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# Performance Evaluation of Ekahau RTLS in Indoor Environments

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***Abstract:*** *The poor performance of global positioning system (GPS) in indoor environments has increased the demand for location based services (LBS) which is growing exponentially. This research work will look at the performance of Ekahau Real Time Location System (RTLS) an indoor positioning system, which is a software-based solution for tracking assets in real time. This work is carried out in different environments to evaluate the performance of Ekahau RTLS. The different experiments are clearly explained and the Experimental results indicate that Ekahau RTLS can achieve 3-5 metres of accuracy in a properly calibrated model. A comparative analysis carried out from the different test environments with different conditions shows that performance of Ekahau RTLS depends on density and placement of access points, quality of site survey and the nature of the experimental environment.*

***Keywords –*** *Ekahau, Real Time Location System, WLAN, RSSI*

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## I. Introduction

Indoor positioning systems have gained popularity over the years, which has led to the development of a large number of location aware services available commercially and for research purposes [1], [2]. The research on indoor positioning systems has grown tremendously as a result of the poor performance of GPS in indoor environments [3-5].

Wireless indoor positioning systems have been very successful in numerous applications. In hospitals, it can be used for asset tracking, patient and staff tracking and workflow [6, 7]. This system also finds immense application in areas like industries, commercial, public safety, daily life and military warfare [8, 9].

The combination of Wi-Fi and RTLS enables tracking of objects or people in real time. Angelo Lamme and Marcus Birkl of Motorola and Siemens are of the opinion that tracking of asset or people is one of the biggest incentives for hospitals, educational systems and companies to roll out Wi-Fi networks [1]. At this time is possible to state that Wi-Fi wireless local area network (WLAN) technology is feasible to provide localization, its main advantage is being a common technology that is provided almost everywhere nowadays [5] and [9]. But some of the shortcomings here affecting the application of this technology in location tracking include multipath effects which may reduce signal strength in indoor scenario.

RTLS has been in existence in some form for over 40 years. It is a method of automatically identifying an asset that is, a person/object by storing and remotely retrieving information from small transponders called RTLS tags. These tags have an antenna built into them that allows transmission and reception of radio waves from an RTLS transceiver [8]. Traditional radio-frequency identification (RFID) use tags, readers, middleware and servers to deploy indoor tracking, but Ekahau does not require readers and can be adjusted to support tens of thousands of tags on a single server. Ekahau RTLS as a commercial positioning system uses existing WLANs and tracks devices where tags are mounted on [2]. Wi-Fi based indoor location system has shown to be both cost-effective since it makes use of existing WLAN infrastructure and is accurate, since they can attain metre-level positioning accuracy. This experimental research will look at the Ekahau RTLS which is a Wi-Fi based location is a tracking system that operates at room, sub-room and building level with accuracy and its performance in different test beds and conditions. The other parts of this work will be divided into sections. Section II will provide a review of some previous work. Section III will focus on experimental methods and design where different test beds, design considerations and experiments in all the test beds will be presented. Sections IV and V provide discussions of experimental results and conclusion respectively.

## II. Review of Previous Work

Although not so much research have been carried out in this area, the few ones performed so far shows that location tracking in indoor environments using Ekahau RTLS is better when compared to other platforms considering certain factors such as a platform of deployment, cost, and accuracy and so on.

One of such work in recent time is [6] where Ekahau RTLS is said to employ a Multi-hypotheses tracking algorithm form of probabilistic algorithm for calculating the location of the device. Furthermore, [4] proposed a History Aware Based Indoor Tracking System (HABITS) which models human movement patterns. This system uses discrete Bayesian filter to calculate the areas that will, or will not, be visited in the future and can be integrated with locating system for example Ekahau RTLS in this case. The result shows that this method improves on the standard Ekahau RTLS in term of accuracy, latency (giving position fixes when Ekahau cannot), reduces cost since a few access points are needed, unlike what is recommended by Ekahau Inc. and can enhance for intelligent prediction since it also employ artificial intelligence.

