Wireless Local Area Network based Indoor Positioning System: A Study on the Orientation of Wi-Fi Receiving Device towards the Effect on RSSI

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Abstract

An indoor positioning system is a location estimation of the user in the indoor environment using the Wireless Local Area Network (WLAN) infrastructure. In the development of the system, a laptop with Wi-Fi module is used to measure and collect the received signal strength (RSS) from each router in existing WLAN. Next, the fingerprint method is applied to identify the uniqueness of the RSSI data on the particular location. This method provides low complexity and allows replication of positioning being applied with minimal setup. Owing to the fluctuation in fading of Wi-Fi signal, a study on the direction and orientation effects of received signal strength indicator (RSSI) on the laptop is conducted to provide a new direction on location estimation in indoor.

Key words: indoor positioning, wireless local area network, fingerprint method, received signal strength

1. Introduction

The indoor positioning system is developed to overcome the poor performance of the Global Positioning System (GPS) in indoor environment which requires a good line of sight with the satellite signal. The system uses the location fingerprint on the existing WLAN infrastructure to perform the positioning. Location fingerprinting requires the build-up of a database of RSS from different Wi-Fi access points taken at different locations across the area of interest. Then, the system scans and receives RSS to find the closest match in the database, and return the likeliest location of the user. The fingerprint method is simple to be applied comparing to techniques such as angle of arrival (AOA), time of arrival (TOA) and cell of origins. This method provides a low cost solution with minimum setup of hardware by utilizing the existing WLAN.

However, some factors may influence the RSS to the Wi-Fi receiving device which will affect performance of the positioning system. It is found that RSS would be affected by the orientation of the receiver and thus degrade the accuracy of positioning [2, 3]. P. Chuanjie suggested that this impact is caused by the orientation of the receiver but can be reduced by averaging the RSS at four orientations in positioning database [3]. Kamol Kaemarungsi proved this effect of orientation is significant and the orientation should be noted during positioning [2].

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In this paper, the effect of the heading direction of the receiver to a wireless router on the collected RSS values is studied. Aside from the previous studies [2, 3], the orientation effect of the receiver with respect to the router is also studied. Then, data analysis is conducted to conclude the effect of the stated factors on RSS from the router to the receiving.

2. Fingerprint method

The fingerprint method requires the positioning system trained with the RSS on each particular location [1, 2]. The collected RSS on the predefined locations are stored in the database of the positioning system. When the object stays at the identified location, the RSS is expected to be similar to the collected data in the database, thus the system is able to estimate the location via the data comparison and return the closest matched location. However, the time taken for RSS data collection in this method is higher when more location points are added. Therefore, to avoid the RSS data collection is repeated owing to the orientation effect of the receiver, experiment is conducted to identify the impact to the collected RSS with the reference to a wireless router.

