

A New Statistical Received Signal Strength (RSS) Model Based Fingerprint Approach for WLAN Indoor Localization Application

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Abstract— In this paper, a new statistical received signal strength (RSS) model is formulated to be used in fingerprint offline mode and online mode for detecting the location accurately. The range and the midrange methods are used in this model that gives a new mean and standard deviation as called in this paper. Also, the frequency distribution patterns are calculated for RSS signals and used in RSS model. WLAN Indoor localization application is developed on Android Smartphone to be used in detecting the accurate location. The application is tested in City Center Mall in Nasr City, Cairo, Egypt and used the unknowing location access points (APs) of this MALL. The RSS model of this paper is used by the application for constructing the radio map of testing area in fingerprint offline mode. In fingerprint online mode, a new searching method is used for matching between the predefined locations of radio map and the online locations. The results give the accurate location correctly except some locations are not determined well.

Keywords— Indoor localization, Wi-Fi technology, Android OS, RSS Fingerprint

I. INTRODUCTION

Wireless local area network (WLAN) standard, IEEE 802.11 operating in the 2.4 GHz Industrial, Scientific, and Medical (ISM) band, has become very popular in public hotspots and enterprise locations during the last few years. Although WLAN is not designed and deployed for indoor localization determination, most of the recent researches started to use the existing WLAN infrastructure to estimate position. Most of the location estimation techniques in wireless networks are based on mapping of each transmitter's signal as in [1]. In a simple model, each point is mapped to the signal strength of each sensible access point. In case of a more complex model, besides the signal strengths other data can also be considered, such as the detailed map of the building, walls, obstructions, etc. To compute the signal strength, numerous propagation models were proposed as in [2]. There are two kinds of modelling based on signal strength for WLAN positioning system, propagation modelling and fingerprinting modelling as in [3]. In indoor environments, interference, multipath propagation of RF signals, and the presence of obstacles and people, lead to a complex spatial distribution of the RSS, which is inaccurately described by simple parametric models [2]. Wireless technology used for

indoor localization has been reviewed in [4]-[9]. While these works are impressive, few have focused on Wi-Fi fingerprint-based localization system. In recent years, significant advances in Wi-Fi localization techniques as in [10]-[16] and its efficient deployment as in [17]-[20] based on Wi-Fi fingerprint are introduced, which have not yet been properly reviewed. Hence the fingerprint approach is more suitable for indoor localization as shown in this paper.

II. A PROPOSED STATISTICAL MODEL FOR RSS DATA SET

There are two important features of a data set include the centre of the data and the spread of the data as in [21]. In statistics, the centre of a set of data is known as the average, and there are several different ways to measure this feature of a data set. The most popular of these are the mean, median, mode, and midrange. The mean of a data set is what is most often meant by the common use of the word average. It is found by first adding all the data values, then dividing by the number of values. The median of a set of data is calculated by listing the data in ascending order, then finding the point that is exactly in the middle. The mode of a data set is the value that occurs with the most frequency. Another measure of centre called the midrange. The midrange is the mean of the maximum and minimum values of the data set.

In a similar fashion, there are different ways to calculate the spread of the data set and the easiest and crudest measure of spread is called the range. In statistics and mathematics, the range is the difference between the maximum and minimum values of a data set, which provides statisticians with a better understanding of how varied the data set is. The range is a very crude measurement of the spread of data because it is extremely sensitive to outliers, and as a result, there are certain limitations to the utility of a true range of a data set to statisticians because a single data value can greatly affect the value of the range.

The standard deviation is another measure of spread that is less susceptible to outliers, but the drawback is that the calculation of the standard deviation is much more complicated. Using the standard deviation, statisticians may determine if the data has a normal curve or other mathematical relationship. If a data behaves in a normal curve, then 68% of the data points will fall within one standard

deviation of the average data or mean data point. The rest of data points will fall outside one standard deviation. The mean and standard deviation are together used to model a data set that has a normal curve (Gaussian curve). Due to the complicated calculation of the standard deviation and the requirements to use 2 and 3 of standard deviation to obtain a full range of a data set, the range of a data set is used in this paper to model the spread of the data set. Also, the midrange method is used to measure the centre of data set instead of using the mean method.

In this paper, a midrange method is used for calculating the average of RSS values and called (Avg_{new}), also the mean of the range that equals the range divided by two as a deviation for RSS distribution is used and called (STD_{new}). The (Avg_{new}) and (STD_{new}) are calculated from equation 1 and 2 for obtaining a new RSS model.

$$Avg_{new} = (RSS_{max} + RSS_{min}) / 2 \quad (1)$$

$$STD_{new} = (RSS_{max} - RSS_{min}) / 2 \quad (2)$$

The Average (Avg) of RSS samples at each time can be calculated using the mean by summing N of RSS samples at each time and dividing the results by N as shown in equation 3. Also the sample standard deviation (STD) can be calculated by equation 4.

$$Avg = \frac{\sum_{i=1}^N RSS_i}{N} \quad (3)$$

$$STD = \sqrt{\frac{1}{N-1} \sum_{i=1}^N (RSS_i - Avg)^2} \quad (4)$$

Many tests are done using the application of this paper to determine the number of APs that achieves good results. This work is done in City Center Mall, Cairo, Egypt, which has many shops and restaurants, without knowing the place of APs and the distances between smart phone and each AP. Locating an object using WLAN APs requires a handover area between APs and the object must be exist in this area to be located. The tests show that the using of four APs gives more accurate results than three APs which was the minimum number required for indoor localization model. Using five APs caused more processing delay than four APs. The effect of using more APs will be investigated perfectly in future work and the application of this paper uses four APs that have the highest RSS values in testing area and the obtaining results were good as shown throughout the paper.

First, the application collects 10 RSS samples from each AP for one time at the first point in the testing area that is called (Switching Dep.). The collected RSS samples from AP1 at (Switching Dep.) point for 20 times are shown in Table 1. Equation 1 and 2 are used for calculating the Avg_{new} and STD_{new} for all four APs for one time as shown in Table 2 and for 20 times as shown in Table 3. Also, equation 3 and 4

are used for calculating the Avg and STD for 10 RSS samples for one time and repeated for 20 times at Switching Dep. point for all four APs as shown in Table 4.

