Measurements of the Received Signal Level and Service Coverage Area at the IEEE 802.11 Access Point in the Building

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Abstract. Access point (AP) is part of a Wireless Local Access Network (WLAN) with its communications using WiFi. AP is used to transmit and receive data to users/clients. The ability of AP to serve users/clients depends on many factors. Moreover, if AP is applied in conditions inside the building. In this study, AP is installed at two points inside the building and then measured in the form of the received signal level (RSL) and service coverage area. One AP measured its performance by 26 measurement points and the other AP measured its performance by 20 measurement points. When AP has measured its performance then another AP position is switched off. Based on the measurement result, the received signal level value is the highest value is about -47 dBm at a distance of 3.2 m, while the lowest is about -79 dBm at a 9.21 m because it is on barrier 2 walls. While based on service coverage area, the area which is far away from the AP then the quality of service becomes bad because the transmitted signal is weakening caused by the distance and the loss of the wall.

1. Introduction

Access point (AP) is part of local radio access network where communications using WiFi. AP is tasked to transmit and receive data to users / clients. The existence of AP is very eagerly awaited by the community because with the AP we can communicate / access the internet cheaply and flexible than cable technology. The quality of service from the AP depends not only on the distance of the user with the AP only. Users who are close to the AP are not guaranteed to have good quality and vice versa for longer distance is not necessarily the worse. This is caused by many factors. Especially for conditions inside the building. Measurable performance in AP systems is received signal, throughput, channel capacity, and service coverage area.

AP placement is very influential on the performance of service area coverage. If not properly planned it will cause interference between the scope of service from the AP. Measurements were made using ORBIT testbed. Performance measured is performance against installed AP density. Interference across the scope of services from APs can be avoided with well-planned AP placements, frequency selection, and setting of AP parameters [1]. In addition, performance analysis of the effect of AP density on Finite-Area Networks was performed [2].
For AP placement in the building, received signal strength (RSS) is affected by multiple paths of AP signals, signal attenuation, and changes in environmental conditions within the building. To overcome this condition, this research is used with k-nearest neighbor (KNN) algorithm for location accuracy in building. The result obtained is improved location accuracy and performance from AP to be better [3]. Accuracy of WiFi localization is measured through a strong collection of signals received within the building by the WiFi trilateration method [4].

In this study, AP is installed at two points within a building and then measured receive signal level and service coverage area. When one AP is measured then the other AP’s position is switched off, then receive signal level and service coverage area is measured. The receive signal level is measured by WiFi Analyzer while the service coverage area is measured by the Heatmapper Ekahau. The results of this measurement aims to improve the ability or performance of existing AP systems.

2. Wireless Local Area Network (WLAN)

The WLAN architecture consists of two services: a basic service set or also called a Basic Service Set (BSS) and an Advanced Service Set (ESS). The minimal BSS configuration consists of one access point and several users. The Extended Service Set (ESS) is a network established to provide extended coverage for wireless or wired users. Extended Service Set consists of several Basic Service Set (BSS) that overlap each other. The connection between two or more BSS infrastructure generates ESS. The architecture of the WLAN can be seen in figure 1 below [5]:

![Figure 1 Arsitektur WLAN](image)

To build a WLAN network configuration, there are several main components required for WLAN networks to connect: Access Point, Wireless LAN Interface, and Mobile / Desktop PC [6]-[7]. AP used in this research is from Unifi product [8].

2.1. Indoor Propagation

In wireless propagation, the success of the information signal to destination will be affected by the surrounding environment. The information signal experiences reflection, absorption, distortion, or obstruction. To understand the propagation inside the building, it is necessary to know the propagation characteristics between the floor and the floor in a building. The propagation path between floors within a building must be determined. The amount of wall attenuation depends on the material used from the wall and the frequency of the passing signal [9]. Thus the received power of indoor propagation which is affected by the wall attenuation becomes [10]:
\[ P_r = P_t G_t G_r \left( \frac{\lambda}{4\pi} \right)^2 d^{-\alpha} 10^{\frac{x_d}{10}} \prod_{m=1}^{M} |\Gamma_m|^2 \]  

(1)

where \( P_t \) is the transmitting power of the AP, \( G_t \) is the gain of the transmitting antenna, \( G_r \) is the gain of the receiving antenna, \( d \) is the AP distance and the user, \( \alpha \) is power of distance, \( \phi \) is the standard deviation of the normal log shadowing, \( \Gamma_m \) and \( M \) respectively denotes the transmission coefficient of the \( m \)-th wall passed by the direct propagation path and the number of walls.