3. Setup of Experiment

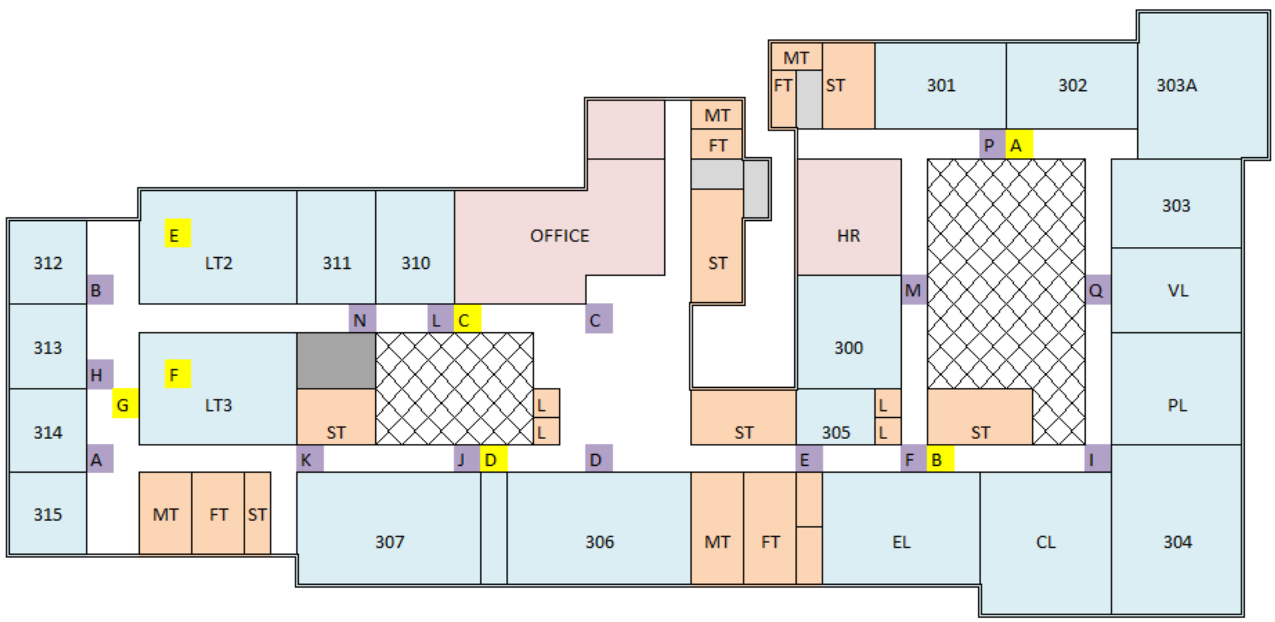


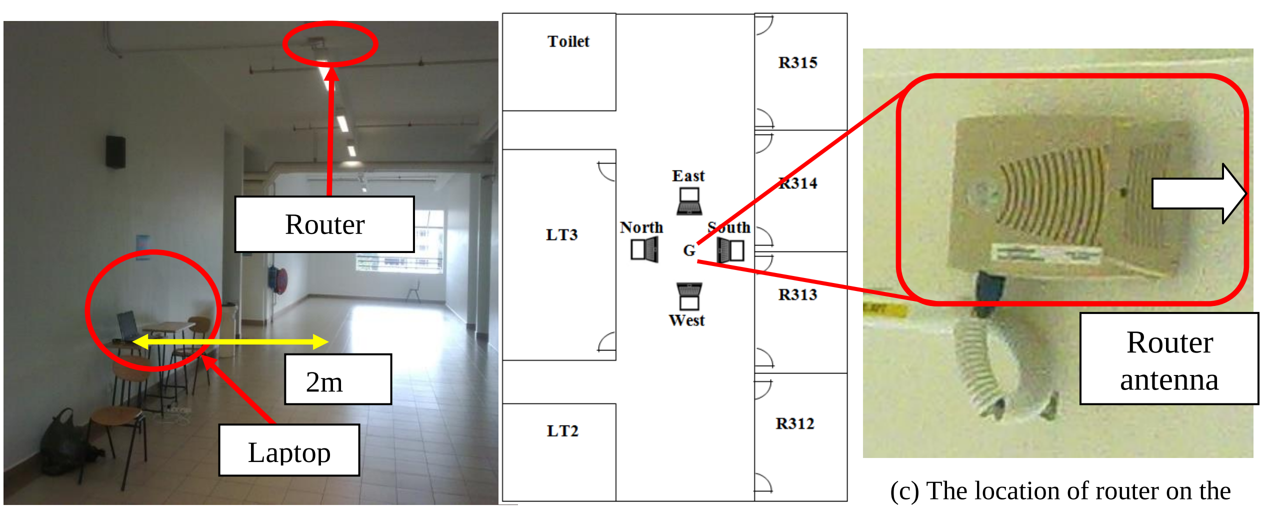
Figure 1. Floor plan of the sample space in the indoor positioning system

Figure 1 shows the predefined sample space which is located at level 3 of KDU College Malaysia, Penang campus. The building is estimated with the sectional area of 110 metres x 50 metres (taken the maximum length and width). The WLAN infrastructure is setup with the coverage of seven wireless routers on this floor. The routers as indicated with yellow highlighted alphabets in Figure 1 are Aruba 61 wireless routers with IEEE 802.11g configuration and 2.4 GHz of operating frequency with non-overlapping channels. On the other hand, the test locations in this project are identified by the coverage of the routers as indicated by purple highlighted alphabets.

In general, the designed positioning system utilizes the Wi-Fi module in the laptop as Wi-Fi receiver to receive the RSS from each router to perform the location estimation. A RSS data collection program is developed to receive the RSS and identify the respective routers via their Media Access Control (MAC) address. In addition, the wireless network interface module from the laptop computer (with i5 2430M, 8GB RAM and 500GB HDD) is Atheros AR9002WB-1NG.