## III. Experimental Methods/ Design

Three locations chosen for the experiments were all located in the Ellison Building of Northumbria University. The first test bed is the D002 Laboratory located in the D block of Ellison Building. This test area had a little human presence when the experiment was conducted. The Laboratory is normally used for lectures and for private studies, It contains tables, chairs, computers, a white board, two filing cabinets, game stations, scanners and an anechoic chamber. The rectangular test area measures 118.85msq. The second test bed is the DOO3 Laboratory located in the D block of Ellison building. This test environment is also used for lectures and private study and is fully equipped with computers, desks, chairs, 8 filing cabinets and about 11 stand-alone 6inches rack each with about 6 routers and switches mounted which indicates the presence of heavy metallic objects which is a challenging environment for the propagation of RF. The test environment is approximately 267msq.

The last test bed consists of the corridor beside D002 and D003 laboratory and the lobby close to the school of Computing, Engineering and Information Sciences (CEIS) Academic Office down to the exit corridors of the Ellison building at Northumbria University. The test environment is an open area and the experiments were conducted at night when human traffic was less dense.

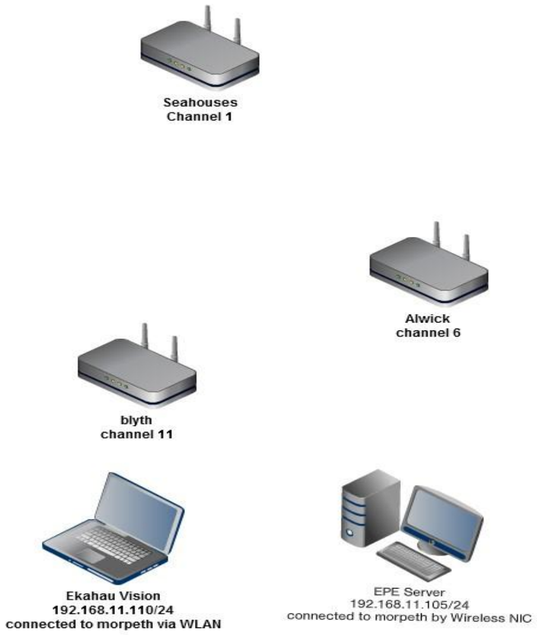


**Fig 1**. WLAN Network infrastructure for experiments

### *A. Design Considerations*

The main reason for the use of non-overlapping channels (1, 6 and 11) are to avoid excessive co-channel interference on the network, however channel assignment does not does not have an effect on the accuracy of RTLS and an alternative design would have been leaving the APs to be dynamic (auto channel). The RTLS requires a dedicated service set identifier (SSID) to enable the tag to communicate with Ekahau's positioning engine (EPE). The SSID Morpeth is used to associate and establish connection between the T301 tag, the EPE server and the Ekahau Vision. The Morpeth access point (AP) is placed in an area that covers the test environment for each of the experiments.

### *B. Experiments in Test beds I*

In Test bed I, the seven different experiments conducted shows that in offline calibration, for experiment I, a site survey is carried out with a positioning model created from floor map of D002. Rails and zones are defined properly on the map. During the calibration, the same orientation is maintained throughout the survey and all the access points are selected on the map to calculate the location estimate. A test survey is carried out with the T301 tag and the map is then saved to the positioning engine. In experiment II, only access points considered as my APs during the survey are selected (Morpeth, Blyth, Alwick, Gorsforth and Seahouses). In experiment III, three APs are used. The three APs are Morpeth, Blyth and Gosforth. Experiment IV uses the same positioning model in experiment I with only one AP (Morpeth) which is associated with the tag.

In Experiment V, no rails or open spaces are defined on the positioning model; no RTLS feature is used to determine positioning accuracy. The positioning model used here is the same as the one used for the experiment I. In experiment VI, a new positioning model is developed from the map of the test area, the positioning model is not calibrated properly to cover the rails drawn on the map and the orientation of the laptop used for the site survey is changed at regular intervals.

In experiment VII, the positioning model developed in experiment II is used, but the physical locations of the APs in the test area are changed from the locations reflected on the map.

In the online phase of all the experiments above, T301A tag is placed on five different points in the test area. For each of the locations, the tag is left for a period of 10 minutes. The RSS for each location of the tag are recorded after periodic and button scans from the tag and the EPE automatically alerts the Ekahau vision of the tag location on the map.

