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Performance Analysis of Location Tracking System for Multiple Levels

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Abstract: Location tracking in an indoor environment is possible with various techniques based on mechanical, acoustical, ultrasonic, optical, infrared, inertial or radio signal measurements. Global Positioning System (GPS) is one of famous tracking system as a feasible and effective outdoor tracking system. Nowadays, location tracking information and visualization of 3D graphics either in outdoor or indoor environment had been presented as one of research issues. Traditional tracking system with 2D-image standard presents only few and dull information to users. In addition 2D localization only supports one level platform (i.e. horizontally). Thus, the 3D location tracking system had been developed to support multilevel network. In this paper we developed a real-time indoor tracking system with 3D locations which are able to provide more useful location tracking information to user using radio signals. This system had been developed for multiple levels building. For this project we used the existing Wireless Local Area Network (WLANs) attached devices called the access point (AP) to the edge of the wired network. Nodes communicate with the AP using a wireless network adapter similar in function to a traditional Ethernet adapter. The signal from the nodes or the APs that using WLAN can be read or calculated using Received Signal Strength Indication (RSSI) due to its low-cost solutions. Besides that, the system operates in the IPv6 network to provide more reliable system. The localization algorithm use is triangulation method which is suitable for indoor environment. In this paper we present the results of the 3D location tracking for one level as well as two level building. The results are comparing in terms of experimental and calculated.

Keywords: indoor location racking; 3 Dimension (3D); Received Signal Strength Indication (RSSI); triangulation method; Internet Protocol Version 6 (IPv6).

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1. Introduction

Location tracking has been of great importance since World War II, when military planners realized its usefulness for targeting, fleet management, positioning, and navigation. Location tracking is not one single technology. Rather, it is the convergence of several technologies that can be merged to create systems that track inventory, livestock or vehicle fleets [1, 2]. Similar systems can be created to deliver location-based services to wireless devices. Current technologies being used to create location-tracking and location-based systems include Geographic Information Systems (GIS), Global Positioning System (GPS), Radio Frequency Identification (RFID), and Wireless Local Area Network (WLAN). Location tracking or location-based service system will use one or a combination of these technologies. The system requires that a node or tag be placed on the object, animal or person being tracked. For example, the GPS receiver in a cell phone or an RFID tag on a DVD can be used to track those devices with a detection system such as GPS satellites or RFID receivers.

Nowadays, companies are finding location-tracking technologies ideal for better managing inventories or fleets of vehicles. Knowing the exact location of each piece of inventory helps to control the supply chain and saves money by not losing those assets that are in transit. Companies, such as retailers, must consider how to track inventory across a wide area, either country or state, and in a smaller area, such as the warehouse or store. On a large scale [3], companies must track their vehicle fleets across the country or the world. GPS is the ideal tracking technology for tracking over large areas. To do this, every vehicle needs to be equipped with a GPS receiver. As the vehicle crosses the country, the GPS satellites track the truck's position. With GPS, the operator can request positioning at anytime. However, GPS is limited in smaller areas or indoors. A good example of where GPS would not be suitable for tracking items is in a warehouse or hospitals. The accuracy provided by GPS is not sufficient for such a small scale. Consider all of the medical equipment, wheelchairs, gurneys and even patients that need to be tracked. GPS is not a practical or cost-effective solution.

Besides that, for smaller areas [3], companies and healthcare organizations would likely use a network of RFID tags and readers to monitor the location of assets or inventory. A wireless LAN also would be more suitable. In such a system, each asset would be tagged with an RFID tag, and readers would be placed in strategic locations to be able to accurately read those tags within a matter of inches. A hospital worker would be able to find the exact room a wheelchair is located and retailers would be able to locate an item on any given shelf.

A wireless local area network (WLAN) [4] links two or more devices using some wireless distribution method (typically spread-spectrum or OFDM radio), and usually providing a connection through an access point to the wider internet. This gives users the mobility to move around within a local coverage area and still be connected to the network. Wireless LANs have become popular in the home due to ease of installation, and the increasing popularity of laptop computers. Public businesses such as coffee shops and malls have begun to offer wireless access to their customers; sometimes for free. Large wireless network projects are being put up in many major cities: New York City, for instance, has begun a pilot program to cover all five boroughs of the city with wireless Internet access.