TABLE 1. THE RSS COLLECTED SAMPLES FROM AP1 FOR 20 TIMES AT SWITCHING DEP. POINT

Collected time	RSS from AP1
1	-64,-67,-59,-65,-63,-73,-67,-66,-71,-62
2	-69,-65,-69,-67,-77,-67,-64,-63,-71,-74
3	-69,-66,-65,-68,-66,-72,-65,-64,-72,-72
4	-75,-65,-64,-63,-65,-65,-74,-69,-65,-74
5	-63,-64,-70,-64,-66,-65,-65,-63,-64,-64
6	-63,-62,-65,-64,-62,-64,-63,-61,-61,-62
7	-65,-62,-62,-65,-65,-64,-65,-62,-63,-64
8	-64,-68,-68,-63,-61,-64,-66,-63,-63,-64
9	-65,-66,-67,-65,-60,-66,-69,-65,-65,-67
10	-66,-65,-64,-62,-61,-61,-62,-63,-66,-63
11	-78,-72,-62,-67,-68,-76,-67,-64,-69,-70
12	-78,-69,-77,-70,-76,-65,-69,-66,-68,-66
13	-70,-73,-71,-73,-66,-73,-70,-73,-66,-66
14	-69,-69,-70,-71,-67,-72,-70,-66,-69,-69
15	-74,-65,-66,-72,-72,-64,-78,-65,-70,-71
16	-73,-68,-67,-68,-66,-69,-72,-69,-70,-71
17	-74,-77,-71,-71,-71,-72,-78,-80,-74,-79
18	-79,-81,-80,-79,-76,-76,-75,-75,-79,-76
19	-74,-76,-79,-76,-70,-76,-78,-79,-73,-74
20	-74,-72,-70,-68,-69,-67,-68,-67,-67,-71

TABLE 2. THE Avg_{new} AND STD_{new} FOR 10 RSS SAMPLES FOR ONE TIME AT SWITCHING DEP. POINT

	AP1 RSS	AP2 RSS	AP3 RSS	AP4 RSS
1	-64	-76	-69	-92
2	-67	-73	-70	-85
3	-59	-72	-69	-89
4	-65	-75	-68	-83
5	-63	-75	-70	-93
6	-73	-75	-71	-86
7	-67	-74	-70	-92
8	-66	-70	-72	-88
9	-71	-76	-81	-90
10	-62	-83	-85	-89
Avg_{new}	-66	-76.5	-76.5	-88
STD_{new}	7	6.5	8.5	5

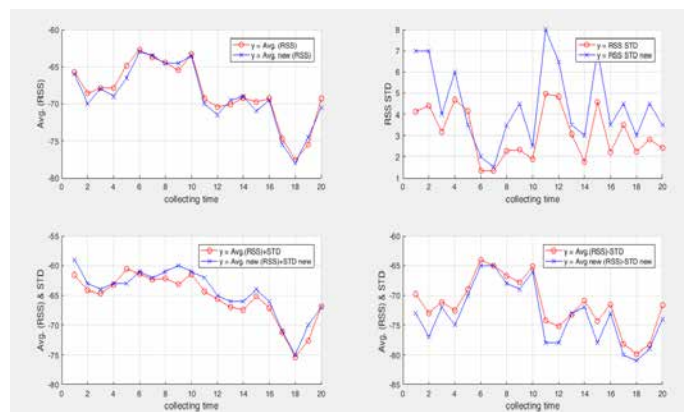
TABLE3. THE AVG_{new} AND STD_{new} FOR 10 RSS SAMPLES FOR 20 TIMES AT SWITCHING DEP. POINT

	AP1 [Avg_{new} , STD_{new}]	AP2 [Avg_{new} , STD_{new}]	AP3 [Avg_{new} , STD_{new}]	AP4 [Avg_{new} , STD_{new}]
Switch.1	[-66, 7]	[-76.5, 6.5]	[-76.5, 8.5]	[-88, 5]
Switch.2	[-70, 7]	[-75, 2]	[-81.5, 4.5]	[-87.5, 4.5]
Switch.3	[-68, 4]	[-75.5, 3.5]	[-84.5, 4.5]	[-84.5, 2.5]
Switch.4	[-69, 6]	[-75, 4]	[-81.5, 3.5]	[-89, 5]
Switch.5	[-66.5, 3.5]	[-73, 5]	[-80.5, 2.5]	[-93, 7]
Switch.6	[-63, 2]	[-77, 5]	[-78.5, 2.5]	[-90.5, 4.5]
Switch.7	[-63.5, 1.5]	[-75.5, 3.5]	[-80, 4]	[-91, 5]
Switch.8	[-64.5, 3.5]	[-76.5, 2.5]	[-84, 6]	[-89, 3]
Switch.9	[-64.5, 4.5]	[-75, 2]	[-80, 2]	[-89, 2]
Switch.10	[-63.5, 2.5]	[-74, 4]	[-81, 3]	[-91.5, 4.5]
Switch.11	[-70, 8]	[-88, 4]	[-92.5, 2.5]	[-94.5, 5.5]
Switch.12	[-71.5, 6.5]	[-89, 6]	[-93, 3]	[-93.5, 3.5]
Switch.13	[-69.5, 3.5]	[-91.5, 5.5]	[-92, 7]	[-93.5, 2.5]
Switch.14	[-69, 3]	[-91, 2]	[-90, 3]	[-93, 4]
Switch.15	[-71, 7]	[-91, 4]	[-90.5, 4.5]	[-93.5, 4.5]
Switch.16	[-69.5, 3.5]	[-90, 2]	[-91.5, 5.5]	[-93.5, 3.5]
Switch.17	[-75.5, 4.5]	[-91, 3]	[-92.5, 3.5]	[-93.5, 2.5]
Switch.18	[-78, 3]	[-90.5, 2.5]	[-92, 5]	[-94, 3]
Switch.19	[-74.5, 4.5]	[-92, 5]	[-91, 3]	[-94, 2]
Switch.20	[-70.5, 3.5]	[-88.5, 2.5]	[-90.5, 2.5]	[-93, 3]

The differences between (Avg & Avg_{new}) and (STD & STD_{new}) of RSS samples of AP1 for 20 times are shown in the two upper views of Figure 1. By summing and subtracting the Avg_{new} and STD_{new} for RSS samples, the RSS_{max} and RSS_{min} are obtained. While, by summing and subtracting the Avg and STD for RSS samples, the RSS_{max} and RSS_{min} are not obtained as shown in Figure 1 in the two lower views and matched with the values RSS_{max} and RSS_{min} in Table 1. Using the Avg_{new} & STD_{new} , the outlier of the range of RSS (RSS_{max} & RSS_{min}) is obtained correctly than using the Avg and STD of RSS samples. Also, the STD_{new} depends on the RSS_{max} & RSS_{min} as shown in Equation 2 but STD depends on the Avg of RSS signals and the value of each RSS signal in the range as shown in Equation 4. So, the Avg_{new} & STD_{new} will be used in the application of this paper.