### *C. Experiments in Test Bed II*

In Test bed II, the seven different experiments conducted shows that in the first experiment, an intense calibration is carried out after a positioning model has been created for the second test environment which is the DOO3 laboratory. Tracking rails are properly defined and the calibration is carried out using the same orientation for the whole site survey. The presence of stand-alone network racks and computer desk has limited the survey locations in the test environment; however the calibration has covered all the area on the map. All APs identified on the radio map are enabled on the map after the walk around and the positioning model developed is saved to the EPE for location estimation. In experiment II, only My APs enabled using the same positioning model and procedure as in experiment I. In experiment III, only three APs which include Morpeth, Blyth and Gosforth and are part of My APs are selected. In experiment IV, the SSID (Morpeth) associated with the tag is the only AP in the network infrastructure used in the experiment; however, other APs which are not part of our network infrastructure are also enabled for the location estimation. In experiment V, the positioning model developed in experiment I is used. Tracking rails and open spaces are not defined in the model. The positioning model with no RTLS feature is saved to the engine for location estimation. In experiment VI, a new positioning model is developed from the floor plan of the test area. Calibration performed is not as intense as they walk around in experiment I. The orientation of the laptop used during the site survey is changed occasionally. A test tracking is carried out with the tag and the new positioning model is saved to the EPE. In experiment VII, the positioning model developed in experiment II is used, but the physical locations of the APs in the test area are changed from the locations reflected on the map. The tag is then placed on same locations used in all the experiments to view the accuracy of the tag in these locations.

In the online Phase, the T301A tag is placed on 5 points on the map, 1 to 2 on the far ends on D003 north, 2 on the south and one point on the central passage of the test area for all experiments. RSS values from periodic scan updates from the tag are recorded for each point followed by the tag location on the map.

### *D. Experiments in Test Bed III*

In this case, only two experiments are performed. In the offline phase, for the experiment I, a positioning model is developed for the test bed using the floor map. In this experiment, only a single AP (Morpeth) is enabled from the existing APs in the network infrastructure but other APs that are not part of the network are enabled in the positioning model. The AP Morpeth is placed in a central point that is within the communication range of the tag. A site survey is carried out in the test environment and tracking rails and open spaces are defined properly on the positioning model.

The positioning model developed in Experiment I was also used for experiment II with no tracking rails defined in the model. A test survey is carried out and the positioning model is exported to the EPE for location estimation.

In the online phase for the two experiments, the tag is placed on five points which include the lobby area, the wheelchair area, enquiry desk in the CEIS office, staircase leading to block D211 and the corridor leading to D003.The RSS values and the tag locations are recorded after periodic scans in each location.

## IV. Results and Discussion

This section is to be discussed under the subsections.

### *E. Test Bed I*

Shown in fig.1 in the offline phase is the signal strength quality of a radio map of the test environment (D002) after the survey was performed.