In telecommunications, received signal strength indication (RSSI) is a measurement of the power present in a received radio signal. RSSI is a generic radio receiver technology metric, which is usually invisible to the user of device containing the receiver, but is directly known to users of wireless networking of IEEE 802.11 protocol family. In an IEEE 802.11 system, RSSI is the relative received signal strength in a wireless environment, in arbitrary units. RSSI can be used internally in a wireless networking card to determine when the amount of radio energy in the channel is below a certain threshold at which point the network card is clear to send (CTS). Once the card is clear to send, a packet of information can be sent. The end-user will likely observe an RSSI value when measuring the signal strength of a wireless network through the use of a wireless network monitoring tool like Wireshark, Wildpacket, Kismet or Inssider.

Internet Protocol Version 6 (IPv6) [5] is a version of the Internet Protocol that is designed to succeed Internet Protocol version 4 (IPv4). IPv4 was the first publicly used Internet Protocol and has been in operation since 1981. IPv6 is an Internet Layer protocol for packet-switched internetworking and provides end-to-end datagram transmission across multiple IP networks. As a datagram service it does not guarantee reliability, a function provided at the Transport Layer. The main driving force for the redesign of Internet Protocol was the foreseeable IPv4 address exhaustion. IPv6 was developed by the Internet Engineering Task Force (IETF), and is described in Internet standard document RFC 2460, published in December 1998. In addition, the features and advantages of IPv6 are larger address space, efficient and extensible IP datagram, efficient route computation and aggregation, improved host and router discovery, mandated new stateless and stateful address autoconfiguration, easy renumbering, mobility support, Mandated Security for IP datagrams.

2. Location Tracking Methods

Generally, location tracking methods have three categories, which are proximity, scene analysis and triangulation.

2.1. Proximity Method

Proximity method [6] can detect object entering a certain area at low cost. The method is also considered as a robust method to track object against electromagnetic noise, especially indoors. An interesting or tracking object will be located once a base station can sense signal from such object which means it has been in an area covered by such base station. Therefore, we can locate object proximately, illustrated in figure1 (a). However, proximity method cannot estimate exact coordination of any objects but the area the object is located. Vision & Media Computing Lab. of Nara institute [7] is a sample of tracking systems using proximity method by using IR sensors, RF tags, and etc.

2.2. Scene Analysis Method

The second method of location tracking system is called scene analysis [6]. As the name, we need to analysis real area in order to measure signal strength of an object at all coordination of such area and store the data into a database. Once the system tracks any objects, the signal strength received from such object will be compared with ones in the database in order to find n nearest coordination and use them to estimate location of the tracking object. The number of coordination depends upon a size of area and a size of grid (the smaller size of grid we take, the higher accuracy we get). This becomes a hard work, especially in a large area and a small size of grid. However, because the signal is measured on real site, the location estimation by scene analysis has high accuracy shown in figure1 (b).

2.3. Triangulation Method

Triangulation [6] generally is one of interesting location tracking methods. The method needs at least three base stations. All three base stations play a role in sensing the strength of signal received from an interesting object or tracking object. Three values of signal strength will be converted to three distance values from the object to all three base stations. The distances will be used to estimate the location of the object by drawing three circles, which have all three base stations as a center point of each circle. The radius of each circle equals the distance we have calculated from the signal strength. The intersection of all three circles will be an estimated location of the tracking object as show in to figure1 (c). The distance from each base station may also be calculated from transmission time once the station receive signal from the object, since transmission time can be converted to distance, if we know the velocity of such signal. Examples of technology using this technique are MIT's Cricket [10], Active Bat System [11], GPS (Global Positioning System) [12], and etc. In this paper the location tracking method uses method in section (2.3) because of the low cost and accuracy. The triangulation method uses RSSI to get signals from the base stations.