TABLE4. THE AVG AND STD FOR 10 RSS SAMPLES FOR 20 TIMES AT SWITCHING DEP. POINT

	AP1 [Avg , STD]	AP2 [Avg , STD]	AP3 [Avg , STD]	AP4 [Avg , STD]
Switch.1	[-65.7, 4.1]	[-74.9, 3.4]	[-72.5, 5.7]	[-88.7, 3.3]
Switch.2	[-68.6, 4.4]	[-75, 1.4]	[-80.8, 2.3]	[-88, 3.2]
Switch.3	[-67.9, 3.2]	[-74.2, 2.4]	[-82.9, 3.4]	[-85.1, 1.6]
Switch.4	[-67.9, 4.7]	[-73.1, 2.5]	[-81.7, 2.2]	[-88.2, 3.7]
Switch.5	[-64.8, 4.2]	[-71.5, 3.4]	[-80.6, 1.8]	[-90.9, 4]
Switch.6	[-62.7, 1.3]	[-75.6, 2.6]	[-78.9, 1.4]	[-90.7, 3.1]
Switch.7	[-63.7, 1.3]	[-75.8, 2.9]	[-80.5, 2.8]	[-90, 3.1]
Switch.8	[-64.4, 2.3]	[-76.3, 1.5]	[-82.9, 3.6]	[-89.5, 2.3]
Switch.9	[-65.5, 2.3]	[-74.7, 1.3]	[-79.8, 1.2]	[-88.6, 1.4]
Switch.10	[-63.3, 1.9]	[-74.8, 2.3]	[-81.1, 2.0]	[-91.9, 2.6]
Switch.11	[-69.3, 5]	[-88.2, 2.7]	[-91.4, 1.8]	[-93, 3.3]
Switch.12	[-70.4, 4.8]	[-89.3, 3.5]	[-91.8, 1.6]	[-93.9, 2.4]
Switch.13	[-70.1, 3.1]	[-90.7, 3.9]	[-90.3, 4.0]	[-94.2, 1.7]
Switch.14	[-69.2, 1.8]	[-91.8, 1.3]	[-89.7, 1.8]	[-91.7, 2.6]
Switch.15	[-69.7, 4.6]	[-90.8, 2.5]	[-90, 3.1]	[-93.4, 3.1]
Switch.16	[-69.3, 2.2]	[-88.8, 1.3]	[-91.6, 3.5]	[-93.6, 2.3]
Switch.17	[-74.7, 3.5]	[-91.3, 2.5]	[-93, 2.7]	[-92.9, 1.5]
Switch.18	[-77.6, 2.2]	[-89.2, 1.5]	[-92, 3.1]	[-94.2, 2.3]
Switch.19	[-75.5, 2.8]	[-91.4, 3.1]	[-92, 2.4]	[-94, 1.3]
Switch.20	[-69.3, 2.4]	[-88.3, 1.7]	[-91.2, 1.5]	[-93.3, 2]

**Figure1.** The difference between the Avg_{new} & STD_{new} and the Avg & STD of RSS samples of AP1

Another parameter is used with these two parameters which is a frequency pattern (F.P.) of RSS samples. The RSS F.P. is calculated as follows: the 10 RSS samples from AP1 as shown in Table 1 are:

RSS = (-64,-67,-59,-65,-63,-73,-67,-66,-71,-62);

RSS max = - 59, and RSS min = -73;

The range: $R = -59 - (-73) = 14$;

Assume the width of classes: $W=1$;

The number of classes: $N = R/W = 14$;

The number of elements in the range: $C= N+1=15$;

The RSS elements in the range are arranged as (-73, -72,-71,-70,-69,-68,-67,-66,-65,-64,-63,-62,-61,-60,-59);

The frequency distribution of RSS signal =10; that equals the number of collected RSS signal at a time. The frequency for each RSS element in the range is calculated and the frequency pattern is calculated by adding the values of each column then multiply by the related frequency number except the values under frequency zero are added only to determine the number of absent RSS signals as shown in Table 5. The Frequency Pattern (F.P.) of the above RSS samples is: (68200000000).

It is noted that 6 is the number of absent RSS samples and $8+2=10$ = the number of collected RSS samples and all the patterns for all APs achieved this.

TABLE5. THE FREQUENCY PATTERN FOR 10 RSS SAMPLES OF TABLE1 OF AP1

RSS Values	Frequency										
	0	1	2	3	4	5	6	7	8	9	10
C=15											
-73		1									
-72	1										
-71		1									
-70	1										
-69	1										
-68	1										
-67			1								
-66		1									
-65		1									
-64		1									
-63		1									
-62		1									
-61	1										
-60	1										
-59		1									
(F.P.)	6	8	2	0	0	0	0	0	0	0	0

III. DEVELOPING ANDROID APPLICATION FOR INDOOR LOCALIZATION

The Android application of this paper is based on RSS statistical model that has been formulated in section II and the three parameters that determine each location in testing area are (Avg_{new} , STD_{new} , and F.P.) of RSS samples. Location fingerprinting method is used in this application and based on RSS statistical model of this paper. Location fingerprinting consists of two modes: offline mode which is known as a training mode and online mode which is known as a positioning mode. In this section, building the database in fingerprint offline mode is shown. Also, detecting the correct location in fingerprint online mode is described. The design of the interface of the developed indoor localization application is introduced.

A. Building the Database in Fingerprint offline Mode

To build the fingerprint database of this work, a proposed statistical model that is described in section II is used to calculate the Avg_{new} , STD_{new} , and F.P. for RSS samples that are received from four APs for each testing point. The procedure for building the database in fingerprint offline mode is shown in Figure 2 and implemented by the application of this paper at two different points (point1 & point 2) for testing and the three parameters of RSS model are calculated and stored in the database of smart phone as tables such as Table 6 and Table 7 which are for AP2 at different points. Thus, each point (location) in the testing area is represented by four tables (one table for each AP).

It is noted that, the RSS signals of Table 6 at time 3 and time 7 have the same F.P., Avg_{new} & STD_{new} , and the number of elements ($C=8$) is also the same. Also, The RSS signals of Table 6 at time 5 and of Table 7 at time10 have the same F.P. & STD_{new} and the number of elements ($C=11$) is also the same, but Avg_{new} is different. Also, The RSS signals of Table 6 at time 10 and time11 have the same F.P. & STD_{new} and the number of elements ($C=9$) is also the same, but Avg_{new} is different.

As well as, the RSS signals of Table 6 at time 14 and of Table 7 at time 8 have the same F.P. & STD_{new} and the number of elements ($C=5$) is also the same, but Avg_{new} is different. Another one in Table 6 at time 18 and in Table 7 at time 2 have the same F.P. & STD_{new} and the number of elements ($C=6$) is also the same, but Avg_{new} is different. Also, the RSS signals of Table 7 at time 1 and time 13 have the same F.P. & STD_{new} , and the number of elements ($C=9$) is also the same, but Avg_{new} is different.

As a result, the F.P. & STD_{new} of RSS samples are the same at the same point and at different points; but the Avg_{new} of RSS samples are the same or not at the same point but not the same at different points although the F.P. & STD_{new} of RSS samples are the same. The investigation is done for all four APs and the same results are achieved at different points in testing area. So, these tables must be summarized for differentiating between locations using Avg_{new} , STD_{new} &