4. Experiment I: the effect of heading direction of laptop towards router antenna

The experiment on the heading direction of the receiving device, the laptop is setup by collecting the RSS data from the wireless router as shown in Figure 2(a). It is noted that the antenna of the router is headed to south direction as in Figure 2(c). The laptop is placed on a table (height of 75 cm) during the data collection throughout the experiment. The laptop is always headed to point G as in the figure above. There are four directions of the laptop is placed, i.e. north, south, east and west with a distance of two metres away from the router origin location for respective directions as in Figure 2(b). At each direction, the developed program in laptop will repeatedly collect the RSS data for one minute with one second of sampling interval. The data is stored in a comma-delimited (CSV) file for data analysis later.



(a) The location of the wireless router and the laptop

(b) The top view of proposed location

(c) The location of router on the ceiling

Figure 2. The setting of experiment I

For ease of simplicity in data collection and analysis, the absolute value of collected RSS is taken and ranged between 0 to 100 as the original RSS is from 0 dBm to -100 dBm. 0 shows the strongest RSS and the signal strength attenuate as the RSS value increases to 100, the weakest strength. Therefore, in this experiment, RSS is considered stronger if it is with a smaller value.

4.1. Results

The results of the experiment is tabulated as shown in Table 1 with the minimum, maximum, average and standard deviation value of the collected RSS data. In one sampling, 60 samples are collected along with each direction. The sampling process is repeated three times to validate the consistency of the RSS.

Table 1 shows the distribution behaviour of the heading direction where the span (maximum – minimum) of each direction reflects the fluctuation range of the signal. The average and standard deviation are calculated based on the 60 samples in individual sampling.

Table 1. The compiled results from data collection on different heading direction

North				
Trial	**1**	**2**	**3**	**Span**
Maximum	51	50	50	1
Minimum	41	41	43	2
Average	46.49	45.12	46.39	1.372
Standard Deviation	3.158	3.103	2.911	0.246

West				
Trial	**1**	**2**	**3**	**Span**
Maximum	46	44	46	2
Minimum	43	42	42	1
Average	44.071	43.227	44.071	0.844
Standard Deviation	0.973	0.605	0.838	0.368

South				
Trial	**1**	**2**	**3**	**Span**
Maximum	57	53	59	6
Minimum	42	42	42	0
Average	51.488	48.500	48.302	3.185
Standard Deviation	6.477	4.984	6.431	1.493

East				
Trial	**1**	**2**	**3**	**Span**
Maximum	53	64	54	11
Minimum	46	48	46	2
Average	48.690	53.231	49.650	4.540
Standard Deviation	1.703	5.070	2.568	3.3671

4.2. Analysis & Discussion

Table 1 and Figure 3 show the RSS receiving performance of laptop at the different direction. The data collected at west direction is most stable and has the smallest standard deviation. This is owing to the placement of the router antenna is toward the west direction. The Wi-Fi signal travels at a relatively shorter distance to the laptop comparing to other directions. Hence, it is the strongest averaged signal among four directions.