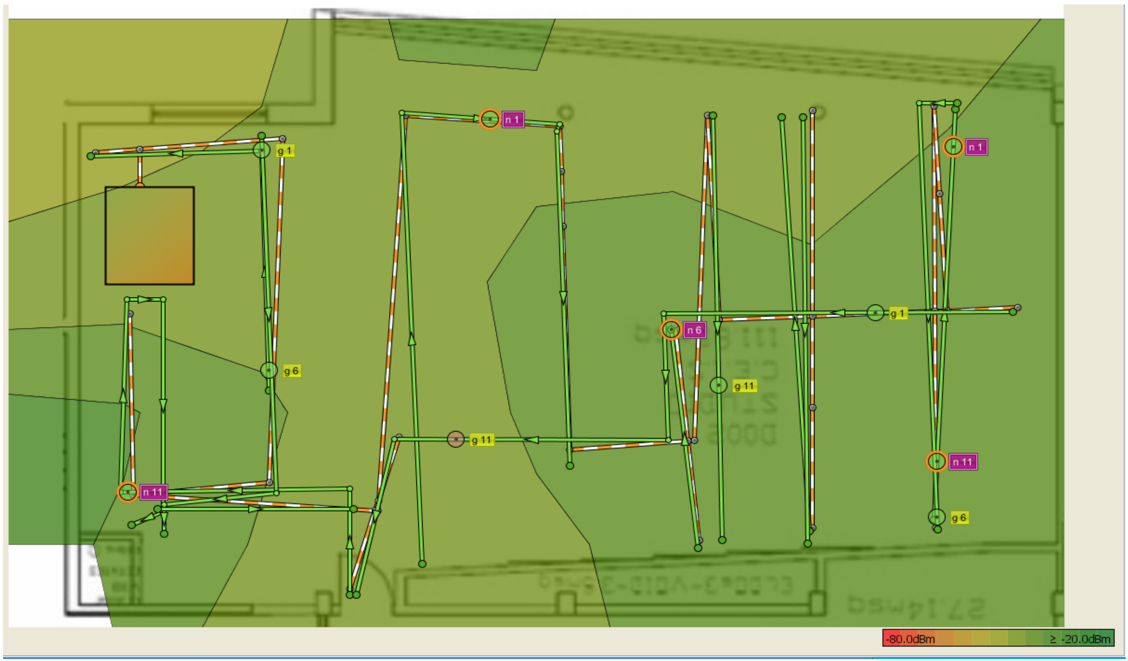


Fig 2. Signal strength of test bed I

The purple points on the model are the APs used for the experiment while the yellow points are other APs identified on the radio map during the survey. During the survey, the recorded RSSI data about the test environment varied from -85dbm to -35dbm which indicates that the overall signal strength of the calibrated map was good.

All active measurements of RSSI data from the APs and tag locations were recorded during the online phase as shown in fig. 3.

It is observed that the recorded RSSI data and APs on the map in Fig 2 indicated with yellow are not part of the network infrastructure and this proves that Ekahau RTLS can make use of existing network infrastructure without directly connecting to the tag. The AP bindings indicate the APs that have been configured with multiple SSIDs. The EPE detects the mac-addresses and identifies them as AP bindings. The tag location was sent to the Ekahau vision to show the location of the tag on the map after the periodic scan. The tag location is shown in Fig 4 below

| Access Points (20) | RSSI | AP Bindings / Warnings |
|---|---|---|
| 68:7F:74:5C:4B:D7 | -37 (ch 11) | - |
| 00:17:0E:AA:A7:A4 | -44 (ch 1) | 5 bound MAC addresses. |
| 00:17:0E:AA:A7:A0 | -45 (ch 1) | 5 bound MAC addresses. |
| 68:7F:74:5C:4D:7F | -47 (ch 1) | - |
| 68:7F:74:5C:4D:69 | -49 (ch 6) | - |
| 00:24:C4:AE:EC:B6 | -55 (ch 6) | 5 bound MAC addresses. |
| 00:24:C4:AE:EC:B4 | -56 (ch 6) | 5 bound MAC addresses. |
| 00:24:C4:AE:EC:B0 | -56 (ch 6) | 5 bound MAC addresses. |
| 68:7F:74:5C:4D:73 | -56 (ch 11) | - |
| 00:24:C4:2E:A6:65 | -58 (ch 11) | 5 bound MAC addresses. |
| 00:24:C4:2E:A6:63 | -60 (ch 11) | 5 bound MAC addresses. |
| 00:24:C4:2E:A6:61 | -60 (ch 11) | 5 bound MAC addresses. |
| 68:7F:74:5C:4B:CA | -65 (ch 1) | - |
| 00:17:0E:D9:B3:F0 | -71 (ch 1) | 5 bound MAC addresses. |
| 00:17:0E:D9:B3:F4 | -72 (ch 1) | 5 bound MAC addresses. |
| 00:17:0E:D9:A6:25 | -72 (ch 6) | 5 bound MAC addresses. |
| 00:17:5A:10:8D:B6 | -72 (ch 6) | 5 bound MAC addresses. |
| 00:17:0E:D9:A6:26 | -72 (ch 6) | 5 bound MAC addresses. |

