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Indoor Wireless Network Coverage Area Optimization

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Abstract

The presence of interference has a significant impact on wireless network connections indoors. Because of the effects of multipath propagation, such as reflection, refraction, and scattering of radio waves by the structure of the building, the sent signal can usually be received in free space or via more than one pathway, and the consequence might be a phenomenon known as multipath fading. For different results, propagation models have been identified, which provide the propagation features of the initial evaluation. There are two types of wireless propagation models: empirical and theoretical models that deal with coverage, overlapping channels, and wireless network performance. The planning system was set out using a practical and theoretical approach. Furthermore, this comparison may aid in determining the accuracy of survey measures in the context of indoor wireless monitoring and provide an estimate of the breadth and performance of wireless networks in the form of a new topology with contour presentation. Layout plan optimization The typical RSSI of a Wi-Fi system ranges from -40 dBm to -55 Dbm, with a power of 17-18 Dbm, and is applied to channels 1 through 11 non-overlapping in the design of networks with multiple APs that are nearby. The new topology represents the optimization outcomes, accompanied by a contour display and dispersed over the region.

***Keywords** : interference, the empirical model, a theoretical model, laying the planning system.*

1. Introduction
1.1 Background

Interference has a significant impact on indoor wireless networks. It is vital to optimizing to generate reliable communication to overcome interference. The optimization application employs two propagation models: theoretical and empirical [1]. The theoretical model is used to calculate the number of transmitters (access points), free space loss, Received Signal Strength (RSSI), the coverage that can be serviced, and attenuation of obstacles in wireless networks (concrete walls, soft partitions, doors, floors). The empirical model entails direct monitoring to gather actual field data [2]. The obtained power level data measuring the wireless network's strength is utilized for optimization, specifically a new topology accompanied by a network contour presentation.

I am writing this final project proposal to describe how to OPTIMIZE THE COVERAGE AREA OF INDOOR WIRELESS NETWORK (Case study: PTIIK Universitas Brawijaya) using measurement and analysis to establish its viability, based on the description above [3]. It is also anticipated to serve as a reference for use in case studies so that wireless network services may be effectively deployed.

1.2 Scope of Problem

This research has the following problem limits, based on the background and problem formulation that have been stated:

1. The planning area is confined to the PTIIK UB building's footprint.
2. Wi-Fi signal optimization employing the propagation aspects calculation technique, namely theoretical and empirical measurements
3. Data security, handover, and analysis of planning expenses and loading are not taken into account.

2. Literature Review

Wireless Local Area Network (WLAN) is a versatile data transmission method that may be used to supplement or replace a traditional LAN network [4]. The process of disseminating the Wi-Fi signal is inextricably linked to the element of propagation. Everything that happens to the wireless signal as it travels from one location to another is referred to as the propagation element of WLAN [5]. The IEEE 802.11 a/b/g/n standards are used in two wireless propagation models: empirical and theoretical models relating to coverage, channel overlapping, and wireless network performance. A theoretical model (measurement) and a practical model are used to plan (monitoring). The number of transmitters (access points), calculation of free space loss, Received Signal Strength (RSSI), the coverage that may be serviced, evaluation attenuation in barriers are all measurement criteria in the theoretical model of propagation (concrete walls, soft partitions, doors, floors).

2.1 Building an 802.11 .-Based Wireless Network

To build a wireless network based on 802.11, it takes an understanding of the following factors:

- Channel Selection

The network requires a minimum distance of the central frequency on the channel to minimize interference.

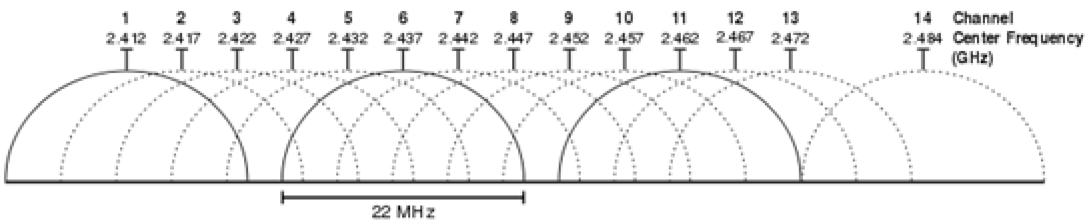

Fig 1. Channel Sharing

- Calculation of Number of Access Points
  To calculate the number of APs, it is done by reviewing the planned coverage area.

