Coverage and Analysis of Obstructed Indoor WLAN using Simulation Software and Optimization Technique

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Abstract

WLAN is a flexible data communication system implemented as an extension to or as an alternative for, a wired LAN. This paper presents the placement of access points (AP) as a nonlinear optimization problem. The work explores 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 and coverage and location of access points using Qualnet simulation software 5.0 and particle swarm optimization technique.

Keywords: Wireless LAN, path loss model, obstructed environment, Qualnet simulation software 5.0, particle swarm optimization.

1. Introduction

Wireless LANs enable users to access network resources and applications securely anytime and anywhere a wireless network is deployed [2]. Access points can nowadays be found in our daily environment, e.g. in many office buildings, public spaces and in urban areas [1]. In the corporate enterprise, wireless LANs are usually employed as the final link between the existing wired network and a group of client computers, giving these users wireless access to the full resources and services of the corporate network across a building or campus [3]. WLAN networks have become very popular means for providing a wireless networking facility for home users, educational institutions, companies etc. due to their ease of installation and their high data rate provision, apart from providing, although limited, mobility to users. [2].

If the APs are placed too far apart, they will generate a coverage gap, but if they are too close to each other, this will lead to excessive co-channel interferences and increases the cost unnecessary [5]. In this paper, we use qualnet simulator for coverage and PSO to determine location in such a WLAN. In the indoor environment the propagated electromagnetic signal can undergo necessary three mechanisms of electromagnetic wave propagation- reflection, diffraction and scattering.

The rest of the paper is organized as follows: Notations are given in section 2. Section 3 provides the mathematical model description and path loss model. Section 4 shows the working of PSO. Section 5 describes the method of testing, setup and methodology. Analysis of results for obstructed environment on first floor and measurements and analysis taken inside rooms with soft and hard partitions using particle swarm optimization are presented in Section 6. Section 7 describes the measurement and analysis for obstructed environment using Qualnet simulation software 5.0. Finally, section 8 concludes the paper.

2. General Notations

Throughout this paper the following notations are used:

a_j	$j = 1\ldots N$	Access point (AP)
r_i	$i = 1\ldots M$	Receiver/user
$d(a_j, r_i)$		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 [5]:

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

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

3. Model Description

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

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

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).

$$g\max = P_t - R_{th} \quad (2)$$

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

$$(\min_j g(a_j, r_i) - g\max)^+ = 0, \quad (3)$$

3.1. 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 [7].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 [5-6]:

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

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 [5-6]:

$$g(a_j, r_i)[dB] = -10\log\left[\frac{G_t G r \lambda^2}{(4\pi)^2 d(a_j, r_i)^2}\right]$$

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 [5-6] can be calculated from:

$$g(a_j, r_i) = g(d_o)[dB] = 20\log\frac{4\pi d_o f}{c} \quad (5)$$

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

$$g(a_j, r_i)[dB] = g(d_o)[dB] + 10\log\left(\frac{d(a_j, r_i)}{d_o}\right)^2 \quad (6)$$

3.2. Path Loss Model for the Obstructed Environments using optimization technique

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 (6) can be written as [5-6]:

$$g(a_j, r_i)[dB] = g(d_0)[dB] + \log(\frac{d(a_j, r_i)}{d_0})^2 + \sum n_{SP} l_{SP} + \sum n_{HP} l_{HP} \quad (7)$$

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.

4. 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. The two basic equations which govern the working of PSO are that of velocity vector and position vector given by:

$$v_{id} = \omega * v_{id} + c_1 r_1 (p_{id} - x_{id}) + c_2 r_2 (p_{gd} - x_{id}) \quad (8)$$

$$x_{id} = x_{id} + v_{id} \quad (9)$$

Here c_1 and c_2 are acceleration constants.