Fig 3. RSSI Data for location I

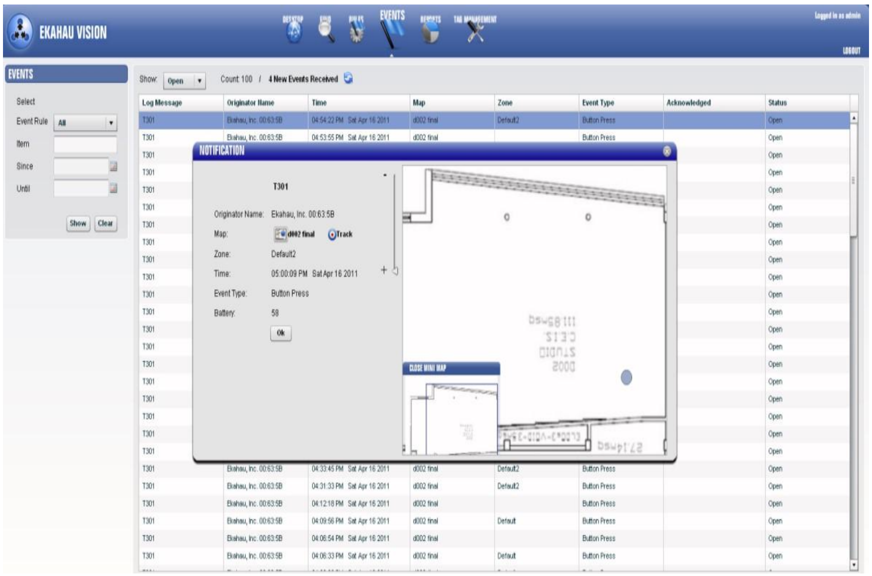


Fig 4. Location 1 of tag on the map experiment I test bed I

Tables 1 through 7 show the positioning accuracy of the tag at different locations in relation to the actual position for test beds I.

**TABLE I. TAG LOCATION RESULTS FOR EXPERIMENT I IN TEST BED I**

| Tag Locations | Accuracy relative to actual location |
|---|---|
| Location 1 | Accurate, less than 1 metre of error |
| Location 2 | Accurate |
| Location 3 | Accurate |
| Location 4 | Accurate, less than 1 metre of error |
| Location 5 | Very accurate. |

**TABLE II. TAG LOCATION RESULTS FOR EXPERIMENT II IN TEST BED I**

| Tag Location | Accuracy relative to actual location |
|---|---|
| Location 1 | Accurate |
| Location 2 | About 2 metres of error |
| Location 3 | Accurate 1 metre error |
| Location 4 | Accurate |
| Location 5 | Very accurate. |

**TABLE III. TAG LOCATION RESULTS FOR EXPERIMENT III IN TEST BED I**

| Tag Location | Accuracy relative to actual location |
|---|---|
| Location 1 | About 3 metres error |
| Location 2 | About 3 metres of error |
| Location 3 | Accurate about 1-2 metres of error |
| Location 4 | About 6metres |
| Location 5 | 4 metres of error |

**TABLE IV. TAG LOCATION RESULTS FOR EXPERIMENT IV IN TEST BED I**

| Tag Location | Accuracy relative to actual location |
|---|---|
| Location 1 | Accurate, less than 1 metre of error |
| Location 2 | 2 metres error |
| Location 3 | 3 metres error |
| Location 4 | 6 metres of error |
| Location 5 | Accurate |

**TABLE V. TAG LOCATION RESULTS FOR EXPERIMENT V IN TEST BED I**

| Tag Location | Accuracy relative to actual location |
|---|---|
| Location 1 | More than 7 metres of error |
| Location 2 | 2 metres error |
| Location 3 | 4 metres error |
| Location 4 | 2 metres of error |
| Location 5 | Accurate |

**TABLE VI. TAG LOCATION RESULTS FOR EXPERIMENT VI IN TEST BED I**

| Tag Location | Accuracy relative to actual location |
|---|---|
| Location 1 | About than 5 metre of error |
| Location 2 | Up to 5 metres error |
| Location 3 | Up to 3 metres error |
| Location 4 | 5 metres error |
| Location 5 | Up to 7 metres error |

**TABLE VII. TAG LOCATION RESULTS FOR EXPERIMENT VII IN TEST BED I**

| Tag Location | Accuracy relative to actual location |
|---|---|
| Location 1 | About 6 metre of error |
| Location 2 | Up to 5 metres error |
| Location 3 | Up to 5 metres error |
| Location 4 | 5 metres error |
| Location 5 | Up to 7 metres error |

***F. Test Bed II***

The radio map below is made up of all the APs in this test environment. The purple points on the map show the locations of My APs while the yellow points indicate other APs in the test bed which are not physically located in the test area. The RSSI from the APs on the map after the calibration phase varied from -90dBm to -30dBm.