TABLE 6. THE F.P, AVG._{NEW} & STD_{NEW} OF AP2 AT POINT1

	Point1: AP2 Frequency Patterns (F.P.)											C	Avg. _{new} /STD _{new}
	0	1	2	3	4	5	6	7	8	9	10		
1	7	5	2	3	0	0	0	0	0	0	0	(14)	(-76.5,6.5)
2	0	2	4	0	4	0	0	0	0	0	0	(5)	(-75,2)
3	2	3	4	3	0	0	0	0	0	0	0	(8)	(-75.5,3.5)
4	4	2	4	0	4	0	0	0	0	0	0	(9)	(-75,4)
5	4	4	6	0	0	0	0	0	0	0	0	(11)	(-73,5)
6	5	3	4	3	0	0	0	0	0	0	0	(11)	(-77,5)
7	2	3	4	3	0	0	0	0	0	0	0	(8)	(-75.5,3.5)
8	0	3	4	3	0	0	0	0	0	0	0	(6)	(-76.5,2.5)
9	0	1	6	3	0	0	0	0	0	0	0	(5)	(-75,2)
10	2	4	6	0	0	0	0	0	0	0	0	(9)	(-74,4)
11	2	4	6	0	0	0	0	0	0	0	0	(9)	(-88,4)
12	5	7	3	0	0	0	0	0	0	0	0	(13)	(-89,6)
13	3	8	2	0	0	0	0	0	0	0	0	(12)	(-91.5,5.5)
14	1	2	0	3	0	5	0	0	0	0	0	(5)	(-91,2)
15	2	5	2	3	0	0	0	0	0	0	0	(9)	(-91,4)
16	1	2	2	0	0	0	6	0	0	0	0	(5)	(-90,2)
17	2	1	6	3	0	0	0	0	0	0	0	(7)	(-91,3)
18	2	1	2	3	4	0	0	0	0	0	0	(6)	(-90.5,2.5)
19	2	8	2	0	0	0	0	0	0	0	0	(11)	(-92,5)
20	1	2	4	0	4	0	0	0	0	0	0	(6)	(-88.5,2.5)

TABLE 7. THE F.P, AVG._{NEW} & STD_{NEW} OF AP2 AT POINT2

	Point2: AP2 Frequency Patterns(F.P.)											C	Avg. _{new} /STD _{new}
	0	1	2	3	4	5	6	7	8	9	10		
1	3	3	4	3	0	0	0	0	0	0	0	(9)	(-86,4)
2	2	1	2	3	4	0	0	0	0	0	0	(6)	(-85.5,2.5)
3	9	4	2	0	4	0	0	0	0	0	0	(15)	(-91,7)
4	1	5	2	3	0	0	0	0	0	0	0	(8)	(-85.5,3.5)
5	4	4	2	0	4	0	0	0	0	0	0	(10)	(-90.5,4.5)
6	6	4	0	6	0	0	0	0	0	0	0	(12)	(-91.5,5.5)
7	4	4	0	6	0	0	0	0	0	0	0	(10)	(-88.5,4.5)
8	1	2	0	3	0	5	0	0	0	0	0	(5)	(-87,2)
9	2	4	2	0	4	0	0	0	0	0	0	(8)	(-87.5,3.5)
10	4	4	6	0	0	0	0	0	0	0	0	(11)	(-87,5)
11	4	6	4	0	0	0	0	0	0	0	0	(12)	(-86.5,5.5)
12	6	4	6	0	0	0	0	0	0	0	0	(13)	(-91,6)
13	3	3	4	3	0	0	0	0	0	0	0	(9)	(-85,4)
14	0	4	6	0	0	0	0	0	0	0	0	(7)	(-86,3)
15	0	1	4	0	0	5	0	0	0	0	0	(4)	(-84.5,1.5)
16	0	2	2	6	0	0	0	0	0	0	0	(5)	(-85,2)
17	1	1	2	3	4	0	0	0	0	0	0	(5)	(-86,2)
18	1	2	8	0	0	0	0	0	0	0	0	(7)	(-85,3)
19	4	3	4	3	0	0	0	0	0	0	0	(10)	(-84.5,4.5)
20	2	6	4	0	0	0	0	0	0	0	0	(10)	(-84.5,4.5)

F.P. of RSS samples. So, another method will be demonstrated to build a new database tables.

1. Scan and select four APs that have the highest RSS signal and store their MAC addresses in the database as one row.
2. Collects 10 RSS samples at the same location from each selected AP.
3. Find the highest RSS value (RSS_{max}) and the lowest RSS value (RSS_{min}) for the 10 RSS samples for each AP that collected in step 2.
4. Calculate Avg_{new} and STD_{new} for the 10 RSS values for each AP using equation 1 and 2.
5. Find the range: $R = RSS_{max} - RSS_{min}$
6. Put the width of classes: $W=1$;
7. Find the number of classes: $N = R/W$; then find the number of elements in the range: $C = N+1$;
8. Select a starting point (RSS_{min}), add the width and rounding up for each RSS samples until (RSS_{max}) and find the frequency for each RSS sample (start from 0 to 10) as shown in Table 5.
9. Calculate the frequency pattern (F.P.) of RSS sample by adding the values of each column then multiply by the related frequency number except the values under frequency zero are added only as shown in Table 5.
10. Store Avg_{new} and STD_{new} , and F.P. in the SQLite database of android smart phone as the radio map for this location for one time.
11. Repeat the above steps at the same location up to 20 times to take the fluctuation of RSS signal into consideration.
12. The above steps are repeated in other points for building a radio map of testing environment.

Figure2. The procedure for calculating the Avg_{new} , STD_{new} and F.P. of the collected RSS samples for building the radio map in fingerprint offline mode

As shown in Table 6 and Table 7, when F.P. starts by zero, it means that all RSS samples of the range are existing and give the lowest STD_{new} , as shown in Table 6 at time 2, the F.P. is: (0240400000), (Avg_{new} , STD_{new}) = (-75, 2) and $C = 5$.

$$Avg_{new} + STD_{new} = -75 + 2 = -73 = RSS_{max}$$

$$Avg_{new} - STD_{new} = -75 - 2 = -77 = RSS_{min}$$

So, the elements of the range are: (-77, -76, -75, -74, -73)

Also, when F.P. starts by the large number such as in Table 6 at time 1, it means that 7 RSS samples are not exist in the range and give hiest STD_{new} , the F.P. is: (7523000000), (Avg_{new} , STD_{new}) = (-76.5, 6.5) and $C = 14$.

$$Avg_{new} + STD_{new} = -76.5 + 6.5 = -70 = RSS_{max}$$

$$Avg_{new} - STD_{new} = -76.5 - 6.5 = -83 = RSS_{min}$$

The elements of the range can not known because 7 elements are not exist, the received elements can be obtained from the database table of AP2 at point 1, the table is similar to Table 1.

The received elements are: (-76, -73, -72, -75, -75, -75, -74, -70, -76, -83); the range is from (-70 to -83). so, the absent elements are: (-71, -77, -78, -79, -80, -81, -82), as a result, the movement of persons is the main issue prevents the RSS samples reach to the smart phone application correctly. Table 6 of AP2 At point1 can be summarized in 4 conditions to simplify the method of searching for correct location as follow:

- 1) $2 < STD_{new} < 6.5$ return +1 (check $Avg_{new} = (-73$ to -92)
 - 2) $STD_{new} = 2$ return 0 (check $Avg_{new} = -75$)
 - 3) $STD_{new} = 6.5$ return 7 (check $Avg_{new} = 76.5$)
- Otherwise such as
- 4) $2 > STD_{new} > 6.5$ return -1 falls and exit

If the procedure of detecting location matched one of the above 3 conditions, it ensures that the location is point 1. Otherwise, it falls and exit to examine another tables. In addition, the returning values can help for reducing the searching process. For example, if the returning value is 0, this makes the searching algorithm look for F.P. starts with zero only and check the Avg_{new} if equals -75 and STD_{new} equals 2, this indicates that is point1. Each table of all APs is summarized in four conditions.