5. Method of Testing

5.1. Setup for AP

We performed our experiment in first case without an obstacle and in the second case with obstacle in the design area has dimensions of 64m x 60m and has 400 users. It has 100 rooms and part of corridors. The data collection site building and google map of the site is given in Fig.1 and Fig.2.The layout of the floor is shown in Fig. 3. The entire wing of the first floor is covered by 10 access points installed at the locations indicated by red symbols in Fig.3. Ten locations of measurement are chosen on the first floor of the Malviya Bhavan building as shown in Fig.3.denoted as A,B,C,D,E,F,G,H,I and J. The specification of the model of Access point is LINK (DWL-3200AP) and IEEE 802.11g standard are used to test the model. We conducted our experiments at the first and second floor of the Malviya Bhavan, IIT Roorkee, Saharanpur Campus. Our data collection system comprised of a laptop, running Windows 2007, MSA 338 handheld spectrum analyser, M304 omnidirectional dipole antenna.

Fig.1 Data collection site building

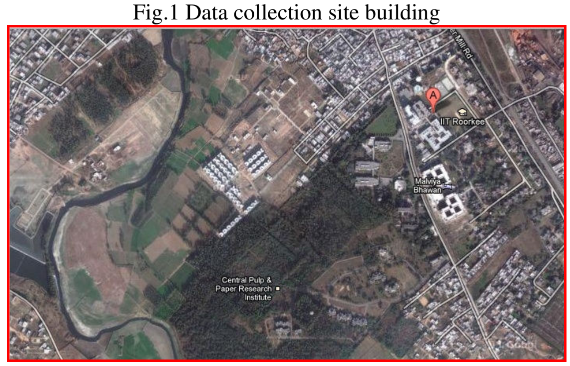

Fig. 2 Google map of the data collection site

Fig.3 Plan of the floor where the experiment was conducted. Readings were collected in the corridors.

5.2. 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 [8].

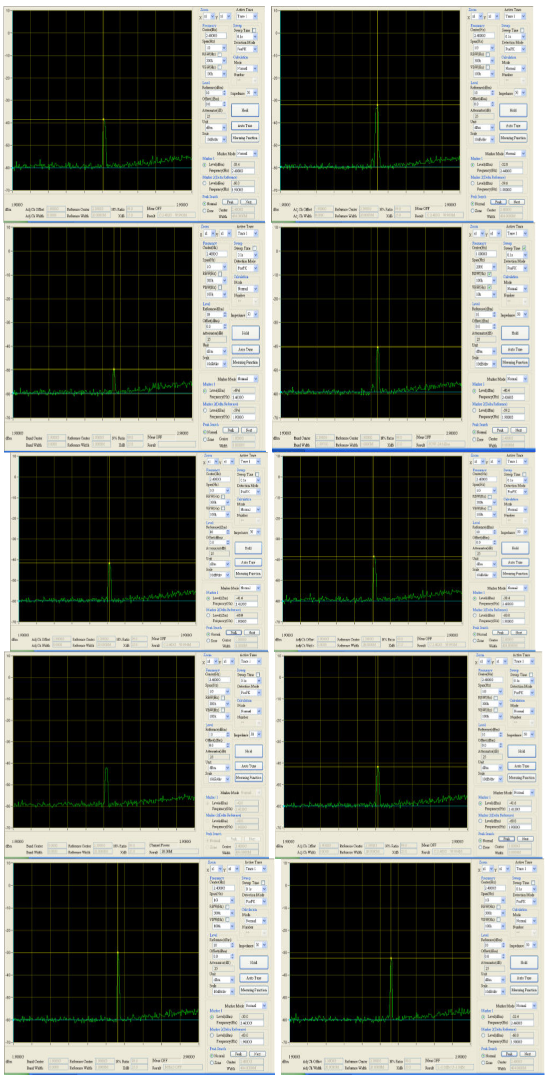

Fig.4 Received Signal Strength calculated using spectrum analyser

6. Analysis of results for obstructed environment on first floor

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

Table 1. 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 1.