2.2. Performance of Access Point

Performance measured in this research is Receive Signal Level and Coverage service area.

2.2.1. Receive Signal Level (RSL)

RSL is an indication of the received power level of an antenna. Therefore, the higher the number of RSLs indicates that the stronger the signal is obtained. Through mathematical calculations that the receive signal can be calculated using equation (1). The obtained signal power is in dBm. While through measurement, received signal power is measured using Wifi Analyzer. Wifi Analyzer can be used to analyze the surrounding Wifi network. This app can get signal quality and network saturation information in just 5 seconds.

2.2.2. Service area coverage

A service area coverage of an AP is required to know the range of installed AP signals and to expand the network for optimal service delivery. Ekahau Heatmapper is software for mapping service area coverage of Wi-Fi networks. This software is easy to use to show the range of installed wireless AP network by adding digital maps.

This software is widely used to observe the coverage area in a place like home, office, school and others. Thus, users easily know where the place is not covered wireless network Wi-Fi. Ekahau Heatmapper software does not provide digital maps, so users are expected to have a digital map. The survey result of Ekahau Heatmapper software, where there are several different colors on each distance difference from AP and user. These colors indicate signal strength. The color differences shown in table 1 [11]:

| Colorful Heatmaps | Signal Strength (dBm) | Signal Quality Category |
|-------------------|-----------------------|------------------------|
| Green             | -40 up to -50         | Excellent              |
| Yellow            | -50 up to -60         | Good                   |
| Orange            | -60 up to -85         | Less                   |
| Red               | -85 up to -100        | Poor                   |

3. Measurement Method

3.1. Room Plan

RSL measurements and service area coverage were carried out in indoor environments of buildings in Dishubkominfo Kabupaten Badung. Room plan for measurement can be seen in figure 2. From figure 2 it can be seen that there are 2 AP mounted on the hall of the building. The first AP was installed on the north and the second AP was installed on the south side of the building. Users are located in each room of the building.
3.2. Measurement of Received Signal level
RSL measurements were performed for the condition of a wall barrier between the AP and the user, where RSL was measured according to the distance between the AP and the user. Measurements are made using an AP device called Ubiquiti wifi UAP and a laptop device that acts as a server. The function of the laptop server to set the Tx rate used. In addition to hardware devices, to perform RSL measurements required software installed on the smartphone client. The software is called Wifi Analyzer. In the software, the measurement is done by making sure the AP is connected to the smartphone by locking one of the AP signals you want to measure. Then run the software so that it will automatically look the measurement results in the form of Received Signal level.

3.3. Measurement of Service Coverage Area
Measurement of service coverage area using Ekahau HeatMapper software. It was done with the aim to know service coverage area in indoor environment at Dishubkominfo Badung, Bali, Indonesia. Further measurement results are analyzed to provide recommendations that the need for additional access points to cover the entire indoor area.

The service coverage area measurement is based on the received signal value previously measured at the measurement points. The quality of the service coverage area of the heatmapper ekahau software depends on the number of wall barriers passed by the AP signal.

4. Measurement Results

4.1. RSL For AP 1
RSL measurement results for AP 1 for 26 points spread over seven rooms. Users in the room, some are blocked by one and two walls. The results of these measurements are then sorted by the closest distance to the furthest distance from the AP position. The results can be seen in table 2 and shown in the graph shown in figure 3.