  $$N_{AP} = \frac{Ctotal}{CAP}$$

  With :

  N_{AP} : Number of Access Points

  C_{total} : Total area to be covered

  C_{AP} : Coverage for one AP with maximum power

  The number of APs can also be viewed from the user's capacity :

  $$N_{AP} = \frac{BW_{user}\ x\ N_{user}\ x\ Activity}{\%Efficiency\ x\ Association\ Rate}$$

  With :
  BW user : The bandwidth required by the user.
  N user : Number of users in the area
  %Activity : Number of active users
  %Efficiency : Channel efficiency

- Calculation of the Serviceable Coverage Area
  To determine the region of AP coverage, the length of the AP diameter must be determined using the MAPL formula (Maximum Allowed Path Loss). MAPL is the maximum propagation attenuation parameter used to keep the user-AP interaction running smoothly.

  $$\text{MAPL} = \text{EIRP} - \text{Margin} - S_{RX}$$

  $$\text{EIRP} = P_{Transmit} - L_{Saluran} + G_{Antena}$$

  With:
  Transmit: Power Transmitter
  Antenna: Antenna Gain
  Fading Margin: 10 dB typical WLAN
  SRX: Receiver Sensitivity

2.2 Wireless Network Strength Measurement

Ekahau and NetSurveyor software conduct measurements using empirical models (monitoring) in all domains. Field data was generated from the empirical results and then measured using a theoretical model (calculation) based on the propagation aspect [6]. The strength of the wireless network is determined by comparing the two propagation models and calculating the received power level.

3. Research Methods

3.1 Study of literature

The qualities, factors, and supporting hypotheses that underpin this research were investigated through a literature review, which included:

a. Wi-Fi concept.

b. Building a Wireless Network.
c. Wireless Network Strength Measurement.

3.2 Needs Analysis
Determine field conditions and identify criteria for creating a signal distribution strategy.

3.3 Design
The optimization design is in the form of a new topology with a contour display[7]. The Aerohive Wi-Fi Planner software will be utilized to help with the design.

3.3.1 Simulation Stage

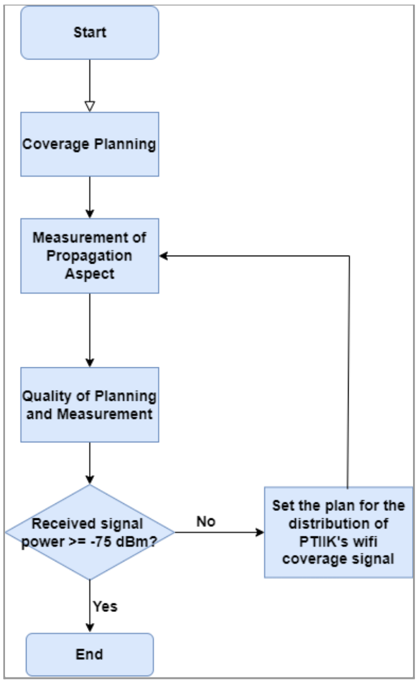

Fig 2. Flowchart of Simulation Stages

3.4 Network Testing
The purpose of Wi-Fi network design testing is to demonstrate the dispersion of signals that can operate and link appropriately according to the specifications of the underlying demands.

3.5 Conclusions
After all system design and testing steps have been accomplished, conclusions are formed. The system's testing and analysis findings develop the findings [8].

4. Measurement and Design

In the PTIIK Universitas Brawijaya building, the design process of the measurement findings for optimizing the wireless network coverage area [9]. The criteria on the theoretical model of the propagation aspect are used to measure the strength of a wireless network:

- The amount of coverage that can be supplied.
- The total number of transmitters (access points)
- Free Space Loss Calculation
- Signal Strength Received (RSSI).
- Barrier attenuation measurement (concrete walls, soft partitions, doors, floors)

The following calculation and measuring processes are required to obtain the measurement results:

1. Calculate the MAPL to determine the maximum permissible distance between the client and the AP.
2. To calculate the needed number of APs, multiply the building area by the AP's coverage area.
3. Attenuation of any impediments, such as solid walls, soft bulkheads, and wooden doors, that impede the signal from the transmitter (AP) to the receiver (client).
4. Place the transmitter as far away from the receiver as possible, then check the received signal limit to see whether it meets the specified minimum limit.
5. If the minimal limit is met, the AP can be built there.