2.4. 3D Triangulation Method

Indoor localization is based on close environment. Referring to figure2, assume the three known nodes as A (*x1*, *y1*, *z1*), B (*x2, y2, z2*), C (*x3, y3, z3*) and unknown node (mobile node) as D (*x*, *y*, *z*) and their distance measurement from D are

$$\text{Distance AD} = \sqrt{(x-x_1)^2 + (y-y_1)^2 + (z-z_1)^2} = r_1$$

$$\text{Distance BD} = \sqrt{(x-x_2)^2 + (y-y_2)^2 + (z-z_2)^2} = r_2$$

$$\text{Distance CD} = \sqrt{(x-x_3)^2 + (y-y_3)^2 + (z-z_3)^2} = r_3$$

Then, eliminating the square roots, r_1^2, r_2^2, r_3^2 is given as follows,

$$(x-x_1)^2 + (y-y_1)^2 + (z-z_1)^2 = r_1^2 \tag{1}$$

$$(x-x_2)^2 + (y-y_2)^2 + (z-z_2)^2 = r_2^2 \tag{2}$$

$$(x-x_3)^2 + (y-y_3)^2 + (z-z_3)^2 = r_3^2 \tag{3}$$

By expanding equations (1), (2) and (3) with eliminating the exponential terms, we get

$$x(x_2-x_1) + y(y_2-y_1) + z(z_2-z_1) = \frac{r_1^2 - r_2^2 + x_2^2 - x_1^2 + y_2^2 - y_1^2 + z_2^2 - z_1^2}{2}$$

$$x(x_3 - x_1) + y(y_3 - y_1) + z(z_3 - z_1) = \frac{r_1^2 - r_3^2 + x_3^2 - x_1^2 + y_3^2 - y_1^2 + z_3^2 - z_1^2}{2}$$

$$x(x_3 - x_2) + y(y_3 - y_2) + z(z_3 - z_2) = \frac{r_2^2 - r_3^2 + x_3^2 - x_2^2 + y_3^2 - y_2^2 + z_3^2 - z_2^2}{2}$$

substitute

$$X_{12} = (x_2 - x_1), Y_{12} = (y_2 - y_1), Z_{12} = (z_2 - z_1)$$

$$X_{13} = (x_3 - x_1), Y_{13} = (y_3 - y_1), Z_{13} = (z_3 - z_1)$$

$$X_{23} = (x_3 - x_2), Y_{23} = (y_3 - y_2), Z_{23} = (z_3 - z_2)$$

and

$$Q_{12} = \frac{r_1^2 - r_2^2 + x_2^2 - x_1^2 + y_2^2 - y_1^2 + z_2^2 - z_1^2}{2}$$

$$Q_{13} = \frac{r_1^2 - r_3^2 + x_3^2 - x_1^2 + y_3^2 - y_1^2 + z_3^2 - z_1^2}{2}$$

$$Q_{23} = \frac{r_2^2 - r_3^2 + x_3^2 - x_2^2 + y_3^2 - y_2^2 + z_3^2 - z_2^2}{2}$$

we get,

$$xX_{12} + yY_{12} + zZ_{12} = Q_{12} \tag{4}$$

$$xX_{12} + yY_{12} + zZ_{12} = Q_{12} \tag{5}$$

$$xX_{12} + yY_{12} + zZ_{12} = Q_{12} \tag{6}$$

By solving equations 4, 5 and 6 it gives equations for *x*, *y*, and *z* (equations 7, 8, and 9). These three equations had been programmed in the system to calculate the location of the mobile node.