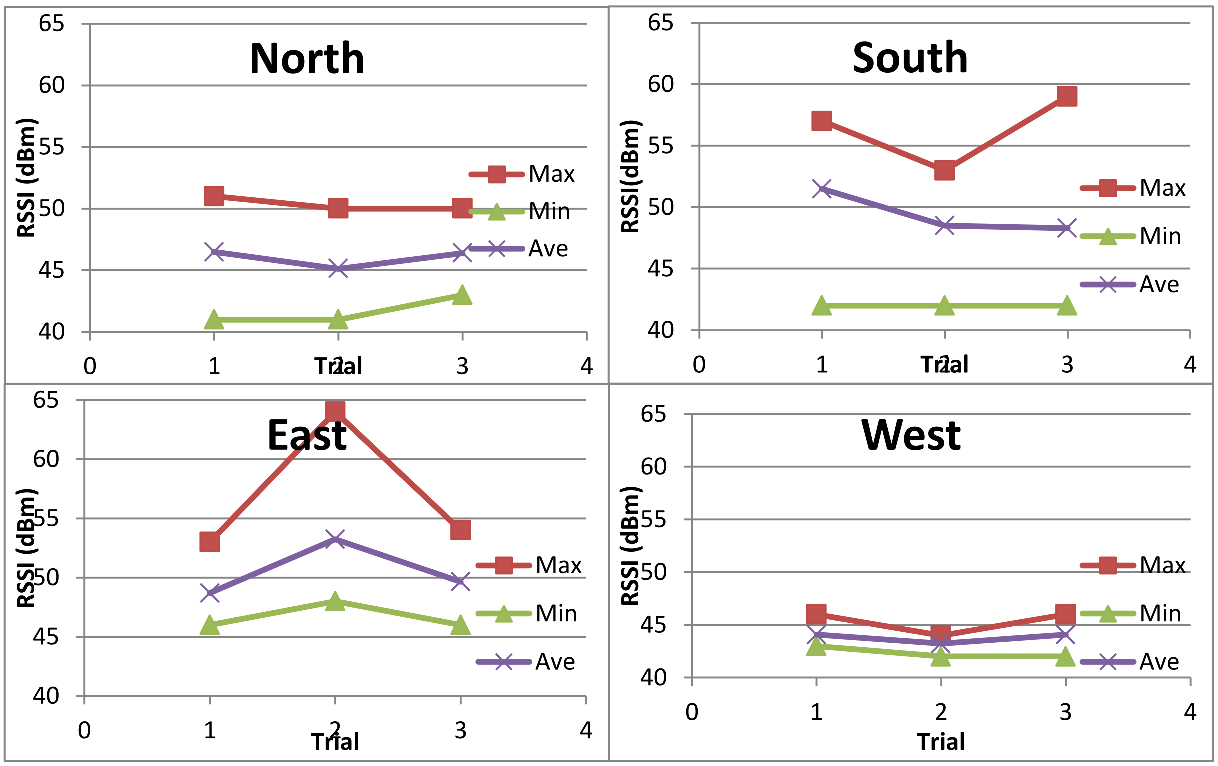


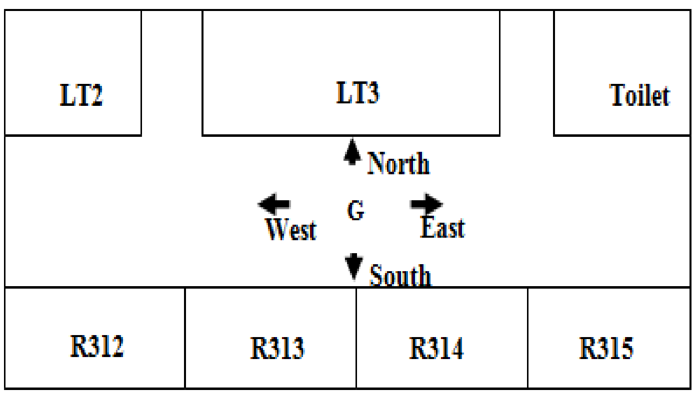
Figure 3. RSS versus heading direction of laptop

At north and south directions, the distance between laptop and the router antenna are comparable. Therefore the receiving performance for both the north and south are near. At the north direction, a wall of room LT3 (Figure 2(b)) is blocked in front of the north direction, therefore the RSS shows a small fluctuation as the wall contributes reflection in the fading of Wi-Fi signal [7]. However, a larger range of fluctuation is observed for the south direction. This is contributed by two wooden doors faced to router that absorb the Wi-Fi signal [7].

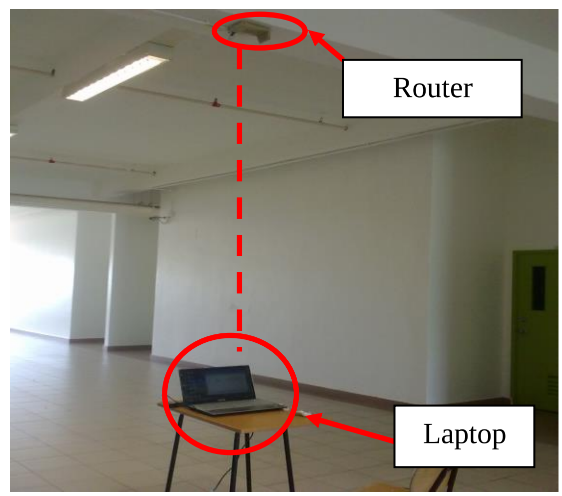
The weakest RSS is collected at east direction as the location is furthest from the router antenna. Therefore, the RSS range of the east direction is highest comparing to the others. In general, the collected RSS data is directly affected by the distance between router antenna and laptop.