6.1. Measurements and analysis taken inside rooms with soft and hard partitions on first floor

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 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 1)

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

Now from the equation (6)

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

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

Now from the equation (7)

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

Table 2. 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)

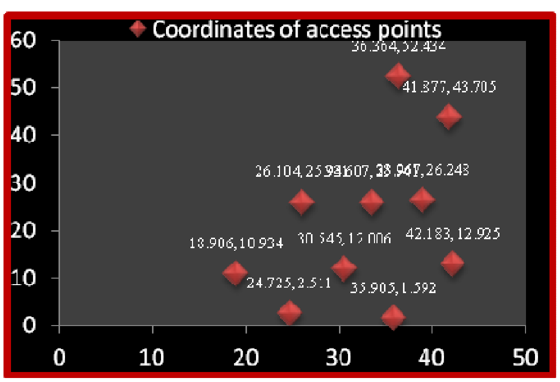

Fig.5 Actual placement of access points

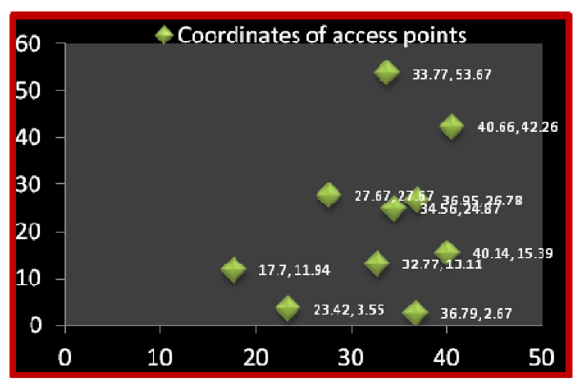

Fig.6 Distribution of access points by using PSO

The received signal strength calculated using the spectrum analyser is shown in Fig. 4. Table 2 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 and the distribution of access point coordinates by using particle swarm optimization is shown in Fig.6. Similarly the results have taken for second floor as well as for ground floor where there is no access point installed but due to floor attenuation factor (FAF) some access of the network found on the staircase near ground floor.

7. 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 3.

Table 3. 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

7.1. 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.7.

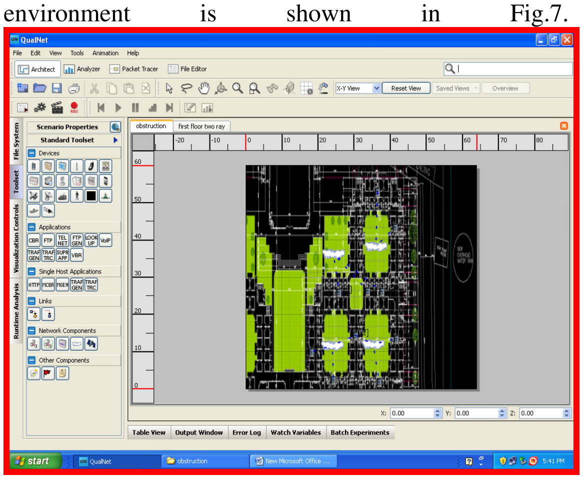

Fig. 7 Simulated Environment for first floor

In Fig. 7 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.