MAPL (Maximum Allowed Path Loss) is required to determine the AP radius. MAPL is the maximum propagation attenuation parameter that may be used to keep the user-AP interaction running smoothly. The following is the formula:

MAPL = EIRP – Margin - S_{RX}
EIRP = $P_{Transmit}$ - $L_{Channel}$ + $G_{Antenna}$
Margin = Fading Margin = 10 dB typical for WLAN
SRX = Receiver Sensitivity
= MCS15 @ -70dBm 802.11n frequency (device specification)

MAPL = $P_{Transmit}$ - $L_{Channel}$ + $G_{Antenna}$ - Margin - S_{RX}
MAPL = 30 – 0 + 4 – 10 – (–70)
MAPL = 94 dB
MAPL = L, then proceed to the equation:
L = L_{FS} + (2 x 10) + (3 x 5)
L = L_{FS} + 35
L_{FS} = MAPL - 35
L_{FS} = 94 - 35
$(\frac{4\,\pi\, d}{\lambda})$ L_{FS} = 59 dB
L_{FS} = 20 Log
61 = 2 Log $\frac{4\ x\ 3{,}14\ x\ d}{0{,}125}$
d = 11,116 m

So, the length of the diameter of AP is 11.166 m

The design can begin when the measuring phase of the theoretical model of the propagation aspect has been completed [10]. The plan contains channel and power configurations that have been tweaked based on current data following a thorough analysis of the situation. Using channels 1 to 11 with non-overlapping applications is beneficial for network designs that include many near-coupled access points since it reduces the power of an AP used nearby [11]. The design is also evaluated in terms of user capacity. As a result, the number of transmitters to be estimated is modified to the user's capacity calculation based on the current situation[12].

- 3rd Floor Library Building

A. Signal strength based on coverage area and transmitter strength coverage

Table 1. Specification of Transmitter Design A Library Floor 3

Name	Model	Type	2.4 GHz	
			Channel	Power
Ch 1 - Pwr 18	AP320	802.11n	Auto(1)	18 dBm
Ch 6 - Pwr 18	AP320	802.11n	Auto(6)	18 dBm

B. Signal strength based on user capacity

Table 2. Specification of 3 Floor Library Design B Transmitter

Name	Model	Type	2.4 GHz	
			Channel	Power
Ch 1* - Pwr 17	AP320	802.11n	1	17 dBm
Ch 2* - Pwr 17	AP320	802.11n	2	17 dBm
Ch 5* - Pwr 17	AP320	802.11n	5	17 dBm
Ch 10* - Pwr 17	AP320	802.11n	10	17 dBm
Ch 6* - Pwr 17	AP320	802.11n	6	17 dBm
Ch 11* - Pwr 17	AP320	802.11n	11	17 dBm

- 5th Floor Library Building

A. Signal strength based on coverage area and transmitter strength coverage

Table 3. Specification of Transmitter Design A Library Floor 5

Name	Model	Type	2.4 GHz

			Channel	Power
Ch 11 - Pwr 18	AP320	802.11n	11	18 dBm
Ch 2 - Pwr 18	AP320	802.11n	2	18 dBm
Ch 1 - Pwr 18	AP320	802.11n	1	18 dBm
Ch 6 - Pwr 18	AP320	802.11n	6	18 dBm
Ch 10 - Pwr 18	AP320	802.11n	10	18 dBm