For detecting a location correctly, one of the three conditions that is described above must be achieved for each one of four APs related to its table at the same time for each location. Also, the same notice is shown in Table 7 at time 15, the F.P. is: (01400500000), (Avg_{new} , STD_{new}) = (-84.5, 1.5) and $C = 4$.

$$Avg_{new} + STD_{new} = -84.5 + 1.5 = -83 = RSS_{max}$$

$$Avg_{new} - STD_{new} = -84.5 - 1.5 = -86 = RSS_{min}$$

So, the elements of the range are: (-83, -84, -85, -86)

Also, when F.P. starts by the large number such as at time 3, it means that 9 RSS samples are not exist in the range and give hiest STD_{new} , the F.P. is: (9420400000), (Avg_{new} , STD_{new}) = (-91, 7) and $C = 15$.

$$Avg_{new} + STD_{new} = -91 + 7 = -84 = RSS_{max}$$

$$Avg_{new} - STD_{new} = -91 - 7 = -98 = RSS_{min}$$

The elements of the range can not known because 9 elements are not exist, the received elements can be obtained from the database table of AP2 at point 2, the table is similar to Table 1. The received elements are: (-91, -91, -90, -91, -84, -91, -90, -98, -87, -85); the range is from (-84 to -98). so, the absent elements are: (-86, -88, -89, -92, -93, -94, -95, -96, -97).

So, at each point in testing area, the lowest STD_{new} and the hiest STD_{new} are storing in database for using in differentiat between different points. The calculations are done for many points in the testing area and many tables are constructed but not introduced in this paper due to their big size.

B. Detecting the Correct Location in Fingerprint Online Mode

The correct location can be determined by the application of this paper using the procedure shown in Figure 3. The application of this paper is implemented on smart phone and detects the matched four APs using their MAC addresses in database and the following RSS values are collected from AP2 as an example to show how the procedure of Figure 3 can detect the correct location.

The collected RSS = (-70,-69,-68,-69,-68,-72,-71,-78,-75, -75);

Using the location procedure that is shown in Figure 3;

$RSS_{max} = -68$ and $RSS_{min} = -78$;

The $STD_{new} = -68 - (-78) / 2 = 10/2 = 5$

$R = -68 - (-78) = 10$; $N=10$, $C = N+1 = 11$;

There are 11 elements in the range which are (-78,-77,-76,-75,-74,-73,-72,-71,-70,-69,-68);

The F.P. is calculated as in Table 5 for 10 RSS samples and the result is (4460000000);

Using the searching algorithm for matching this pattern with the tables stored in database, it is found that this pattern is matching with pattern number (5) in Table 6 of point 1 and with pattern number (10) in Table 7 of point 2 and may be matched with other patterns of other points that not introduced in this paper. Add and subtract the Avg_{new} and STD_{new} of that matching patterns.

The result of pattern 5 of Table 6 of point 1 is:

$Avg_{new} + STD_{new} = -73 + 5 = -68$,

$Avg_{new} - STD_{new} = -73 - 5 = -78$,

$[RSS_{max}, RSS_{min}] = [-68, -78]$.

The result of pattern 10 of Table 7 of point 2 is:

$Avg_{new} + STD_{new} = -87 + 5 = -82$,

$Avg_{new} - STD_{new} = -87 - 5 = -92$,

$[RSS_{max}, RSS_{min}] = [-82, -92]$.

It is noted that the location is point 1. If the procedure achieves matching results for other three APs (AP1, AP3, AP4), thus the application returns the location is point1. From the above calculations, it is shown that using the similar patterns for matching reduces the processing time that is wasted when matching is applied on every pattern in database and summing and subtracting every Avg_{new} and STD_{new} for each pattern to calculate RSS_{max} and RSS_{min} which are used for comparing between received signals in online mode.

Also, the four conditions in the above can be using in this case as follows:

The $STD_{new} = -68 - (-78) / 2 = 10/2 = 5$, thus condition 1 is achieved,

- 1) $2 < STD_{new} < 6.5$ return +1 (check $Avg_{new} = (-73$ to $-92)$)

it is found that this is matching with pattern number (5) in Table 6 of point 1 such that $(Avg_{new}, STD_{new}) = (-73, 5)$, thus the location is point 1. The same method is used for AP1, AP3, and AP4 and one of the three conditions must be

achieved related to table of each AP to detect that the location is point1.

1. Scans and selects four APs that have the highest RSS signal and detects their MAC addresses for searching in database until obtaining the MAC addresses of them as stored in offline mode as one row
2. Collects 10 RSS samples from each AP.
3. Calculates The RSS_{max} , RSS_{min} , STD_{new} , and F.P. for the collected 10 RSS samples for each AP.
4. Compare the resulted F.P. that calculated in step 3 with all patterns of these four APs until matching occurs.
5. Select the similar patterns from all four tables of APs of all testing point.
6. Add and subtract the Avg_{new} and STD_{new} of that similar patterns for obtaining RSS_{max} and RSS_{min} respectively as shown in Equation 1 and 2.
7. Compare the obtaining RSS_{max} and RSS_{min} of similar patterns with the RSS_{max} and RSS_{min} determined in step 3.
8. If matching occurred, return the location.
9. If matching not occur, exit and start searching in another table related to another location.
10. To speed the process of matching, one of the four conditions must be achieved related to table of each AP to detect the correct location using the STD_{new} .

- 1) $(STD_{new})_{min} < STD_{new} < (STD_{new})_{max}$ return +1
check $Avg_{new} = (Avg_{new})_{max}$ to $(Avg_{new})_{min}$ related to the value of STD_{new} .
- 2) $STD_{new} = (STD_{new})_{min}$ return 0
check $Avg_{new} = (Avg_{new})_{min}$ related to the value of $(STD_{new})_{min}$
- 3) $STD_{new} = (STD_{new})_{max}$ return the first digit of F.P.
check $Avg_{new} = (Avg_{new})_{max}$ related to the value of $(STD_{new})_{max}$

Otherwise such as

- 4) $(STD_{new})_{min} > STD_{new} > (STD_{new})_{max}$ return -1 falls and exit

Figure 3. The procedure for detecting the correct location in fingerprint online mode

Figure 4 shows the two modes of fingerprint approach of this work and the parameters used in offline mode and in online mode for detecting the correct location. In the fingerprint offline mode, radio map database is constructed by storing the three parameters of RSS model for four APs as a one row $\{[Avg_{new}]_{1:4}, [STD_{new}]_{1:4}, [F.P.]_{1:4}\}$ for each point in the testing area that covered by the four APs related to this area. In fingerprint online mode, the searching algorithm is used for matching the similar RSS F.P. and the related RSS_{max} and RSS_{min} with radio map database as

described above. After the matching occurred, the location name is returned. If there are no similar patterns, the application finds the matching pattern directly in any table in database such as the unmarked patterns in Table 6 and 7. The calculations are done for all points in the testing area and many tables are constructed but not introduced in this paper due to their big size. As a result, the RSS signal cannot be represented by distribution function such as Gaussian distribution as in [22].