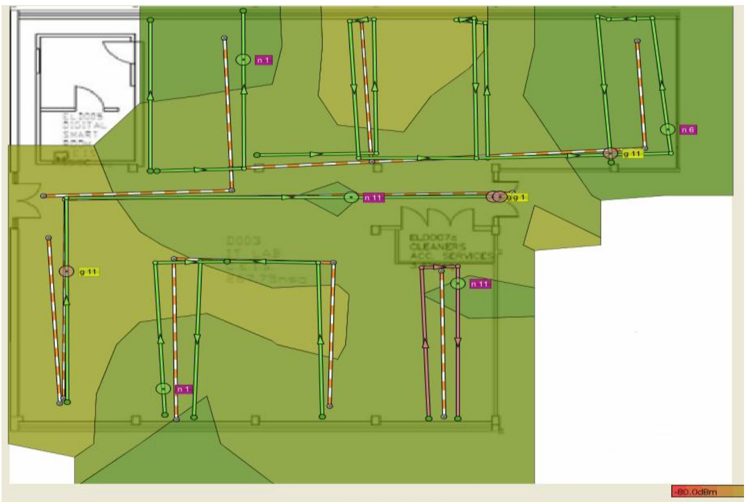

Fig 5. Signal strength of All APs in test bed II

**TABLE VIII. TAG LOCATION RESULTS FOR EXPERIMENT I IN TEST BED II**

| Tag Location | Accuracy relative to actual location |
|---|---|
| Location 1 | About 2 metres of error |
| Location 2 | 2 metres error |
| Location 3 | Accurate |
| Location 4 | Accurate |
| Location 5 | Accurate |

**TABLE IX. TAG LOCATION RESULTS FOR EXPERIMENT II IN TEST BED II**

| Tag Location | Accuracy relative to actual location |
|---|---|
| Location 1 | About 3 metres of error |
| Location 2 | About 5 metres error |
| Location 3 | Accurate |
| Location 4 | Accurate |
| Location 5 | Accurate |

**TABLE X. TAG LOCATION RESULTS FOR EXPERIMENT III IN TEST BED II**

| Tag Location | Accuracy relative to actual location |
|---|---|
| Location 1 | About 3 metres of error |
| Location 2 | About 3 metres error |
| Location 3 | About 3 metres of error |
| Location 4 | About 6 metres of error |
| Location 5 | About 3 metres of error |

**TABLE XI. TAG LOCATION RESULTS FOR EXPERIMENT IV IN TEST BED II**

| Tag Location | Accuracy relative to actual location |
|---|---|
| Location 1 | About 2 metres of error |
| Location 2 | About 8 metres error |
| Location 3 | About 6 metres of error |
| Location 4 | 3 metres error |
| Location 5 | About 5 metres error |

**TABLE XII. TAG LOCATION RESULTS FOR EXPERIMENT V IN TEST BED II**

| Tag Location | Accuracy relative to actual location |
|---|---|
| Location 1 | About 2 metres of error |
| Location 2 | About 3 metres error |
| Location 3 | About 7 metres of error |
| Location 4 | About 6 metres of error |
| Location 5 | About 4 metres of error |

**TABLE XIII. TAG LOCATION RESULTS FOR EXPERIMENT VI IN TEST BED II**

| Tag Location | Accuracy relative to actual location |
|---|---|
| Location 1 | About than 5 metre of error |
| Location 2 | Accurate |
| Location 3 | Up to 3 metres error |
| Location 4 | 5 metres error |
| Location 5 | Up to 7 metres error |

**TABLE XIV. TAG LOCATION RESULTS FOR EXPERIMENT VII IN TEST BED II**

| Tag Location | Accuracy relative to actual location |
|---|---|
| Location 1 | About 8 metres of error |
| Location 2 | Up to 6 metres error |
| Location 3 | Up to 5 metres error |
| Location 4 | Up to 8 metres error |
| Location 5 | Up to 7 metres error |