B. Signal strength based on user capacity

Table 4. Specification of Transmitter Design A Library Floor 5

Name	Model	Type	2.4 GHz	
			Channel	Power
Ch 9 - Pwr 17	AP320	802.11n	9	17 dBm
Ch 4 - Pwr 17	AP320	802.11n	4	17 dBm
Ch 6 - Pwr 17	AP320	802.11n	6	17 dBm
Ch 1 - Pwr 17	AP320	802.11n	1	17 dBm
Ch 7 - Pwr 17	AP320	802.11n	7	17 dBm
Ch 2 - Pwr 17	AP320	802.11n	2	17 dBm
Ch 5 - Pwr 17	AP320	802.11n	5	17 dBm
Ch 11 - Pwr 17	AP320	802.11n	11	17 dBm
Ch 8 - Pwr 17	AP320	802.11n	8	17 dBm
Ch 2 - Pwr 17	AP320	802.11n	2	17 dBm
Ch 10 - Pwr 17	AP320	802.11n	10	17 dBm

- Building A Floor 1st

A. Signal strength based on coverage area and transmitter strength coverage

Table 5. Product Specification Transmitter Design A Building A Floor 1

Name	Model	Type	2.4 GHz

			Channel	Power
Ch 1 - Pwr 18	AP320	802.11n	1	18 dBm
Ch 2 - Pwr 18	AP320	802.11n	2	18 dBm
Ch 6 - Pwr 18	AP320	802.11n	6	18 dBm
Ch 5 - Pwr 18	AP320	802.11n	5	18 dBm
Ch 11 - Pwr 18	AP320	802.11n	11	18 dBm
Ch 7 - Pwr 18	AP320	802.11n	7	18 dBm

B. Signal strength based on user capacity

Table 6. Product Specification Transmitter Design B Building A Floor 1

Name	Model	Type	2.4 GHz	
			Channel	Power
Ch 10 - Pwr 17	AP320	802.11n	10	17 dBm
Ch 3 - Pwr 17	AP320	802.11n	3	17 dBm
Ch 9 - Pwr 17	AP320	802.11n	9	17 dBm
Ch 6 - Pwr 17	AP320	802.11n	6	17 dBm
Ch 11 - Pwr 17	AP320	802.11n	11	17 dBm
Ch 3 - Pwr 17	AP320	802.11n	3	17 dBm
Ch 5 - Pwr 17	AP320	802.11n	5	17 dBm
Ch 1 - Pwr 17	AP320	802.11n	1	17 dBm
Ch 8 - Pwr 17	AP320	802.11n	8	17 dBm

- Building A Floor 2nd

A. Signal strength based on coverage area and transmitter strength coverage

Table 7. Product Specification Transmitter Design B Building A 2nd Floor

Name	Model	Type	2.4 GHz	
			Channel	Power

Ch 6 - Pwr 18	AP320	802.11n	6	18 dBm
Ch 5 - Pwr 18	AP320	802.11n	5	18 dBm
Ch 10 - Pwr 18	AP320	802.11n	10	18 dBm
Ch 11 - Pwr 18	AP320	802.11n	11	18 dBm
Ch 1 - Pwr 18	AP320	802.11n	Auto(1)	18 dBm

B. Signal strength based on user capacity

Table 8. Product Specification Transmitter Design B Building A 2nd Floor

Name	Model	Type	2.4 GHz	
			Channel	Power
Ch 8* - Pwr 17	AP320	802.11n	8	17 dBm
Ch 1* - Pwr 17	AP320	802.11n	1	17 dBm
Ch 9* - Pwr 17	AP320	802.11n	9	17 dBm
Ch 10* - Pwr 17	AP320	802.11n	10	17 dBm
Ch 7* - Pwr 17	AP320	802.11n	7	17 dBm
Ch 1* - Pwr 17	AP320	802.11n	1	17 dBm
Ch 2* - Pwr 17	AP320	802.11n	2	17 dBm
Ch 4* - Pwr 17	AP320	802.11n	4	17 dBm
Ch 6* - Pwr 17	AP320	802.11n	6	17 dBm
Ch 1* - Pwr 17	AP320	802.11n	1	17 dBm
Ch 11* - Pwr 17	AP320	802.11n	11	17 dBm
Ch 2* - Pwr 17	AP320	802.11n	2	17 dBm
Ch 5* - Pwr 17	AP320	802.11n	5	17 dBm
Ch 5* - Pwr 17	AP320	802.11n	5	17 dBm
Ch 1* - Pwr 17	AP320	802.11n	1	17 dBm

