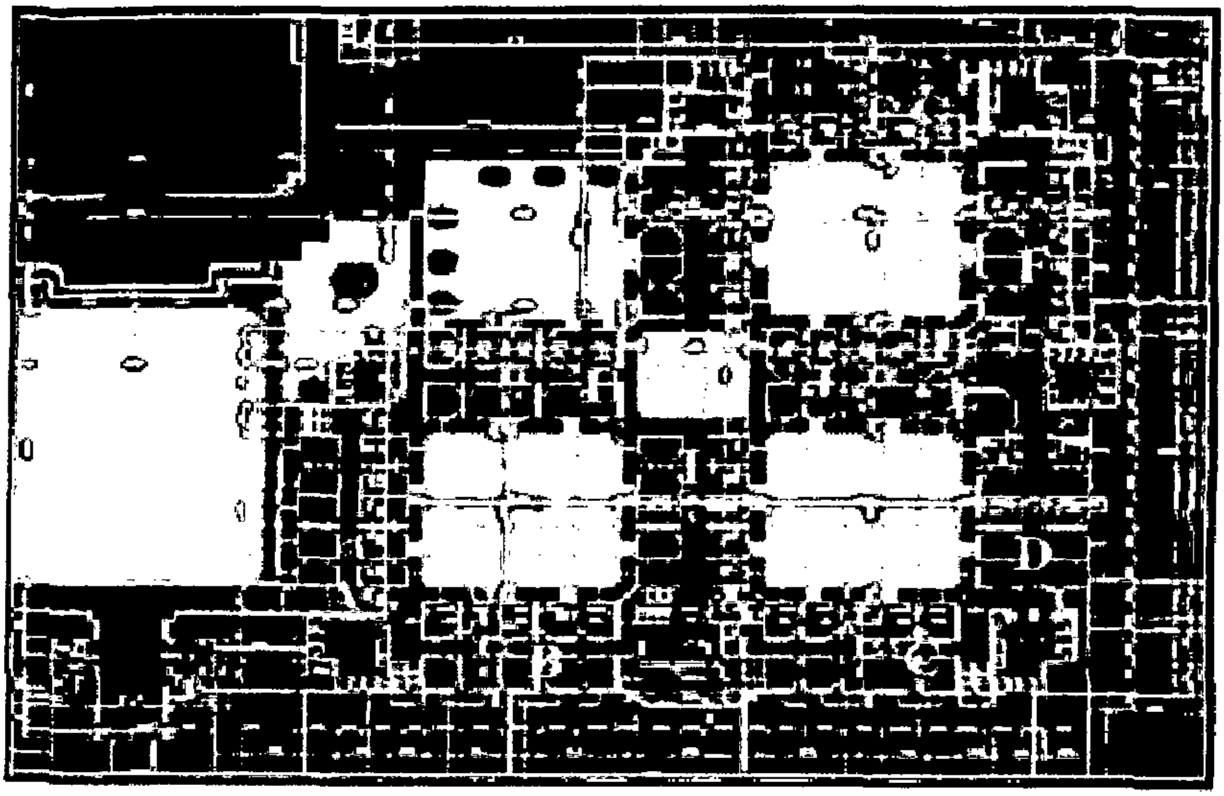


Fig. 3.3 Plan of the first floor where the experiment was conducted.

Readings were collected in the corridors.

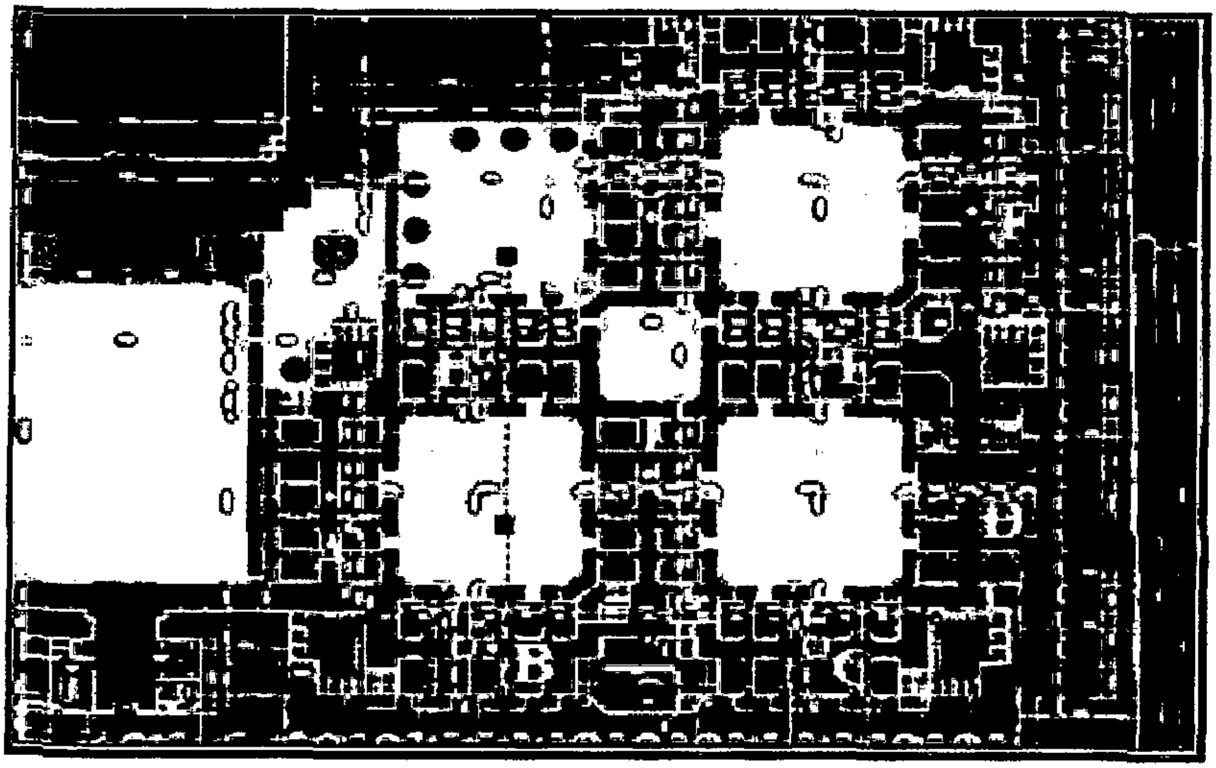


Fig. 3.4 Plan of the second floor where the experiment was conducted.

Readings were collected in the corridors.

3.4.3 Description of Measurement Scenarios

In the present analysis three different scenarios such as closed corridor, open corridor and hostel rooms are considered for measurements. The scenarios used are considered for developing path loss equations, by which a generalization for propagation in an indoor environment at 2.4 GHz is obtained. The scenarios are described as follows:

Scenario1: Closed Corridor

A closed corridor on the first and second floor of the hostel building is used for signal measurements. This corridor is closed on both sides with walls. This corridor is 3m high and 2m wide. Signal measurements are taken at every five feet interval in the middle of the corridor. Fig. 3.2 shows the layout of the building and Fig. 3.3 and Fig. 3.4 gives the plan of the first and second floor and shows the different locations at which measurements are taken.

Scenario2: Open corridor

An open corridor on the first and second floor of the hostel building is used for signal measurements. The corridor is open on one side and closed with a wall on the other side. This corridor is 3m high and 2.5m wide. Signal measurements are taken at every five feet interval in the middle of the corridor. Fig. 3.2 shows the layout of the building and Fig. 3.3 and Fig. 3.4 gives the plan of the first and second floor and shows the different locations at which measurements are taken.

Scenario3: Hostel Room with obstacles

A hostel room with furniture and computers is considered for signal measurements. This room is 3m by 3m. Signal measurements are taken at every two feet interval diagonally across the room. Fig. 3.2 shows the layout of the building and Fig. 3.3 and Fig. 3.4 gives the plan of the first and second floor and shows the different locations at which measurements are taken.

3.5 Methodology

Once the priority area has been identified the data has been collected nearby access points which require a connection to the wired LAN and a source of power. The signal strength has been measured using 3.3GHz Spectrum analyzer with omnidirectional dipole antennas at number of points around the access point. The coverage has been checked using qualnet simulation software in those priority areas that are within range. While in other places the aim is to identify the points where the available bandwidth is likely to drop below the theoretical maximum, typically where the signal strength falls below -70dBm [80].

3.6 Measurement and analysis using Qualnet simulation software

Qualnet simulation provides a comprehensive environment for designing protocols, creating and animating experiments and analyzing the results of those experiments. In the present work, using spectrum analyzer, the received signal strength of the access points has been calculated using omnidirectional antenna. And by using this data we have analyzed the optimum coverage effect of the users using simulation software for the coverage area of the site.

3.6.1 Analysis of results for line of sight and free space on the first floor

The analysis of the work has been carried out on the first floor with the line of sight and in free space, the signals has been captured at different point locations in corridors of the hostel building using Qualnet simulation software. Using simulation software, the simulated environment has been created at the 10 different access point locations from A to J is shown in Fig. 3.5 for the first floor.

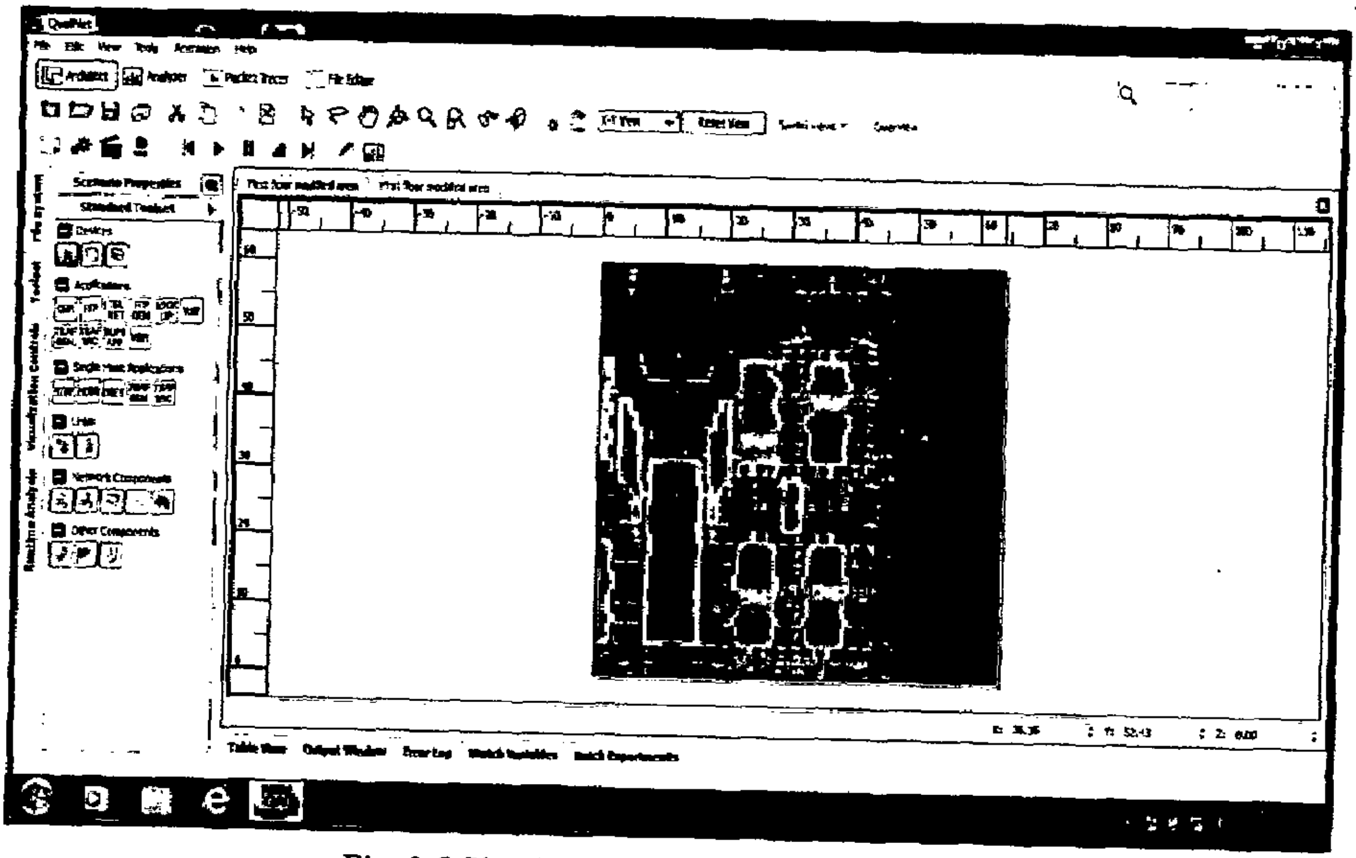


Fig. 3.5 Simulated Environment for first floor

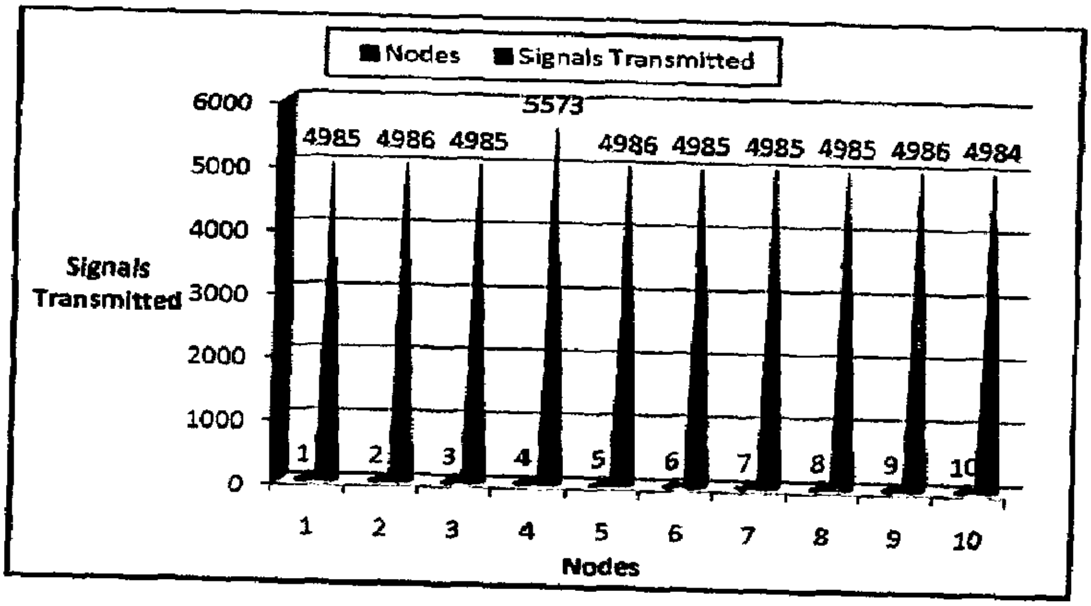


Fig. 3.6 Signals transmitted at physical Layer

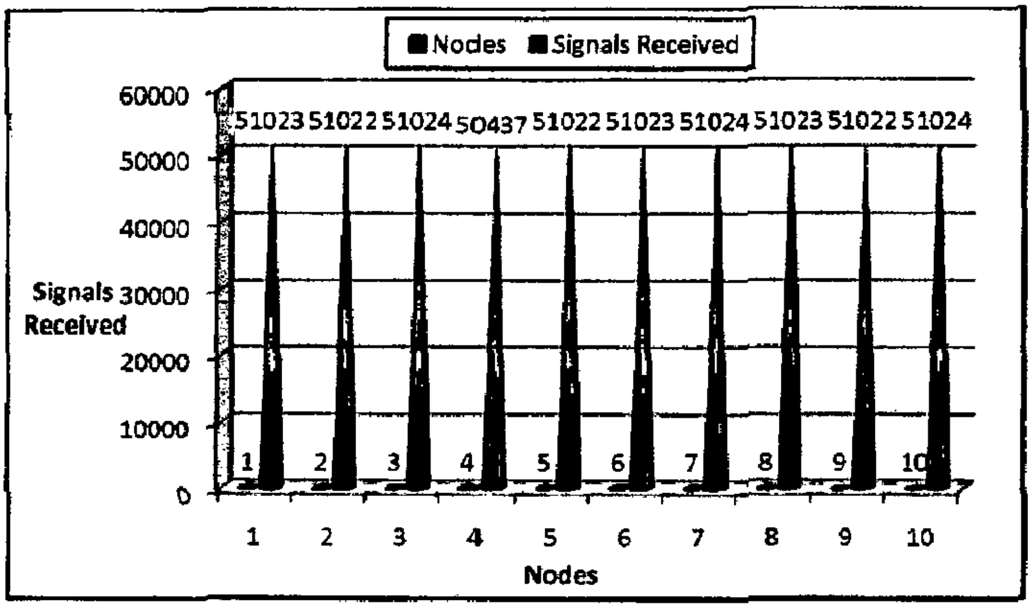


Fig. 3.7 Signals received from physical Layer forwarded to MAC

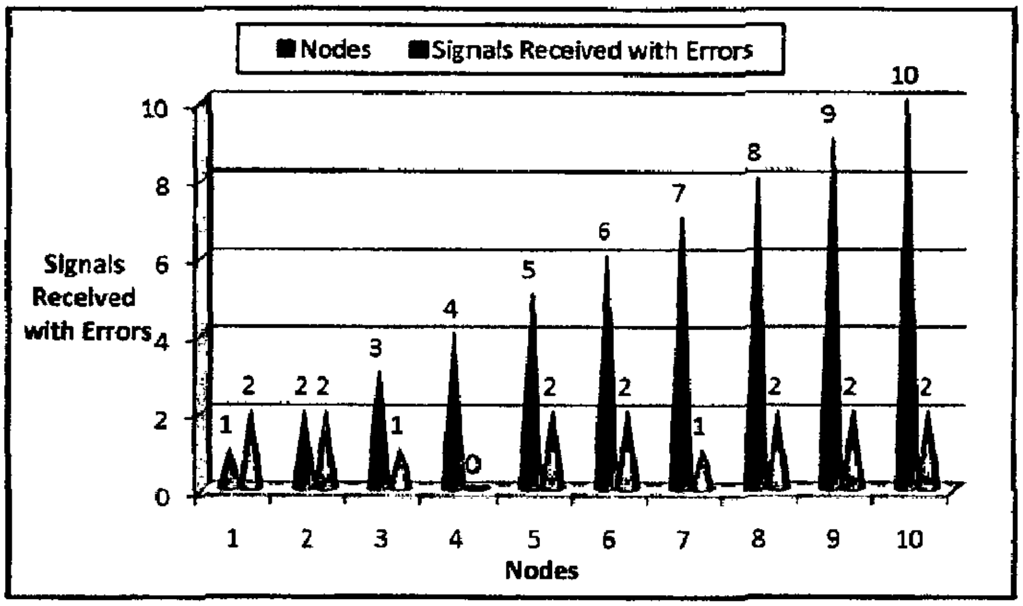


Fig. 3.8 Signals Received But With Errors

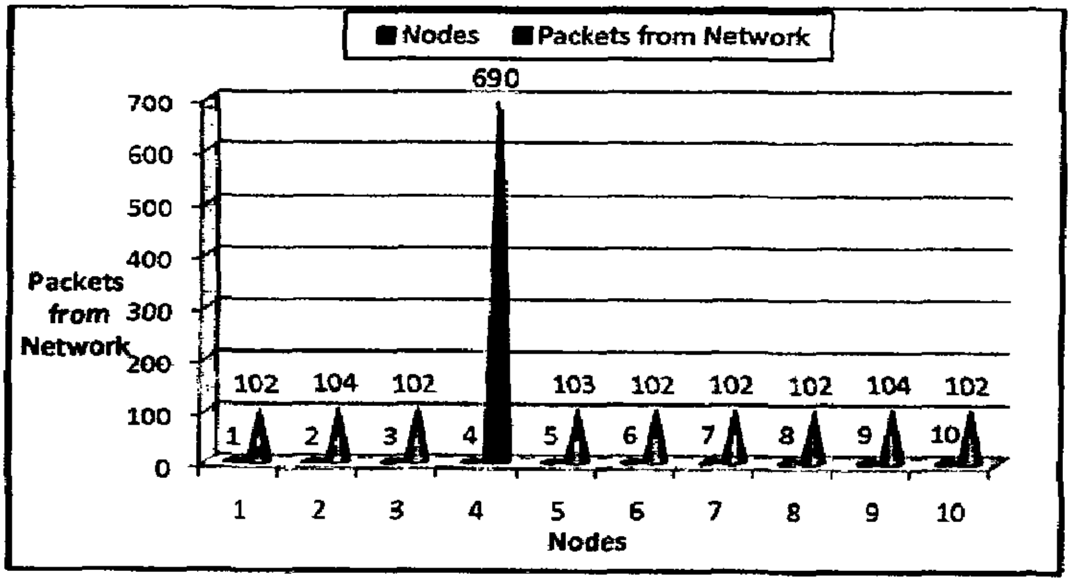


Fig. 3.9 Packets from network at MAC layer

Fig. 3.6 shows the transmission of the signals at the physical layer for 10 different node positions of the access points. Here it can be seen that there is a slight variation in signal transmission at node 4 (access point D) .Fig. 3.7 shows the signals received from the physical layer and then forwarded to the MAC layer it indicates that there is no such variation in receiving the signals. Fig. 3.8 shows the signals which are received with errors at the 10 different nodes.Here it can be seen that there is no signal received with errors at node 4 (access point D) where there is slight variation at nodes 1,3 and 7 (access point A,C and G) and almost similar number of signals received with errors at other access points. Finally Fig. 3.9 shows the signals or packets from network layer are received at the MAC layer and there is a drastic variation at node 4 (access point D) while there is no such variation at any other node (access point). Instead of using the free space and line of sight environment, the packets received from network at MAC layer because of the distance travelled by the electromagnetic wave from transmitter to receiver, the signal losses and due to which there is an increment at node 4.

3.6.2 Analysis of results for line of sight and free space on the second floor

The analysis of the work has been carried out on the second floor with the line of sight and in free space, the signals has been captured at different point locations in corridors of the hostel building using Qualnet simulation software. Using simulation software, the simulated environment has been created at the 9 different access point locations from A to I as shown in Fig. 3.10 for the second floor.

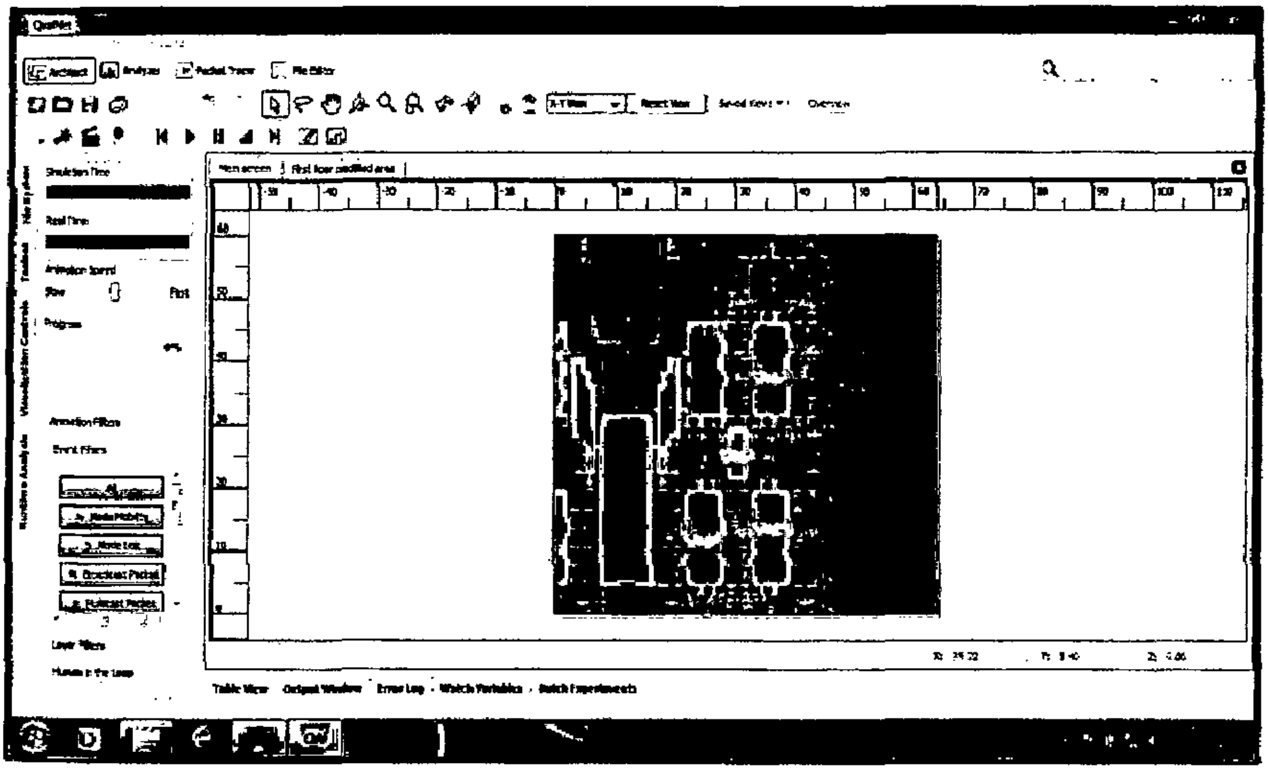


Fig. 3.10 Simulated environment for second floor

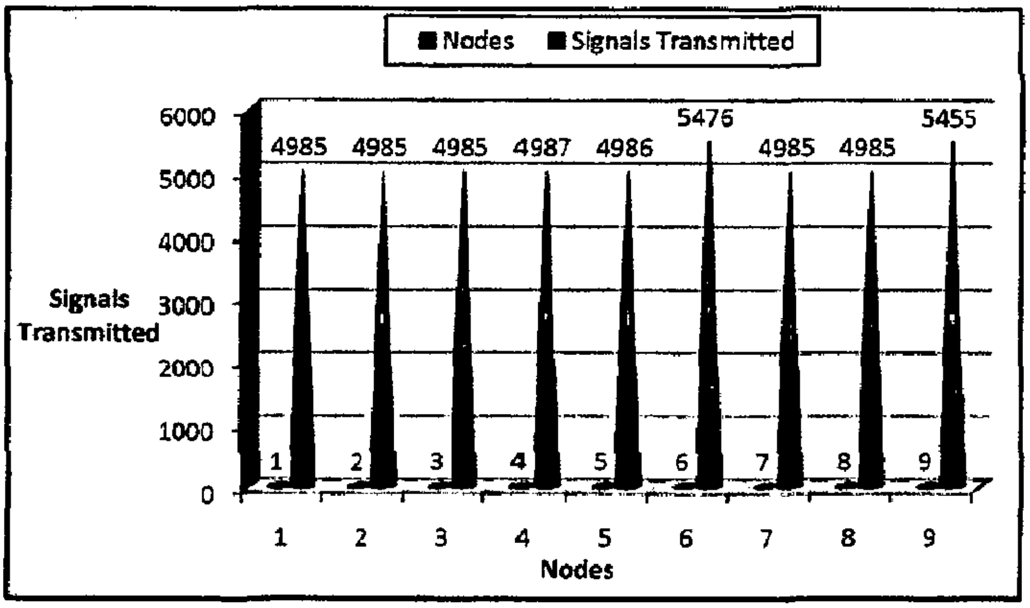


Fig. 3.11 Signals transmitted at physical layer

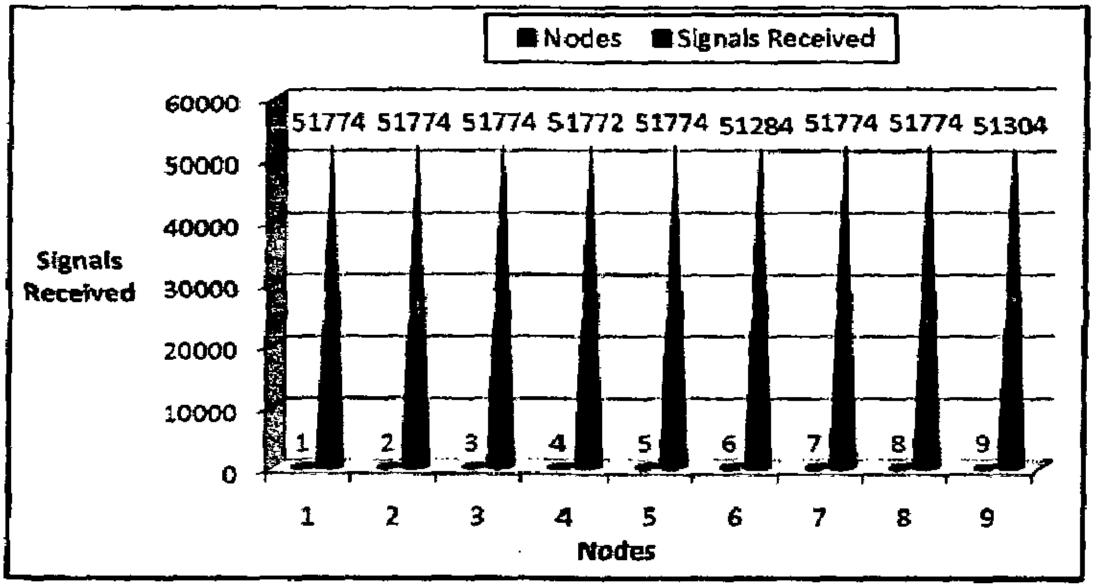


Fig. 3.12 Signals received from physical Layer forwarded to MAC

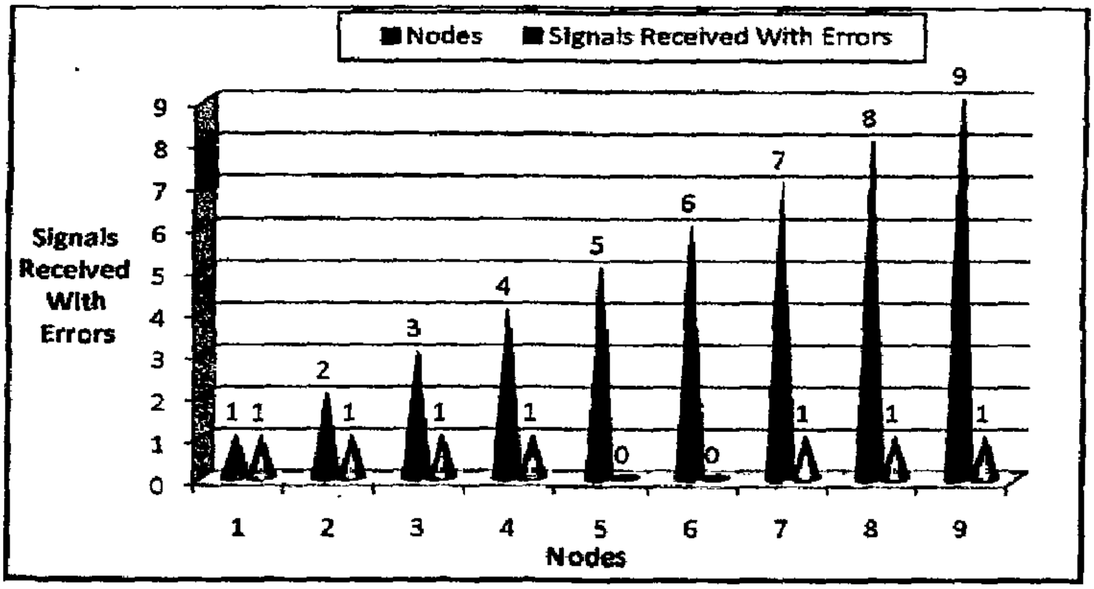


Fig. 3.13 Signals received but with errors

Fig. 3.11 shows the transmission of the signals at the physical layer at 9 different node positions of the access points. Here it can be seen that there is a slight variation in signal transmission at node 7 (access point G) and node 9 (access point I). In Fig. 3.12 shows the signals received from the physical layer and then forwarded to the MAC layer it indicates that there is no such variation in receiving the signals. Fig. 3.13 shows the signals which are received with errors at the different nodes. Here it can be seen that there is no signal received with errors at node 5 (access point E) and at node 6 (access point F) and almost similar number of signals received with errors at other access points.

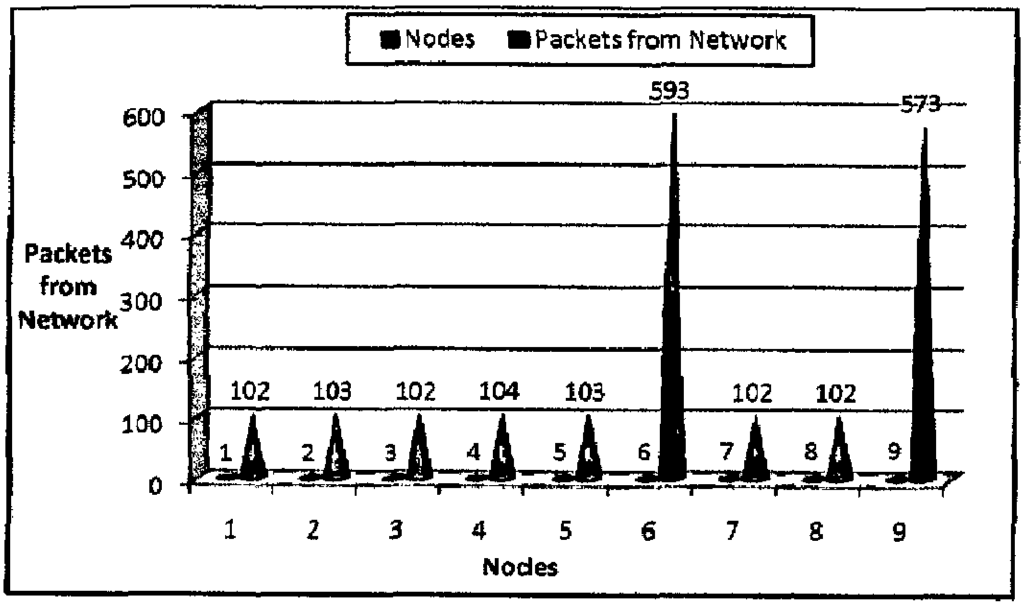


Fig. 3.14 Packets from network at MAC layer

Finally Fig. 3.14 the signals or packets from network layer are received at the MAC layer and there is a drastic variation at node 6 (access point F) and at node 9 (access point I) while there is no such variation at any other node (access point). Instead of using the free space and line of sight environment, the packets received from network at MAC layer because of the distance travelled by the electromagnetic wave from transmitter to receiver, the signal losses and due to which there is an increment at node 6(access point F) and node 9(access point I).