$$z = \frac{-t \pm \sqrt{t^2 - 4ru}}{2r} \quad (7)$$

$$x = g + zh \quad (8)$$

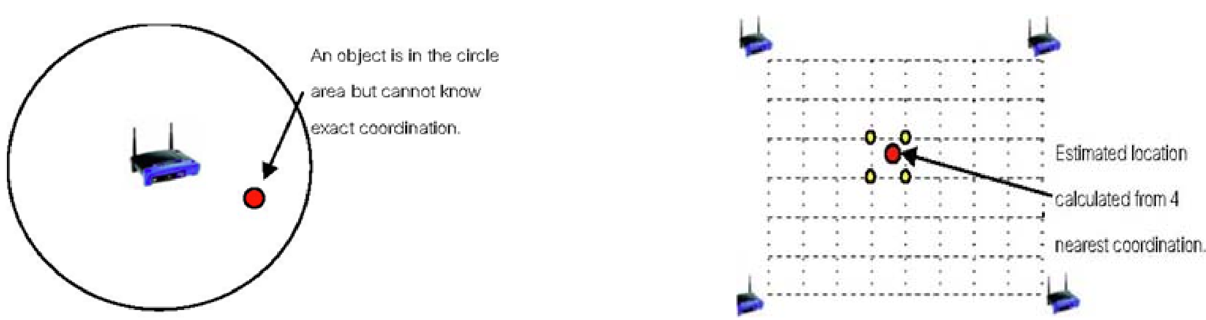
$$y = \frac{d - ze}{v} \quad (9)$$

2.5. Experiment Setup

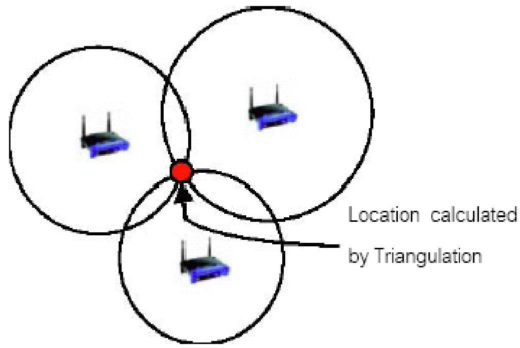
The 3D location tracking system has been tested at two levels. The system runs in Linux in the environment with floors. The three Access Points (APs) was attached at fixed positions and communicate with a mobile node (MN). In order to determine an exact location, it is necessary to locate the mobile node in the triangular plane formed by the three APs. The system was evaluated in a real test environment. Figure3 shows the two level testbed environments, with three APs, mobile node, location server, and a hub.

The area used was 12.16meters x 11.16meters x 2.09 (length x width x height). The location server was attached at fixed positions as the APs and can locate everywhere, not necessary within the triangle or near the triangle.

The mobile node is able to move around freely. However, the mobile node is necessary to attached within the plane of ABC to receive the best message signal from the three APs. Then, the mobile nodes will extract the signal strength received. The signals strengths values will be send to the location server. The location server calculates the location of mobile node and shows the results. The location server also shows the value of three signals strength receives and distances of mobile node from three APs (r_1, r_2, r_3).



(a) (b)



(c)

Figure1. **(a)** Proximity method. **(b)** Scene Analysis method. **(c)** Triangulation Method.