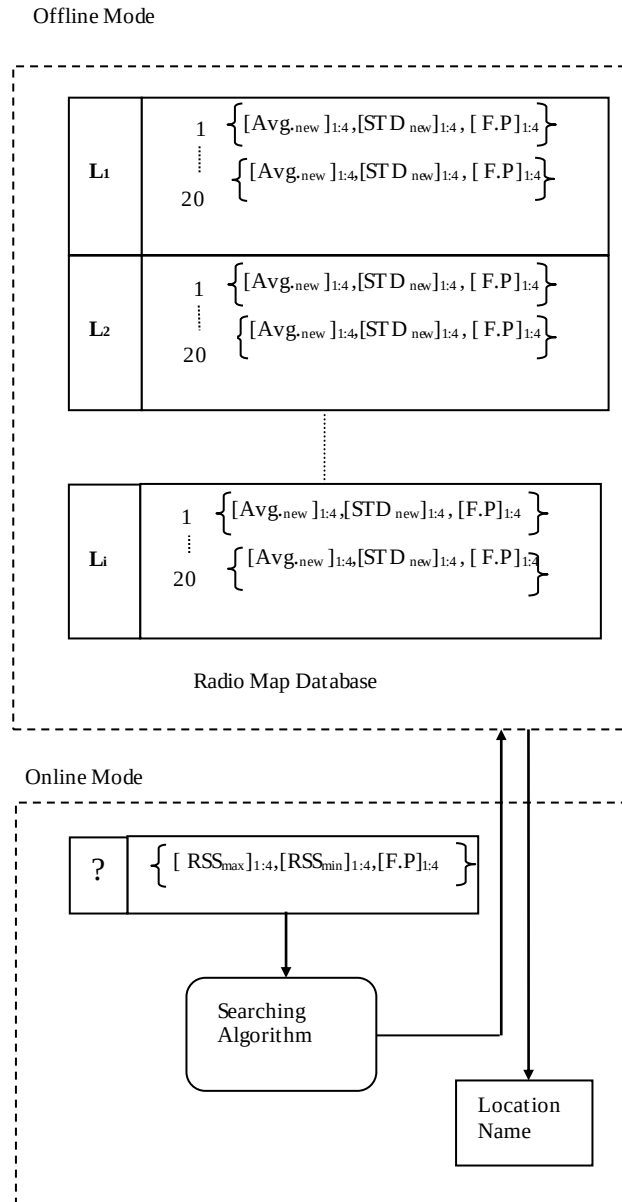


Figure 4. Fingerprinting offline mode and online mode of application

IV. DESIGNING ANDROID ID APPLICATION INTERFACE FOR INDOOR LOCALIZATION

In this paper, an Android application is developed for indoor localization using Android Studio 2.3.3 and works on a smart phone (tablet Samsung GT-P5200, Android 4.2.2 Kitkat) to collect data. The application uses the existing infrastructure of WLAN APs without the need of knowing the places of APs. At each testing point, fingerprint offline mode is used to establish fingerprint database which is saved in smart phone instead of using a separate server. Figure 5 shows the interface of the Android application when collecting data. The upper part in the left side is used to input the name of the testing point such as Switching 1. Store offer is used to input the offer that is provided by the stores when using this application in Malls and this offer appears to the user when he is passing beside the store. The MAC addresses of the four APs that have highest RSS values are obtained by application as shown in Figure 5.

ADDSTORE button is used to collect the RSS values from the four access points which will be used by RSS statistical model to calculate the F.P., Avg.new and the STDnew and then store them in the fingerprint database in the smart phone's memory. STARTMONITOR button is used to acquire the position. STOPMONITOR is used to stop monitor. The person who carries the smart phone can click on STARTMONITOR button of application on smart phone for detecting his correct location.

Using the application of this work for testing the model, The four Avg.new and STDnew of the four APs with their RSS frequency patterns must be achieved to detect that is the correct location, the result that is shown in Figure 6 shows the correct location is Switching2, and Figure 7 shows the correct location is Switching3 that are related to testing point Switching

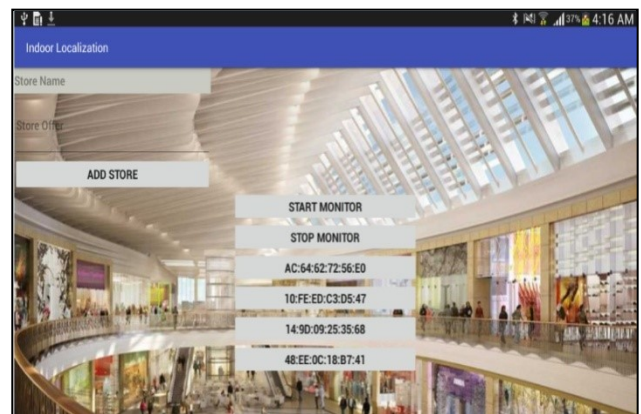


Figure 5. Screenshot of Indoor Localization Application Interface

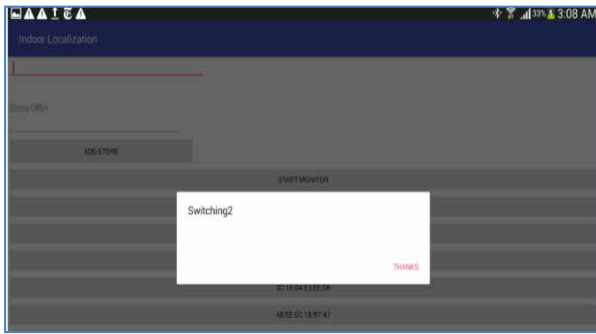


Figure 6. The correct location is Switching2

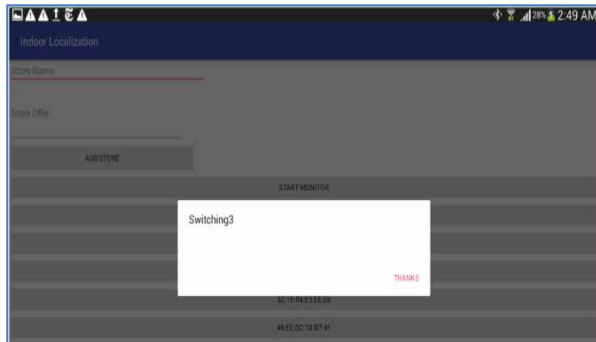


Figure7. The correct location is Switching3

V. PERFORMANCE EVALUATION OF THE PROPOSED MODEL AND APPLICATION

The main problem faced the implementation of this work and caused interfering between adjacent locations in fingerprint online mode is aliasing. Aliasing means, that there are several distinct locations receiving the same signal strength of an AP, this is due to variations in the signal strength caused by obstacles, although the two locations are not in the same distance to the AP. This was a difficult problem to be avoided because the place of APs used in this work is not be known and the movement of people is changing randomly with the constant of obstacles of the building such as walls. In the future work, the effect of using more APs will be studied well such that the aliasing problem may be solved by increasing the number of APs.

Due to the aliasing problem, when testing the application at one location gives another location when the distance between the two locations is taken in fingerprint offline mode equals to 4 meters. and when extended the distance between the two locations to 5 meters, the probability of the interfering between locations is reduced. The following screenshots of the results show this problem.