3.7 Summary

In this chapter after site surveying the Qualnet simulation software is used to find the coverage effect of the users on different points on the first floor and second floor. By using spectrum analyzer tool the analysis and measurement for the collection of the data in free space and line of sight scenario was conducted. The variation in the signals received at receiver depends upon the higher traffic in corridors in that time because more users were using this access point in that time. It has been observed that for finding proper placement the unnecessary number of APs has been reduced and therefore saving installation cost of WLAN.

CHAPTER 4

PLACEMENT OF ACCESS POINTS OF INDOOR WLAN USING PARTICLE SWARM OPTIMIZATION TECHNIQUE

In indoor WLAN-based positioning system, the main constraint is to provide radio coverage on all assigned areas, which is a common requirement for communication and positioning of access points [95]. This chapter focuses on the optimal placement and assessment of access points. The mathematical model of the problem is discussed and Particle Swarm Optimization (PSO) Technique is used for solving the model.

The measurements have been conducted in the Malviya Bhawan, Boys Hostel Building, IIT Roorkee, Saharanpur Campus to collect data for optimization. Using MSA338 3.3 GHz Spectrum Analyzer, the received signal strength at each access points has been calculated using omnidirectional antenna.

In the section 4.1, brief description of the related work is given. The work plan of the calculation of location of access points using optimization technique is shown in section 4.2. The optimization problem is given in section 4.3. In section 4.4, the Model Description and path loss model is given. Solution of the model and working of PSO is given in section 4.5. Data collection at site and set up for experimental data is given in section 4.6. Section 4.7 presents the methodology and section 4.8, presents the analysis of results. Finally section 4.9, presents the brief summary of this chapter.

4.1 Related Work

In case of WLAN, researchers have applied different optimization techniques. A summary of some of the interesting works where optimization has been applied in indoor WLAN are as follows:

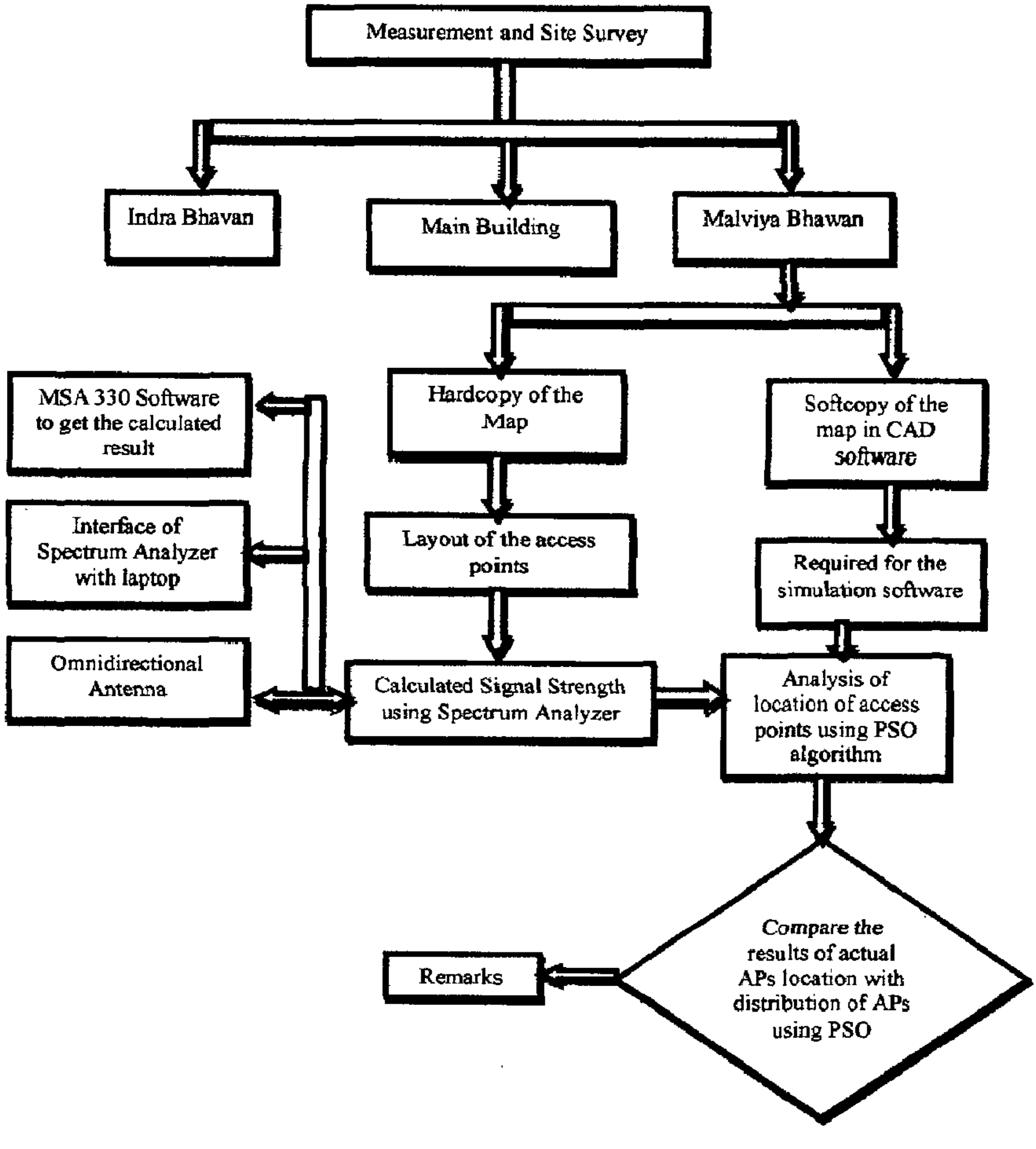
Mari Kobayashi, et.al [45] has applied very fast simulated annealing to search for an approximate optimal solution using orthogonal frequency division multiplexing (OFDM) for high data rate indoor WLAN. Max Kamenetsky, et.al [44] has described the methods for obtaining a close-to-optimal positioning of WLAN APs and evaluates their performance in a typical downtown or campus environment using pruning for obtaining an initial set of transmitter positions and refining these by using either neighbourhood search or simulated annealing. S. Kouhbor, et. al [68] has described a discrete gradient optimization mathematical model developed to find the optimal number and location of APs and also S. Kouhbor, et. al [75] has described the mathematical model that finds the minimum number of APs for indoor buildings and placement so that the physical security of the network is maintained. Widyawan, et.al [88] has described one-slope model and multiwall model to find the influence of measured and predicted fingerprint in indoor locations. A. W. Reza, et.al [4] has described Genetic algorithm with Breath First Search (BFS) to determine the minimum number of transmitters and their corresponding locations to achieve the optimum indoor wireless coverage. A brief summary of related works on optimization techniques in indoor WLAN is shown in Table 4.1.

Table 4.1 Related works on optimization technique

S.No.	Paper	Model	Technique	Available Information	Authors	Year
1	Optimal Access Point placement in Simultaneous Broadcast System using OFDM for Indoor WLAN	Ray Tracing Model	Very Fast simulated Annealing Algorithm (VFSA)	Discontinuous Cost Function has many local minima	Mari Kobayashi, et.al [45]	IEEE PIMRC 2000
2	Coverage Planning for Outdoor Wireless LAN systems	Path Loss Model	Pruning, Neighborhood Search and Simulated Annealing	Discrete Search Space	Max Kamenetsky et.al [44]	IEEE-2002
3	Optimal Placement of Access Point in WLAN Based on a New Algorithm	Path Loss Model	Discrete Gradient Optimization Algorithm	Non-smooth, Non convex, has many local minima	S.Kouhbor, et.al[68]	IEEE-July 2005
4	Physical Security Enhancement in WLAN Systems	Path Loss Model	A New Global optimization Algorithm (AGOP)	Non differentiable, Non convex	Shahnaz Kouhbor et.al[75]	ISSNIP-IEEE 2007
5	Influence of Predicted and Measured Fingerprint on the Accuracy of RSSI-based Indoor Location Systems	empirical propagation model and semi-deterministic model.	Nearest Neighbour and Particle Filter algorithm	scalable and adaptive indoor location system	Widyawan, et.al[88]	WPNC, IEEE 2007
6	A Novel Integrated Mathematical Approach of Ray-Tracing and Genetic Algorithm for Optimizing Indoor Wireless Coverage	Ray-Tracing	Genetic algorithm with Breath First Search(BFS)	large scale path loss and small scale fading	A. W. Reza, et.al[4]	Progress In Electro-magnetics Research, Nov 2010

4.2 Work plan

The measurements have been conducted in the Malviya Bhawan, Boys Hostel Building, IIT Roorkee, Saharanpur Campus to collect data for simulation & optimization. Using Spectrum Analyzer, the received signal strength of the access points has been calculated using omnidirectional antenna. The work plan of the calculation of location of access points using optimization technique is shown in Flowsheet 4.1.



Flowsheet4.1 The work plan for the calculation of location of access points

4.3 Optimization Problem

The general non-linear optimization problem is defined as:

Minimize / Maximize $f(\bar{x})$, where $f : R^n \to R$ ⟶ Objective function

Subject to: $x \in S \subset R^n$

where *S* is defined by:

$$\left.\begin{array}{l} g_j(\bar{x}) \le 0,\ j = 1,2,\ldots,p \\ h_k(\bar{x}) = 0,\ k = 1,2,\ldots,q \\ a_i \le x_i \le b_i\ (i = 1,\ldots\ldots,n). \end{array}\right\} \longrightarrow \text{Constraints}$$

where p and q are the number of inequality and equality constraints respectively, a_i and b_i are lower and upper bounds of the decision variable x_i.

Any vector x satisfying all above constraints is called feasible solution. The best of the feasible solution is called an optimal solution. If the objective function and all constraints are linear, then the model is called Linear Programming Problem (LPP). If the solution has an additional requirement that the decision variables are integers then the model is called Integer Programming Problem (IPP). If some variables are integers and other variables are real then the problem is called Mixed Integer Programming Problem (MIPP). If the objective function and/or constraints are nonlinear then the problem is called Non-Linear Programming Problem (NLPP). In our case the presence of obstacles and interferences causes signal to reach a receiver through several paths with various strengths and hence the objective function is nonsmooth and discontinuous due to the characteristics of the building and small change in the position of the users that can change with time. Particle Swarm Optimization Algorithm (PSO) is used for present analysis and it can be applied to a wide range of nonsmooth functions.

General Notations

Throughout this chapter the following notations are used:

a_j	$j = 1\ldots N$	Access point (AP)
r_i	$i = 1\ldots M$	Receiver/user
$d(a_j, r_i)$	Distance between AP and receiver	

$g(a_j, r_i)$ Path loss from i_{th} user to access point j

$g\max$ Maximum tolerable path loss

P_t Transmit power

P_r Received power

R_{th} Receive threshold

Ap 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 [68]:

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

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

4.4 Model Description

In the present study the objective function is to minimize the path loss. Mathematically it may be given as:

$$\min g(a_j, r_i) \le g\max \ \forall i = 1, \ldots, M \quad \ldots (4.1)$$

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

$$g\max = P_t - R_{th} \quad \ldots (4.2)$$

The above inequality equation (4.1) can be expressed in the equality form as:

$$(\min_j g(a_j, r_i) - g\max)^+ = 0, \quad \ldots (4.3)$$

4.4.1 Path Loss Model

The propagation of radio waves is characterized by several factors: (a) free space loss. (b) Attenuated by the objects on the propagation path such as windows, walls, table, chair and floors of building. (c) The signal is scattered and can interfere with itself [16].The basic propagation model is based on free space propagation. 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 [68-75]:

$$P_r(a_j, r_i) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d(a_j, r_i)^2} \quad \text{... (4.4)}$$

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 (3×10^8 meter per second) and f is the frequency of radio 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 [68-75]:

$$g(a_j, r_i)[dB] = -10\log\left[\frac{G_t G_r \lambda^2}{(4\pi)^2 d(a_j, r_i)^2}\right] \quad \text{... (4.5)}$$

The above equation does not hold, when points a_j 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 [68-75] can be calculated from:

$$g(a_j, r_i) = g(d_0)[dB] = 20\log\frac{4\pi d_0 f}{c} \quad \text{... (4.6)}$$

Therefore, path loss function in free space at a distance greater than d_0 is given by

$$g(a_j, r_i)[dB] = g(d_0)[dB] + 10\log\left(\frac{d(a_j, r_i)}{d_0}\right)^2 \quad \text{... (4.7)}$$

4.5 Solution of the Model

The mathematical model discussed in section 4.4, is non–linear and non–smooth therefore standard powerful optimization techniques (Newton based, quasi-Newton methods, conjugate gradient search method, steepest descent method are suitable for continuous functions only and cannot be applied to it. In the present work, PSO, one of the recent search techniques is applied for obtaining the solution to the mathematical model discussed in section 4.3. In the next section, a brief working of PSO is explained.

4.5.1 Working of PSO

For a D-dimensional search space the position of the i[th] particle is represented as $X_i = (x_{i1}, x_{i2}, ..., x_{id}, ..., x_{iD})$. Each particle maintains a memory of its previous best position $P_i = (p_{i1}, p_{i2}, ..., p_{id}, ..., p_{iD})$. The best one among all the particles in the population is represented as $P_g = (p_{g1}, p_{g2}, ..., p_{gd}, ..., p_{gD})$. The velocity of each particle is represented as $V_i = (v_{i1}, v_{i2}, ..., v_{id}, ..., v_{iD})$, is clamped to a maximum velocity $V_{max} = (v_{max,1}, v_{max,2}, ..., v_{max,d}, ..., v_{max,D})$, which is specified by the user. During each generation each particle is accelerated toward the particles previous best position and the global best position. At each iteration a new velocity value for each particle is calculated based on its current velocity, the distance from the global best position. The new velocity value is then used to calculate the next position of the particle in the search space. This process is then iterated a number of times or until a minimum error is achieved. The two basic equations which govern the working of PSO are that of velocity vector and position vector given by:

$$v_{id} = \omega * v_{id} + c_1 r_1 (p_{id} - x_{id}) + c_2 r_2 (p_{gd} - x_{id}) \quad (4.8)$$

$$x_{id} = x_{id} + v_{id} \quad (4.9)$$

Here c_1 and c_2 are acceleration constants. They represent the weighting of the stochastic acceleration terms that pull each particle toward personal best and global best positions. Therefore, adjustment of these constants changes the amount of tension in the system. Low of these constants allow particles to roam far from the target regions before tugged back, while high values result in abrupt movement toward, or past, target regions. The constants r_1, r_2 are the uniformly generated random numbers in the range of [0, 1]. Inertia weight, ω is employed to control the impact of the previous history of velocities on the current velocity, thereby influencing the trade-off between global and local exploration abilities of the particles. It can be a positive constant or even a positive linear or nonlinear function of time.

4.5.2 Parameter settings for PSO

PSO has few control parameters which are to be carefully fine tuned to get the appropriate results. In the present study, we have considered the following parameters; population size is kept 20. Acceleration constants c_1 and c_2 are fixed as 2.0. The inertia w is taken to be linearly decreasing (0.9 – 0.4)

4.5.3 Computational Steps of basic PSO algorithm

Step 1 Initialize PSO parameters

Step 2 Randomly initialize the positions and velocities of all particles

Step 3 Evaluate the fitness function values of all particles in the swarm

Step 4 Update particles personal best position and global best position (i.e. p_i and p_g)

Step 5 Set t = 1, t refers the iteration number

Step 6 Update the velocity vector using Eqn.

$$v_{id} = \omega * v_{id} + c_1 r_1 (p_{id} - x_{id}) + c_2 r_2 (p_{gd} - x_{id}) \quad (4.8)$$

Step 7 Update particle's position using Eqn.

$$x_{id} = x_{id} + v_{id} \quad (4.9)$$

Step 8 Evaluate particle's fitness values

Step 9 Update P_i and P_g

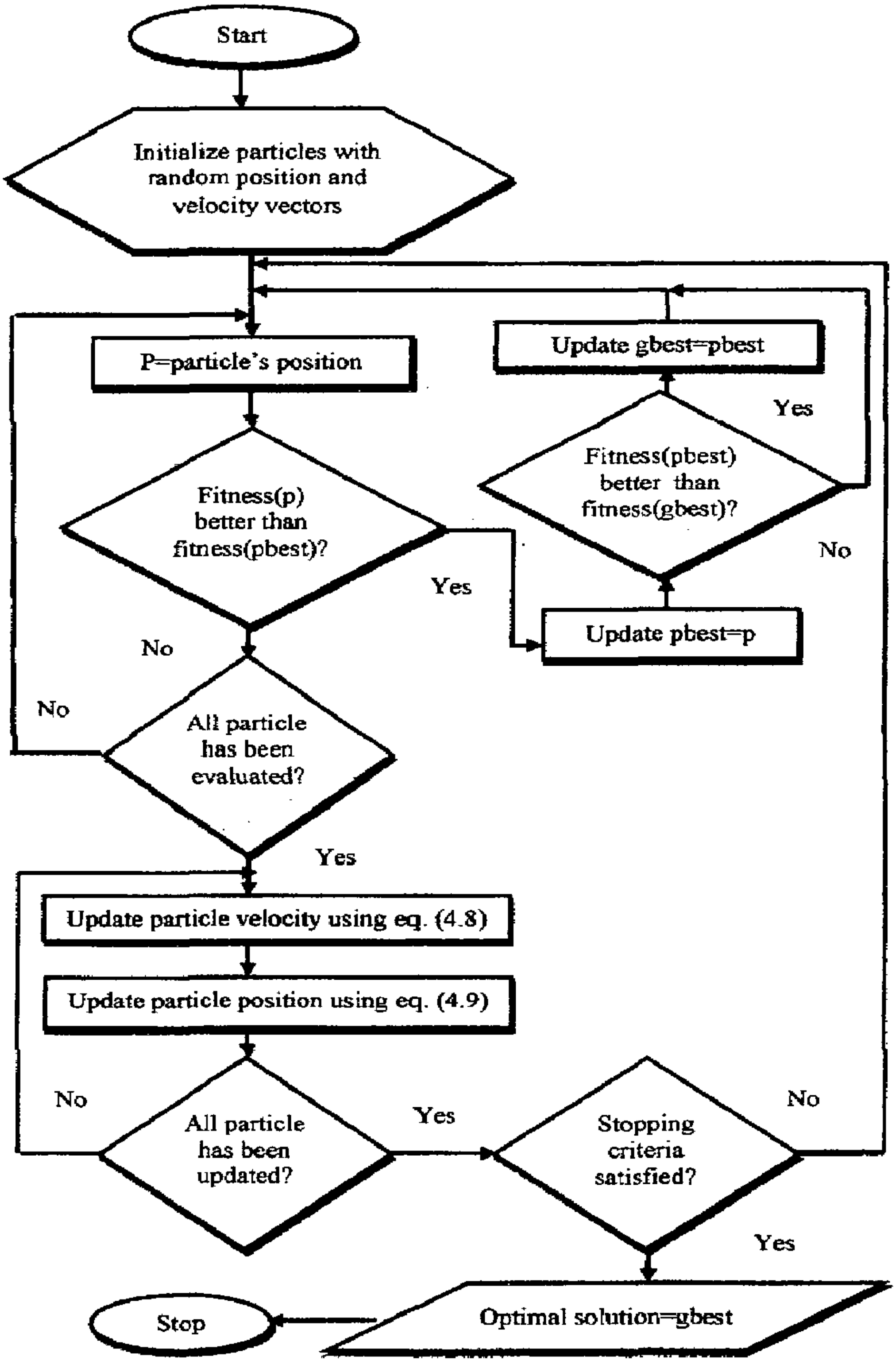
Step 10 Set t = t+1

Step 11 If (Stopping criteria is reached) then go to step 12

Else go to step 6

Step 12 Print the global best particle and the corresponding fitness function value

Flowsheet 4.2 shows the Particle Swarm Optimization algorithm.



Flowsheet4.2 The Particle Swarm Optimization algorithm

4.6 Data collection at site

Experiments are conducted in the Malviya Bhawan, Boys Hostel, Saharanpur campus, IIT Roorkee to collect the data for optimization technique. The facility is a four floor (Ground floor to third floor) building and nineteen access points are distributed around the building in different block points installed by the network administrator in the corridors of the building. None at the ground level, ten on the first floor, nine on the second floor and none on the third floor. The access points are not evenly distributed over each floor and some access points are purposely placed, so as to cover the floor above or below its location, as well as its immediate surrounding area. Front view of the building and data collection site is given in Fig. 4.1(a-e)

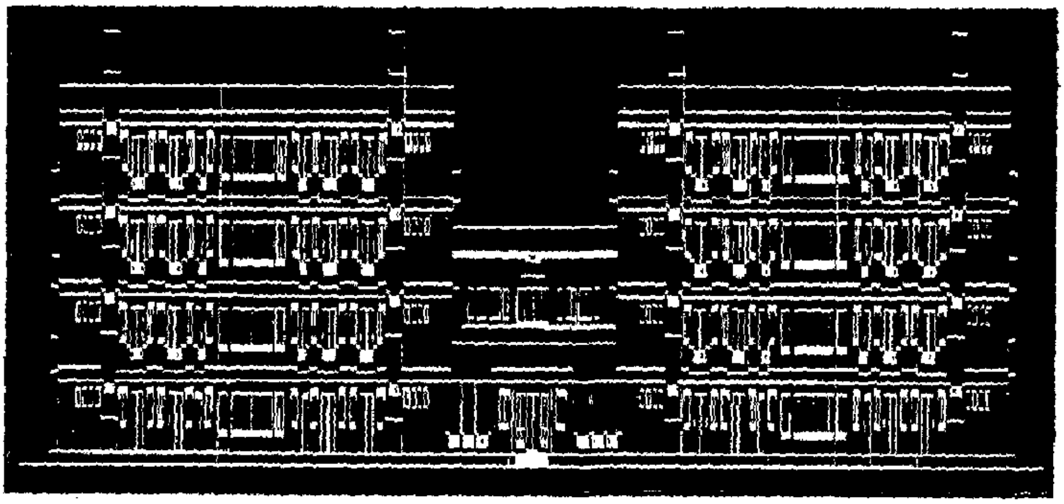


Fig. 4.1(a) gives a front view of the building

Fig. 4.1(b) Google map of the data collection site

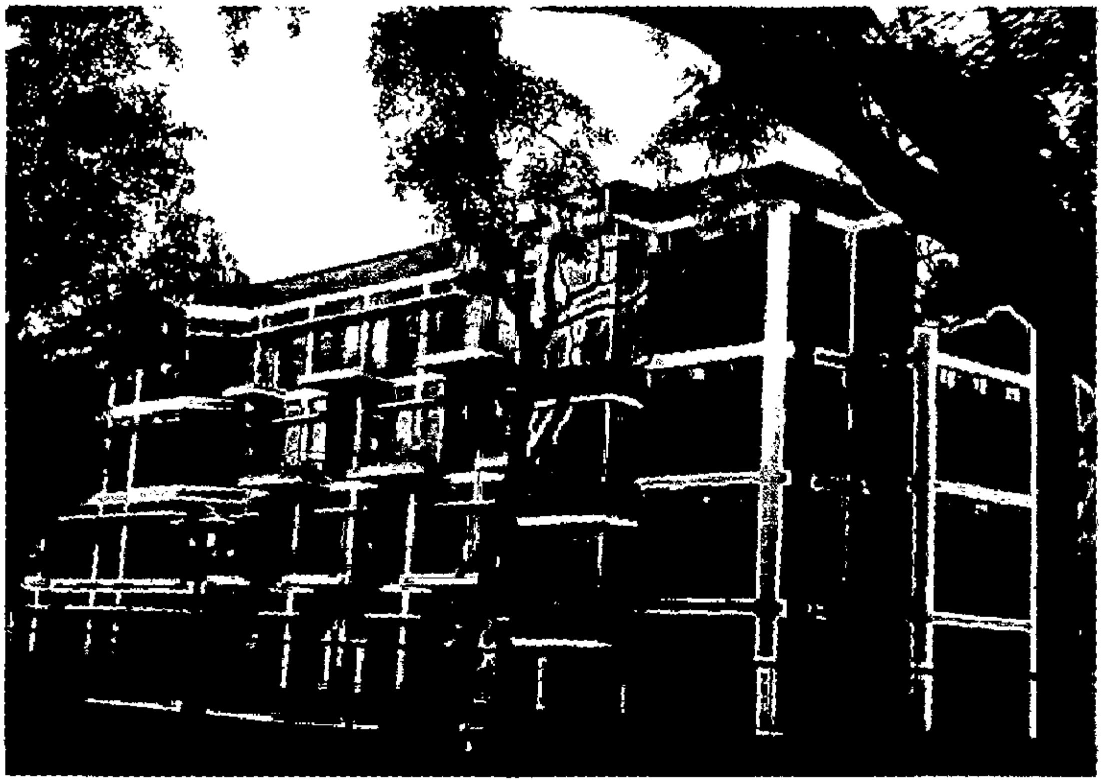


Fig. 4.1(c) Data collection site building

Fig. 4.1 (d) Corridor of the building where the access points installed

Fig. 4.1 (e) Access point AP (link dwl-3200ap)

4.6.1 Data collection

We have performed our experiment in building considering free space and line of sight in the design area of dimensions of 64m x 60m and have 400 users on four floors. Fig. 4.2 shows the layout of the building, the access points have been located at first floor and second floor. The plan of the floor where the experiments are conducted is shown in Fig. 4.3 for first floor. The first floor has 100 rooms with 100 users and part of corridors with ten access points installed in the corridors. The entire wing of the first floor is covered by ten access points installed at the locations of the corridors indicated by red symbols in Fig. 4.3. Ten locations for measurement are chosen on the first floor of the Malviya Bhavan building as shown in Fig 4.3 denoted as A, B, C, D, E, F, G, H, I and J.

The plan of the second floor where the experiments are conducted is shown in Fig. 4.4. The entire wing of the second floor is covered by nine access points installed at the locations indicated by red symbols in Fig. 4.4. The second floor has 100 rooms with 100 users and part of corridors with nine access points installed in the corridors. This is shown in Fig. 4.4 and the access points are denoted as A, B, C, D, E, F, G, H and I.

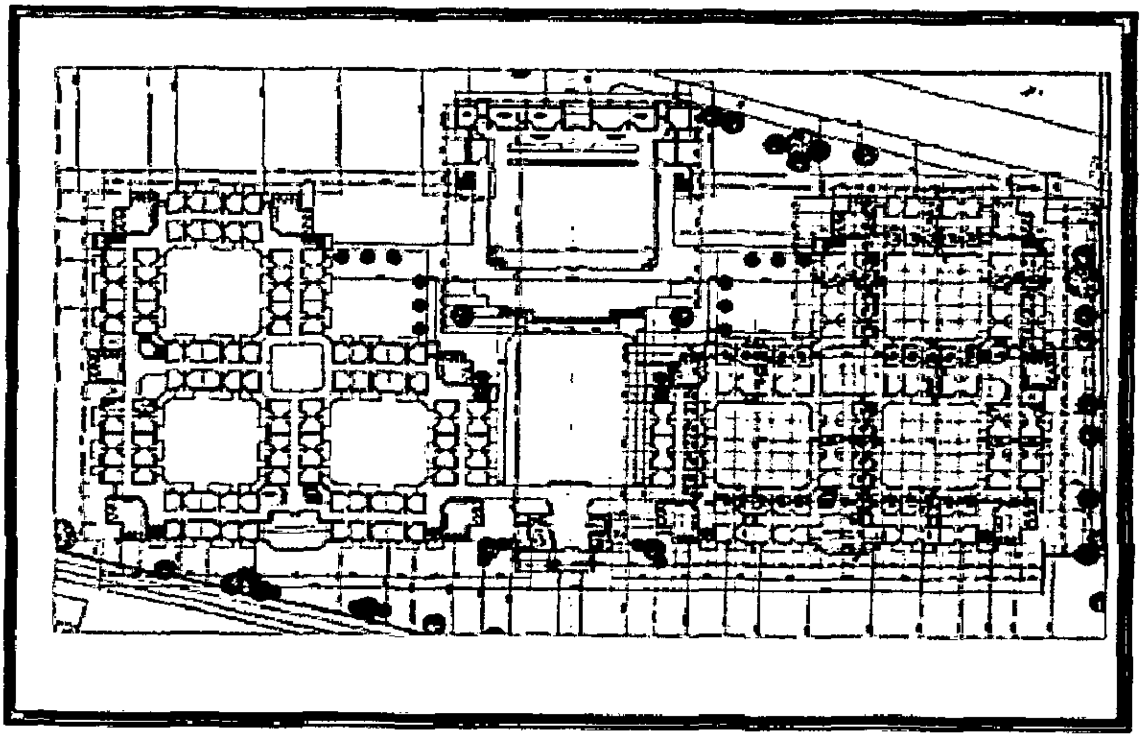


Fig. 4.2 Layout of the building

4.6.2 Set up for experimental data

The data are collected at the first and second floor of the building.

Domain Area: Malviya Bhawan, Boys Hostel, IIT Roorkee, Saharanpur Campus

Area: 64m X 60m

Type: Four floor Building

Standard: IEEE 802.11g

Device: Laptop running Windows 2007, MSA 3.3GHz Spectrum Analyzer, M304 Omnidirectional Antenna, Access Point AP (LINK DWL-3200AP)

Tools and Software used: Developer C++, MAS 300 PC software for Spectrum Analyzer

Optimization Technique: Particle Swarm Optimization

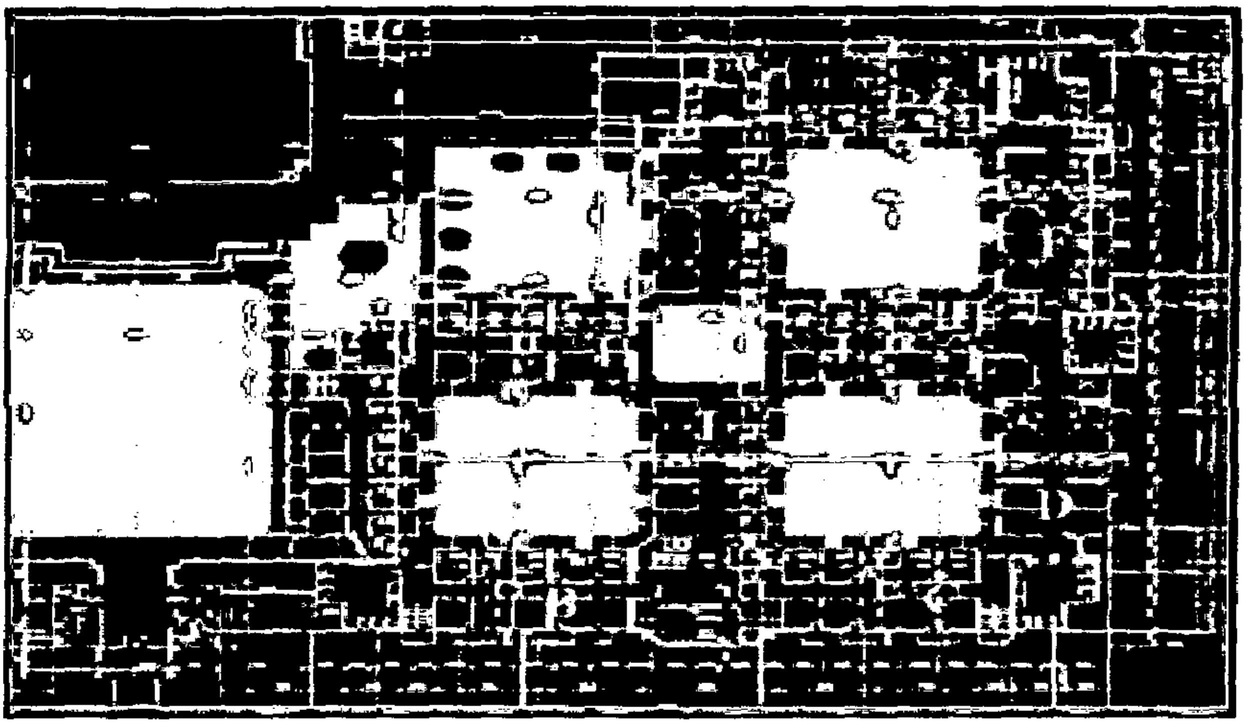


Fig. 4.3 Plan of the first floor where the experiment was conducted. Readings were collected in the corridors.