Table 2. RSL of AP 1

| No. | Distance (m) | RSL (dB) | No. | Distance (m) | RSL (dB) |
|-----|--------------|---------|-----|--------------|---------|
| 1.  | 3.2          | -47     | 14. | 8.06         | -77     |
| 2.  | 3.77         | -55     | 15. | 8.07         | -61     |
| 3.  | 3.9          | -55     | 16. | 8.6          | -62     |
| 4.  | 4.24         | -55     | 17. | 9.21         | -79     |
From figure 3 it shows that RSL at some point of measurement decreased significantly. Maximum RSL obtained is -40 dBm and lowest RSL reach -79 dBm. The decrease in RSL values occurs with increasing user distance to the AP. Based on equation (1), the RSL value depends on distance, shadowing, and damping of the wall. There are several points with almost the same distance having different RSL values. This is because the user with almost the same distance is located in a different room where one user is blocked by one wall and another user is blocked by two walls.

| No. | Distance (m) | RSL (dB) | No. | Distance (m) | RSL (dB) |
|-----|--------------|----------|-----|--------------|----------|
| 5.  | 5.2          | -57      | 18. | 9.5          | -62      |
| 6.  | 5.4          | -58      | 19. | 9.89         | -64      |
| 7.  | 5.83         | -58      | 20. | 9.96         | -65      |
| 8.  | 7.2          | -59      | 21. | 11.5         | -64      |
| 9.  | 7.28         | -72      | 22. | 11.88        | -66      |
| 10. | 7.28         | -73      | 23. | 13.5         | -70      |
| 11. | 7.5          | -60      | 24. | 13.64        | -70      |
| 12. | 7.61         | -61      | 25. | 13.82        | -72      |
| 13. | 8.06         | -77      | 26. | 14.08        | -76      |

Figure 3. RSL and Distance for AP 1

4.2. RSL For AP 2

RSL measurement results for AP 2 for 2 points spread over five rooms. Users in the room, some are blocked by one and two walls. The results of these measurements are then sorted by the closest distance to the furthest distance from the AP position. The results can be seen in table 3 and shown in the graph shown in figure 4.

Table 3. RSL of AP 2

| No. | Distance (m) | RSL (dB) | No. | Distance (m) | RSL (dB) |
|-----|--------------|----------|-----|--------------|----------|
| 1.  | 4.5          | -50      | 11. | 8.9          | -67      |
| 2.  | 4.92         | -52      | 12. | 9.43         | -69      |
| 3.  | 4.92         | -54      | 13. | 9.48         | -58      |
| 4.  | 6.26         | -55      | 14. | 9.96         | -58      |
| 5.  | 6.5          | -56      | 15. | 10.25        | -73      |
| 6.  | 6.8          | -56      | 16. | 11.18        | -74      |
| 7.  | 6.8          | -56      | 17. | 11.4         | -62      |
From figure 4 it shows that RSL at some point of measurement decreased significantly. Maximum RSL obtained is -50 dBm and lowest RSL reach -78 dBm. The decrease in RSL values occurs with increasing user distance to the AP. Based on equation (1), the RSL value depends on distance, shadowing, and damping of the wall. There are several points with almost the same distance having different RSL values. This is because the user with almost the same distance is located in a different room where one user is blocked by one wall and another user is blocked by two walls.

|   |     |    |    |    |    |
|---|-----|----|----|----|----|
| 8. | 7.61 | -56 | 18. | 11.8 | -78 |
| 9. | 7.81 | -67 | 19. | 13.03 | -65 |
| 10. | 8.07 | -58 | 20. | 13.34 | -66 |

Figure 4. RSL and Distance for AP 2

4.3. Service Coverage Area for AP 1

Measurement of service coverage area for AP 1 is done by first switching off AP 2. The measurement is done based on the route of the users seen in figure 5. The result of Ekahau HeatMapper software can be seen in figure 5. From figure 5 it can be seen that the service quality of AP 1 shown in the form of colors. The dark green color indicates excellent service quality lies in areas close to AP 1. Light green means good service quality and yellow color indicates less service quality for users located further from AP 1. In addition to color, the Ekahau HeatMapper software also appears traces -the movement of users and hotspots that are active around at the time of measurement. The results of the measurements are then used as a consideration for the addition of AP to cover the entire room in the building.