The experiment is done in 4 locations in City Center MALL which are (Ravin, Max, Carina stores and Einstein coffee) using the four APs that are shown in Figure 8. The objective of this experiment is detecting the similarity of RSS signals of the AP at different locations which causes the obtaining of incorrect locations.

LM-Retail(fc:0a:81:32:ee:40)	Happiness(fc:0a:81:32:ee:46)	Wooqer(fc:0a:81:32:ee:42)	LM-Retail(fc:0a:81:33:0d:70)
-84	-82	-84	-91
-82	-81	-80	-87
-77	-77	-78	-88
-83	-83	-83	-86
-83	-82	-83	-89
-84	-85	-87	-89
-78	-77	-80	-87
-82	-82	-85	-89
-86	-84	-87	-87
-84	-86	-84	-92

Figure 8. Screenshot of the captured RSS samples from four APs as stored in smart phone database in offline mode

At the store named Ravin as shown in Figure 9, the application detects that there are three RSS records in the Einstein coffee database table matched with the online measurements at Ravine store location. So the result is Einstein because the RSS signal is changed due to the movement of people at that time of measurement and the received RSS signal values for the four APs are found in Einstein coffee database table not in Ravin store table. This testing is done with leave about 4 meters between stores and coffee at offline mode. Also, Figure 10 shows the interfering between Einstein coffee and Max & Ravin stores. As well as, Figure 11 shows the interfering between Einstein coffee and Max stores.

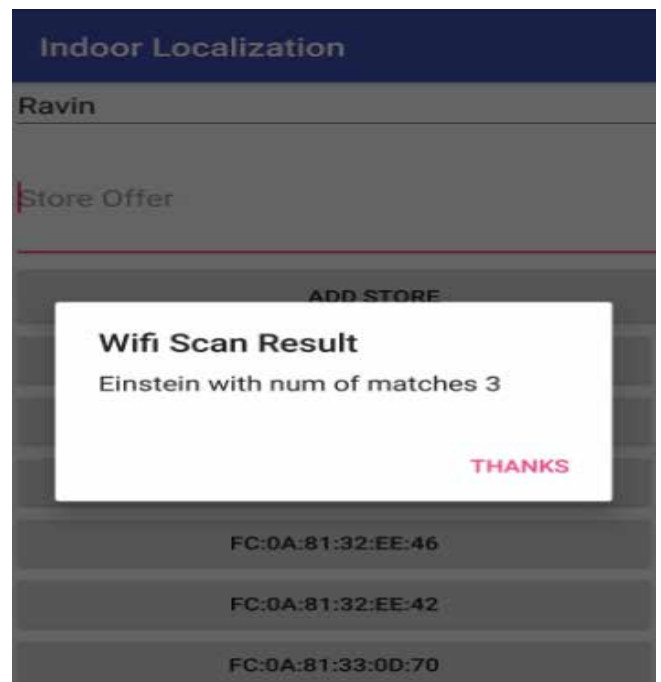


Figure 9. Online mode Screenshot of the matched RSS samples with four meters between locations

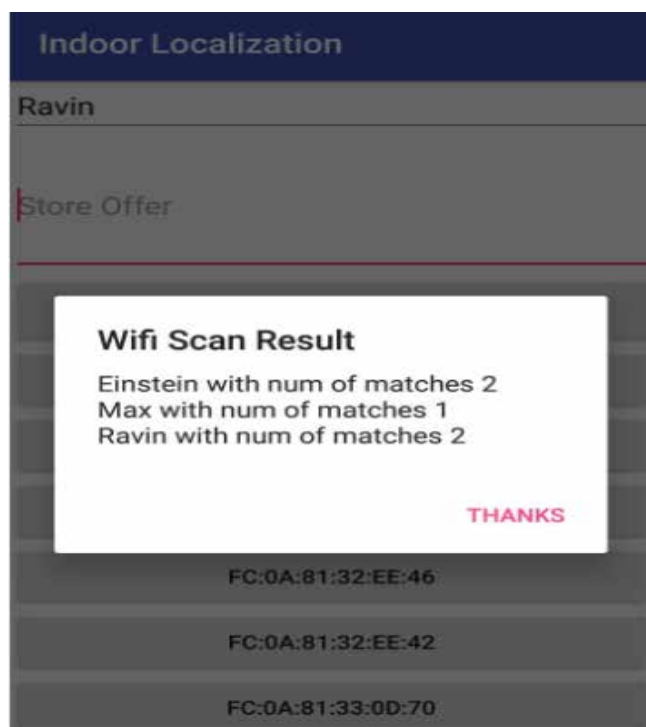


Figure 10. Online mode Screenshot of the matched RSS samples with four meters between locations

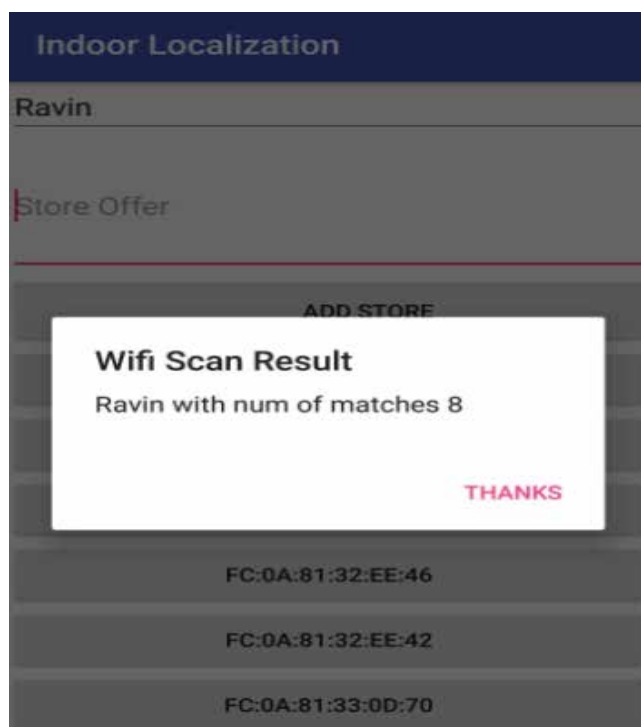


Figure 12. Online mode Screenshot of the matched RSS samples with five meters between locations

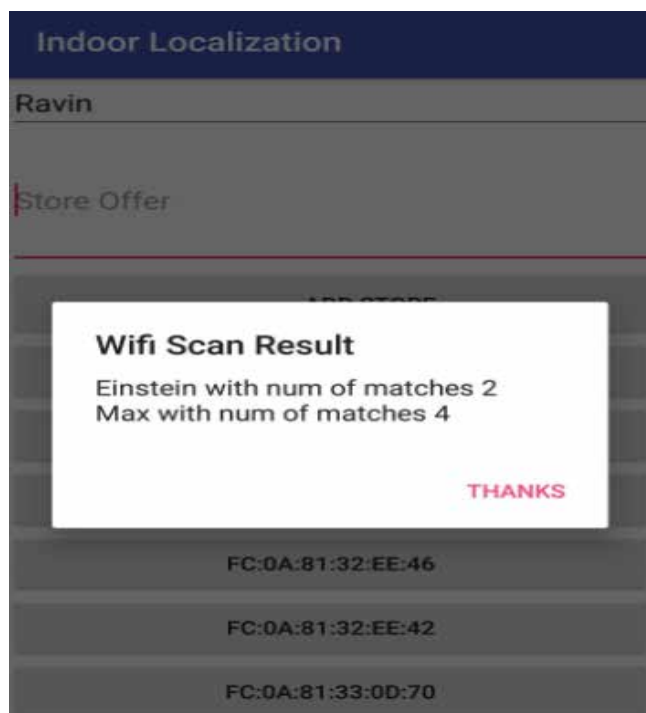


Figure 11. Online mode Screenshot of the matched RSS samples with four meters between locations