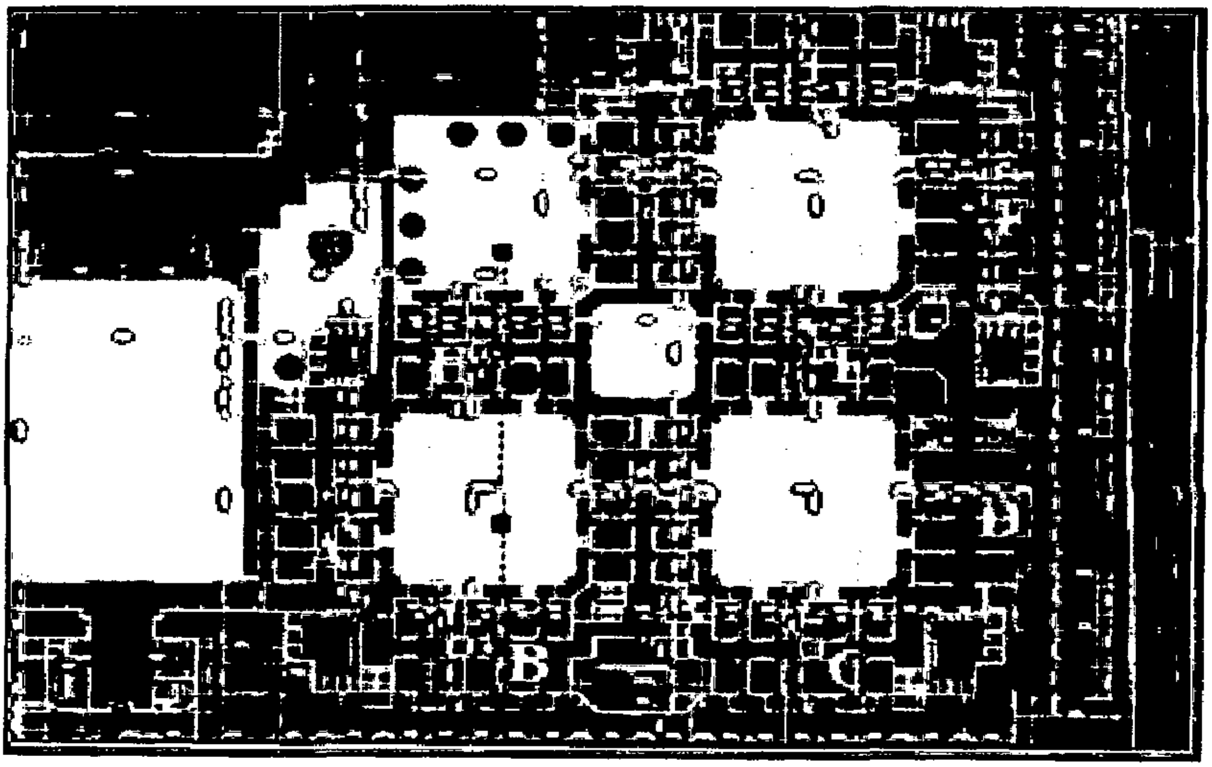


Fig. 4.4 Plan of the second floor where the experiment was conducted.
Readings were collected in the corridors.

4.6.3 Description of Measurement Scenarios

In the present analysis three different scenarios such as closed corridor, open corridor and hostel rooms are considered for measurements. The scenarios used are considered for developing path loss equations, by which a generalization for propagation in an indoor environment at 2.4 GHz is obtained. The all three scenarios have been discussed in chapter 3.

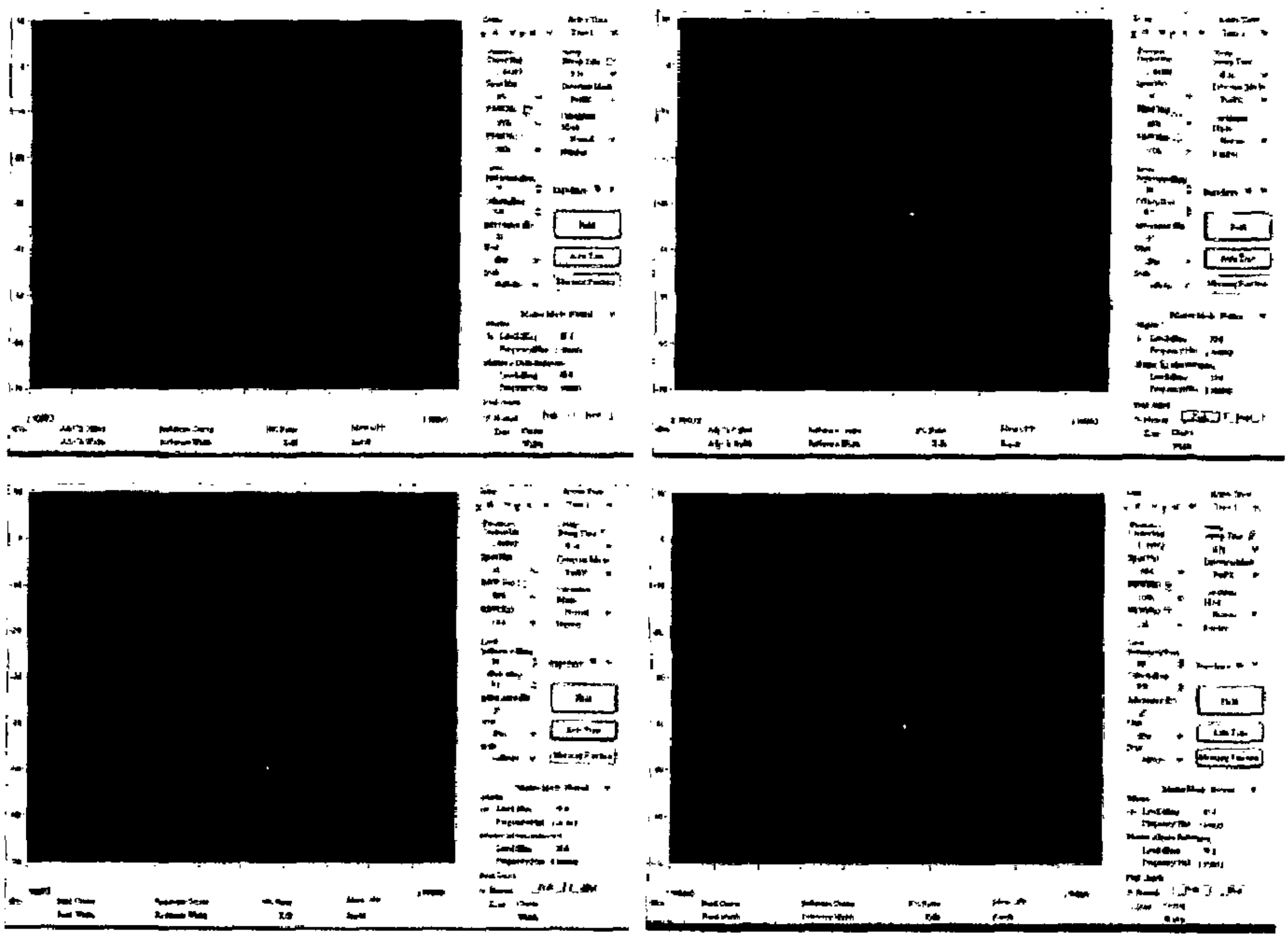
4.7 Methodology

Once the priority area has been identified the data has been collected nearby access points which require a connection to the wired LAN and a source of power. The signal strength has been measured using 3.3GHs Spectrum Analyzer with omnidirectional dipole antennas, at a number of points around the access point. The coverage and location of access points has been checked using optimization technique in those priority areas that are within range. While in other places the aim was to identify the points where the available bandwidth is likely to drop below the theoretical maximum, typically where the signal strength falls below -70dBm [80].

4.8 Analysis of Results

4.8.1 Scenario 1: Closed Corridor for first floor

The received signal strength calculated using the spectrum analyzer is shown in Fig. 4.5 (a) and Fig. 4.5 (b). Fig. 4.6 shows the signal Strength calculated using spectrum analyzer versus locations of access points. The optimal placement of access points for 100 users on first floor with transmitter power of 21dBm is shown in Table 4.2. The actual placement of access point coordinates is shown in Fig. 4.7 and the distribution of access point coordinates by using particle swarm optimization is shown in Fig. 4.8.



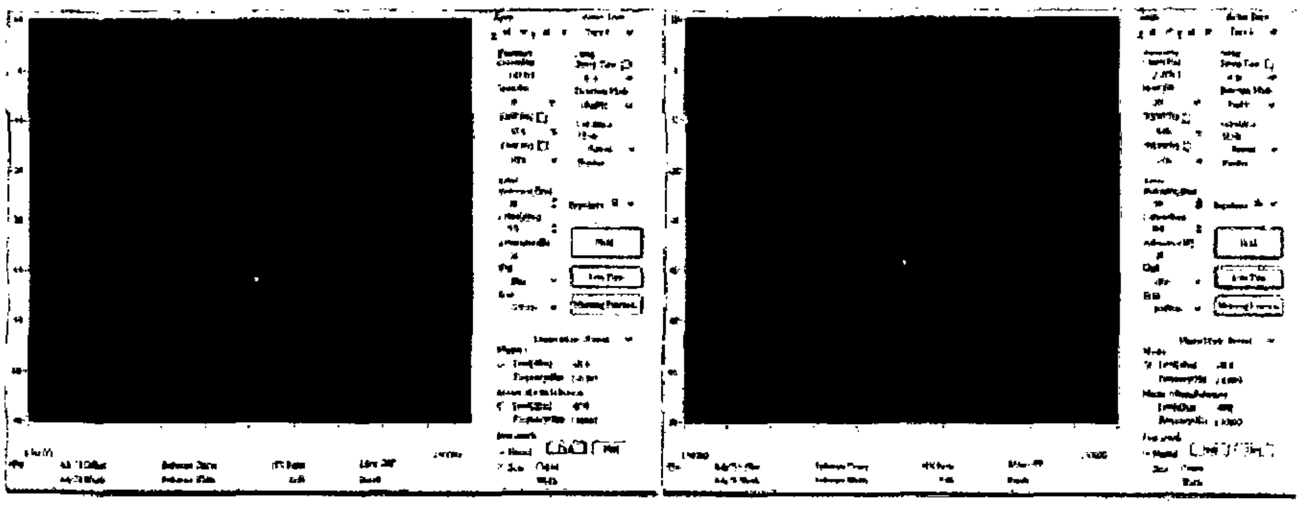


Fig. 4.5(a) Received Signal Strength calculated using spectrum analyzer for A to F access points

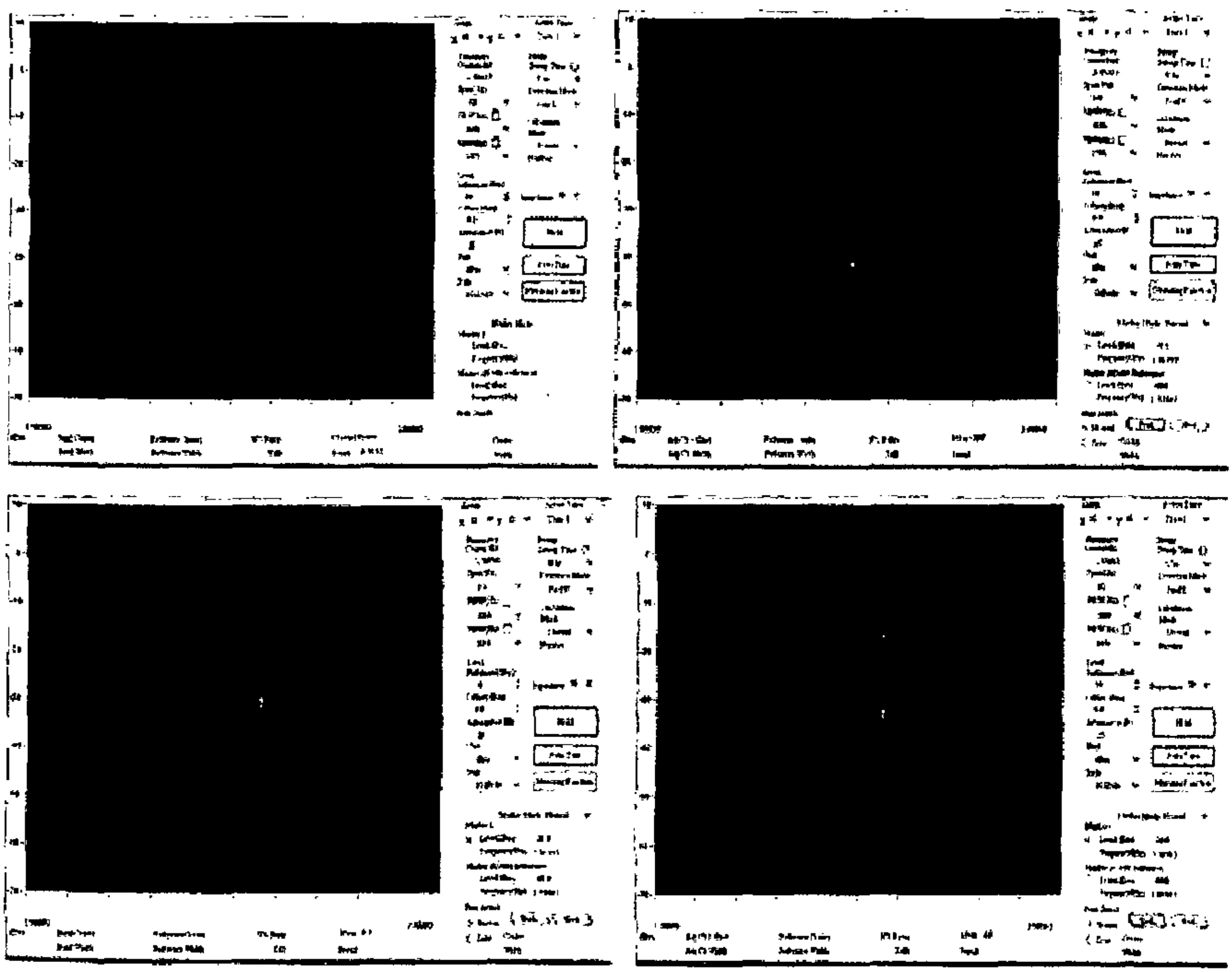


Fig. 4.5 (b) Received Signal Strength calculated using spectrum analyzer for G to J access points

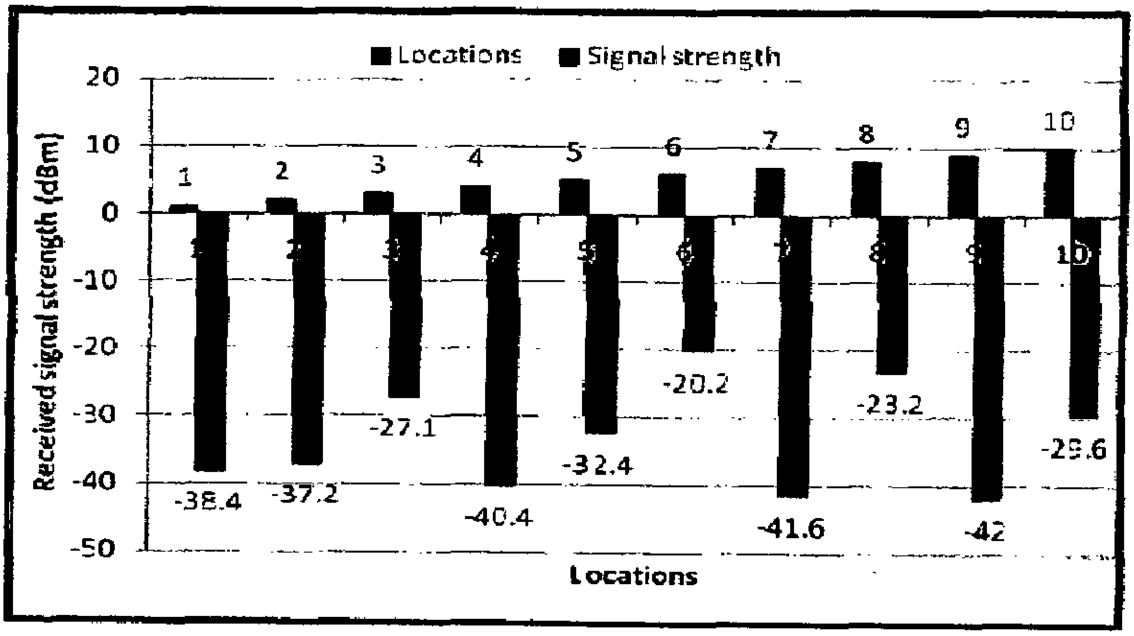


Fig. 4.6 Signal Strength calculated using spectrum analyzer versus locations

Table 4.2 Optimal placement of APs for 100 users on first floor with Pt =21dBm

Locations of Access points	**Received signal strength R_{th} (dBm)**	**Actual placement of Access point coordinates**	**Access point coordinates by PSO**
Location A	-38.4	(18.90, 10.93)	(22.16, 11.32)
Location B	-37.2	(24.72, 2.51)	(27.34, 4.54)
Location C	-27.1	(35.90, 1.59)	(38.25, 1.09)
Location D	-40.4	(42.19, 12.92)	(38.98, 10.25)
Location E	-32.4	(38.97, 26.24)	(40.54, 24.25)
Location F	-20.2	(41.88, 43.70)	(40.98, 44.72)
Location G	-41.6	(36.36, 52.43)	(32.22, 50.35)
Location H	-23.2	(26.10, 25.94)	(25.12, 24.23)
Location I	-42.0	(30.54, 12.00)	(32.45, 10.26)
Location J	-29.6	(33.60, 25.94)	(30.25, 24.31)

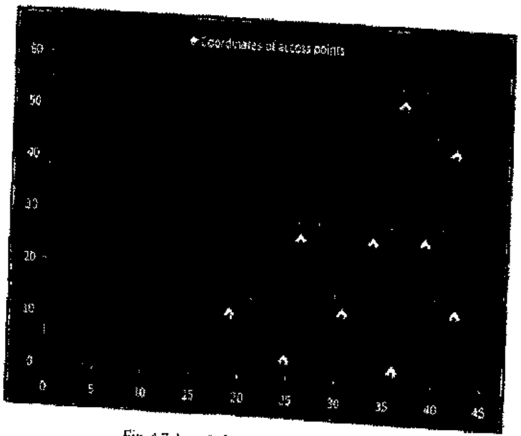


Fig. 4.7 Actual placement of access points

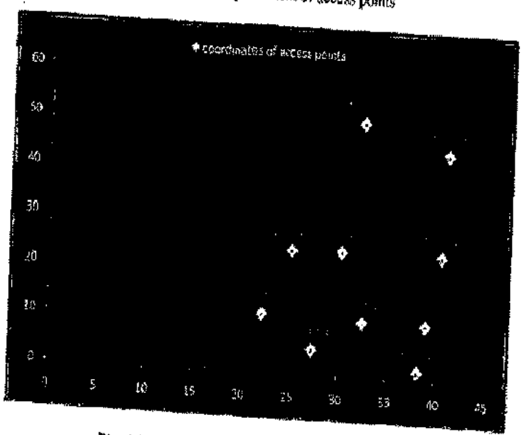


Fig. 4.8 Distribution of access points by using PSO

Table 4.2 compares the coordinates of actual placement of 10 access point (A-J) with the coordinates obtained by PSO for different received signal strength. It was observed that the coordinates obtained by PSO are very much similar to the actual coordinates. This is also evident from the Fig. 4.7 and Fig. 4.8 which shows the actual placement of access point and placement of access points obtained by PSO respectively. This shows that PSO can be an attractive alternative for determining the location of access points.

4.8.2 Scenario 1: Closed Corridor for second floor

The received signal strength calculated using the spectrum analyzer is shown in Fig. 4.9(a) and Fig. 4.9(b). Fig. 4.10 shows the signal Strength calculated using spectrum analyzer versus locations. The optimal placement of nine access points for 100 users on second floor with transmitter power of 21dBm is shown in Table 4.3. The actual placement of access point coordinates is shown in Fig. 4.11 and the distribution of access point coordinates by using particle swarm optimization is shown in Fig. 4.12.

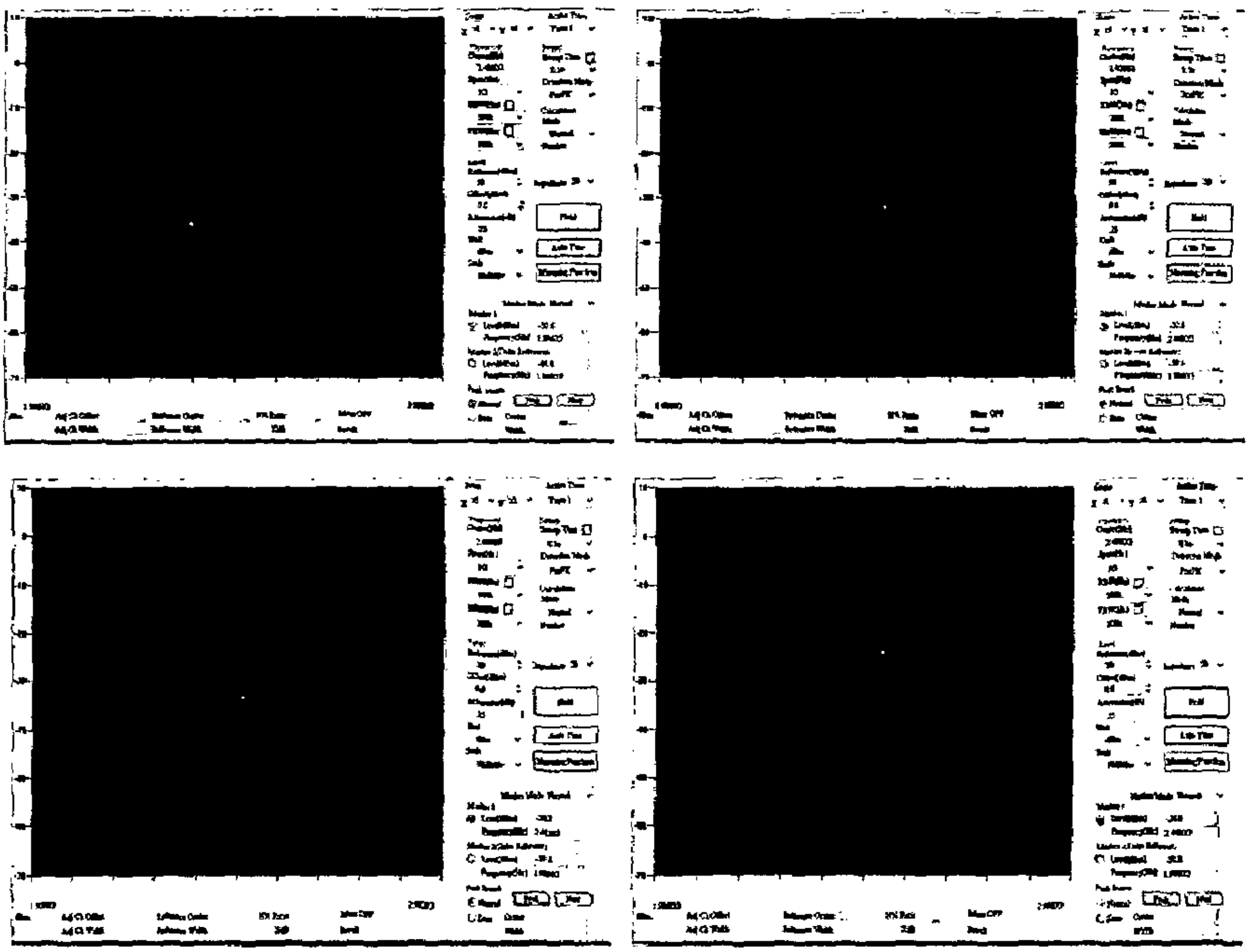


Fig. 4.9(a) Received Signal Strength calculated using spectrum analyzer for A to D access points

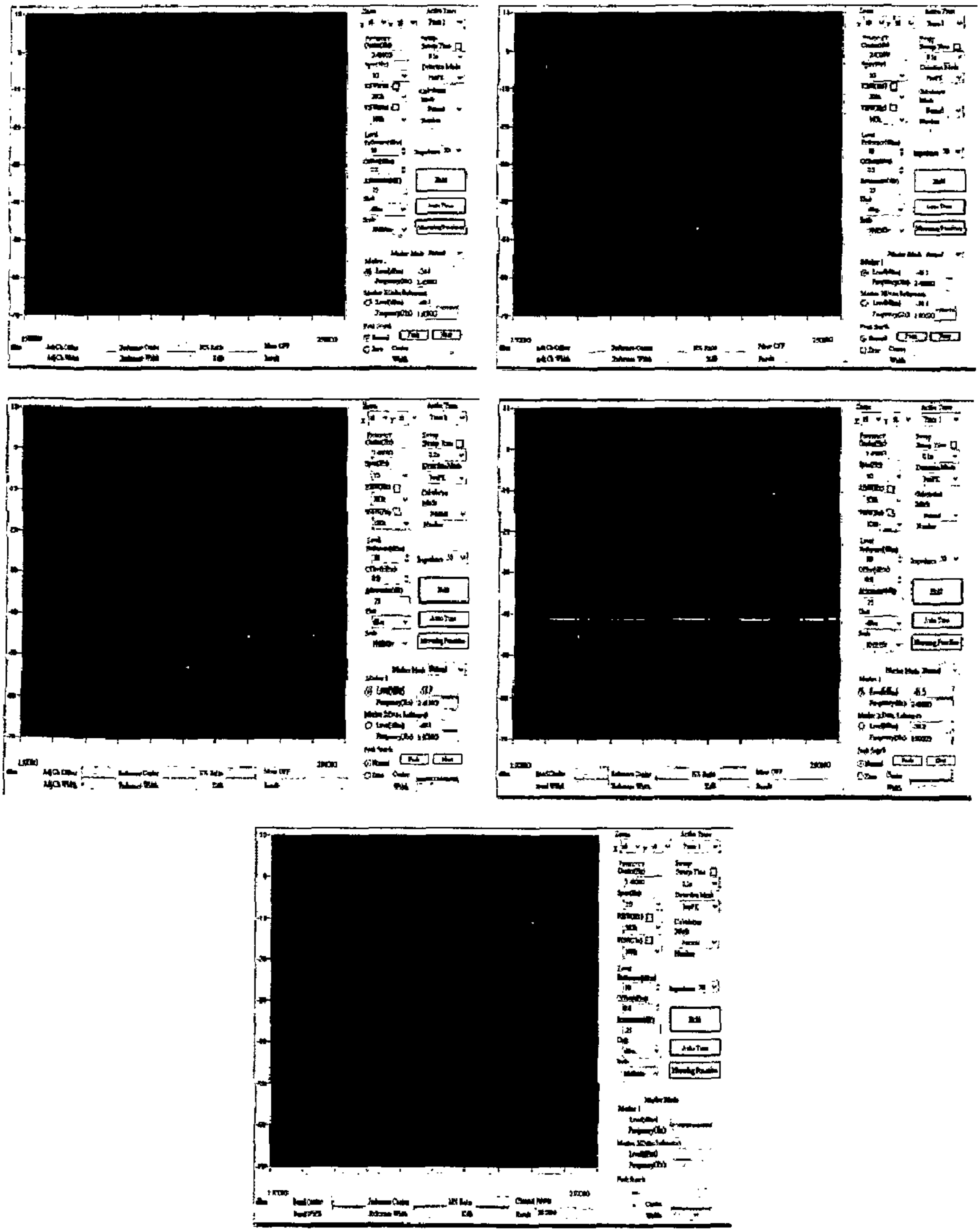


Fig. 4.9(b) Received Signal Strength calculated using spectrum analyzer for E to I access points

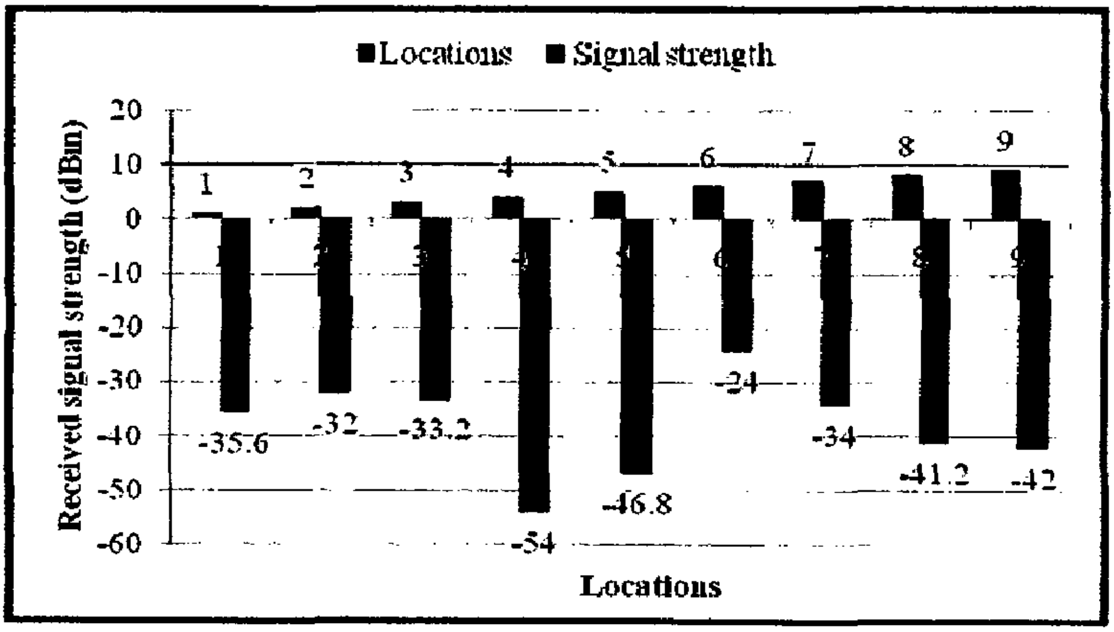


Fig. 4.10 Signal Strength calculated using spectrum analyzer versus locations

Table 4.3 Optimal placement of APs for 100 users on second floor with Pt =21dBm

Locations of Access points	Received signal strength Rth (dBm)	Actual placement of Access point coordinates	Access point coordinates by PSO
Location A	-35.6	(19.21,13.38)	(18.25, 15.11)
Location B	-32.0	(25.34,0.98)	(23.43, 1.05)
Location C	-33.2	(36.06,1.59)	(35.21, 2.12)
Location D	-54.0	(41.11,12.92)	(39.78, 13.11)
Location E	-46.8	(35.44,26.09)	(36.22, 25.55)
Location F	-24.0	(41.57,38.95)	(40.13, 40.12)
Location G	-34.0	(30.39,38.49)	(31.23, 35.98)
Location H	-41.2	(25.03,25.79)	(24.56, 24.59)
Location I	-42.0	(30.24,15.22)	(31.24, 17.17)

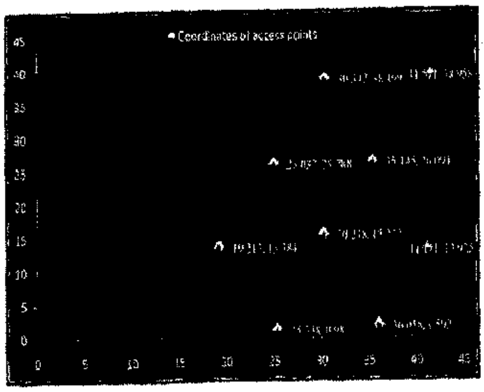


Fig. 4.11 Actual placement of access points

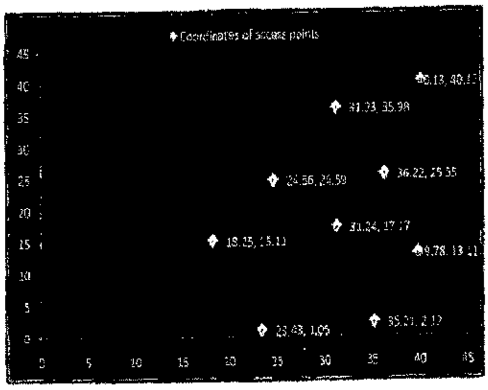


Fig. 4.12 Distribution of access points by using PSO

In Table 4.3, results obtained by PSO are compared with the actual placement of access points (A-I) for the second floor. These results are also shown with the help of Fig. 4.11 and Fig. 4.12.

Once again it was observed that placement of access points obtained by PSO are similar to the actual results.

4.9 Summary

In this chapter particle swarm optimization technique has been used to find the location of the access points for the coverage of the users. This chapter provides the results of the comparison between actual APs location and measured APs locations using PSO. The analysis of measurements in free space and line of sight scenario was conducted and it has been observed that the actual location of access points is somewhat similar to the placement of access points obtained by PSO on the second floor while there is a little overlapping in the location of access points on first floor obtained by PSO.