### G. Test Bed III

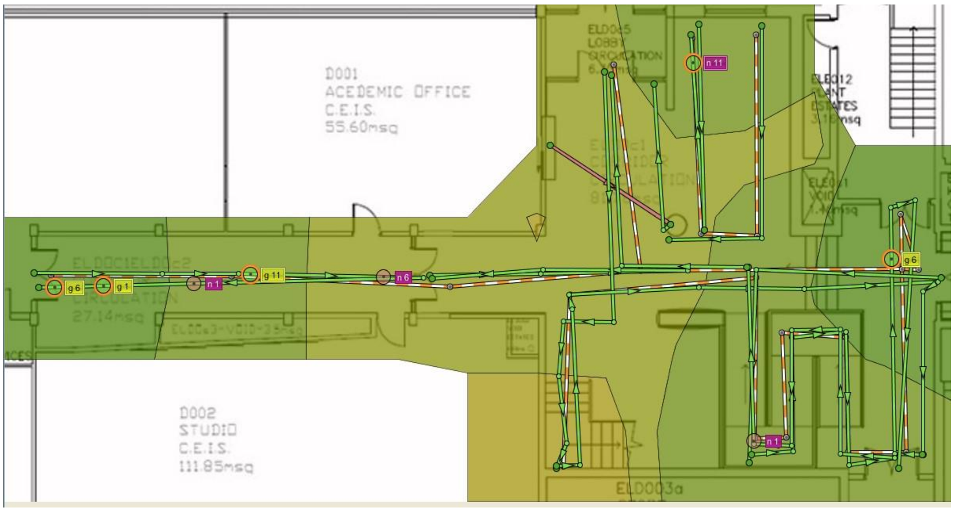


Fig 6. Signal strength of the positioning model of experiment I test bed III

The quality of the signal strength observed from the positioning model above shows that a major part of the test environment has a poor signal strength which is as a result of the learned position of the APs of recorded RSSI data during the survey. This experiment shows the effect of the poor positioning model. Another effect of the poorly calibrated model is seen in the calibration quality of the test area shown in Fig 6.

**TABLE XV. TAG LOCATION RESULTS FOR EXPERIMENT I IN TEST BED III**

| Tag Location | Accuracy relative to actual location |
|---|---|
| Location 1 | Very accurate |
| Location 2 | Accurate |
| Location 3 | Very accurate |
| Location 4 | Very accurate |
| Location 5 | Accurate (about 1 metre error) |

**TABLE XVI. TAG LOCATION RESULTS FOR EXPERIMENT II IN TEST BED III**

| Tag Location | Accuracy relative to actual location |
|---|---|
| Location 1 | Accurate |
| Location 2 | About 8 metres error |
| Location 3 | About 7 metres of error |
| Location 4 | About 7 metres of error |
| Location 5 | About 10 metres of error |

In all, the entire experiments were designed to investigate the accuracy achieved by Ekahau RTLS, investigate how the number of APs used in location estimation will affect the accuracy of a tag in a particular location, and verify the importance of the RTLS features in the ESS software and the effects of a poorly calibrated model.

From the set of experiments conducted in the different test environments, it is observed that the accuracy of the tag at each location decreases with the reduction of APs. The location estimation of the tag for experiment I and II in test bed I and II and experiment I for test bed III were accurate for almost all tag locations as shown in tables I, II, VIII, IX AND XV when compared to the other experiments where only selected APs were used for location estimation. This result suggests that the number of APs in a tracked area can improve location accuracy.

A comparative analysis on the location accuracy of the three test beds using the well calibrated models in experiment I for all the test beds shows that the tag achieved higher accuracy in test bed II than the other test environments. These results suggest that tags perform best in open environments where there is not much distortion in the propagation of RF signals. The result obtained in test bed I and II is in agreement that multipath is one of the factors affecting the accuracy of location estimation in dynamic environments [2], [9].

## V. Conclusion

This research is conducted to evaluate the performance of Ekahau RTLS in different indoor environments. Ekahau RTLS as one of indoor positioning system is a positioning system that is based on Scene Analysis and multi hypothesis probabilistic algorithm. It is a cost effective location awareness solution that achieves 3-5m accuracy, using an existing network infrastructure.

Although Ekahau is seen as a leading RTLS solution for indoor positioning system, the accuracy achieved by Ekahau RTLS depends on so many factors such as quality of site survey, the number of access points, placement of the access points, and nature of the indoor environment. A good and qualitative site survey will translate to generation of good positioning model which increases accuracy. The use of an adequate number of access points and proper placement will increase wireless coverage, thereby increasing positioning accuracy of the tracked devices. However, multipath is one of the factors affecting accuracy of location estimation in dynamic environments.

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