Ch 3* - Pwr 17	AP320	802.11n	3	17 dBm
Ch 11* - Pwr 17	AP320	802.11n	11	17 dBm
Ch 11* - Pwr 17	AP320	802.11n	11	17 dBm
Ch 6* - Pwr 17	AP320	802.11n	6	17 dBm
Ch 6* - Pwr 17	AP320	802.11n	6	17 dBm

- B Building

A. Signal strength based on coverage area and transmitter strength coverage

Table 9. Specifications of Design A Transmitter B . Building

Name	Model	Type	2.4 GHz	
			Channel	Power
Ch 7 - Pwr 18	AP320	802.11n	7	18 dBm
Ch 6 - Pwr 18	AP320	802.11n	6	18 dBm
Ch 11 - Pwr 18	AP320	802.11n	11	18 dBm
Ch 1 - Pwr 18	AP320	802.11n	1	18 dBm

B. Signal strength based on user capacity

Table 10. Specifications of Design B Transmitter B . Building

Name	Model	Type	2.4 GHz	
			Channel	Power
Ch 1* - Pwr 17	AP320	802.11n	1	17 dBm
Ch 11* - Pwr 17	AP320	802.11n	11	17 dBm
Ch 10* - Pwr 17	AP320	802.11n	10	17 dBm
Ch 8* - Pwr 17	AP320	802.11n	8	17 dBm
Ch 5* - Pwr 17	AP320	802.11n	5	17 dBm
Ch 2* - Pwr 17	AP320	802.11n	2	17 dBm
Ch 6* - Pwr 17	AP320	802.11n	6	17 dBm

Ch 3* - Pwr 17	AP320	802.11n	3	17 dBm
Ch 9* - Pwr 17	AP320	802.11n	9	17 dBm

5. Implementations

The implementation of the simulated design is covered in this chapter. After seeing the propagation features of PTIIK, meaning the use of empirical and theoretical models, a commission may begin [13]. The design is then put into action in the simulation by measuring and changing the strength of the wireless network distributed throughout the region to the predicted limit (-75 dB) [14].

Signal strength is also evaluated depending on the number of users in the region and coverage area, and transmitter strength coverage[15]. The throughput must be decided as a trade-off for the user's quality of service while determining the wireless network's capacity[16]. The WLAN has a throughput of 24.7 Mbps, with a preset minimum throughput of 100 Kbps.

The formula for determining the maximum number of active users that a single AP may supply is as follows:

$\Sigma user = \frac{throughput\ aktual}{throughput\ user}$
$\Sigma user = \frac{24700\ kbps}{100\ kbps}$
$\Sigma user = 247$

So the % of active users : $\frac{247}{150}$
= 1,64 = 164%

So that the bandwidth of each user for each AP =
$\frac{(Datarate/2)}{max\ user} = \frac{(54000/2}{247} = 109{,}3$ Kbps

So the number of AP can be calculated as follows :
$N_{AP} = \frac{BWuser\ x\ Nuser\ x\ Activity}{\%Efficiency\ x\ Association\ Rate}$

BW user : 109,3 Kbps = 0,1093 Mbps
Total user : 150
% Activity rate : 164%
Network Efficiency : 50%
Baseline/AP : 8mbps

$N_{AP} = \frac{0{,}1093\ x\ 150\ x\ 1{,}64}{0{,}5\ x\ 8} = 6{,}75 = 7$ AP

According to these estimations, 7 APs can service 150 users. If the class has an expected 40 active users, two APs are required in that class.

6. Testing and Analysis

The findings of testing and analysis of the network system that has been implemented are presented in this chapter—specifically, a comparison of the theoretical and practical assessments of user capacity findings[17].

6.1 In the process of measuring the strength of a wireless network based on the criteria on the theoretical model of the propagation aspect, it has been obtained :

- Coverage that can be served.

The length of the AP Engenius EAP 9550 that can be stretched, according to the measurements, is 11,166 m.

- Number of transmitters (access points).