CHAPTER 5

COVERAGE AND ANALYSIS OF OBSTRUCTED ENVIRONMENT IN INDOOR WLAN

In indoor environment, signal propagation is different from that of outdoor propagation particularly in terms of distance and the surrounding objects. As a result, the measured signal strength is usually less than that predicted by an optimization model. To achieve results with more accuracy and to represent more realistic indoor propagation model, the surrounding environment has to be considered. These include walls, floors, ceilings and various partitions made up of different materials. The signal strength configuration changes in the presence of an obstruction in the path of the radio wave propagation. There are mainly five factors affecting the propagation, which plays an important role in deciding the indoor coverage area. These are reflection, diffraction and scattering, wall attenuation and floor attenuation factor occurring during transmission from transmitter to receiver point [69]. It should be noted that indoor channels are highly dependent upon the placement of walls and partitions within the building, as placement of these walls and partitions dictates the signal path inside a building. In such cases, a model of the environment is a useful design tool in constructing a layout that leads to efficient communication strategies. Thus, analysing this gives us better estimation of signal strength configurations.

In the present work, the study of the signal strength has been for each receiver points along with the effect of the obstacles and interferences in the building as different materials produce varying amount of attenuation in the coverage region.

In the section 5.1, brief description of the related work is given. Section 5.2 describes the work plan of the the coverage effect and analysis of obstructed environment. In section 5.3 and 5.4, a brief description of wall attenuation factor and floor attenuation factors is given. In the section 5.5, the path loss model for the obstructed environments using optimization technique has been given. In section 5.6, 5.7 and 5.8 the analysis of the results for obstructed environment on first floor, second floor and ground floor is examined. In section 5.9, the analysis for the obstructed environment using qualnet5.0 simulation software for first floor and second floor is given. Section 5.10, summarizes the brief summary of this chapter.

5.1 Related work

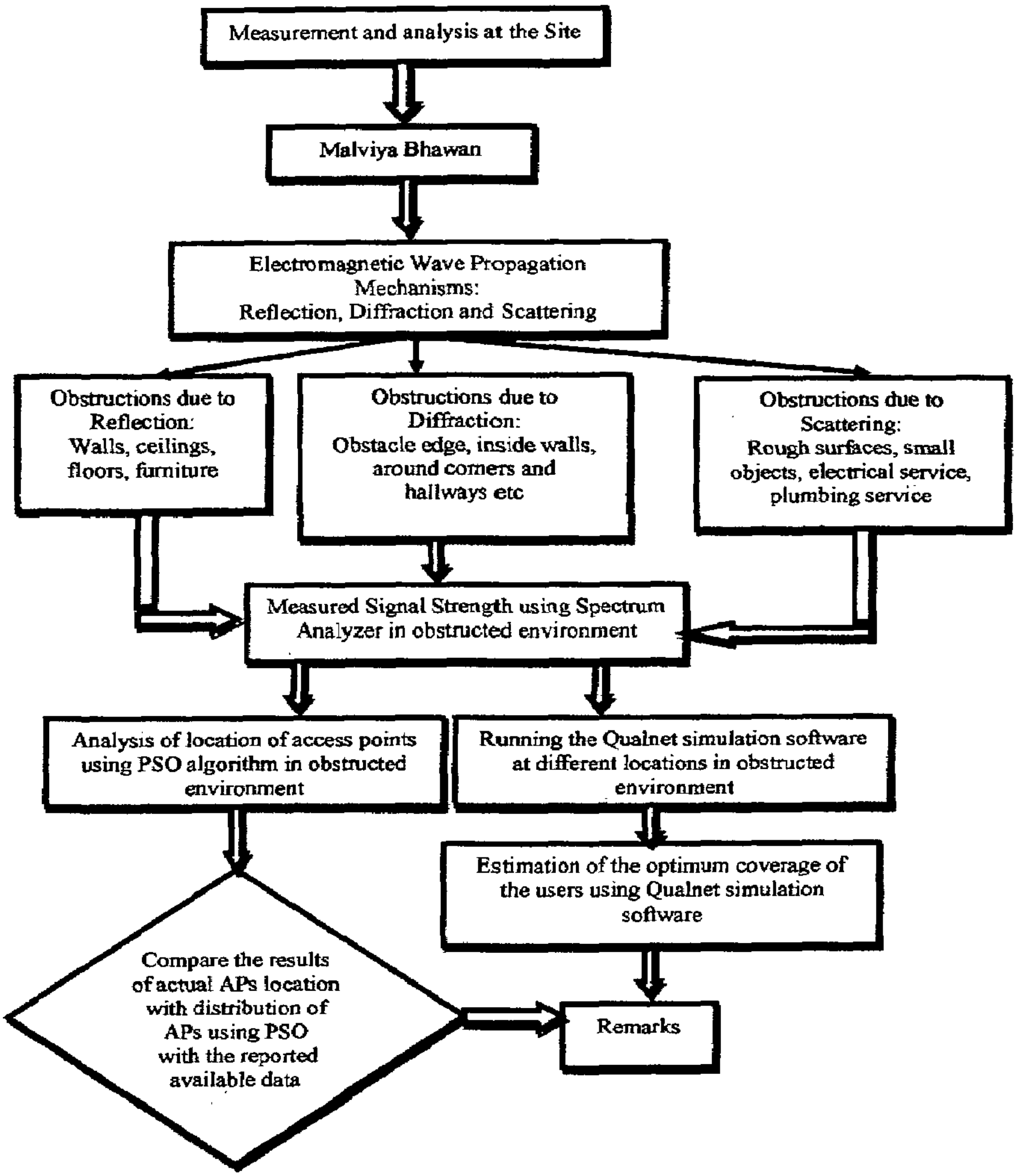
Robert Akl, et.al [67] has Log-distance Path Loss Model and Log-Normal Shadowing (Empirical model), and Two-Ray Model (Deterministic model) were used in determining path loss equations for different scenarios in indoor WLAN.S. Kouhbor, et.al [72] has used a new global optimization (AGOP) algorithm to solve optimal coverage problems for a design area with different number of users. Shih-Hau Fang et al [76] has used maximizing SNR algorithm in indoor WLAN to deploy APs so as to reduce the positioning errors where the signal is maximized and the noise is minimized simultaneously. Amardeep Kaur et.al [9] has used OPNET modeller 9.1 to analyse the performance of the IEEE 802.11 indoor wireless Local area networks. Traoré Soungalo et. al [83] has used OPNET modeller 9.1 for improving WLAN performance such as data rate, physical characteristics and fragmentation threshold. Related works on obstructed environment is shown in Table 5.1.

Table 5.1 Related works on obstructed environment

S.No.	Paper	Model	Technique	Available Information	Authors	Year
1	Indoor Propagation Modeling at 2.4 GHZ for IEEE 802.11 Networks	log-distance path loss model, log normal shadowing and two ray model	Chi-square Goodness-of-Fit Test and curve fitting	Closed corridor, open corridor, classroom , computer lab	Robert Akl, et.al [67]	Sixth IASTED International Multi-conference on wireless and optical communications, July 2006
2	Coverage in WLAN: Optimization Model and Algorithm	Path Loss Model	A global optimization algorithm (AGOP)	Non-smooth, Non convex, has many local minima	S.Kouhbor, et.al[72]	March 2007
3	A Novel Access Point Placement Approach for WLAN-based Location Systems		maximizing SNR algorithm		Shih-Hau Fang et al [76]	WCNC , IEEE 2010
4	Performance Analysis and Enhancement of IEEE 802.11 Wireless Local Area Networks		OPNET modeler 9.1	Data rate, Fragmentation threshold, RTS/CTS threshold, buffer size and physical characteristics	Amardeep Kaur et.al [9]	Global Journal of Computer Science and Technology January 2010
5	Evaluating and Improving Wireless Local Area Networks Performance	Indoor Path Loss model	OPNET 9.1 Simulation Software	data rate, physical characteristics and fragmentation threshold .	Traore Soungalo, et.al[83]	Int. Journal of Advancements in Computing TechnologyMarch2 011

5.2 Work plan

The measurements have been conducted in the Malviya Bhawan, Boys Hostel Building, IIT Roorkee, Saharanpur Campus to collect data for simulation & optimization. Using Spectrum Analyzer, the received signal strength of the access points has been calculated using omnidirectional antenna. The work plan of the coverage effect and analysis of obstructed environment in indoor WLAN is shown in Flowsheet5.1.



Flowsheet5.1 The work plan for coverage effect and analysis of obstructed environment

5.3 Wall Attenuation Factor (WAF)

The obstruction caused due to walls is indicated using the Wall Effect Factor (WEF) or Wall Attenuation Factor (WAF). Walls reflect the electromagnetic radiation falling on it producing a shadow region behind it. The attenuation produced depends on the material and thickness of the wall. The losses in the wireless signal observed, when the receiver is in another floor as the access point, is called Floor Attenuation factor (FAF). Floor Attenuation factor depends on type of the material separating the floors and is frequency dependent. WAF is calculated by finding the difference between the signal strength values for two sets of points, equidistant from the access point but one set having the LOS and the other having a wall blocking the access point.

5.3.1 Obstacles to signal strength and partition losses

Signal strength is the strength of the signal produced by a radio transmitter at a particular location, usually expressed as microvolts or millivolts per meter of effective receiving antenna height. Partitions that are formed as a part of the building structure are called as *hard partitions*, and partitions that may be moved and which do not span to the ceiling are called *soft partitions* [24]. In general, objects absorb or reflect signal strength and degrade or block the signal. Identify any potential obstacles or impediments in the area to be served [28]. For example:

Walls – especially if the wall is composed of heavier construction materials, such as concrete.

Ceiling tiles – particularly if they are made of material such as metal.

Furniture – especially pieces that are largely made of metal.

Natural elements – such as water, trees, and bushes and not only outdoors, but also in many lobbies, courtyards or other interior public spaces.

Coated glass – transparent glass generally does not greatly degrade signal strength. But it may do so if it is coated with a metalized film or has a wire mesh embedded in it.

In Table 5.2 the reported available data for the Signal Attenuation through various obstructions at 2.4 GHz is shown.

Table 5.2 Signal Attenuation through various obstructions at 2.4 GHz

Obstructions	Reported Signal Attenuation through various obstructions
Metal Frame Glass Wall into Building	6 dB
Brick Wall	6 dB
Wooden Block Wall	4 dB
Metal Door in Brick Wall	12.4 dB
Brick Wall next to Metal Door	3dB
Window in a Brick Wall	2 dB
Human	4 dB

For the present analysis we consider the obstacles in indoor environment such as brick walls, wooden doors, windows, furniture and moving human being. Reported available data for these obstructions is taken at 2.4 GHz as shown in Table 5.2.

5.4 Floor Attenuation Factor (FAF)

The Floor Attenuation Factor (FAF) is calculated by finding the difference between the signal strength values for two sets of survey points, equidistant from the access point but one set lying in the same floor as the access point and the other lying in a different one [2]. This model is most sensitive for the concrete wall and metal partitions. On the same floor the path loss rate is almost constant but it increases when ray comes in contact with concrete wall, the path loss exponent does not increase at high rate after the next floor.

5.5 Path Loss Model for the Obstructed Environments using optimization technique

Rays passing through an obstruction are attenuated. The amount of absorption depends on the dielectric properties of the material. From chapter 4, equation (4.7) is taken for analysis.
Therefore, path loss function in free space at a distance greater than d_0 is given by

$$g(a_i,r_i)[dB] = g(d_0)[dB] + 10\log\left(\frac{d(a_i,r_i)}{d_0}\right)^2 \qquad (5.1)$$

The RF (radio frequency) path between transmitter and receiver is affected by the distance between the two terminals and the type and number of obstacles (walls, doors, windows, furniture, etc). Thus, including loss caused by partitions in path loss model, equation (5.1) can be written as [68-75]:

$$g(a_j, r_i)[dB] = g(d_0)[dB] + \log(\frac{d(a_j, r_i)}{d_0})^2 + \sum n_{SP} l_{SP} + \sum n_{HP} l_{HP} \quad (5.2)$$

Where n_{SP} represents the number of soft partitions of a particular type and l_{SP} represents the loss in dB attributed to a particular soft type partitions, n_{HP} represents the number of hard partitions related to a particular type and l_{HP} represents the loss in dB associated with a particular hard type partitions. The soft partition consists of movable objects like furniture, users etc. While hard partitions comprises of fixed objects like walls, doors, window etc. A move around corner of the building or a wall can cause the received signal to drop suddenly. Data collection site with obstructions is shown in Fig. 5.1(a). For different obstructions the signal strength measurements between transmitter and receiver have been taken using spectrum analyzer at the 10 access points and plan of first floor of the selected shown by red symbols and locations A to J as shown in Fig. 5.1.

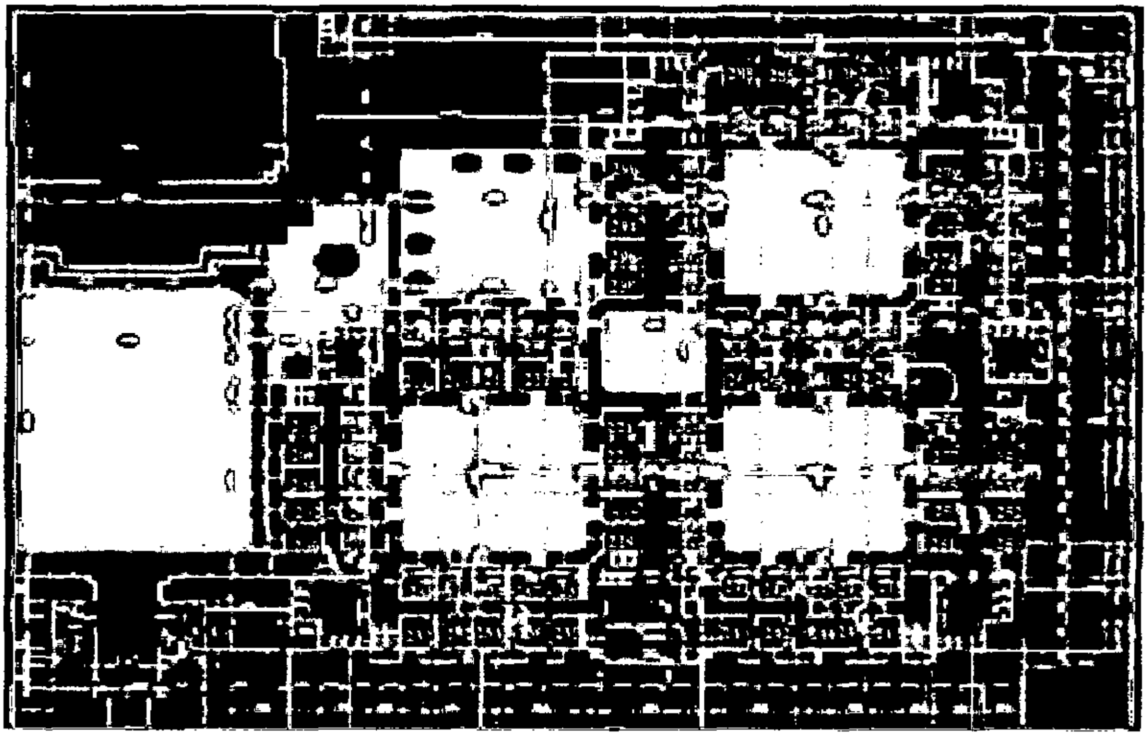


Fig. 5.1 Location of access points for first floor obstructions

5.6 Analysis of results for obstructed environment on first floor

Results for obstructed environment on first floor have been analyzed by using optimization technique the analysis of each is described in the following subsections:

5.6.1 Measurement and analysis taken near staircase with soft partitions

Measurements taken near staircase where the presence of human being is possible and it is a soft partition then

n_{SP}= number of soft partition=1 each

l_{SP}=loss due to soft partition=4dB (as given in table 5.1)

$$n_{SP}\ l_{SP} = 1*4 = 4\text{dB}$$

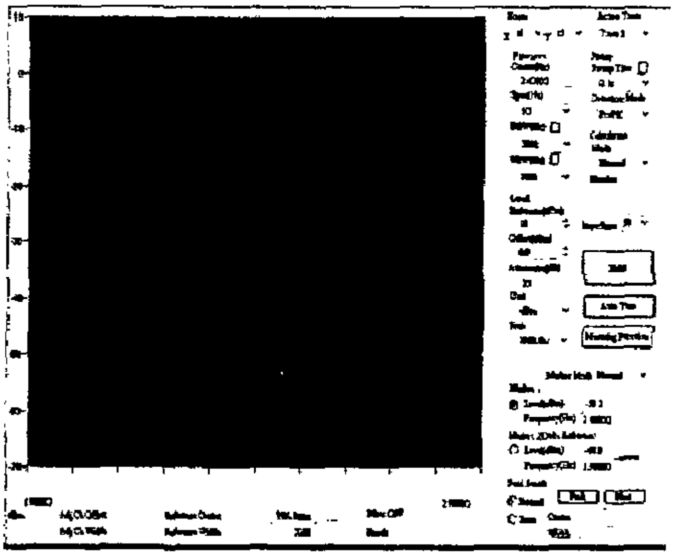
Now from the equation (5.1)

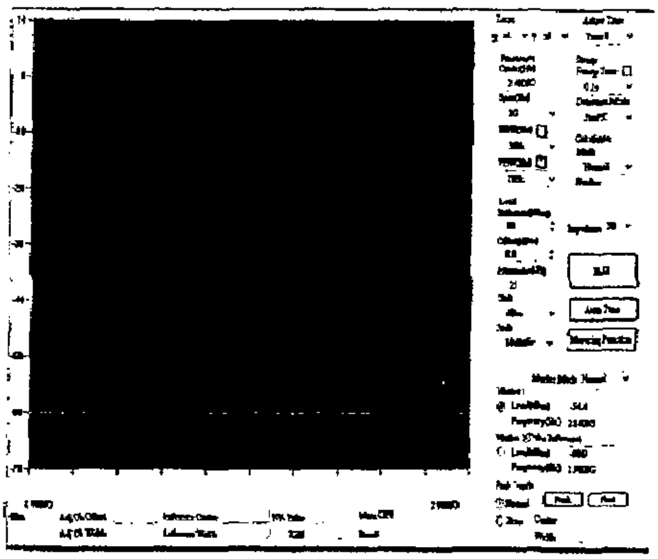
$$g(a_j, r_i)[dB] = g(d_o)[dB] + 10\log\left(\frac{d(a_j, r_i)}{d_o}\right)^2$$

Now from the equation (5.2)

$$g(a_j, r_i)[dB] = g(d_o)[dB] + 10\log\left(\frac{d(a_j, r_i)}{d_o}\right)^2 + 4\text{dB}$$

The received signal strength calculated using the spectrum analyzer is shown in Fig. 5.2 (a) and Fig. 5.2 (b). Table 5.3 shows the measurements taken near staircase for different access points. The actual placement of access point coordinates is shown in Fig. 5.3 and the distribution of access point coordinates by using particle swarm optimization is shown in Fig. 5.4.





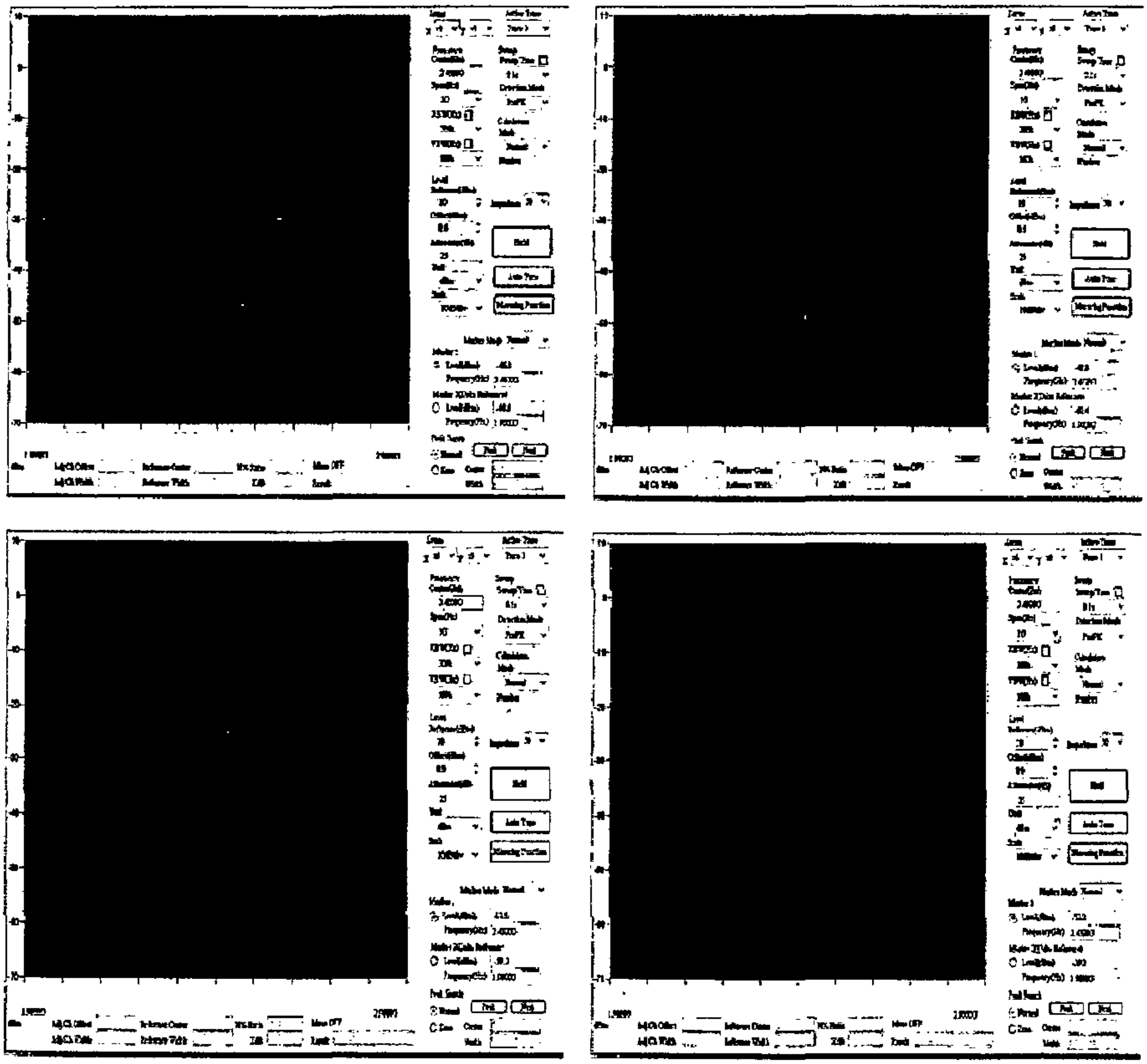


Fig. 5.2(a) shows the received signal strength calculated near staircase using the spectrum analyzer for A to F access points

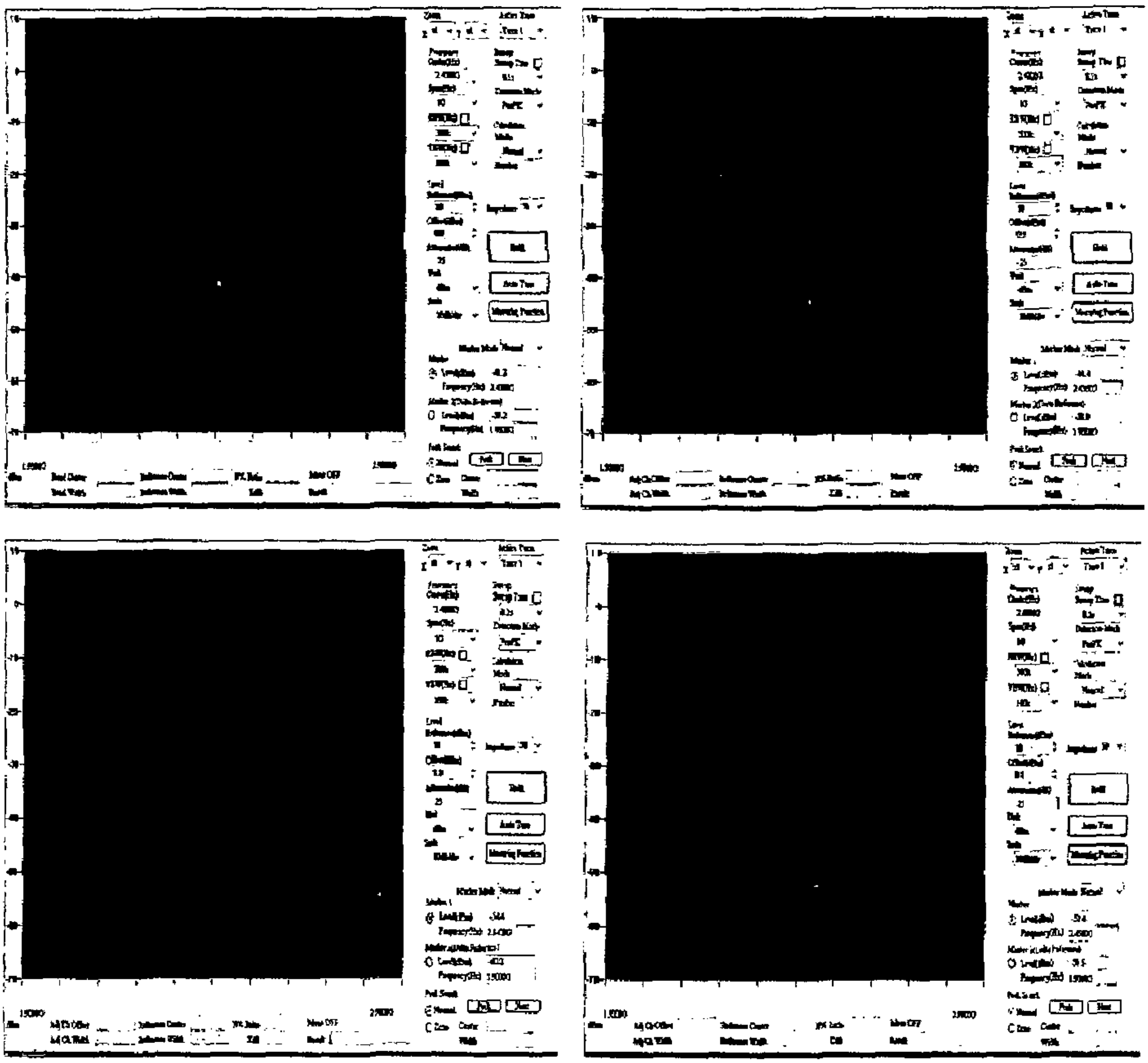


Fig. 5.2(b) shows the received signal strength calculated near staircase using the spectrum analyzer for G to J access points

Table 5.3 Measurements and analysis taken near staircase for different access points

S.No.	Access point location	Positions	Distance between T-R separation(m)	Signal Strength (dBm)	Actual placement of Access point coordinates	Access point coordinates by PSO
1	Location A	Stairs near room A-209	12.6m	-53.2	(18.90, 10.93)	(20.21, 7.23)
2	Location B	Stairs near room A-238	12.5m	-54.4	(24.72, 2.51)	(26.50,1.91)
3	Location C	Stairs near room A-248	9.5m	-46.8	(35.90, 1.59)	(36.85, 1.76)
4	Location D	Stairs near room A-258	11.8m	-48.8	(42.19, 12.92)	(40.20, 10.56)
5	Location E	Stairs near room A-260	4.6m	-52.0	(38.97, 26.24)	(37.73, 25.98)
6	Location F	Stairs near room A-278	6.2m	-52.0	(41.88, 43.70)	(40.66, 45.34)
7	Location G	Stairs near room A-288	13m	-41.2	(36.36, 52.43)	(34.45, 50.23)
8	Location H	Stairs near room A-210	16.4m	-44.4	(26.10, 25.94)	(25.22, 27.67)
9	Location I	Stairs near room A-229	6.2m	-54.4	(30.54, 12.00)	(32.24, 11.40)
10	Location J	Stairs near room A-261	12.7m	-52.4	(33.60, 25.94)	(34.56, 24.87)

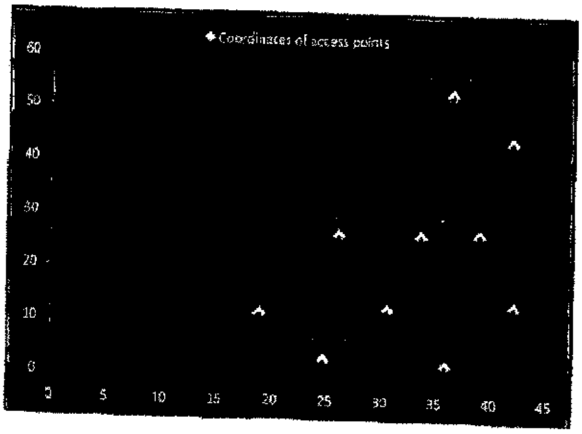


Fig. 5.3 Actual placement of access points

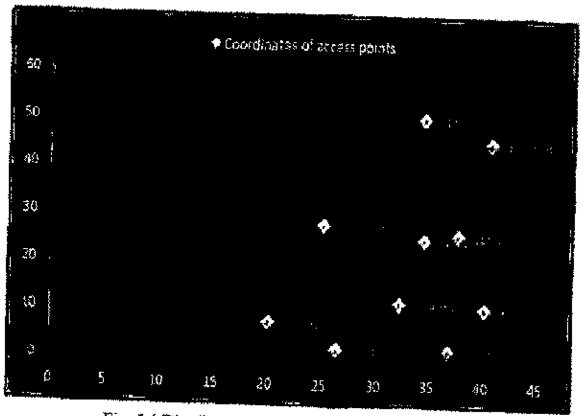


Fig. 5.4 Distribution of access points by using PSO

5.6.2 Measurements and analysis taken inside rooms with hard partitions

In the present selected site measurements taken inside rooms where the presence of wall, glass window and they are the hard partitions so

n_{HP}=number of hard partitions wall and glass window=1 each

l_{HP}=loss due to hard partition wall and glass window=6dB and 2dB (as given in Table 5.1)

$$n_{HP}\, l_{HP} = (1+1)*(6+2) = 16\text{dB}$$

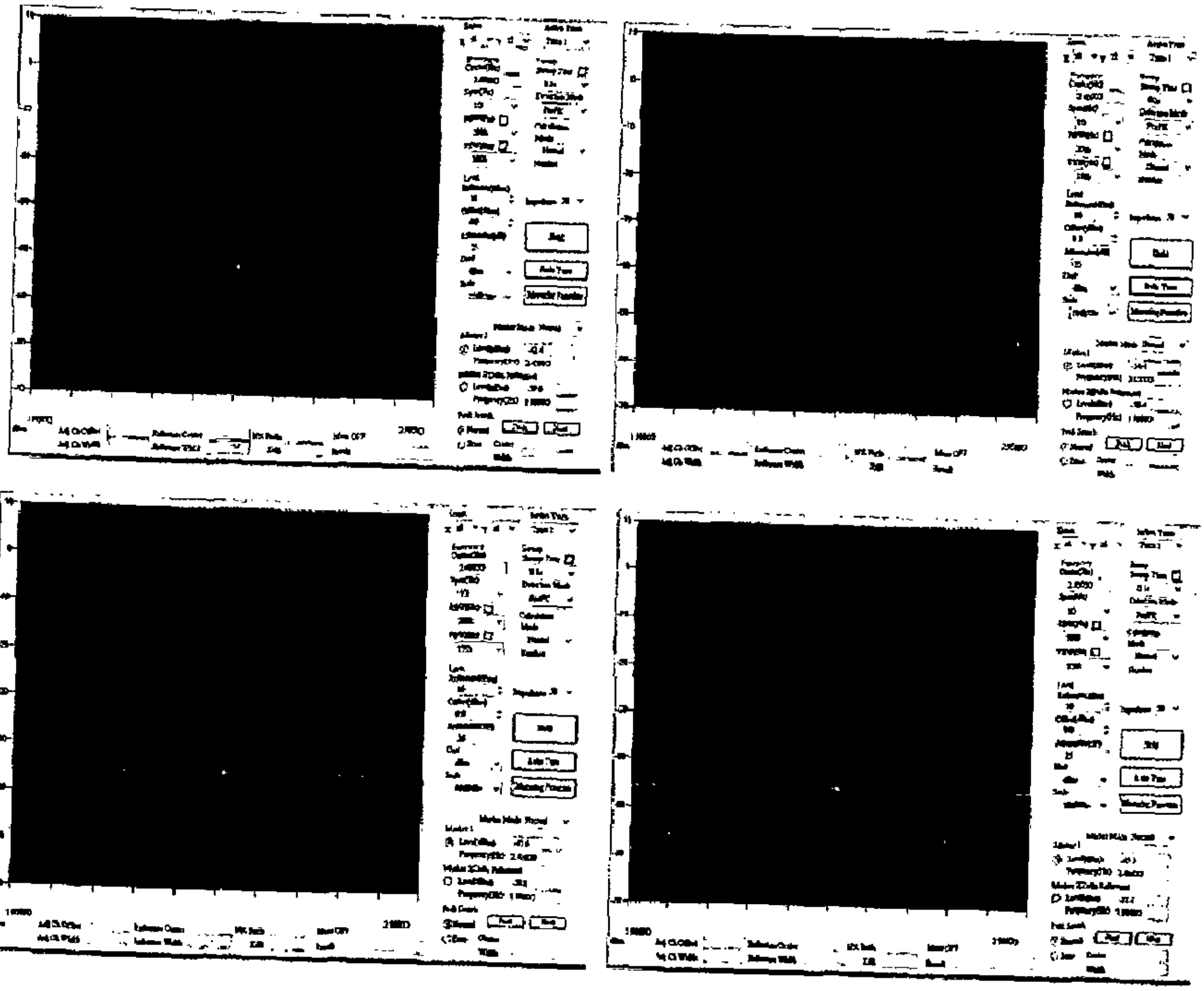
Now from the equation (5.1)

$$g(a_j, r)[dB] = g(d_o)[dB] + 10\log\left(\frac{d(a_j, r)}{d_o}\right)^2$$

Now from the equation (5.2)

$$g(a_j, r)[dB] = g(d_o)[dB] + 10\log\left(\frac{d(a_j, r)}{d_o}\right)^2 + 16 \text{ dB}$$

The received signal strength calculated using the spectrum analyzer is shown in Fig. 5.5(a) and Fig. 5.5(b). Table 5.4 shows the measurements taken inside rooms taking wall as obstruction for different access points. The actual placement of access point coordinates is shown in Fig. 5.6 and the distribution of access point coordinates by using particle swarm optimization is shown in Fig. 5.7.