5. Experiment II: the effect of orientation of laptop at fixed location

In experiment I, the laptop is located by fixing 2 metres distance away from the wireless router and its screen is defaulted to face to the centre, i.e. point G (Figure 4). Experiment II is conducted with the aim to investigate the various heading directions of the laptop with fixed location by using the same laptop and configurations. Figure 4 shows the setup of the experiment with four heading directions of the laptop screen right under the wireless router. The RSS sampling is applied by orienting the laptop as in Figure 4(b) to face north, south, east and west. At each orientation, the laptop collects the RSS data using the same setting in experiment I, i.e. data collection for one minute with one second sampling interval and stored in a comma-delimited (CSV) file.



(a) The floor map of the wireless router and the defined directions



(b) The location of the laptop vertical to the wireless router

(c) The placement of the laptop with respect to the defined directions

Figure 4. The setup for experiment II

5.1. Results

Table 2 shows the RSS data of the laptop at different orientations with the minimum, maximum, average and standard deviation values. Each sampling consists of 60 samples and the sampling on each direction is repeated five times to validate the consistency of the RSS.

The results for the effect of direction show the distribution behaviour of the direction where the maximum and minimum of each direction reflects the range of fluctuation of the signal shows in Table 2. The analysis of the fluctuation in fading of Wi-Fi signal is crucial to identify the range of RSS in the positioning database.

Table 2. The compiled results from data collection at different orientation

Facing North						
Trial	**1**	**2**	**3**	**4**	**5**	**Average**
Maximum	46	47	46	46	47	46.4
Minimum	42	44	43	42	43	42.8
Average	44.03	45.51	44.56	44.51	44.85	44.69
Standard Deviation	0.862	0.883	0.852	1.052	1.167	0.963

Facing East						
Trial	**1**	**2**	**3**	**4**	**5**	**Average**
Maximum	52	63	53	53	61	56.4
Minimum	47	48	48	48	46	47.4
Average	48.60	50.40	50.35	50.56	53.41	50.67
Standard Deviation	1.215	3.826	1.418	1.314	4.995	2.554

Facing South						
Trial	**1**	**2**	**3**	**4**	**5**	**Average**
Maximum	51	50	49	48	47	49
Minimum	43	44	44	44	44	43.8
Average	45.90	46.34	46.41	45.31	45.80	45.95
Standard Deviation	1.930	1.559	1.482	1.137	1.203	1.462

Facing West						
Trial	**1**	**2**	**3**	**4**	**5**	**Average**
Maximum	53	56	52	52	53	53.2
Minimum	48	45	46	43	45	45.4
Average	50.18	50.74	48.33	47.02	48.39	48.94
Standard Deviation	1.768	3.625	1.633	2.089	2.301	2.283

5.2. Analysis & Discussion

From Figure 5, the orientation at north direction shows smallest range of fluctuation and low average of RSS data. It is followed by south, west and east directions. However, not all horizontal orientations of the laptop have the same level of RSS. The orientation at north and south directions shows closed RSS average values with small range of fluctuation. This is owing to the orientation at these two directions is aligned to the router antenna direction and therefore at both orientations, laptop receives better average RSS comparing to weaker RSS at east and west directions.

From this experiment, it is proven that the orientation does have effect on the collected RSS. This fact has to be taken into consideration so that the RSS is more consistent and precise.