From reviewing the results of the calculation of the planned coverage area, namely with the formula $N_{AP} = \frac{Ctotal}{CAP}$ then we get the number of transmitters:

a. 3rd floor library building

The number of transmitters is expected to be two. The design results in optimization in the form of a new topology, as well as a network contour display that can cover the full 3rd storey library building by using channels 1 and 6 at 18dbm power, with a resulting RSSI average of -50dbm.

b. 5th floor library building

The number of transmitters is expected to be five. The design results in optimization in the form of a new topology, as well as a network contour display that can cover the full 5th story library building by using channels 1, 10, 6, 2, 11 with 18dbm power and a consequent RSSI average of -55dbm.

c. Polytechnic building A 1st floor

The number of transmitters is expected to be six. By using channels 1, 7, 6, 2, 11, 5 with a power of 18dbm and an average RSSI of -55dbm, the design results in optimization in the form of a new topology accompanied by a network contour display that may cover the full area of the 1st floor of the Polytechnic Building A.

d. Polytechnic building A 2nd floor

The number of transmitters is expected to be five. The design results in an optimization in the form of a new topology, as well as a network contour display that can span the full 2nd floor of poltek. The resultant RSSI average is -50dbm after applying channels 6, 1, 11, 10, 5 with a power of 18dbm.

e. B Building

The number of transmitters is expected to be four. The design results in optimization in the form of a new topology, as well as a network contour display that can cover the full area of building B by using channels 1, 6, 11, and 7 at 18dbm power, with a resultant RSSI average of -55dbm.

6.2 In the process of measuring the strength of the wireless network based on the capacity of the user, it has been obtained :

The number of users that can be served by 1 transmitter or AP Engenius EAP 9550 is 40 active users based on the calculation formula $N_{AP} = \frac{BWuser\ x\ Nuser\ x\ Activity}{\%Efficiency\ x\ Association\ Rate}$ with a capacity per user up to 109.3 Kbps.

a. 3rd floor library building

The number of transmitters is expected to be six. The design results in optimization in the form of a new topology followed by a network contour display that can cover the full 3rd story library building by applying channels 1, 6, 5, 11, 10, 2 with 17dbm of power and an RSSI average of -50dbm[18].

b. 5th floor library building

The number of transmitters is expected to be 13 units. The design results in optimization in the form of a new topology, as well as a network contour display that can cover the full area of the 5th floor library building by using channels 1, 6, 5, 11, 10, 3, 2, 8, 9, 1, 4, 2, 7 with 17dbm of power and an RSSI average of -45dbm[19].

c. Polytechnic building A 1st floor

The number of transmitters is expected to be nine. The design resulted in an optimization in the form of a new topology, which was accompanied by a network contour display that could span the whole space of the Polytechnic's first floor. A structure created by using channels 1, 6, 10, 5, 11, 3, 9, 3, 8 with a power of 17dbm and an average of The RSSI as a result is -45dbm.

d. Polytechnic building A 2nd floor

The number of transmitters is believed to be around 20. The design results in optimization in the form of a new topology, which is complemented by a network contour presentation that may encompass the Polytechnic's full area. Applying channels 1, 6, 5, 11, 10, 3, 2, 8, 9, 1, 4, 11, 1, 6, 5, 11, 1, 6, 7, 2 with 17dbm of power to a building on the second story results in an RSSI average of -40dbm.

e. B building

The number of transmitters is expected to be nine. The design results in optimization in the form of a new topology, as well as a network contour display that can cover the full area of building B by using channels 1, 6, 5, 11, 10, 2, 8, 9, 3 with a power of 17dbm and an RSSI average of - 40dbm[20].

7. Conclusions

a. Theoretical and empirical propagation features are calculated to optimize the indoor wireless network coverage area, which improves the form of a new topology and a network contour display that can cover the whole intended area. A rise in the average RSSI value from -100 dBm to -55 to -40 dBm indicates optimization in all regions.
b. Path interference, or the existence of reflections and changes in signal direction while passing through anything different in mass such as walls, doors, and soft barriers to diminish the signal intensity of the access point, causes the discrepancy in findings between measurements and computations.
c. Indoor wireless network interference is reduced by adjusting the power and channel settings. They minimize the power of an AP, namely in a classroom with an area of 18 dBm of energy and a diameter length of 11.166 m for the Engenius EAP 9550 AP. In a network architecture with several APs close together, the applied channels are right 1 to 11 non-overlapping.

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