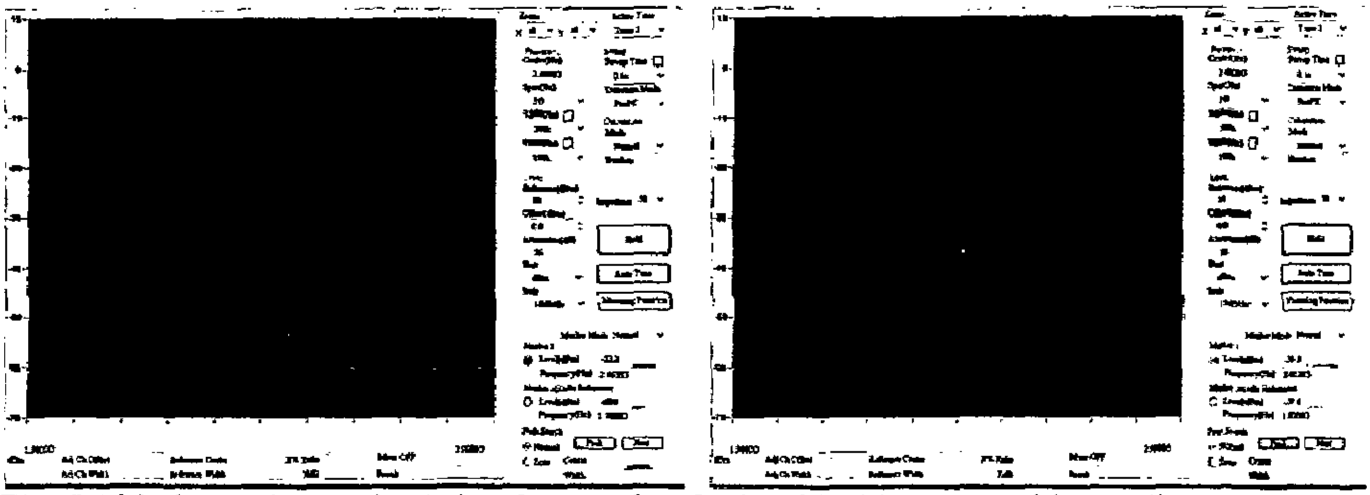


Fig. 5.5(a) shows the received signal strength calculated inside rooms taking wall as obstruction using the spectrum analyzer for A to F access points

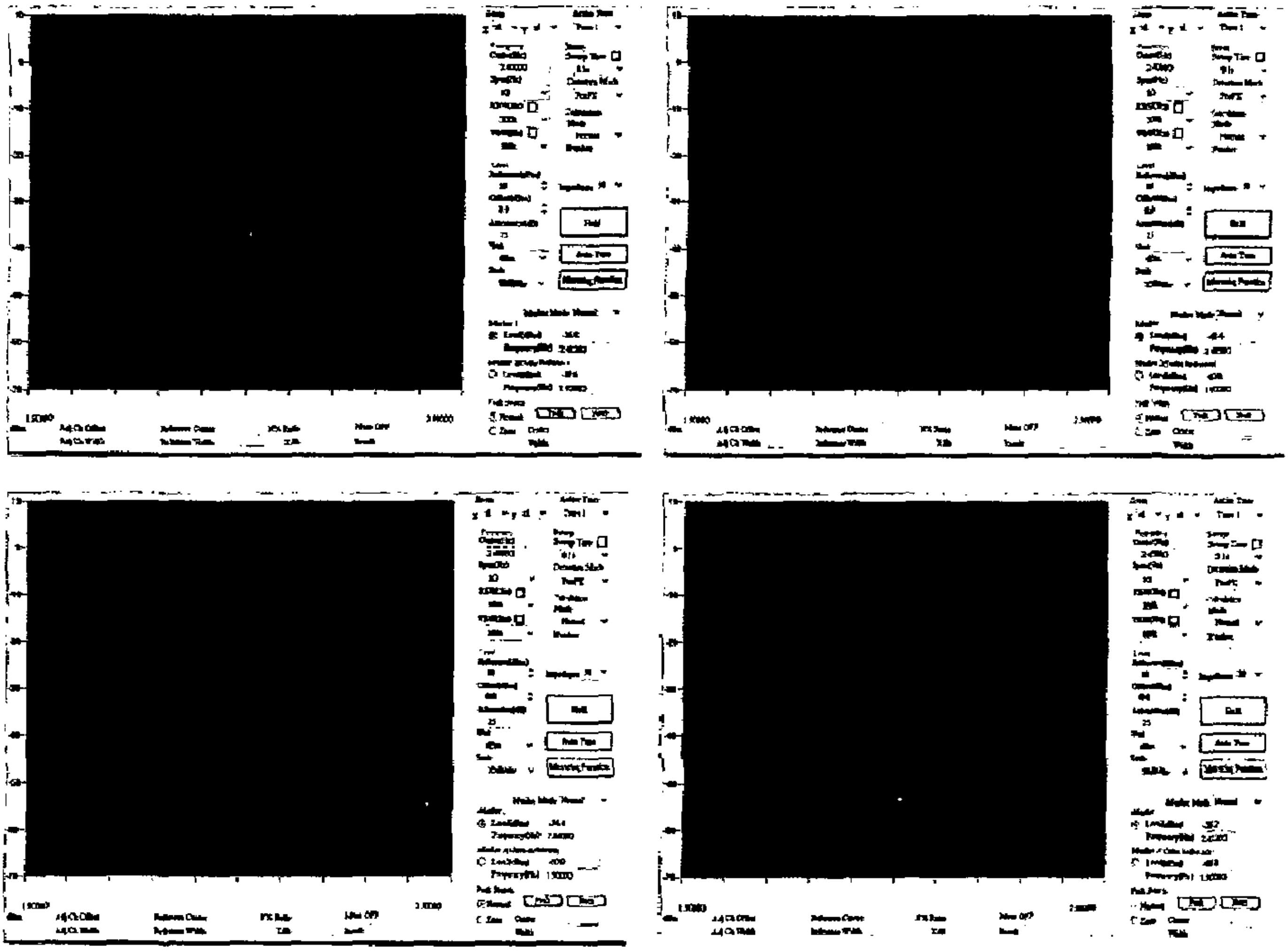


Fig. 5.5(b) shows the received signal strength calculated inside rooms taking wall as obstruction using the spectrum analyzer for G to J access points

Table 5.4 Measurements and analysis taken inside rooms taking wall as obstruction for different access points

S.No.	Access point location	Positions	Distance between T-R separation in (m)	Signal Strength (dBm)	Actual placement of Access point coordinates	Access point coordinates by PSO
1	Location A	Inside room A-202	4m	-42.4	(18.90, 10.93)	(17.19, 11.87)
2	Location B	Inside room A-232	4m	-23.8	(24.72, 2.51)	(23.17, 1.85)
3	Location C	Inside room A-249	5.83m	-45.6	(35.90, 1.59)	(34.38, 2.91)
4	Location D	Inside room A-254	4m	-45.6	(42.19, 12.92)	(38.99, 11.98)
5	Location E	Inside room A-267	8.7m	-53.2	(38.97, 26.24)	(37.17, 23.64)
6	Location F	Inside room A-277	4m	-36.8	(41.88, 43.70)	(40.78, 42.78)
7	Location G	Inside room A-284	4.13m	-50.0	(36.36, 52.43)	(34.96, 50.83)
8	Location H	Inside room A-219	4.41m	-48.4	(26.10, 25.94)	(25.98, 23.56)
9	Location I	Inside room A-226	4.41m	-54.4	(30.54, 12.00)	(32.44, 11.98)
10	Location J	Inside room A-266	4.41m	-54.0	(33.60, 25.94)	(34.10, 23.34)

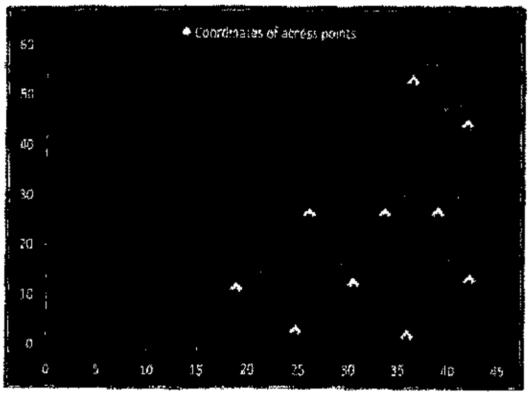


Fig. 5.6 Actual placement of access points

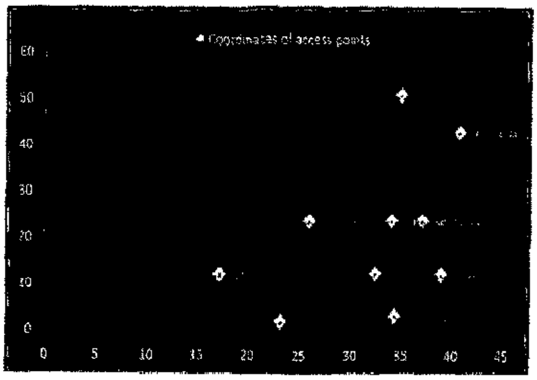


Fig.5.7 Distribution of access points by using PSO

5.6.3 Measurements and analysis taken inside rooms with hard partitions

In the present selected site measurements taken inside rooms where the presence of wall, glass window and closed door and they are the hard partitions then

Nw =number of hard partitions wall, glass window and door =1 each

l_{HP}=loss due to hard partition wall, glass window and door =6dB, 2dB and 2dB (as given in table 5.1)

$$n_{HP}\, l_{HP} = (1+1+1)*(6+2+4) = 36\text{dB}$$

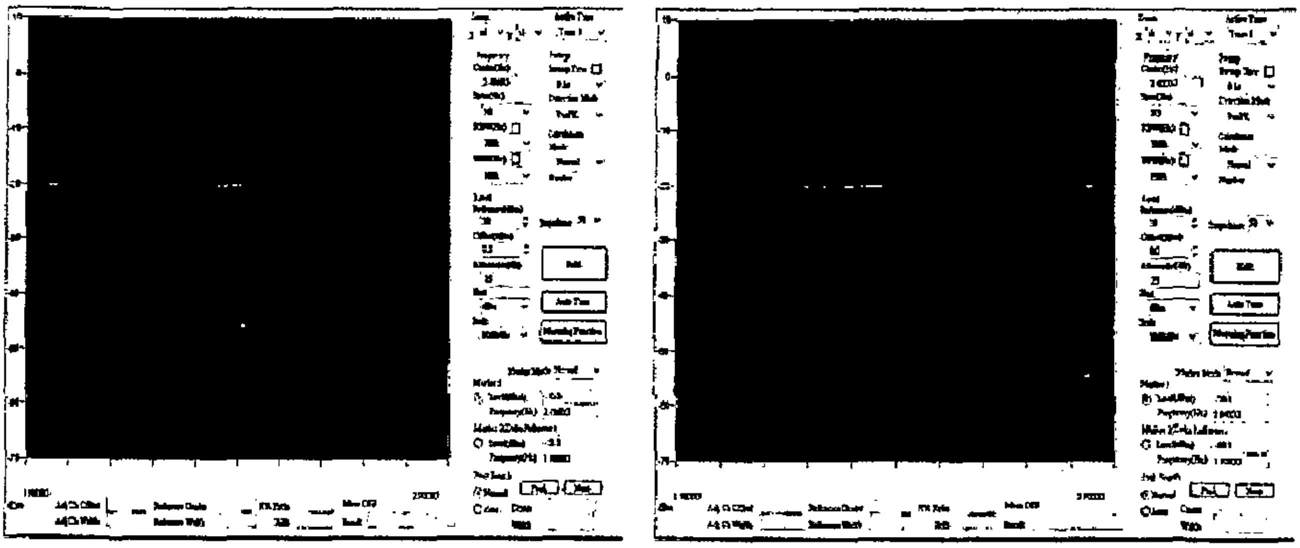
Now from the equation (5.1)

$$g(a_i, r_i)[dB] = g(d_o)[dB] + 10\log\left(\frac{d(a_i, r_i)}{d_o}\right)^2$$

Now from the equation (5.2)

$$g(a_i, r_i)[dB] = g(d_o)[dB] + 10\log\left(\frac{d(a_i, r_i)}{d_o}\right)^2 + 36 \text{ dB}$$

The received signal strength calculated using the spectrum analyzer is shown in Fig. 5.8(a) and Fig. 5.8(b). Table 5.5 shows the measurements taken inside rooms taking wall as obstruction and closed door for different access points. The actual placement of access point coordinates is shown in Fig. 5.9 and the distribution of access point coordinates by using particle swarm optimization is shown in Fig. 5.10.



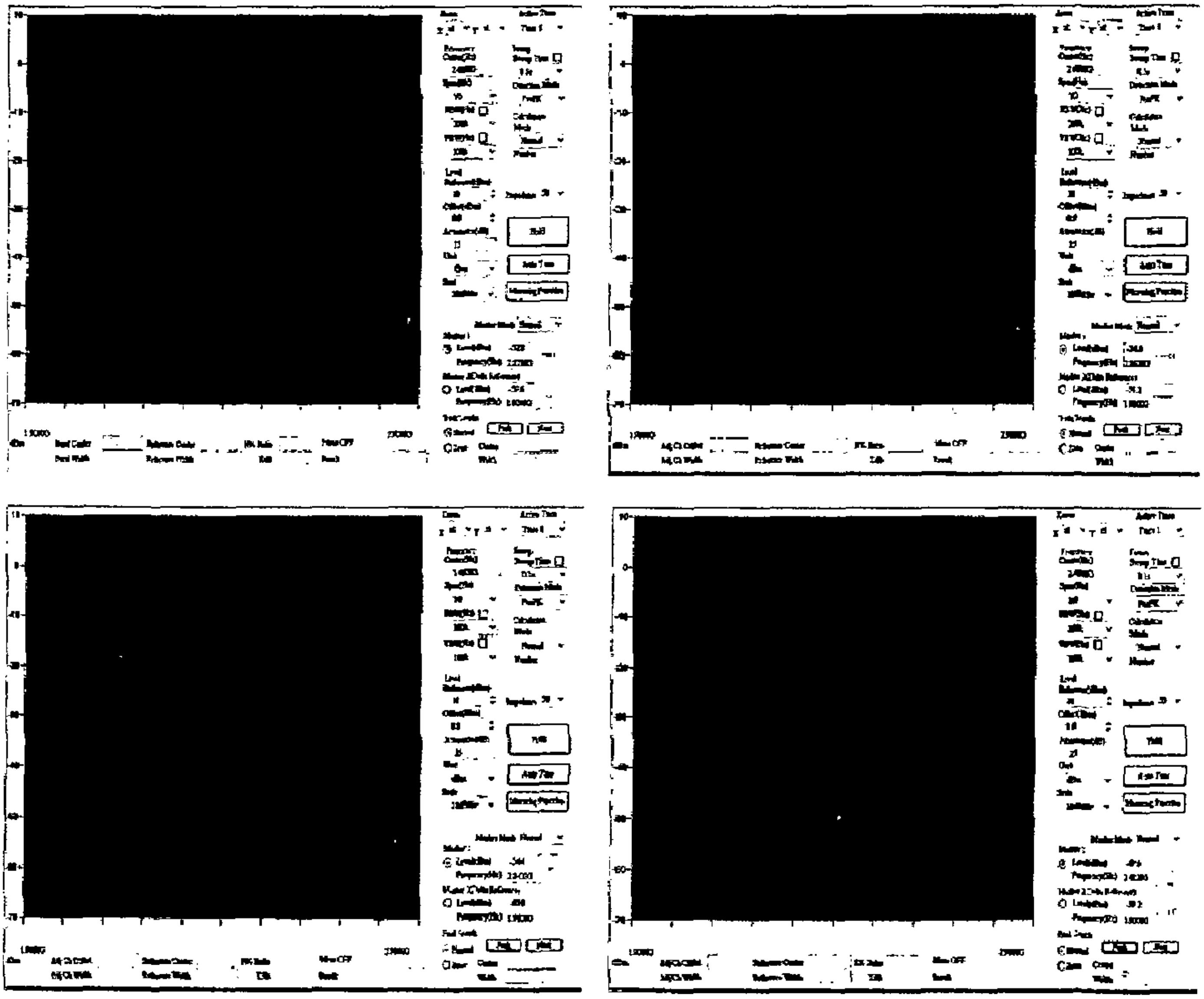


Fig. 5.8(a) shows the received signal strength calculated inside rooms with hard partitions using the spectrum analyzer for A to F access points

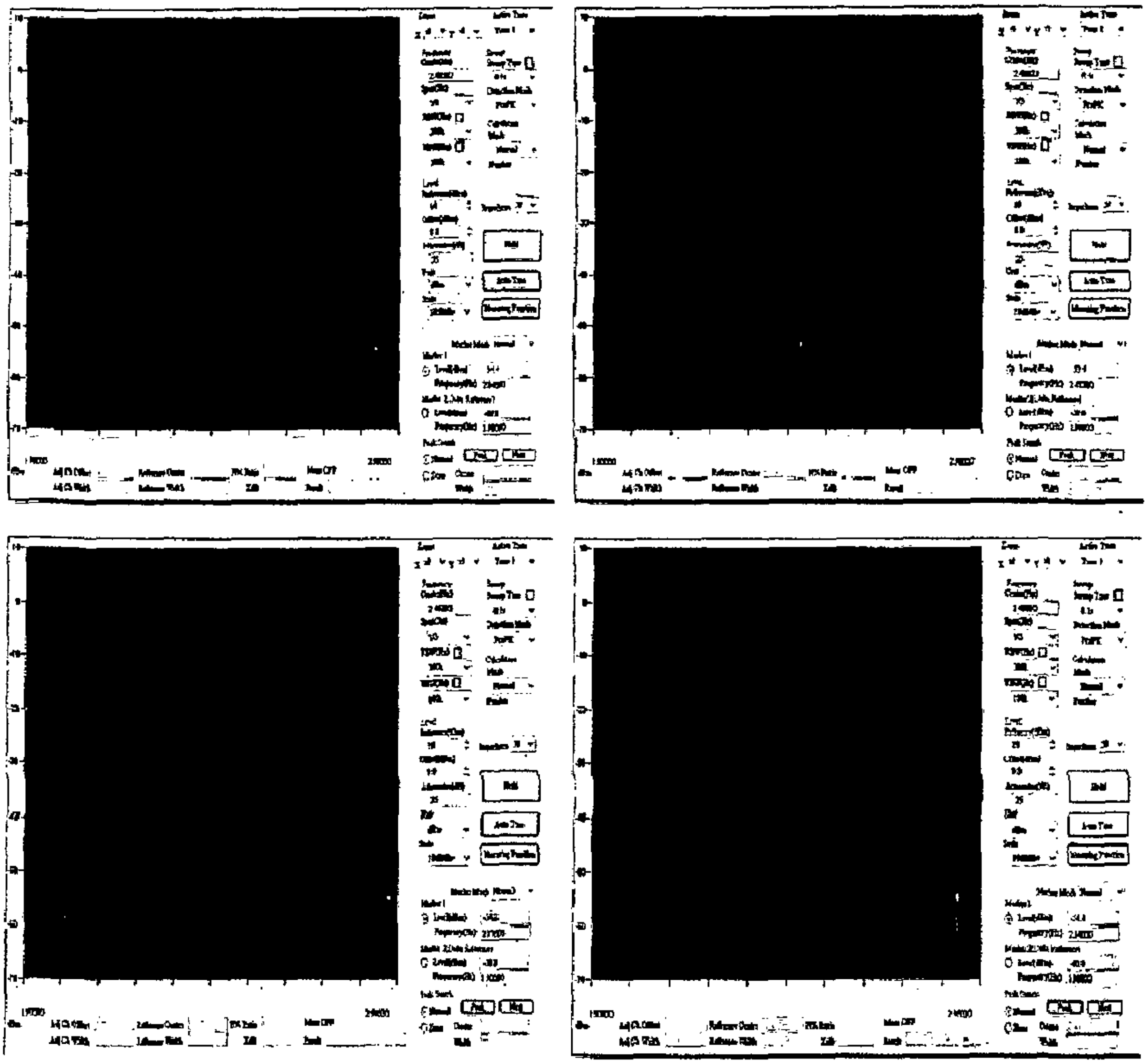


Fig. 5.8(b) shows the received signal strength calculated inside rooms with hard partitions using the spectrum analyzer for G to J access points

Table 5.5 Measurements taken inside rooms with hard partitions for different access points

S.No.	Access point location	Positions	Distance between T-R separation in (m)	Signal Strength (dBm)	Actual placement of Access point coordinates	Access point coordinates by PSO
1	Location A	Inside room A-200 door closed	4.41m	-45.6	(18.90, 10.93)	(20.19, 11.23)
2	Location B	Inside room A-232 door closed	4m	-54.4	(24.72, 2.51)	(22.47, 1.15)
3	Location C	Inside room A-249, door closed	5.83m	-52.8	(35.90, 1.59)	(34.69, 1.77)
4	Location D	Inside room A-254, door closed	4m	-55.2	(42.19, 12.92)	(40.79, 11.99)
5	Location E	Inside room A-267, door closed	8.7m	-54.4	(38.97, 26.24)	(37.77, 25.74)
6	Location F	Inside room A-277, door closed	4m	-50.8	(41.88, 43.70)	(43.89, 42.30)
7	Location G	Inside room A-284, door closed	4.13m	-54.4	(36.36, 52.43)	(35.34, 53.63)
8	Location H	Inside room A-219, door closed	4.41m	-53.6	(26.10, 25.94)	(27.91, 22.96)
9	Location I	Inside room A-226, door closed	4.41m	-54.8	(30.54, 12.00)	(33.84, 14.84)
10	Location J	Inside room A-266, door closed	4.41m	-54.4	(33.60, 25.94)	(32.20, 25.94)

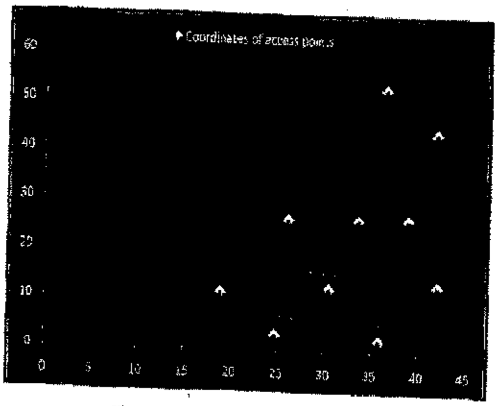


Fig. 5.9 Actual placement of access points

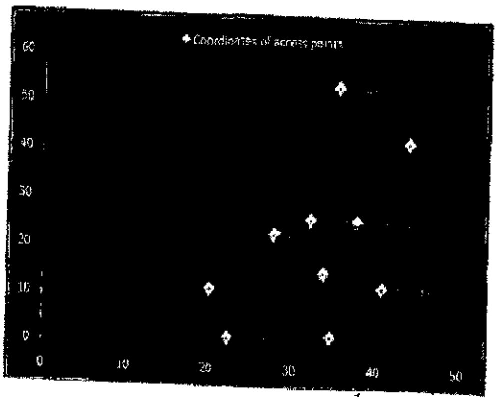


Fig 5.10 Distribution of access points by using PSO

5.6.4 Measurements and analysis taken inside rooms with soft and hard partitions

Measurements taken inside rooms where the presence of human being, desk, and table is possible and these are soft partitions then

n_{SP} = number of soft partitions human being, desk, table=1 each

l_{SP}=loss due to soft partitions human being, desk, table =4dB, 4dB and 4dB (as given in table 5.1)

$$n_{SP}\, l_{SP} = (1+1+1)*(4+4+4) = 36\text{dB}$$

n_{HP}=number of hard partitions wall, glass window, almirah and door=1 each

l_{HP}=loss due to hard partitions wall, glass window, almirah and door =6dB, 2dB, 4dB and 4dB (as given in Table 5.1)

$$n_{HP}\, l_{HP} = (1+1+1+1)*(6+2+4+4) = 64\text{dB}$$

Now from the equation (5.1)

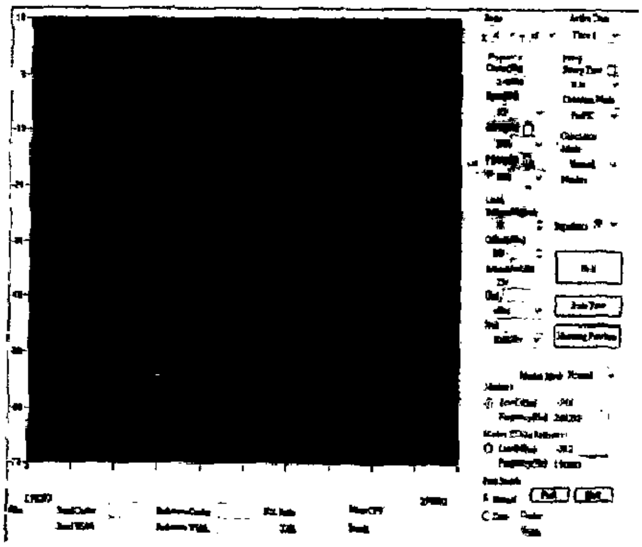
$$g(a_j, r_i)[dB] = g(d_o)[dB] + 10\log\left(\frac{d(a_j, r_i)}{d_o}\right)^2$$

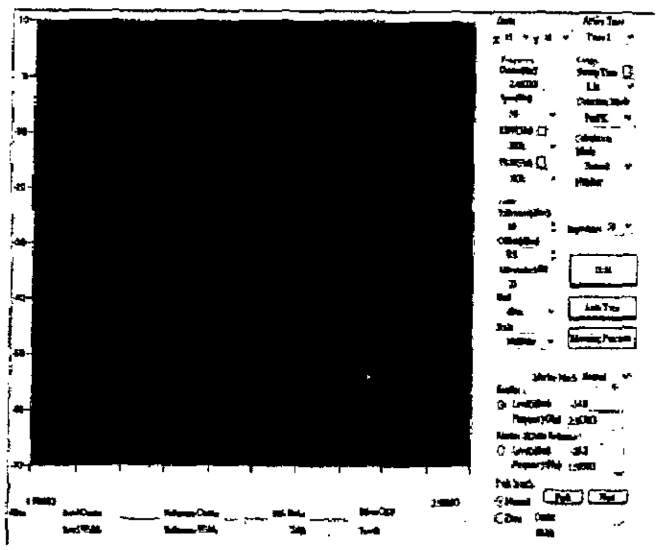
$$n_{SP}\, l_{SP} + n_{HP}\, l_{HP} = 36+64=100\text{dB}$$

Now from the equation (5.2)

$$g(a_j, r_i)[dB] = g(d_o)[dB] + 10\log\left(\frac{d(a_j, r_i)}{d_o}\right)^2 + 100\ \text{dB}$$

The received signal strength calculated using the spectrum analyzer is shown in Fig. 5.11(a) and Fig. 5.11(b). Table 5.6 shows the measurements taken inside rooms taking wall, human, desk, table, almirah etc. as obstruction and closed door for different access points. The actual placement of access point coordinates is shown in Fig. 5.12 and the distribution of access point coordinates by using particle swarm optimization is shown in Fig. 5.13.





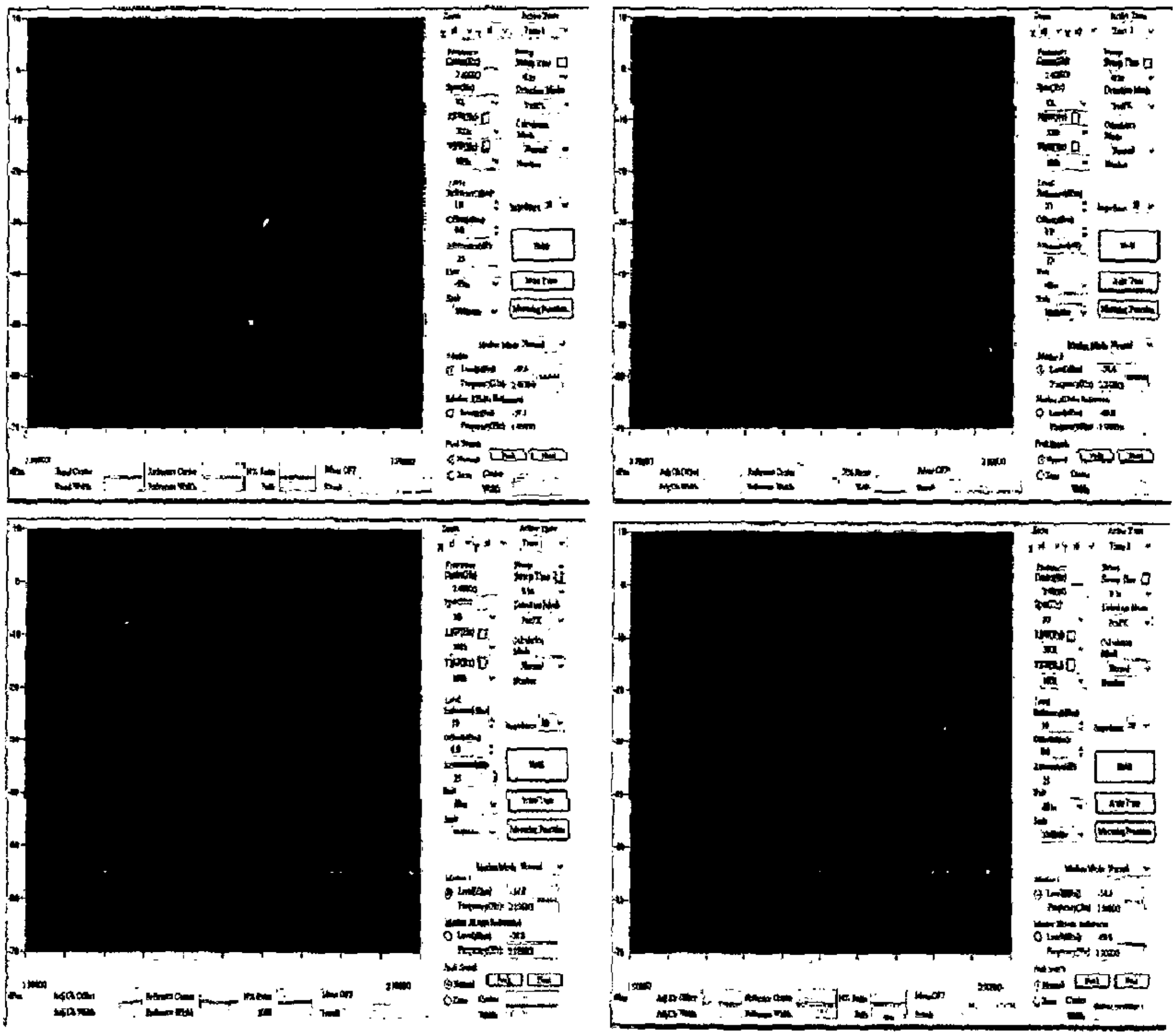


Fig. 5.11(a) shows the received signal strength calculated inside rooms with soft and hard partitions using the spectrum analyzer for A to F access points