Figure 5. Service Coverage Area for AP 1
4.4. Service Coverage Area for AP 2
Measurement of service coverage area for AP 2 is done by first switching off AP 1. The measurement is done based on the route of the users seen in figure 6. The result of Ekahau HeatMapper software can be seen in figure 6. From figure 6 it can be seen that the service quality of AP 2 shown in the form of colors. The dark green color indicates excellent service quality lies in areas close to AP 2. Light green means good service quality and yellow color indicates less service quality for users located further from AP 2. In addition to color, the Ekahau HeatMapper software also appears traces -the movement of users and hotspots that are active around at the time of measurement. In contrast to the measurement results in AP 1, on the measurement of AP 2 detected many hotspots are active. The results of the measurements are then used as a consideration for the addition of AP to cover the entire room in the building.

![Figure 6. Service Coverage Area for AP 2](image)

5. Conclusions
AP network performance measured is RSL and Service Coverage Area by using Wifi Analyzer and Ekahau HeatMapper. AP performance measurements were performed in buildings in Dishubkominfo. From the measurement results obtained the performance of AP 1 is RSL done on 26 points spread in seven rooms. RSL at several points of measurement decreased significantly with the maximum RSL obtained is -40 dBm and lowest RSL reach -79 dBm. The performance of AP 2 is done for 20 spots spread over five rooms. RSL obtained at some measurement points decreased significantly. Maximum RSL obtained is -50 dBm and lowest RSL reach -78 dBm. The decrease in RSL values occurs with increasing user distance and AP. Based on equation (1), the RSL value depends on distance, shadowing, and damping of the wall. The performance of service coverage area, service quality of AP is shown in the form of colors. The dark green color indicates excellent service quality, light green means good service quality, and yellow shows a less service quality.

Reference

[1] Ergin M A, Ramachandran K, and Gruteser M, 2007 Understanding the Effect of Access Point Density on Wireless LAN Performance Proceedings of the 13th annual ACM international conference on Mobile computing and networking

[2] Alireza Banani S., Andrew W.E., and Raviraj S. A., 2015 Analyzing the Impact of Access Point Density on the Performance of Finite-Area Networks IEEE Transactions on Communications vol. 63, issue 12 Dec 2015
[3] Yu F, Jiang M, Liang J, Qin X, Hu M, Peng T, and Hu X, 2014 5G WiFi Signal-Based Indoor Localization System Using Cluster k-Nearest Neighbor Algorithm International Journal of Distributed Sensor Networks Volume 2014

[4] Bobescu B and Alexandru M, 2015 Mobile Indoor Positioning Using WiFi Localization, Review of the Air Force Academy vol. 28, no. 1

[5] Gultom, D.I., 2011. Packet Delay Analysis Voip On Ad-Hoc Wireless Lan Network (IEEE 802.11). Universitas Sumatera Utara [Institutional Repository].

[6] Alexander T, 2007, Optimizing and Testing WLANs Proven Techniques for Maximum Performance, Elsevier Inc : United States of America

[7] Razak, I dan Ulfiah, F. 2009. A Study Of The Signal Quality Characteristics Of Building Profiles With Radio Propagation Modeling In The Indoor WLAN System, Media Elektrik, vol. 4, no. 1 [Indonesian Proceedings]

[8] https://www.ubnt.com

[9] Rappaport, T. S., 2002, Wireless Communication Principles and Practice, Prentice-Hall, USA.

[10] Gunantara N and Hendrantoro G, 2013 “Multi-Objective Cross Layer Optimization for Selection of Cooperative Path Pairs in Multihop Wireless Ad hoc Networks”, Journal of Communications Software and Systems, vol. 9, no. 3.

[11] https://www.ekahau.com/products/heatmap/faq/#pane3