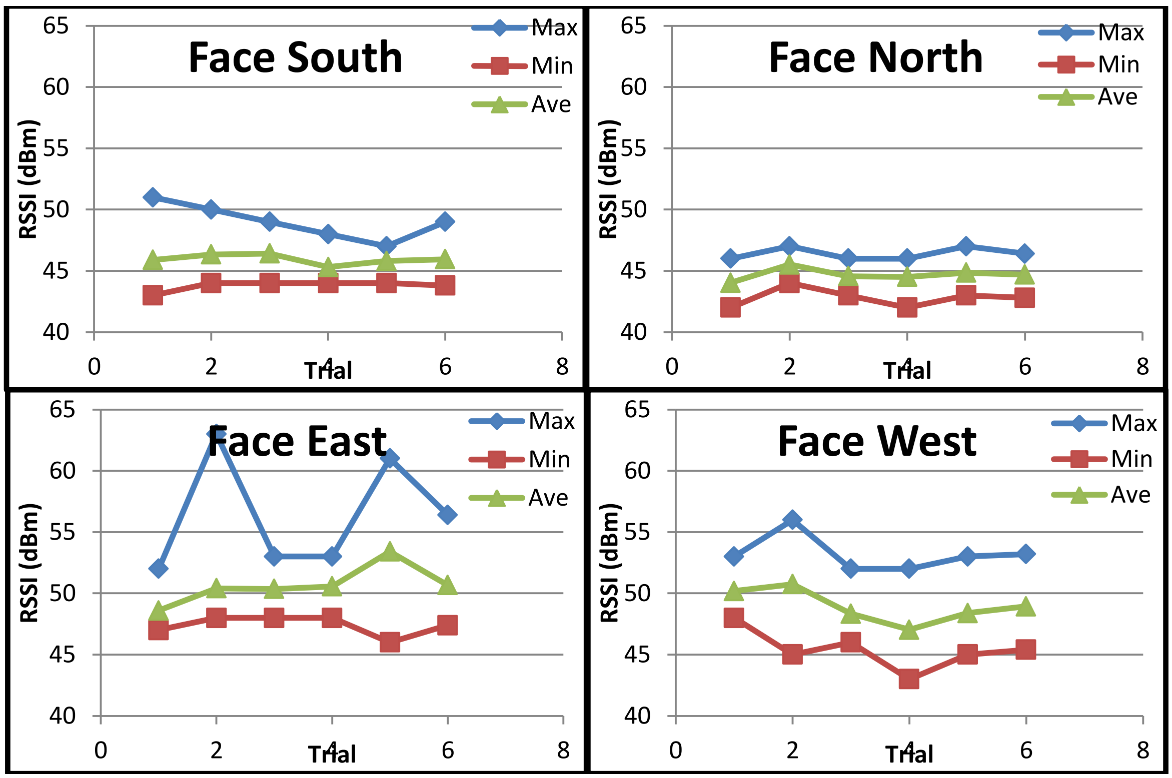


Figure 5. RSS versus orientation of receiving device

6. Additional Discussion

Mestre used the hybrid technique with various types of filter include nearest neighbour, k. nearest neighbour (KNN) and fuzzy logic to process the RSS data to improve the accuracy of his positioning system [5]. On the other hand, Qingyuan combined Kernel and KNN as RSS data pre-processing for his system to secure the accuracy and precision [1]. These approaches were aimed to overcome the fluctuation in Wi-Fi signal fading before the positioning can be done.

From this project, the RSS is directly captured and compared with database. This shows a low complexity of positioning with some study on restriction and precaution done while conducting the system. From the experiment, the orientation is suggested to be fixed at one facing to ensure the stability of the system. As from limiting the factors that might affect the variation of the RSS signal also help to improve the system. This can simplify the system and make the process of positioning to be fast and effective. With the restriction on the orientation on the wireless receiving device during the positioning, the system would be able to provide a good performance positioning.

7. Conclusion

The indoor positioning system is designed to perform the positioning in indoor environment with low complexity and minimal hardware setup. However, the effect of the direction and orientation has to be taken into consideration to allow a more stable performance in terms of system response and location estimation. On any individual wireless router, the heading direction of the Wi-Fi receiving device is affected by the line of sight (LOS) between router antenna and the device. Hence, the better LOS between them guarantees the consistency of the RSS data and thus improves the performance of indoor positioning system. On the other hand, the placement of the device by orientation of the device facing to certain directions under the router is related with the alignment of the device to the router antenna. For a stable performance, the receiving device is suggested to fix at an orientation with strong RSS such as aligning it same line to the router antenna. Besides that, the effect of human body on the RSS is yet to be discovered as the A.M. Ladd stated that there is an effect of resonance frequency on human body when signal is travel at 2.4GHz [4]. As a conclusion, the heading direction of the device is affected by placement of the receiving device to the wireless router while the orientation of the device affects the RSS values.

Acknowledgements

Thanks to all individuals and departments in KDU College Penang Campus throughout the project. Besides that, the guidance from Mr. Koay is much appreciated. Nevertheless, my family support and caring allow me to complete the experiment and research.

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