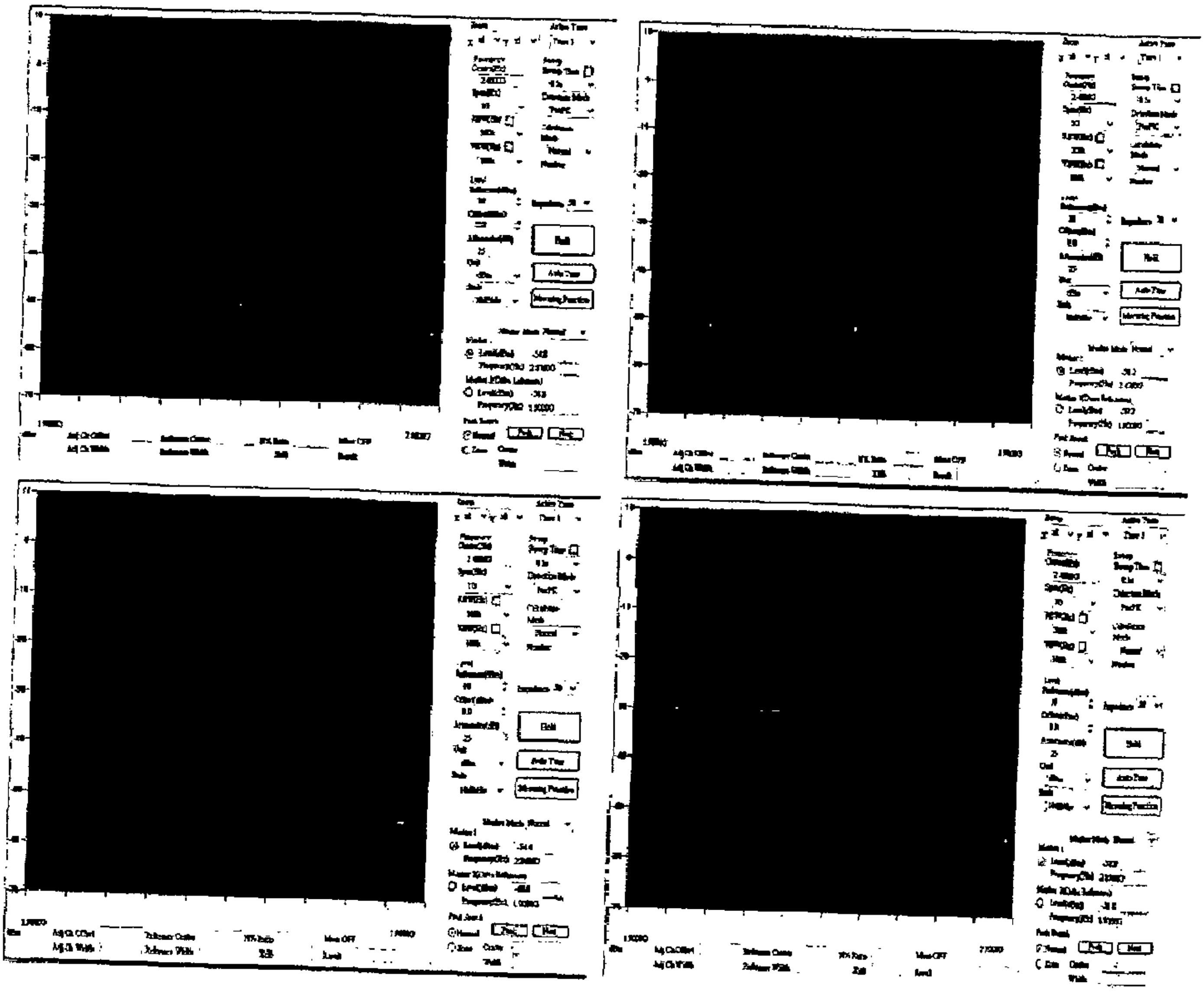


Fig. 5.11(b) shows the received signal strength calculated inside rooms with soft and hard partitions using the spectrum analyzer for G to J access points

Table 5.6 Measurements taken inside rooms with soft and hard partitions for different access points

S.No.	Access point location	Positions	Distance between T-R separation in (m)	Signal Strength (dBm)	Actual placement of Access point coordinates	Access point coordinates by PSO
1	*Location A*	*Inside room A-200,human, desk, door open*	*4.41m*	*-54.0*	*(18.90, 10.93)*	*(17.70, 11.94)*
2	Location B	Inside room A-232,human, desk, door open	4m	-54.0	(24.72, 2.51)	(23.42, 3.55)
3	Location C	Inside room A-249,on bed, door open	5.83m	-50.0	(35.90, 1.59)	(36.79, 2.67)
4	Location D	Inside room A-254, table, almirah, human	4m	-54.4	(42.19, 12.92)	(40.14, 15.39)
5	Location E	Inside room A-267,table,almirah door closed	8.7m	-54.8	(38.97, 26.24)	(36.95, 26.78)
6	Location F	Inside room A-277, table, almirah, human, door closed	4m	-54.4	(41.88, 43.70)	(40.66, 42.26)
7	Location G	Inside room A-280, table, bed, almirah, human, door closed	7.19m	-54.8	(36.36, 52.43)	(33.77, 53.67)
8	Location H	Inside room A-219, table, almirah, human, door open	4.41m	-51.2	(26.10, 25.94)	(27.67, 27.67)
9	Location I	Inside room A-226, desk, human, door open	4.41m	-54.4	(30.54, 12.00)	(32.77, 13.11)
10	Location J	Inside room A-266, desk, human, door open	4.41m	-54.8	(33.60, 25.94)	(34.56, 24.87)

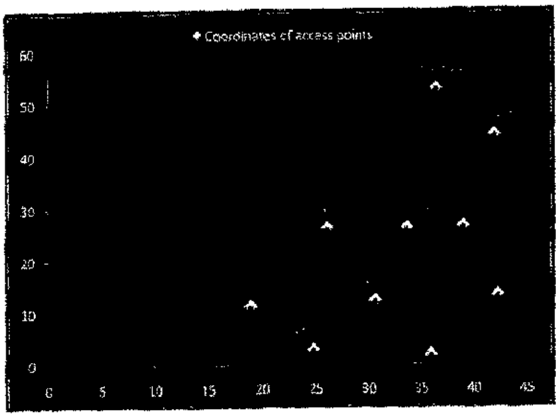


Fig. 5.12 Actual placement of access points

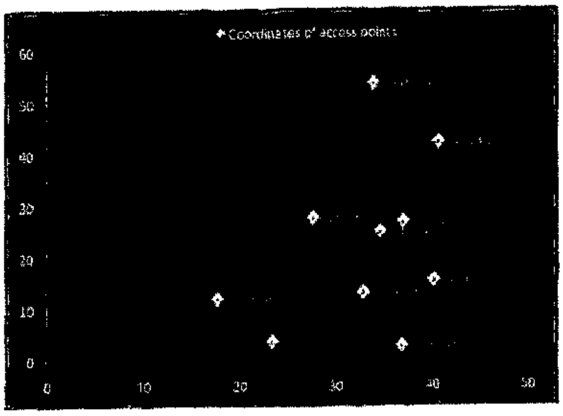


Fig.5.13 Distribution of access points by using PSO

5.7 Analysis of results for obstructed environment on second floor

The signal strength configuration changes in the presence of an obstruction in the path of the waves. Obstructions can include walls, ceilings, humans (possibly moving), and so on. For different obstructions the signal strength measurements between transmitter and receiver have been taken using spectrum analyzer at the 9 access points shown by red symbols and locations A to I on the second floor is shown in Fig. 5.14.

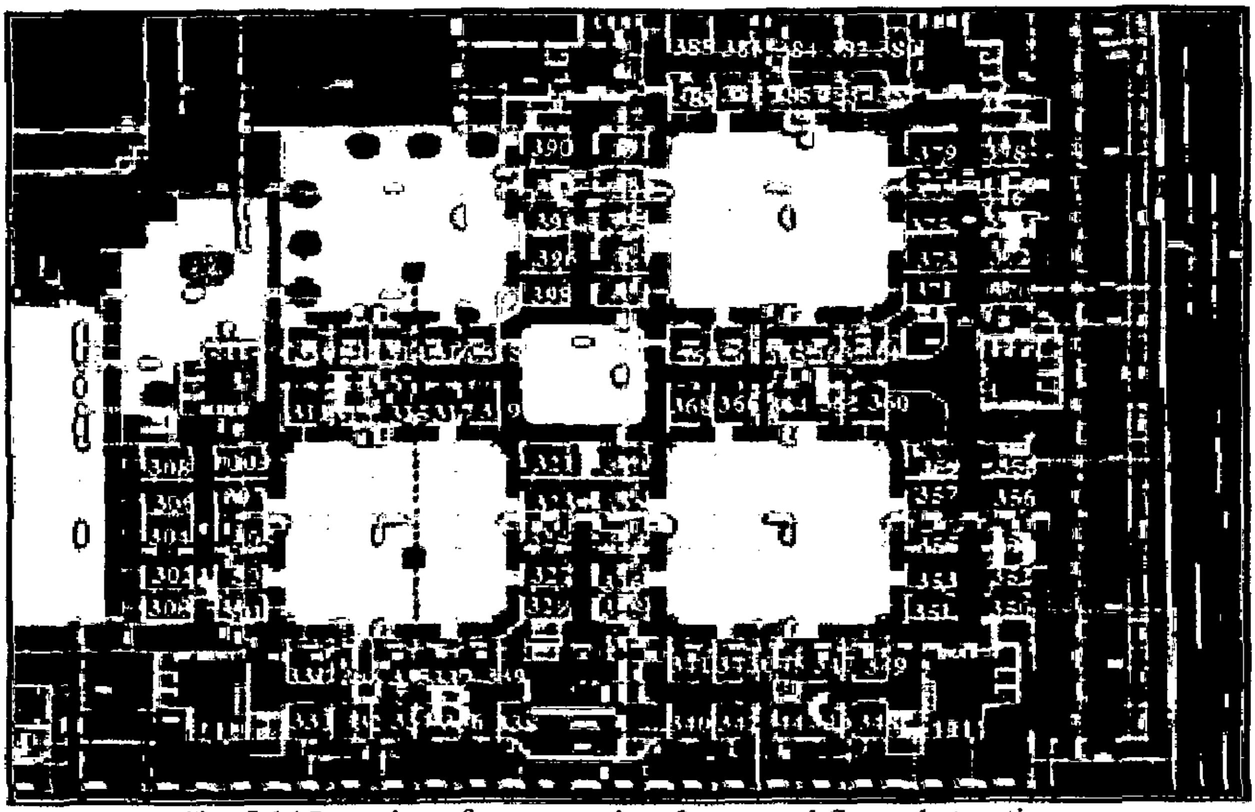


Fig. 5.14 Location of access points for second floor obstructions

5.7.1 Measurements and analysis taken near staircase with soft partitions

Measurements taken near staircase where the presence of human being is possible and it is a soft partition then

n_{SP}= number of soft partition=1 each

l_{SP}=loss due to soft partition=4dB (as given in table 5.1)

$$n_{SP}\, l_{SP} = 1*4=4dB$$

Now from the equation (5.1)

$$g(a_i,r_i)[dB] = g(d_0)[dB] + 10\log\left(\frac{d(a_i,r_i)}{d_0}\right)^2$$

Now from the equation (5.2)

$$g(a_j, r_i)[dB] = g(d_0)[dB] + 10\log\left(\frac{d(a_j, r_i)}{d_0}\right)^2 + 4\text{dB}$$

The received signal strength calculated using the spectrum analyzer is shown in Fig. 5.15(a) and Fig. 5.15(b). Table 5.7 shows the measurements taken near staircase as obstruction for different access points. The actual placement of access point coordinates is shown in Fig. 5.16 and the distribution of access point coordinates by using particle swarm optimization is shown in Fig. 5.17.

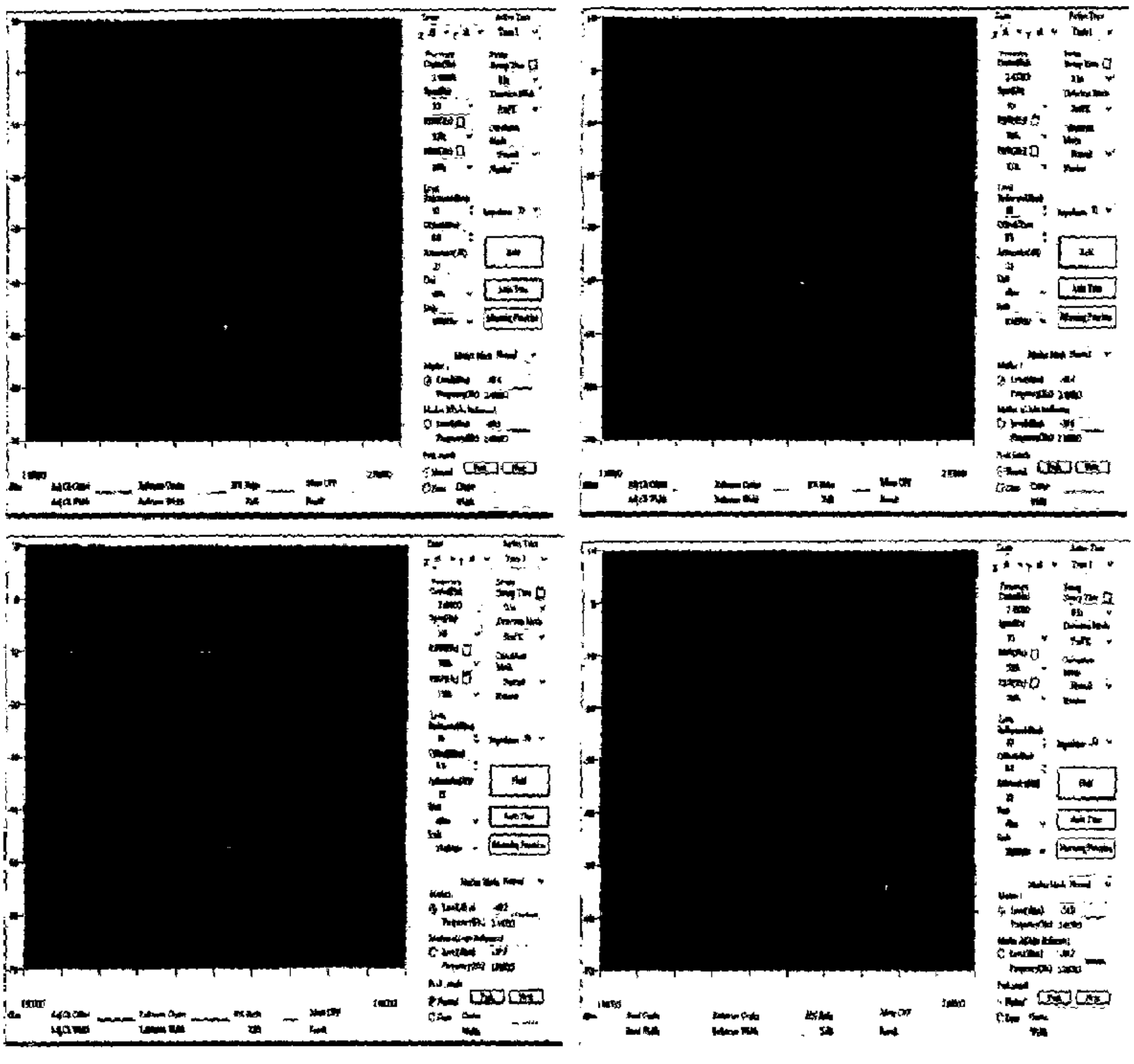


Fig. 5.15(a) shows the received signal strength calculated near staircase as obstruction using the spectrum analyzer

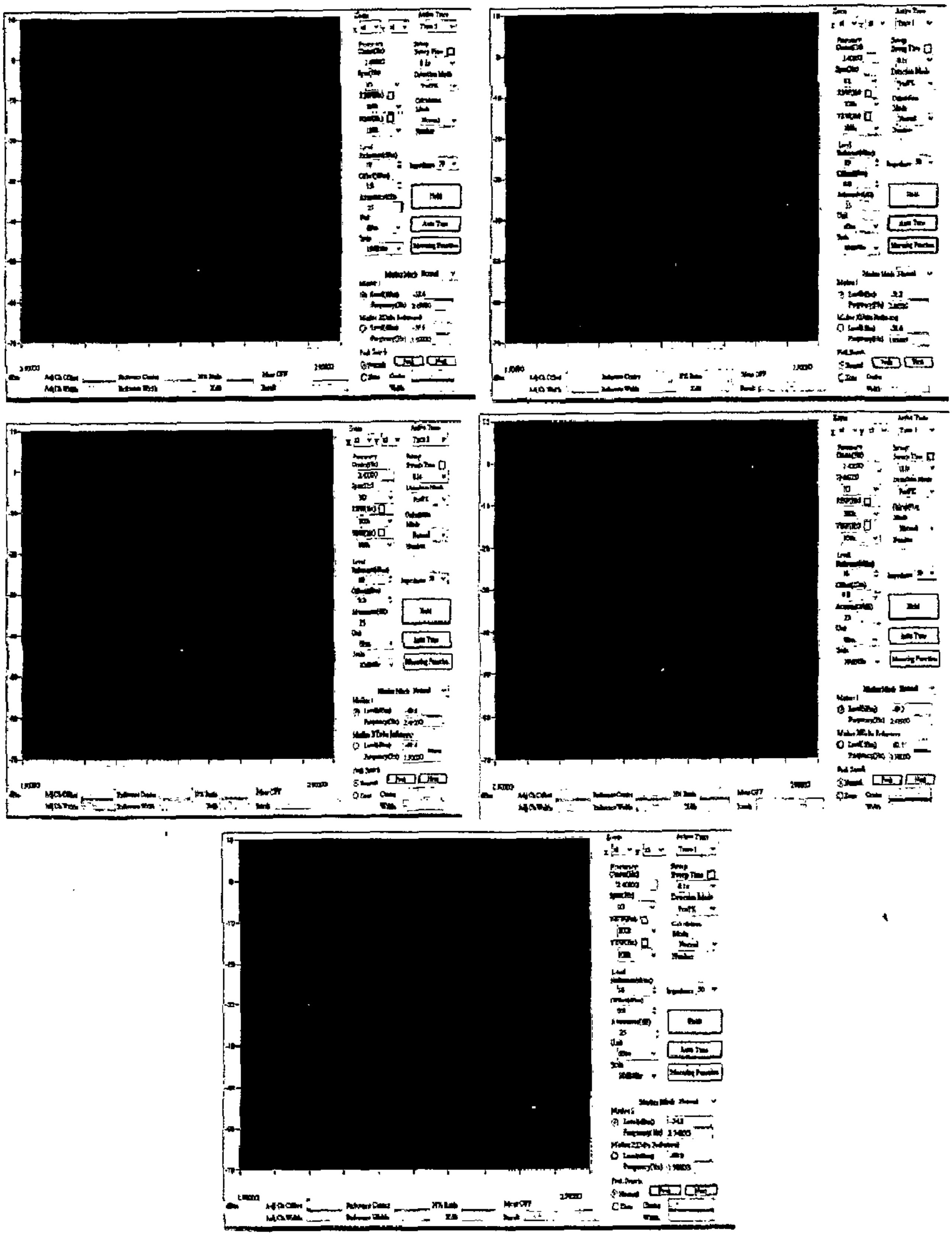


Fig. 5.15(b) shows the received signal strength calculated near staircase as obstruction using the spectrum analyzer

Table 5.7 Measurements taken near staircase as obstruction for different access points

S.No.	Access point location	Positions	Distance between T-R separation(m)	Signal Strength (dBm)	Actual placement of Access point coordinates	Access point coordinates by PSO
1	Location A	Stairs near room A-308	12.6m	-48.4	(19.21,13.38)	(18.82,12.28)
2	Location B	Stairs near room A-338	12.5m	-40.4	(25.34,0.98)	(24.84,1.98)
3	Location C	Stairs near room A-349	9.5m	--47.2	(36.06,1.59)	(34.16,2.34)
4	Location D	Stairs near room A-359	11.8m	-54.0	(41.11,12.92)	(43.13,11.32)
5	Location E	Stairs near room A-260	4.6m	-52.4	(35.44,26.09)	(32.56,23.99)
6	Location F	Stairs near room A-370	6.2m	-51.2	(41.57,38.95)	(42.37,37.85)
7	Location G	Stairs near room A-390	13m	-43.6	(30.39,38.49)	(32.29,36.48)
8	Location H	Stairs near room A-311	16.4m	-49.2	(25.03,25.79)	(24.83,24.88)
9	Location I	Stairs near room A-329	6.2m	-54.8	(30.24,15.22)	(32.89,14.29)

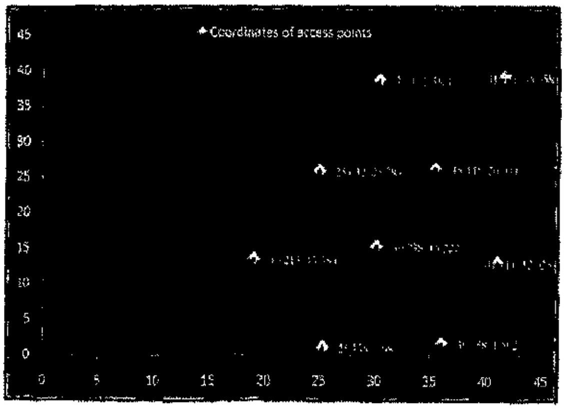


Fig. 5.16 Actual placement of access points

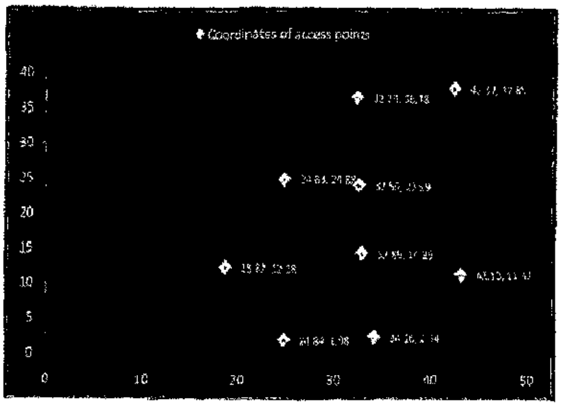


Fig. 5.17 Distribution of access points by using PSO

5.7.2 Measurements and analysis taken inside rooms with hard partitions

Measurements taken inside rooms where the presence of wall, glass window and they are the hard partitions so

Nhp=number of hard partitions wall and glass window=1 each

l_{HP}=loss due to hard partition wall and glass window=6dB and 2dB (as given in Table 5.1)

$$n_{HP}\, l_{HP} = (1+1)*(6+2) = 16\text{dB}$$

Now from the equation (5.1)

$$g(a_i,n)[dB] = g(d_o)[dB] + 10\log\left(\frac{d(a_i,n)}{d_o}\right)^2$$

Now from the equation (5.2)

$$g(a_i,n)[dB] = g(d_o)[dB] + 10\log\left(\frac{d(a_i,n)}{d_o}\right)^2 + 16\text{ dB}$$

The received signal strength calculated using the spectrum analyzer is shown in Fig. 5.18(a) and Fig. 5.18 (b). Table 5.8 shows the measurements taken inside rooms taking wall as obstruction for different access points. The actual placement of access point coordinates is shown in Fig. 5.19 and the distribution of access point coordinates by using particle swarm optimization is shown in Fig. 5.20.

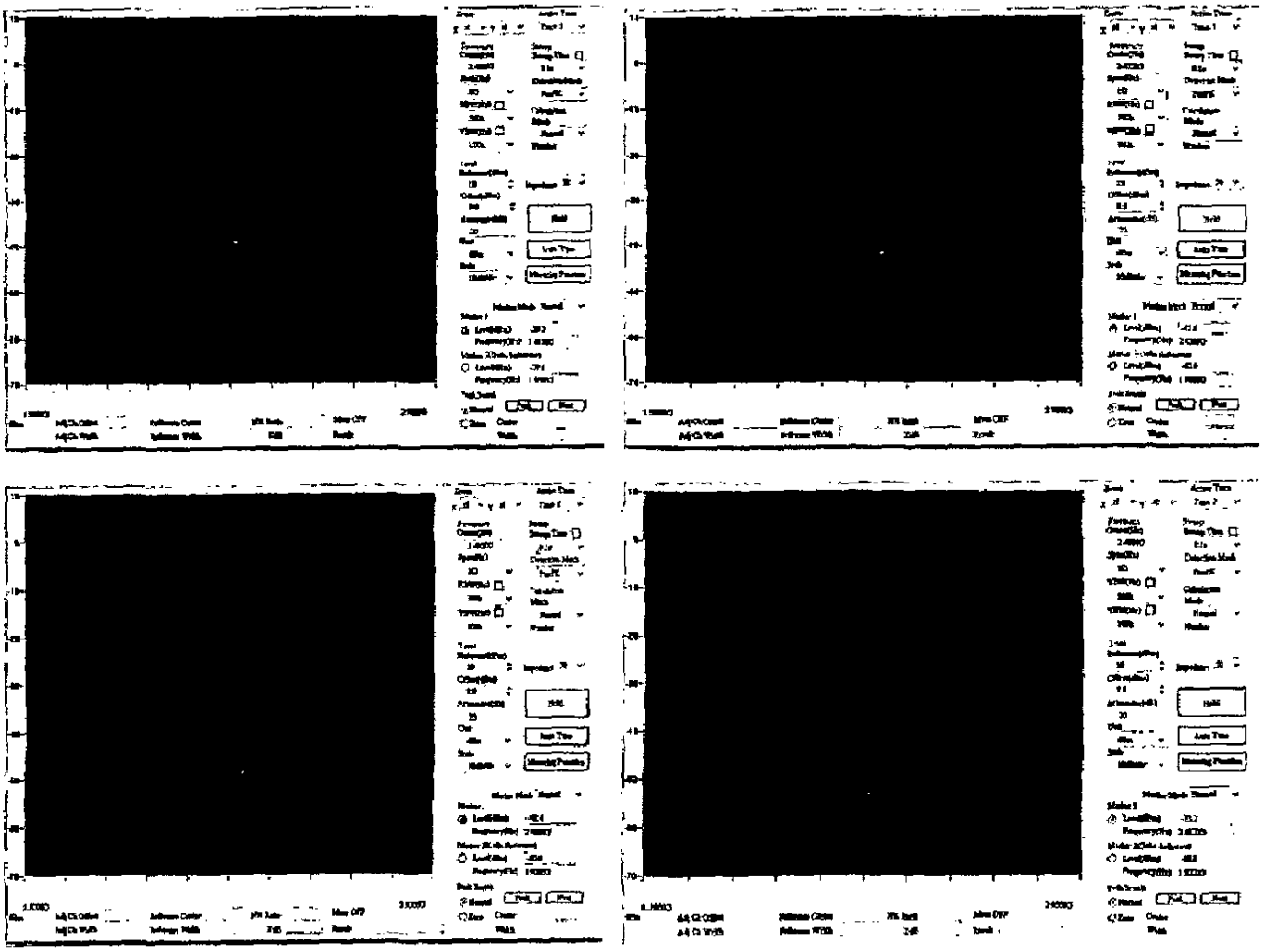


Fig. 5.18(a) shows the received signal strength calculated inside rooms with hard partitions using the spectrum analyzer

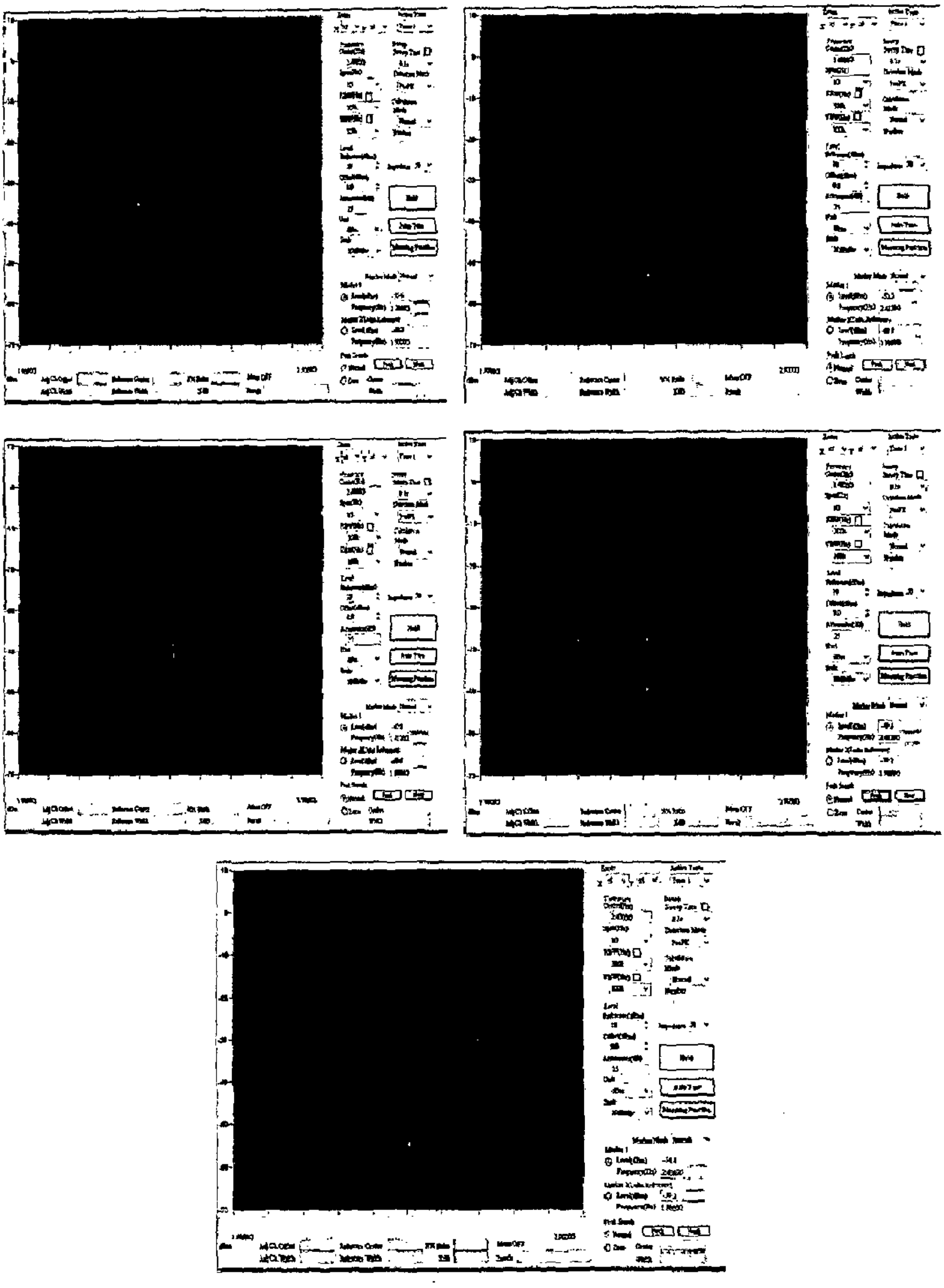


Fig. 5.18(b) shows the received signal strength calculated inside rooms with hard partitions using the spectrum analyzer

Table 5.8 Measurements taken inside rooms with hard partitions for different access points

S.No.	Access point location	Positions	Distance between T-R separation in (m)	Signal Strength (dBm)	Actual placement of Access point coordinates	Access point coordinates by PSO
1	Location A	Inside room A-304	4m	-41.2	(19.21,13.38)	(18.34,12.28)
2	Location B	Inside room A-338	4m	-41.6	(25.34,0.98)	(22.35,1.92)
3	Location C	Inside room A-349	5.83m	-48.4	(36.06,1.59)	(34.86,0.99)
4	Location D	Inside room A-355	4m	-54.0	(41.11,12.92)	(40.10,14.42)
5	Location E	Inside room A-365	8.7m	-35.6	(35.44,26.09)	(34.40,24.19)
6	Location F	Inside room A-379	4m	--54.0	(41.57,38.95)	(40.56,36.23)
7	Location G	Inside room A-397	4.13m	-40.8	(30.39,38.49)	(33.78,34.79)
8	Location H	Inside room A-313	4.41m	-50.8	(25.03,25.79)	(24.33,23.58)
9	Location I	Inside room A-322	4.41m	-54.4	(30.24,15.22)	(31.15,16.11)

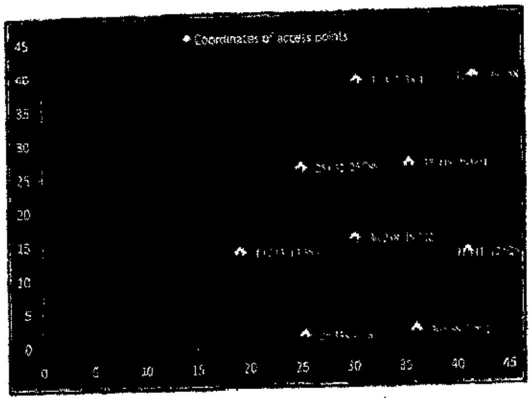


Fig. 5.19 Actual placement of access points

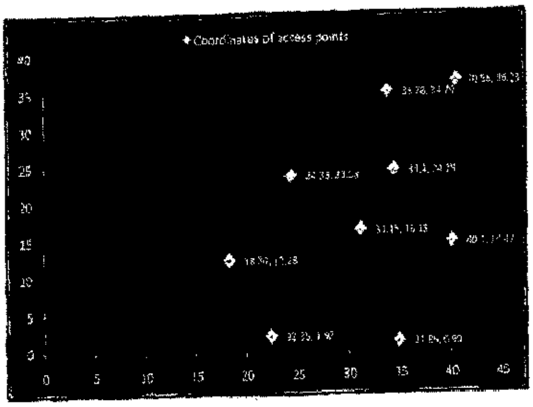


Fig. 5.20 Distribution of access points by using PSO

5.7.3 Measurements and analysis taken inside rooms with hard partitions

Measurements taken inside rooms where the presence of wall, glass window and closed door and they are the hard partitions then

n_{HP}=number of hard partitions wall, glass window and door =1 each

l_{HP}=loss due to hard partition wall, glass window and door =6dB, 2dB and 2dB (as given in table 5.1)

$$n_{HP}\, l_{HP} = (1+1+1)*(6+2+4) = 36\text{dB}$$

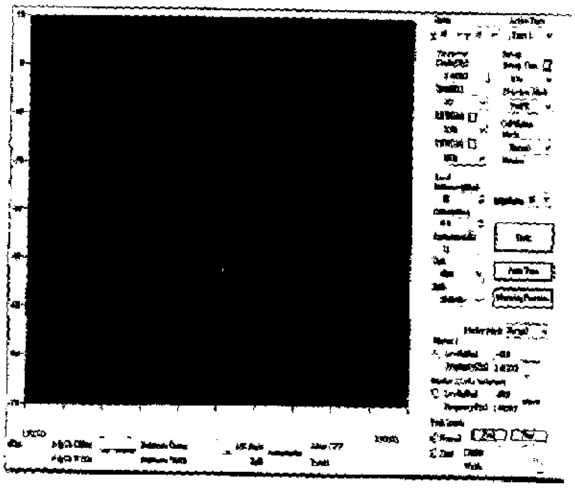
Now from the equation (5.1)

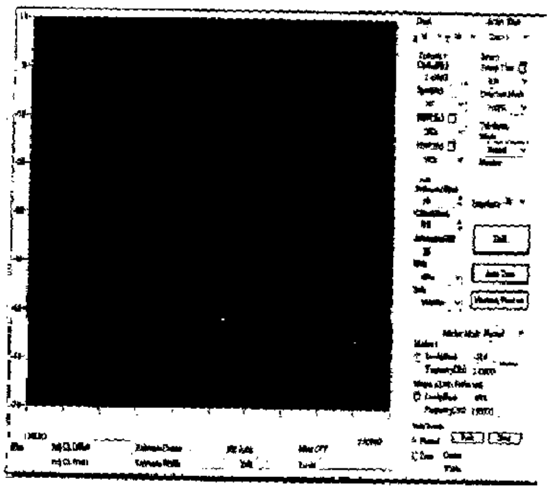
$$g(a_i, n)[dB] = g(d_o)[dB] + 10\log\left(\frac{d(a_i, n)}{d_o}\right)^2$$

Now from the equation (5.2)

$$g(a_i, n)[dB] = g(d_o)[dB] + 10\log\left(\frac{d(a_i, n)}{d_o}\right)^2 + 36 \text{ dB}$$

The received signal strength calculated using the spectrum analyzer is shown in Fig. 5.21(a) and Fig. 5.21(b). Table 5.9 shows the measurements taken inside rooms taking wall as obstruction for different access points. The actual placement of access point coordinates is shown in Fig. 5.22 and the distribution of access point coordinates obtained by using particle swarm optimization is shown in Fig. 5.23.