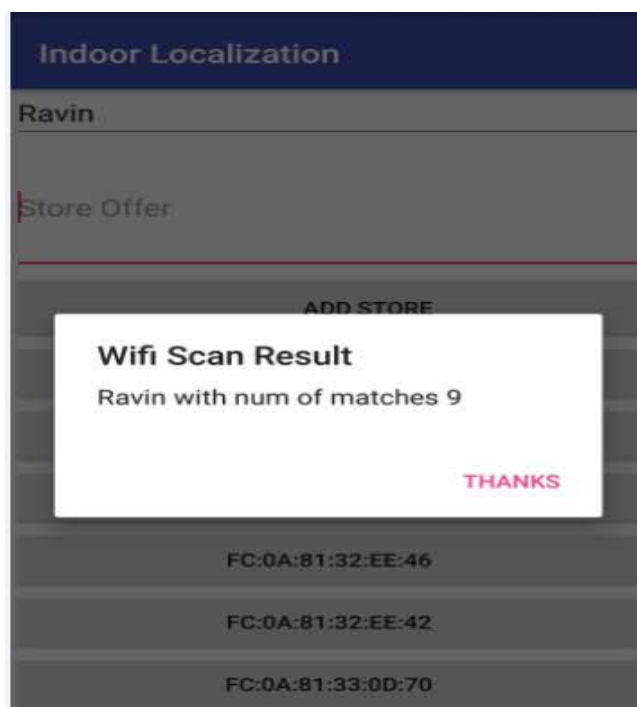


Figure 13. Online mode Screenshot of the matched RSS samples with five meters between locations

As shown in Figure 12 and in Figure 13, the number of matched records in Rabin table increases for the correct location (Rabin) when the distance between locations increased to five meters. It is noted that during the implementation of application, the increasing in distance between adjacent locations to 5 meters gives more accurate location than four meters. Also, the performance of the proposed application can be evaluated by calculating the installation costs. The installation costs of such localization system are considered very low because the Wireless LAN infrastructure is already installed. Although the proposed application is running on smart phone and the training data is stored on database of it, in the case of complete this system to be ready to implement in the MALL, a server is needed to provide the application for the clients. The server capabilities depend on the number of served clients and must be dedicated for localization only to achieve the needed performance.

As well as, the performance of the proposed application can be evaluated by comparing with other system or research. Due to the lack of standard in this field and most of researchers use different methods to develop indoor applications, the comparison is very difficult. The properties of RSS that obtained from the investigation of the proposed model and application of this work can be compared with the properties of RSS modeling for WLAN location fingerprint in [22] as shown in Table 8.

TABLE 8. COMPARISON BETWEEN RSS MODELING OF [22] AND RSS MODELING OF THIS PAPER

	RSS Modeling of [22]	RSS Modeling of this paper
Modeling Type	Fingerprint modeling	Fingerprint modeling
Average	Mean	Mid-range
Standard Deviation	STD	STD _{new}
Number of AP	3 APs	4 APs
Accuracy (the distance between two locations)	5.5 meters	4-5 meters
APs location	Known location	Unknown Location
Infrastructure Cost	Setup Cost: laptop computer equipped with an Orinoco WLAN card and client manager software.	No setup Cost: Android Studio 2.3.3 works on a smart phone (tablet Samsung GT-P5200, Android 4.2.2 Kitkat)

As shown in Table 8, the accuracy of the proposed system (5 meters) is higher than the accuracy of system of [22] that is (5.5 meters). Also, using of STD_{new} is very simple in computation than STD that makes the obtaining of the correct location faster.

As well as, the performance of the proposed application can be evaluated by comparing with other system such as Ekahau [23]. It was created to supplement GPS indoors in 2002, since GPS signals are not visible inside buildings. The system is a software-based solution, so it can be used with existing wireless systems, of course by optimizing the deployment of the access points. An average error of 1.5 meters is achieved by having three APs in a 640 square meters site, 4 meters distance between sample points for measuring fingerprint data and 1.5 seconds scan interval. It can reach 1 meter accuracy by using 7 APs.

TABLE 9. COMPARISON BETWEEN EKAHAU SYSTEM AND RSS MODELING OF THIS PAPER

	EKAHAU SYSTEM	RSS Modeling of this paper
Modeling Type	Fingerprint modeling and Bayesian	Fingerprint modeling
Average	Median	Mid-range
Standard Deviation	STD	STD _{new}
Number of AP	3 APs	4 APs
Accuracy (the distance between two locations)	4 meters	4-5 meters
APs location	Known location	Unknown Location
Infrastructure Cost	Setup Cost: Implementing a specific Wi-fi Network for Ekahau system	No setup Cost: Android Studio 2.3.3 works on a smart phone (tablet Samsung GT-P5200, Android 4.2.2 Kitkat)

VII. CONCLUSIONS

In this paper, Android application based on a new RSS model and fingerprinting is developed. The RSS midrange and a range which depending on RSS_{max} and RSS_{min} are used for constructing the RSS model instead of using a traditional mean and standard deviation which depending on the Avg. of RSS samples and the value of each sample in RSS set.

In addition, the F.P. & STD_{new} of RSS samples are the same at the same point and at different points; but the Avg._{new} of RSS samples are the same or not at the same point but not the same at different points although the F.P. & STD_{new} of RSS samples are the same, this helps in differentiating between

points and obtaining an accurate location. Thus, the RSS samples cannot be represented by distribution function such as Gaussian distribution due to the similarity of RSS F.P. in different points. But this similarity in RSS F.P. helps in searching in database by reducing the searching time for obtaining the correct location because the processing for calculation the range of RSS samples is done on the similar patterns only. Although the midrange is not popular as the mean, it achieves best statistical description of RSS signals in indoor environment. The application of this paper is tested in City Center Mall in Nasr City, Cairo, Egypt, and the result of testing gives the location name correctly except some locations are not determined well.

As well as, the distance between adjacent locations is adjusted to five meters instead of four meters which improves the accuracy of the proposed application and reduces the effect of the aliasing problem. The comparison is done with other indoor localization research and with Ekahau system. The results of the comparison can be used by other researchers as a guide for improving the indoor localization system. The using of smart phone for indoor localization provides more possibilities as well as simplify the implementation and facilitate the deployment. More measurements and tests required for overcome the limitations of the proposed model and will be addressed in the future work.

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