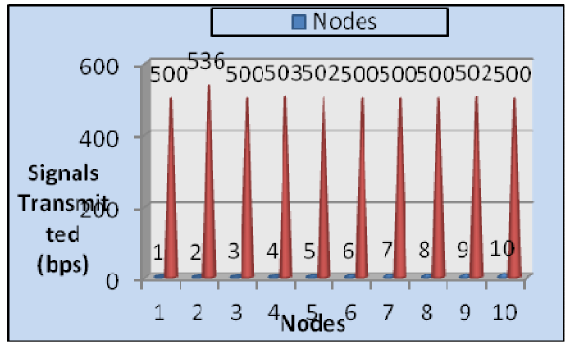

Fig.8 Signals transmitted at physical layer

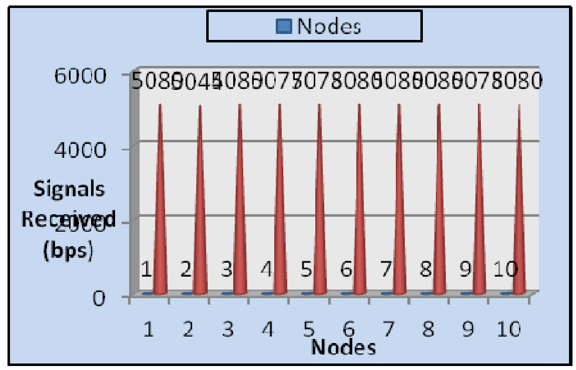

Fig. 9 Signals received from physical layer forwarded to MAC

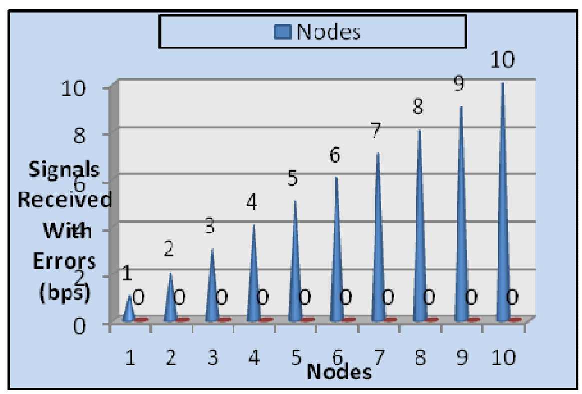

Fig. 10 Signals received but with errors

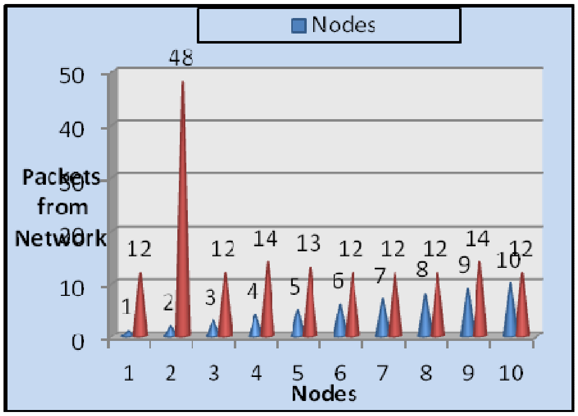

Fig. 11 Packets from network at MAC layer

Fig. 8 shows the signals transmitted at physical layer has been shown for the 10 nodes as access points. Fig. 9 shows the signals received from Physical layer forwarded to MAC, Fig.10 shows the Signals received but with errors and Fig. 11 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.

8. Conclusion

In this paper the investigation and the comparison between simulation and location measurements by optimization had been accomplished and analyzed. This paper 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.

References

1. Traoré Soungalo, Li Renfa, Zeng Fanzi, Evaluating and Improving Wireless Local Area Networks Performance, *International Journal of Advancements in Computing Technology*, Vol. 3, Number 2, (March 2011), pp.156-164.
2. Wireless LAN Solutions At-A-Glance - Cisco

   www.cisco.com/web/AP/wireless/pdf/WirelessLAN.pdf _United States
3. IEEE 802.11b Wireless LANs

   http://www.3com.com/other/pdfs/infra/corpinfo/en_US/50307201.pdf
4. Particle Swarm Optimization (PSO)

   www23.homepage.villanova.edu/varadarajan.../PSO_meander-line.p...
5. S. Kouhbor, J. Ugon, A. Kruger, A. Rubinov, Optimal Placement of Access Point in WLAN Based on a New Algorithm, *proc. Of the International Conference on Mobile Business-IEEE/ICMB,* pp. 592-598 (July 2005)
6. Shahnaz Kouhbor, Physical Security Enhancement in WLAN Systems. ISSNIP-IEEE (2007), pp. 733-738.
7. Binghao Li, Andrew Dempster, Chris Rizos, Joel Barnes, Hybrid Method for Localization Using WLAN. Spatial Sciences Conference (2005)

   www.gmat.unsw.edu.au/snap/publications/lib_etal2005c.pdf
8. GD/JANET/TECH, Surveying Wireless Networks (2008)
   www.ukema.ac.uk/documents/.../technical../