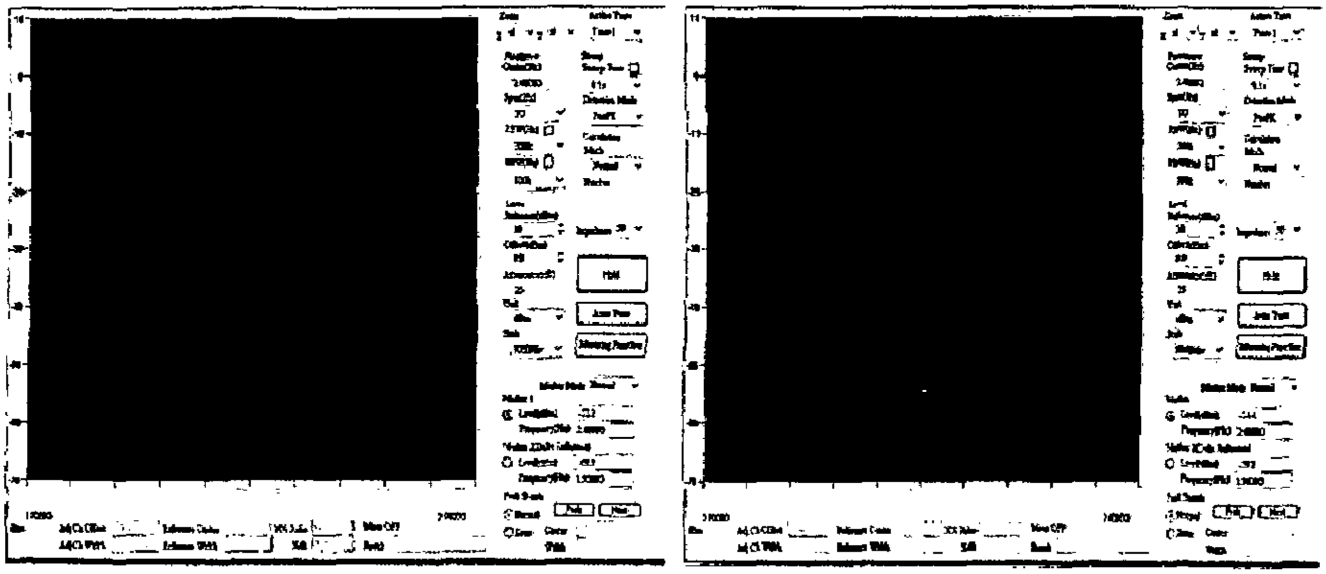
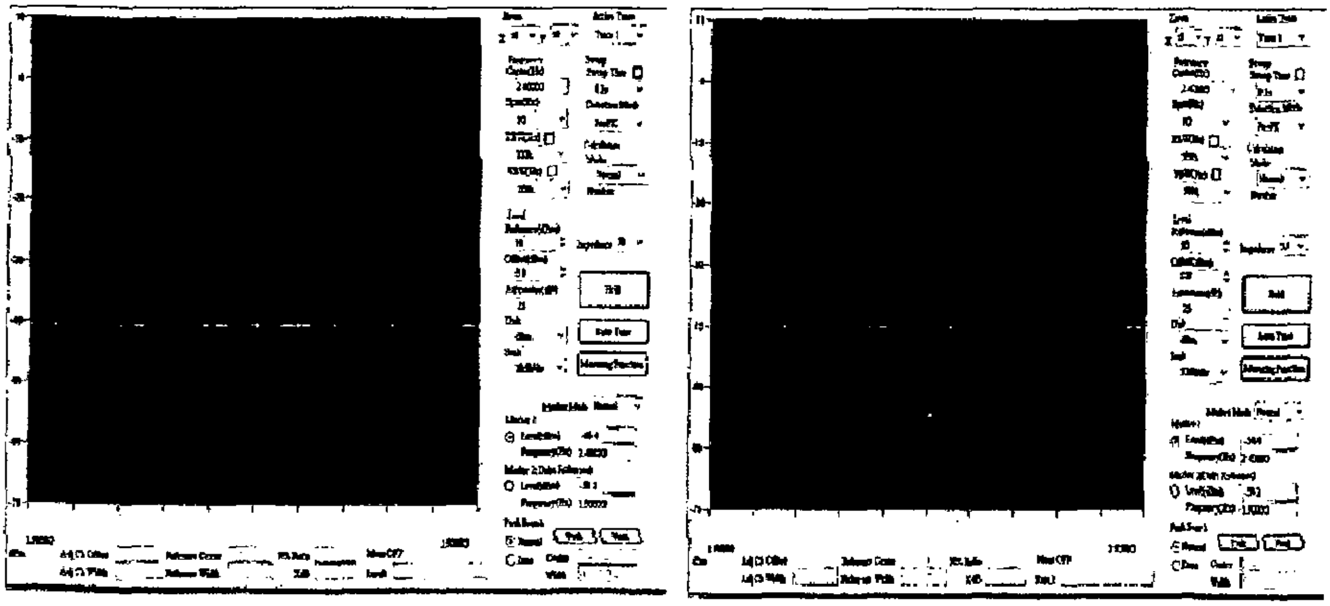


Fig. 5.21(a) shows the received signal strength calculated inside rooms with hard partitions using the spectrum analyzer



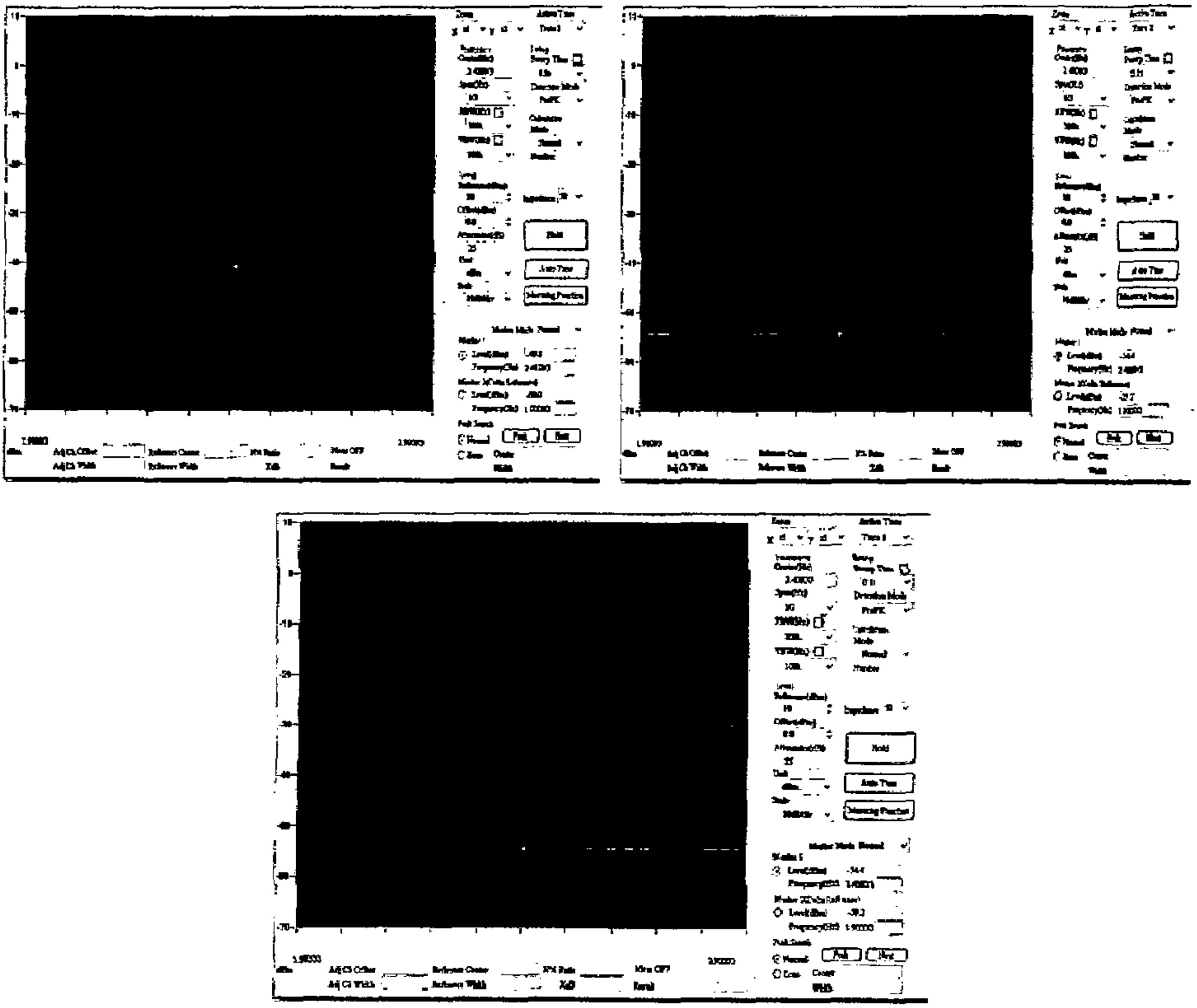


Fig. 5.21(b) shows the received signal strength calculated inside rooms with hard partitions using the spectrum analyzer

Table 5.9 Measurements taken inside rooms with hard partitions different access points

S.No.	Access point location	Positions	Distance between T-R separation in (m)	Signal Strength (dBm)	Actual placement of Access point coordinates	Access point coordinates by PSO
1	Location A	Inside room A-304, door closed	4.41m	-42.0	(19.21,13.38)	(21.23,14.23)
2	Location B	Inside room A-338, door closed	4m	-51.6	(25.34,0.98)	(25.33,1.08)
3	Location C	Inside room A-342, door closed	5.83m	-53.2	(36.06,1.59)	(35.06,1.48)
4	Location D	Inside room A-355, door closed	4m	-54.4	(41.11,12.92)	(40.10,12.91)
5	Location E	Inside room A-365, door closed	8.7m	-40.4	(35.44,26.09)	(33.56,25.28)
6	Location F	Inside room A-379, door closed	4m	-54.4	(41.57,38.95)	(40.56,37.94)
7	Location G	Inside room A-397, door closed	4.13m	-40.8	(30.39,38.49)	(31.33,37.45)
8	Location H	Inside room A-313, door closed	4.41m	-54.4	(25.03,25.79)	(23.73,27.77)
9	Location I	Inside room A-329, door closed	4.41m	-54.4	(30.24,15.22)	(31.56,15.19)

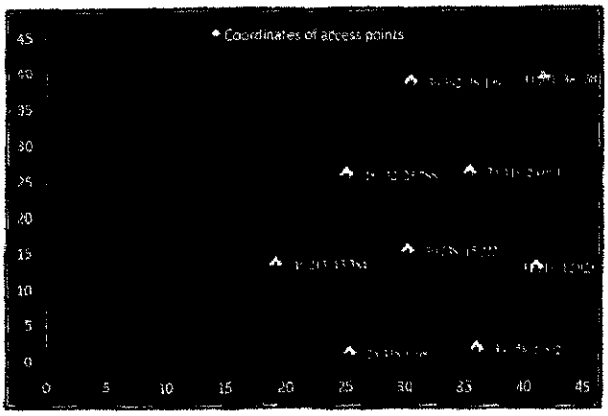


Fig. 5.22 Actual placement of access points

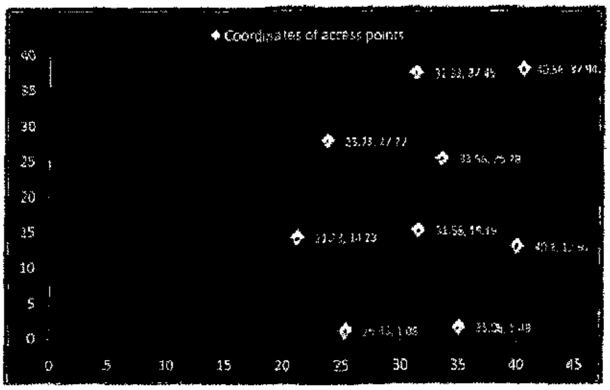


Fig. 5.23 Distribution of access points by using PSO

5.7.4 Measurements and analysis taken inside rooms with soft and hard partitions

Measurements taken inside rooms where the presence of human being, desk and table is possible and these are soft partitions then

Ns = number of soft partitions human being, desk, table=1 each

l_{SP}=loss due to soft partitions human being, desk, table =4dB, 4dB and 4dB (as given in table 5.1)

$$n_{SP}\, l_{SP} = (1+1+1)*(4+4+4) = 36\text{dB}$$

n_{HP}=number of hard partitions like wall, glass window, almirah and door=1 each

l_{HP}=loss due to hard partitions wall, glass window, almirah and door =6dB, 2dB, 4dB and 4dB (as given in Table 5.1)

$$n_{HP}\, l_{HP} = (1+1+1+1)*(6+2+4+4) = 64\text{dB}$$

Now from the equation (5.1)

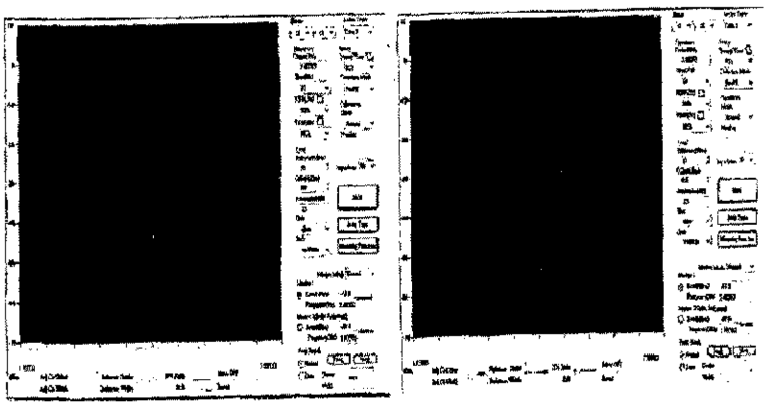
$$g(a,n)[dB] = g(d_o)[dB] + 10\log\left(\frac{d(a,n)}{d_o}\right)^2$$

$$n_{SP}\, l_{SP} + n_{HP}\, l_{HP} = 36+64 = 100\text{dB}$$

Now from the equation (5.2)

$$g(a,n)[dB] = g(d_o)[dB] + 10\log\left(\frac{d(a,n)}{d_o}\right)^2 + 100\ \text{dB}$$

The received signal strength calculated using the spectrum analyzer is shown in Fig. 5.24(a) and Fig. 5.24 (b). Table 5.10 shows the measurements taken inside rooms taking wall, human, desk, table, almirah etc. as obstruction and closed door for different access points. The actual placement of access point coordinates is shown in Fig. 5.25 and the distribution of access point coordinates obtained by using particle swarm optimization is shown in Fig. 5.26.



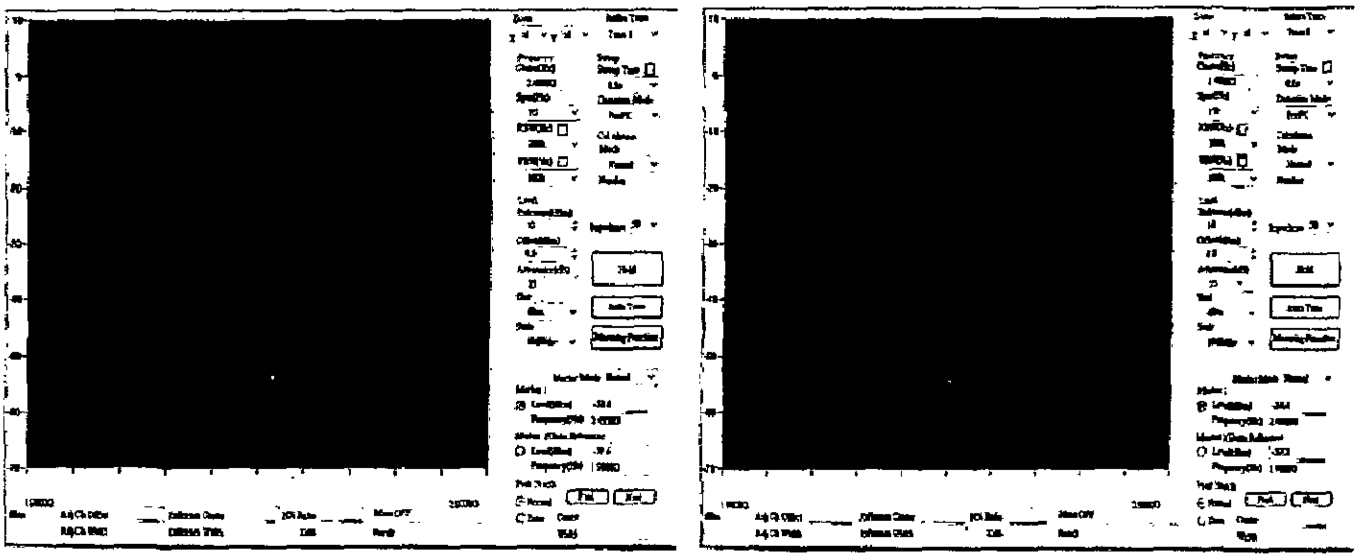
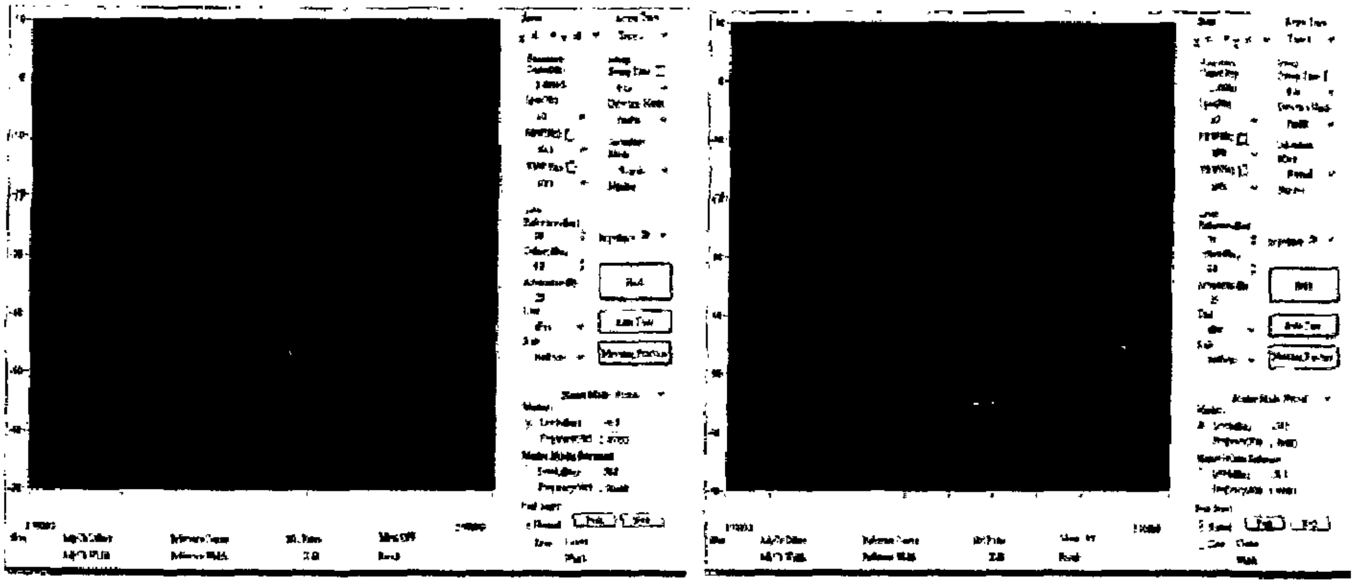


Fig. 5.24(a) shows the received signal strength calculated inside rooms with soft and hard partitions using the spectrum analyzer



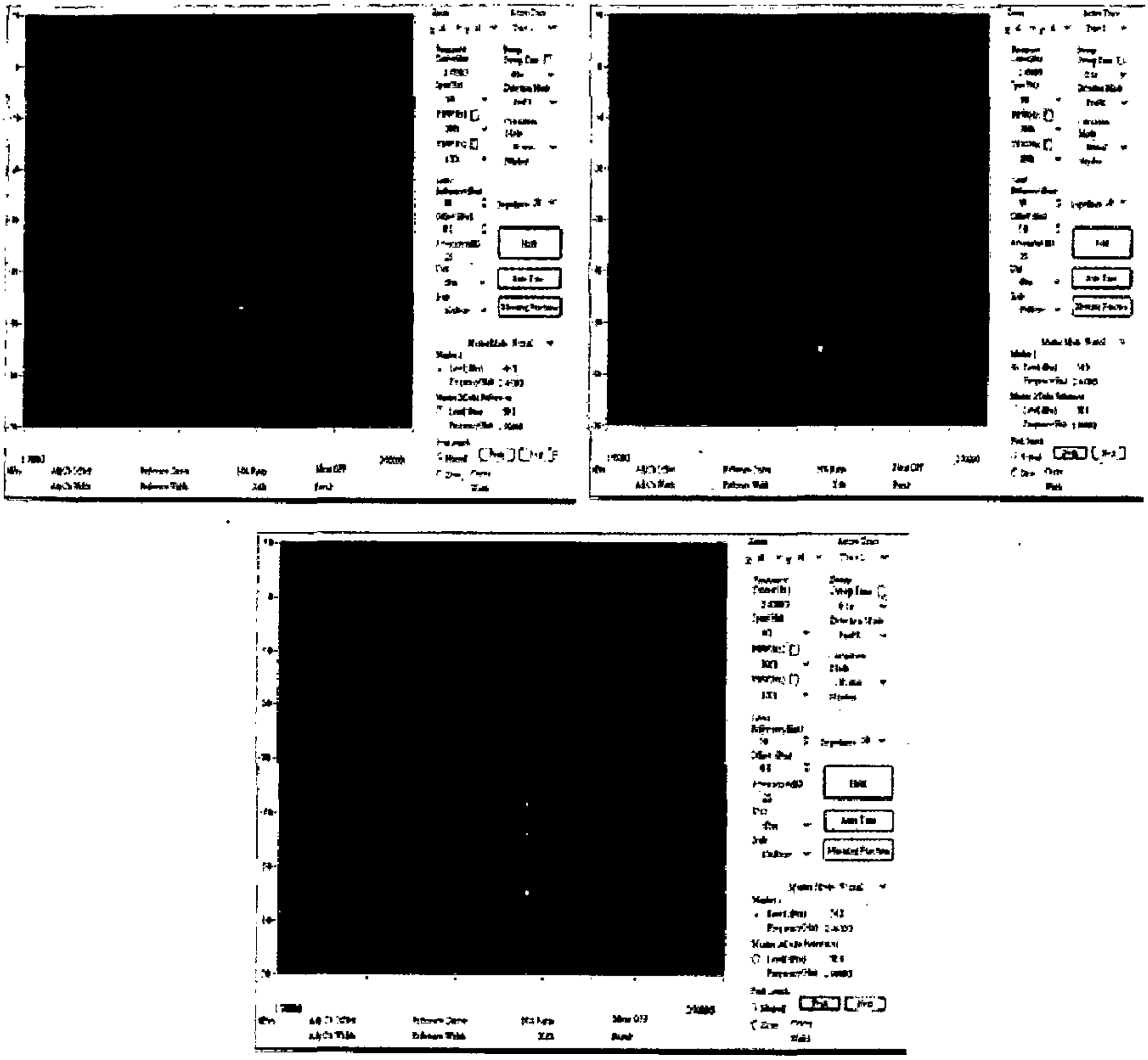


Fig. 5.24(a) shows the received signal strength calculated inside rooms with soft and hard partitions using the spectrum analyzer

Table 5.10 Measurements taken inside rooms with soft and hard partitions for different access points

S.No.	Access point location	Positions	Distance between T-R separation in (m)	Signal Strength (dBm)	Actual placement of Access point coordinates	Access point coordinates by PSO
1	Location A	Inside room A-304,human, desk, door open	4.41m	-43.6	(19.21,13.38)	(20.11,14.48)
2	Location B	Inside room A-338,human, desk, door open	4m	-54.0	(25.34,0.98)	(25.36,1.38)
3	Location C	Inside room A-342, bed, almirah, door closed	5.83m	-53.6	(36.06,1.59)	(34.06,1.43)
4	Location D	Inside room A-355, table, almirah, human	4m	-54.4	(41.11,12.92)	(43.31,13.12)
5	Location E	Inside room A-365, table, almirah, human	4m	-46.8	(35.44,26.09)	(34.23, 25.29)
6	Location F	Inside room A-379, table, almirah, human, door closed	4m	-54.8	(41.57,38.95)	(40.47,36.85)
7	Location G	Inside room A-397, table, bed, almirah, human, door closed	7.19m	-46.8	(30.39,38.49)	(32.59,36.88)
8	Location H	Inside room A-313, table, almirah, human, door open	4.41m	-54.8	(25.03,25.79)	(24.23,24.65)
9	Location I	Inside room A-329, desk, human, door open	4.41m	-54.8	(30.24,15.22)	(32.14,14.29)

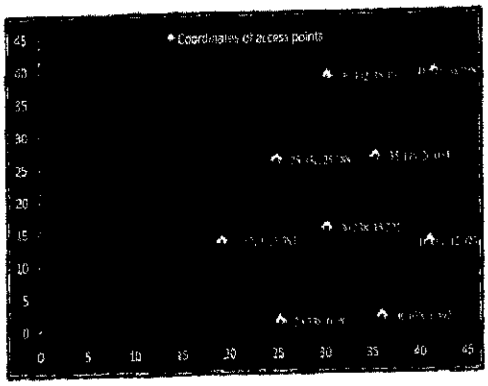


Fig. 5.25 Actual placement of access points

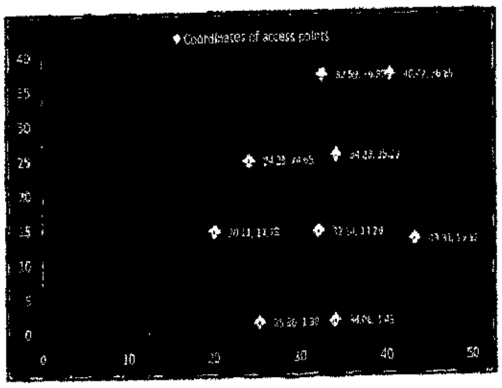


Fig. 5.26 Distribution of access points by using PSO

5.8 Analysis of results for obstructed environment on ground floor

On the ground floor there is no access point installed but due to the access points at the first floor the floor attenuation factor (FAF) occurs with different obstructions. The signal strength measurement between transmitter and receiver have been taken using spectrum analyzer at the 10 access points shown in Fig. 5.1, by red symbols and locations A to J on the first floor.

5.8.1 Measurements taken near staircase and corridors with soft partitions

Measurements taken near staircase and corridors where the presence of human being is possible and it is a soft partition then

n_{SP} = number of soft partition=1 each

l_{SP} =loss due to soft partition=4dB (as given in table 5.1)

$$n_{SP}\, l_{SP} = 1*4 = 4\text{dB}$$

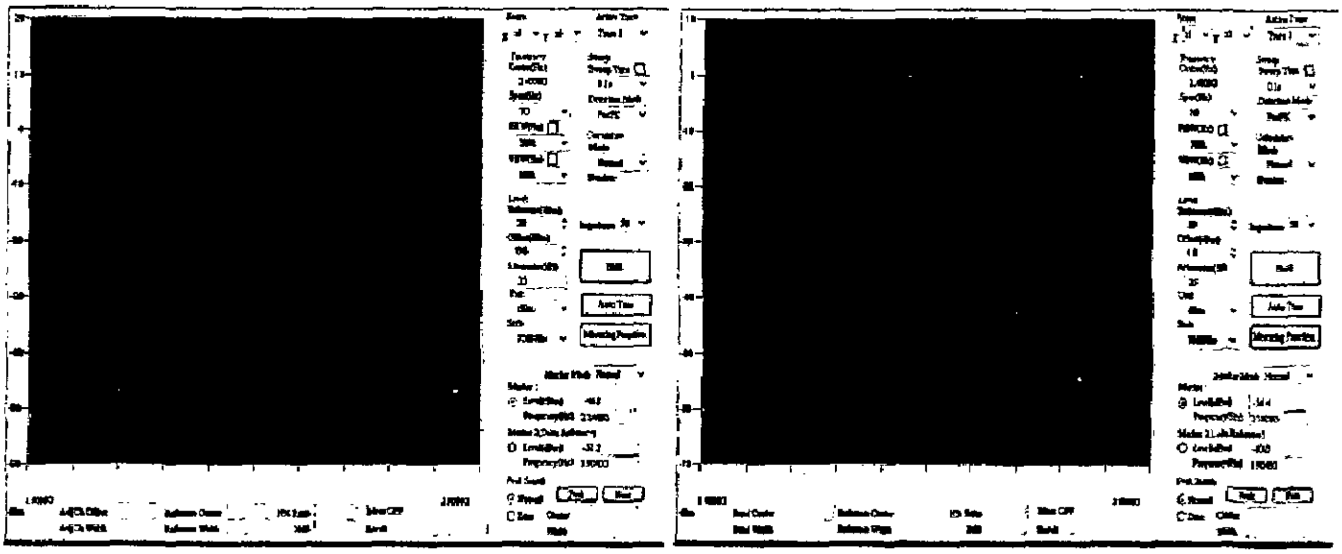
Now from the equation (5.1)

$$g(a_j, r_i)[dB] = g(d_0)[dB] + 10\log\left(\frac{d(a_j, r_i)}{d_0}\right)^2$$

Now from the equation (5.2)

$$g(a_j, r_i)[dB] = g(d_0)[dB] + 10\log\left(\frac{d(a_j, r_i)}{d_0}\right)^2 + 4\text{dB}$$

The received signal strength calculated in the corridors of ground floor taking floor, wall and door as obstruction using the spectrum analyzer is shown in Fig. 5.27. Table 5.11 shows the measurements taken in the corridors taking floor, wall and door as obstruction with different access points.



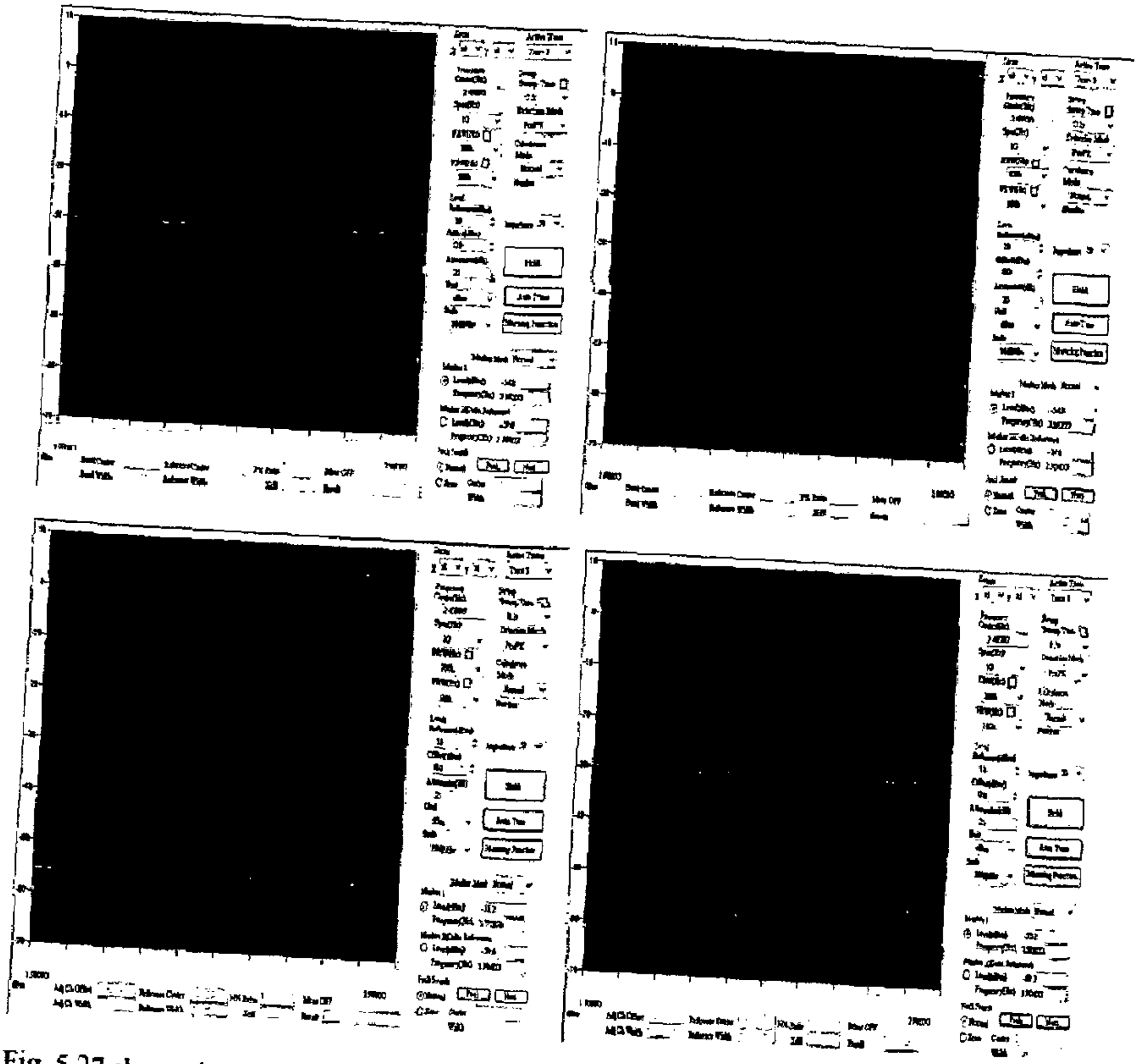


Fig. 5.27 shows the received signal strength calculated in the corridors of ground floor with soft partitions using the spectrum analyzer

Table 5.11 Measurements taken in the corridors with soft partitions with different access points

S.no.	Access point location	Positions	Signal Strength (dBm)
1	Location A	Below on floor(A-102 & A103)	-46.8
2	Location A	Below one floor(A-106 & A-107)	-54.4
3	Location A	Below one floor(Staircase AG1)	-54.8
4	Location B	Below on floor(A-134 & A135)	54.8
5	Location B	Below one floor(Staircase AG2)	-55.2
6	Location B	Below one floor(Front of common room and Staircase AG3)	-55.2

It has been observed from the Table 5.11 that very low signal strength is present on the ground floor because there is no access point installed on this floor but due to the presence of access points at the first floor, floor attenuation factor (FAF) occurs with different obstructions and it results in very low coverage for the users.

5.9 Measurement and analysis for obstructed environment using qualnet simulation software 5.0

The QUALNET 5.0 simulation design tool is used for performance coverage of the WLAN access points installed by the network administrator at different locations in the Malviya Bhawan, Boys Hostel Building, IIT Roorkee, Saharanpur Campus. Simulation environment parameters selection for present analysis is shown in Table 5.12.

Table 5.12 Simulation parameter

Parameter	Value
Area	64m x 60m
No. of Nodes	10
Frequency	2.4 GHz
Simulation Time	60sec
Node Placement	Random
Mobility Model	Random waypoint
Propagation Model	Two Ray
Channel Bandwidth	5.5 Mbps
Traffic Type	CBR
Routing Protocol	Bellman Ford
MAC Protocol	IEEE 802.11g

The propagation of electromagnetic wave is subjected to phenomena such as reflection, diffraction and scattering within an indoor environment such as walls, ceiling and tables. All these objects can block the shortest path between transmitter and receiver [69]. Also the signal strength is dependent on many factors including the physical attributes of the building, the contents (furniture) of the building and the restrictions on suitable installation sites [35].

5.9.1 Analysis of results for obstructed environment on first floor

On the first floor with obstructed environment the signals has been captured in different point locations such as inside rooms taking wall, human, desk, table, almirah and door open or closed etc. as obstruction using Qualnet simulation software. The simulated environment is shown in Fig. 5.28.

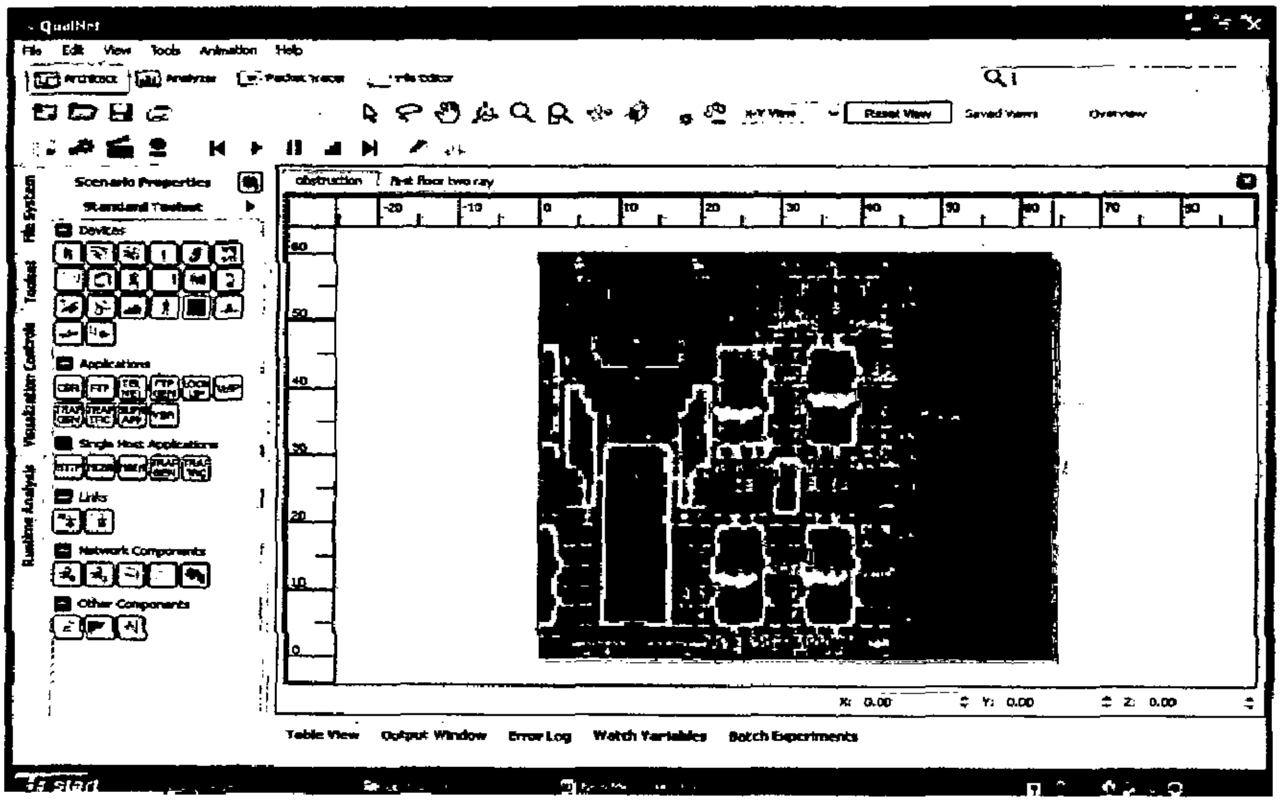


Fig. 5.28 Simulated Environment for first floor

In Fig. 5.28 the simulated environment using simulation software for the first floor is shown in which A to J, 10 nodes are taken as access points and the dotted arrow represents the connection between the access points to the wireless network to a wired LAN. While running the Qualnet simulation software the performance coverage of the users in the indoor site area is estimated.

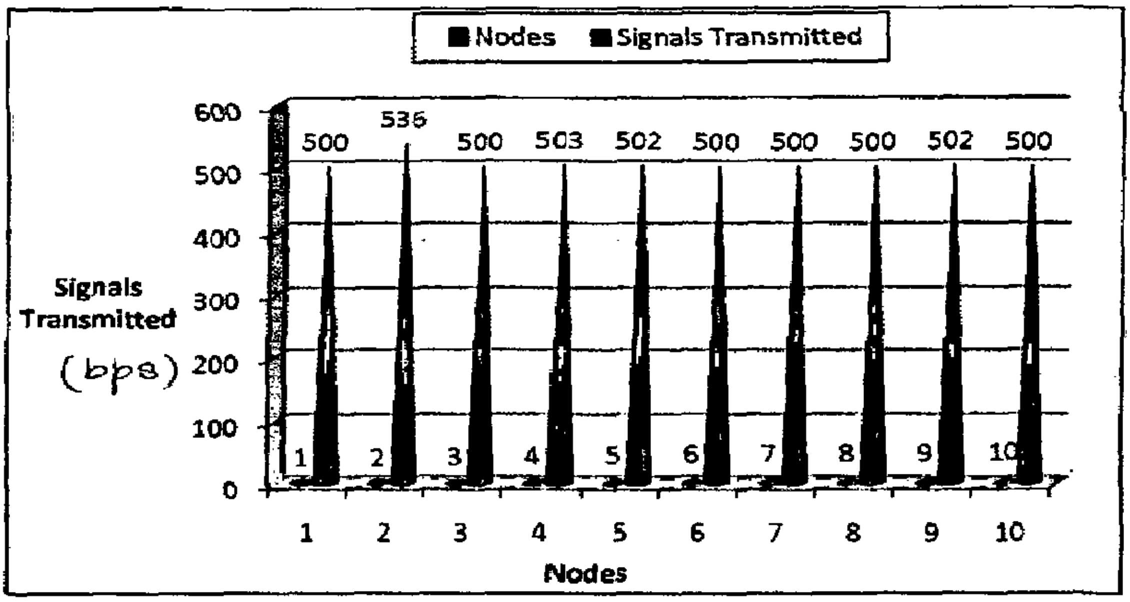


Fig. 5.29 Signals transmitted at physical layer

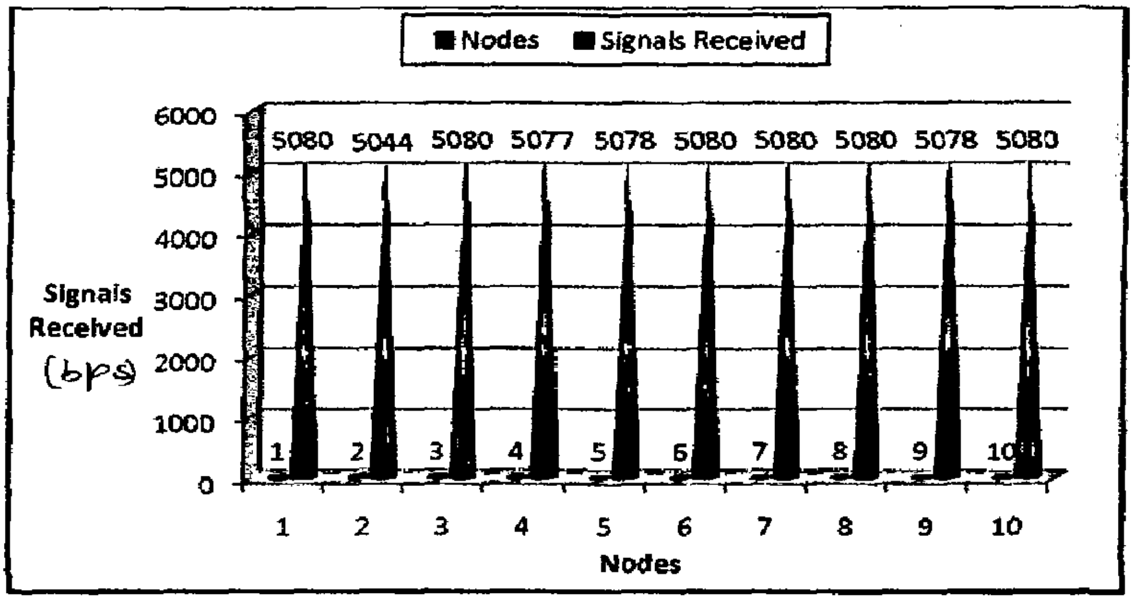


Fig. 5.30 Signals received from physical layer forwarded to MAC

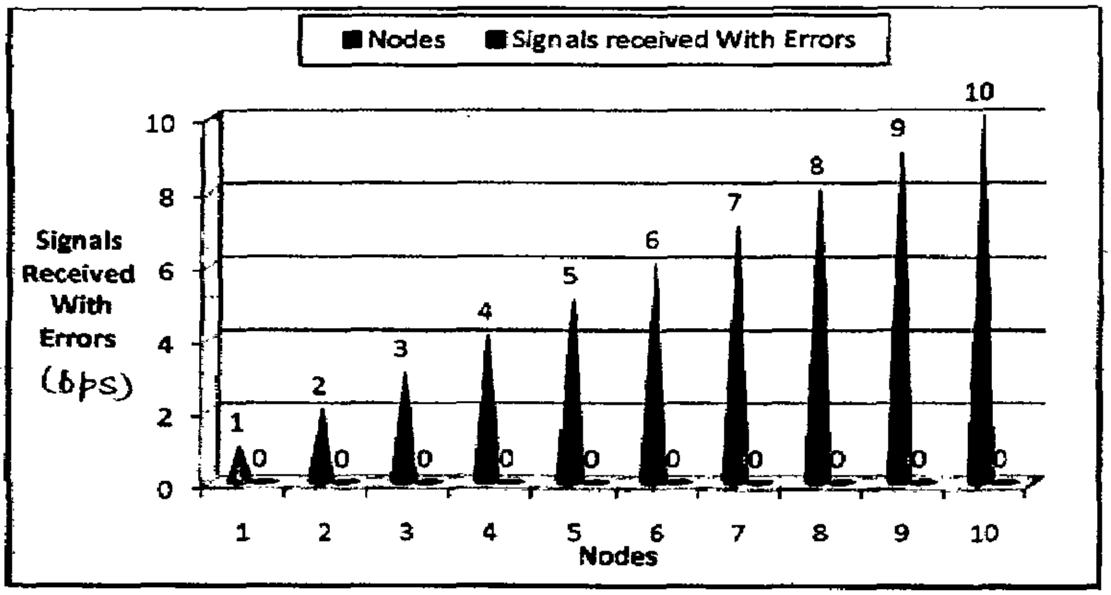


Fig. 5.31 Signals received but with errors

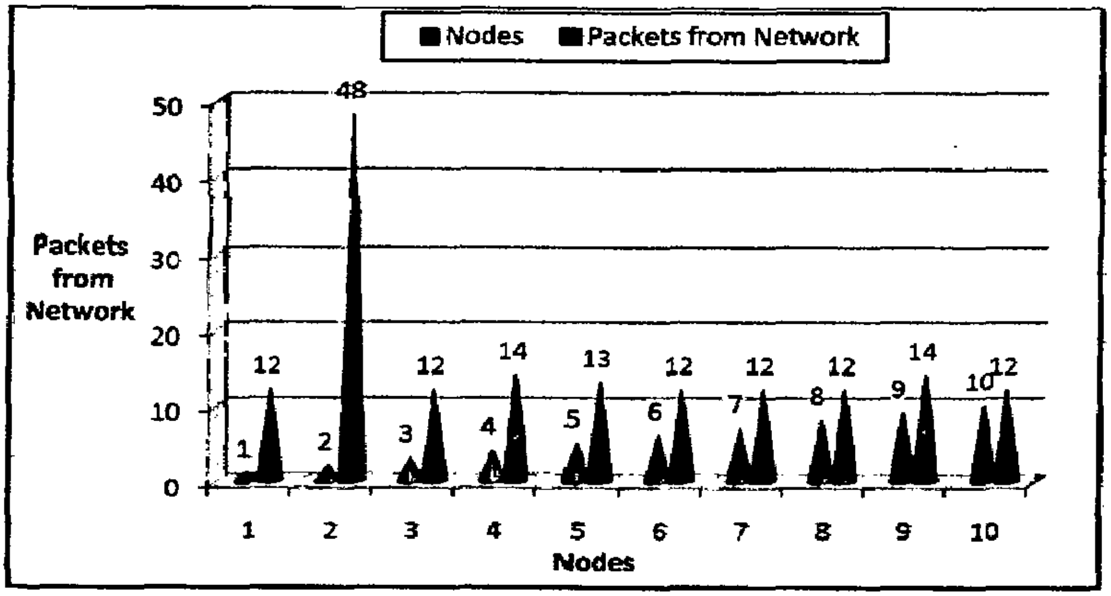


Fig. 5.32 Packets from network at MAC layer

Fig. 5.29 shows the signals transmitted at physical layer has been shown for the 10 nodes as access points. Fig. 5.30 shows the signals received from Physical layer forwarded to MAC, Fig. 5.31 shows the Signals received but with errors and Fig. 5.32 shows the packets from network at MAC layer, the variation of increment at node 2 (access point B) depends on the higher traffic in corridors, rooms, stairs in that time for example in night because more users were using these access point in that time. Also due to the presence of interferences such as static and dynamic for example wooden doors, brick wall, desk, chair, moving human being etc. .

5.9.2 *Analysis of results for obstructed environment on second floor*

On the second floor with obstructed environment the signals has been captured in different point locations such as inside rooms taking wall, human, desk, table, almirah and door open or closed etc. as obstruction using Qualnet simulation software. The simulated environment is shown in Fig. 5.33.

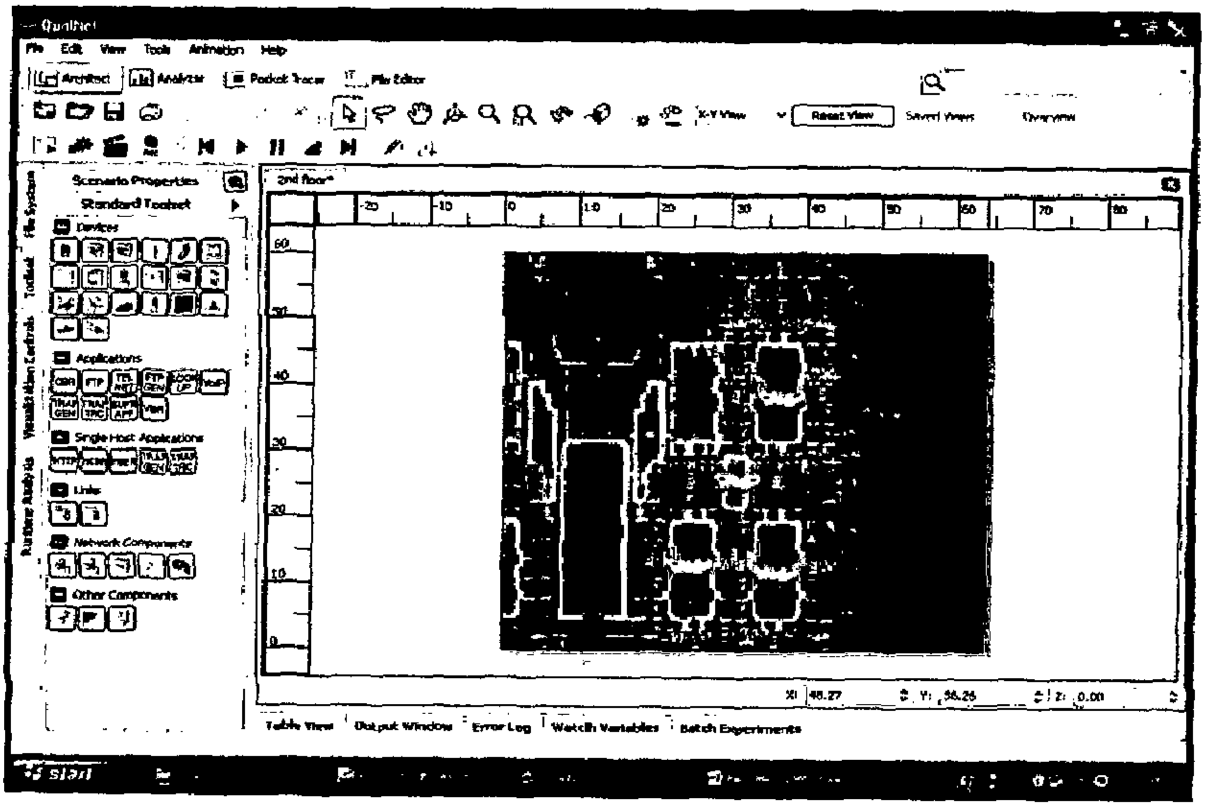


Fig. 5.33 Simulated Environment for second floor

In Fig. 5.33 the simulated environment for the first floor is shown in which A to I, 9 nodes are taken as access points and the dotted arrow represents the connection between the access points to the wireless network to a wired LAN by means of Ethernet cable which act as a central transmitter and receiver of WLAN radio signals. While running the Qualnet simulation software the performance coverage of the users in the indoor site area is estimated.

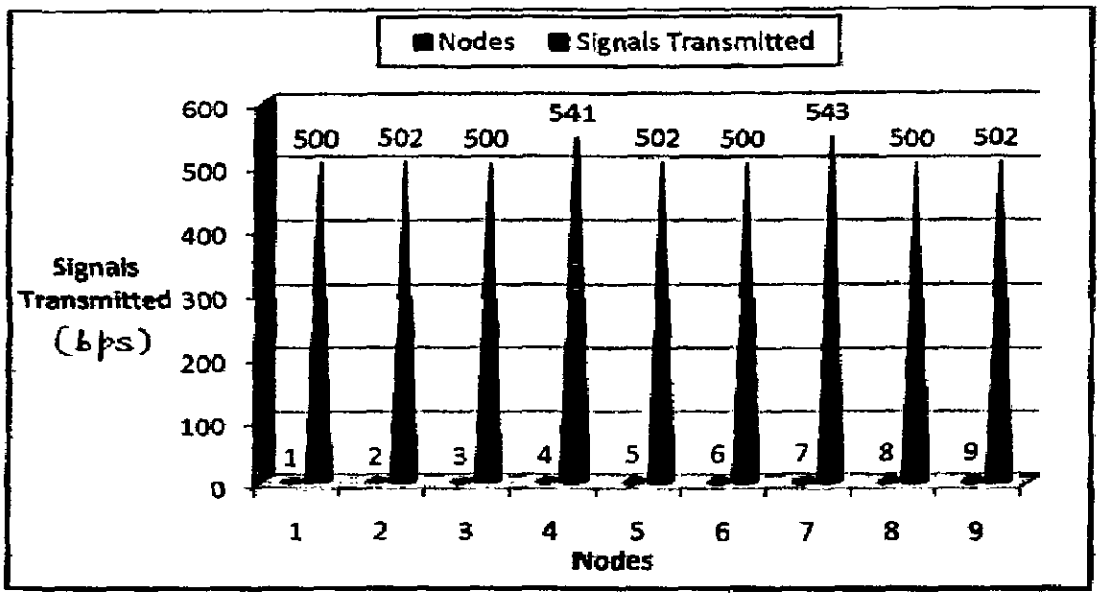


Fig. 5.34 Signals transmitted at physical layer

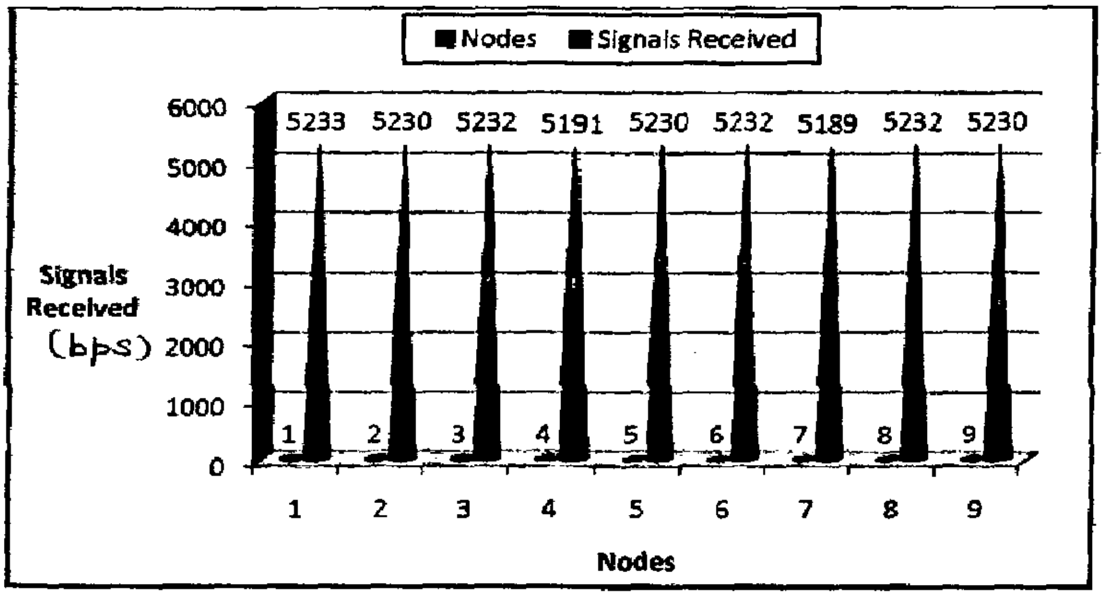


Fig. 5.35 Signals received from physical layer forwarded to MAC

Fig. 5.34, shows the signals transmitted at physical layer has been shown for the 10 nodes as access points. Fig. 5.35, shows the signals received from Physical layer forwarded to MAC, Fig. 5.36 shows the Signals received but with errors.

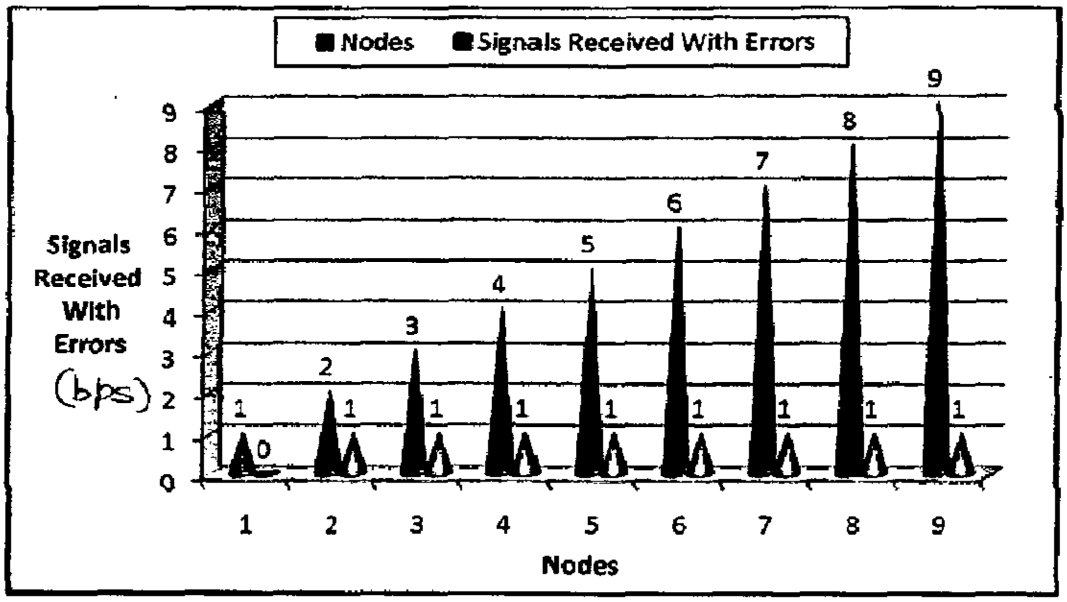


Fig. 5.36 Signals received but with errors

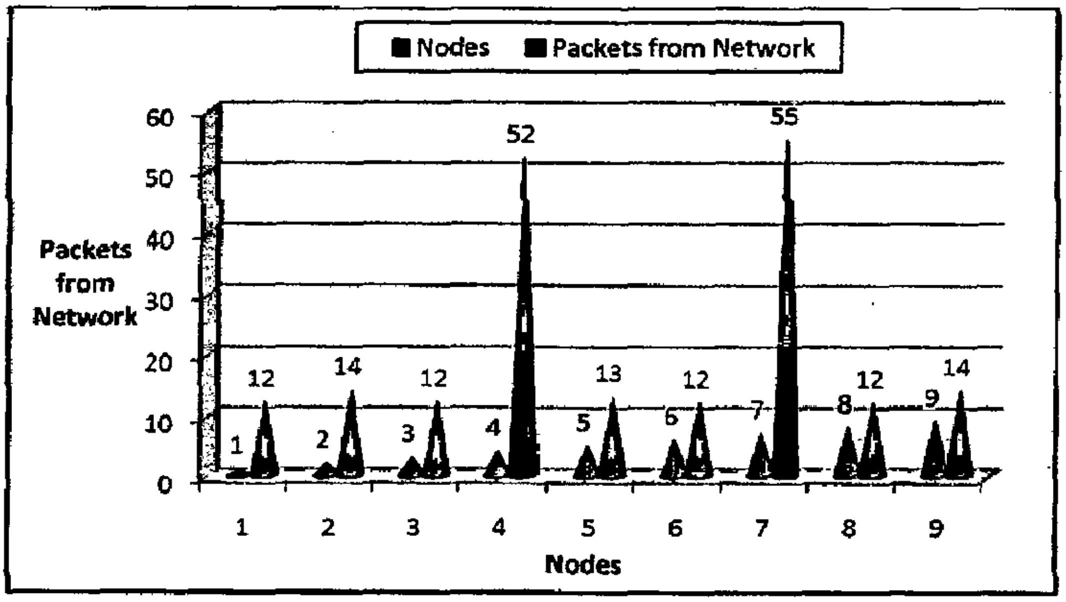


Fig. 5.37 Packets from network at MAC layer

Fig. 5.37 shows the packets from network at MAC layer, the variation of increment at node 4 (access point D) and node 7 (access point G) depends on the higher traffic in corridors, rooms, stairs in that time for example in night because more users were using these access point in that time and less users were present in afternoon. Also due to the presence of interferences such as static and dynamic for example wooden doors, brick wall, desk, chair, moving human being etc.

5.10 Summary

In this chapter the investigation and the comparison between simulation and location measurements by optimization had been accomplished and analyzed. This chapter provides the coverage effect of users using Qualnet simulation software and the results of comparison between the actual location of access points and the locations obtained by PSO in obstructed environment. The coverage area was varying between scenarios and there were different levels of signal strength for each receiver location depends on the obstacles between the receiver and the transmitter in the non line of sight (NLOS) environment. It has been observed that the number of access points can be reduced so as to save the cost of installation of access points.

CHAPTER 6
CONCLUSION AND FUTURE WORKS

The primary objective of the present work is to analyze the measured data in terms of signal strength in the indoor WLAN 802.11g at Malviya Bhavan, Boys Hostel Building, Indian Institute of Technology, Roorkee, Saharanpur Campus coverage using optimization technique and simulation. In this chapter, some concluding remarks and future scope regarding this work are given in section 6.1 and 6.2.

6.1 Conclusion

The QUALNET 5.0 simulation design tool is used for the performance coverage of the WLAN access points installed in the Boys hostel building in which Random Waypoint Model and Bellman Ford Algorithm have been used for free space and of line of sight(LOS). Two Ray model has been used in case of non line of sight (NLOS) in which interferences and obstructions are present in the building. The optimum coverage of the users has been estimated using simulation software for the coverage area of the site.

Particle Swarm optimization (PSO) is used for determining the optimal location of APs installed at Malviya Bhawan. The results of the locations of APs obtained by PSO are compared with the actual placement of APs.

Simulation and Optimization technique is used for analysing the path losses obtained by the effects of multipath propagation such as reflection, diffraction and scattering and the interferences caused by the obstacles such as soft partitions like tables, chairs, desk, human being and by the hard partitions like wooden door, brick wall, almirah and other elements in the indoor environment as there are many variables in building construction that affect 2.4GHz transmission because the building used has its own characteristics depending on the materials and the physical structure in LOS and NLOS. The variation in the signals received at receiver depends upon the higher traffic in corridors in that time because more number of users were using access points in that time for example in night time.

Some conclusions that can be drawn are as follows:

- Simulation is an effective tool for determining and analysing the performance coverage and path losses due to various effects.

- Use of an efficient optimization technique like that PSO, can help in defining the effective location of APs.
- It has also been observed that PSO is effective in scenarios where soft/ hard partitions are present.
- Use of optimization and simulation is very beneficial in real life scenarios as they help in predicting the placement of APs, which play in important role in today's net savvy world. It has also been observed from the analysis is that the number of access points can be reduced so as to save the cost of installation of access points.

6.2 Future work

In future the work can be extended in several directions. For example the model can be enhanced to:

- Include other effects such as refraction and fading.
- Incorporate more detailed effects due to people walking by, and other obstructions in the room.
- Study the effects of multiple reflections.
- Include effects due to the characteristics of the AP. I have made an approximation of the AP as a fixed point, radiating rays uniformly in all directions. This is not true in real life, but depends on the specific antenna involved. The distribution pattern of the antenna can also be reflected in the model.
- Study in greater detail the causes of discrepancies between the actual and the observed data.

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