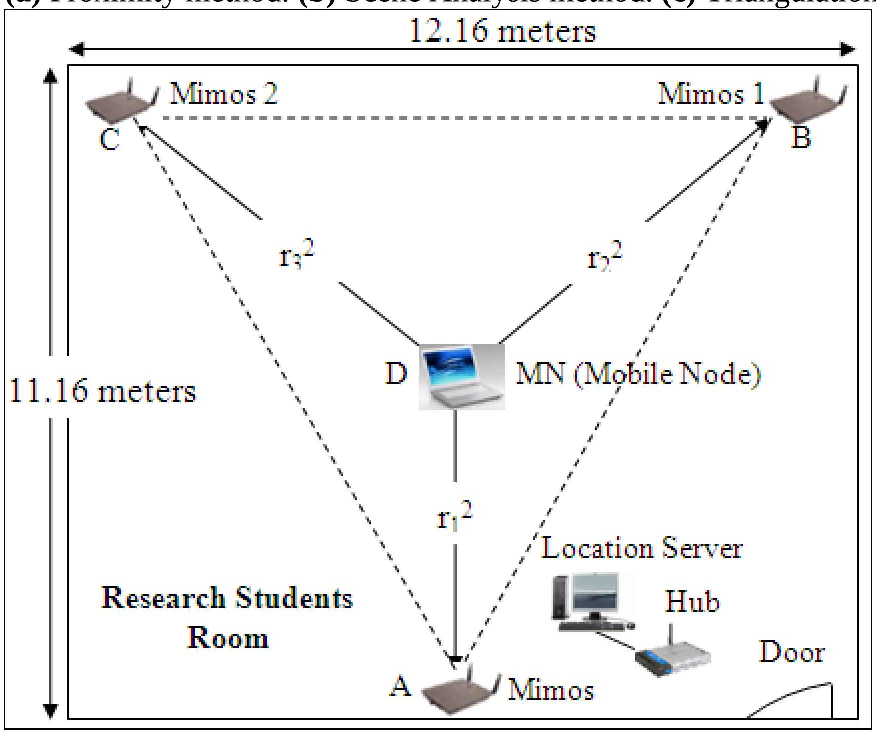


Figure2. Testbed environment (2D view).

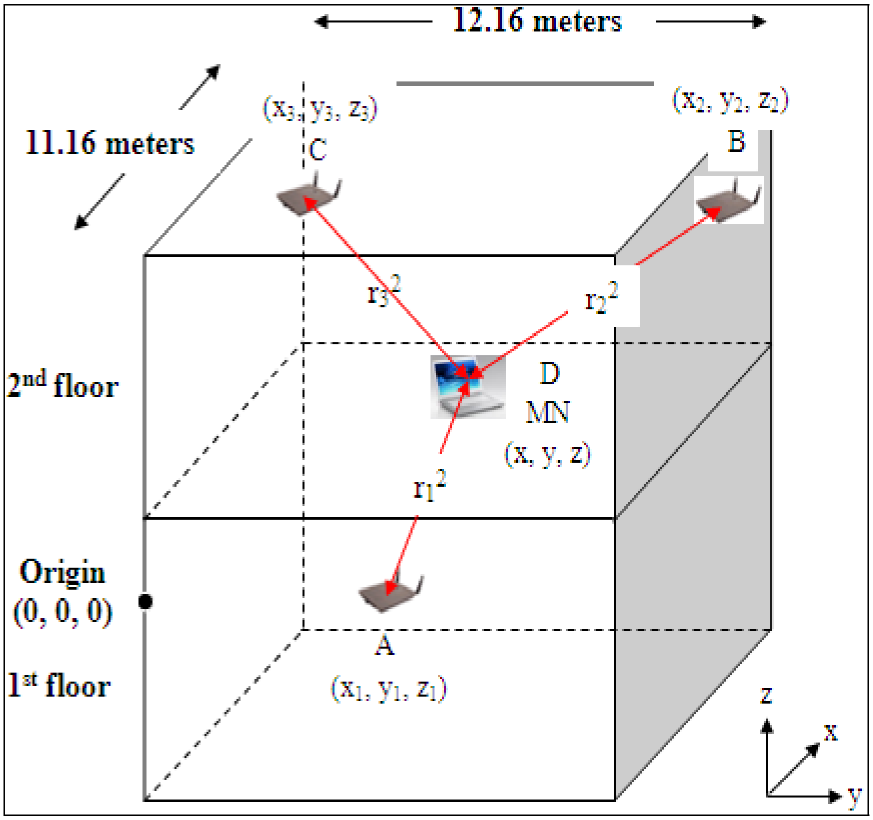


Figure3. Testbed environment (3D view).

3. Results

Based on the algorithms described in the previous section, several tests had been performed, where the location of mobile node was calculated at different points in the rooms. Table 1 shows the differences and the errors between real and measured position of mobile node on three different testbed. The measured readings was collected from the testbed. The real values show the real position by using measuring tape. The errors were differences between measured and real value.

By comparing the measured and real value, table 1 shows the error for coordinates x, y, and z was between 0 to 6 meters. From this observation, testbed 1, 2 and 3 shows the error of z was a least and x was a highest. On the other hand, testbed 1 and 2 show the errors between 0 to 5 meters compared to testbed 3 visualizes the error between 0 to 6 meters. These shows between the three tables, testbed 3 gives the best results because both y and z axis gives the least error even though the x coordinate gives high of error.

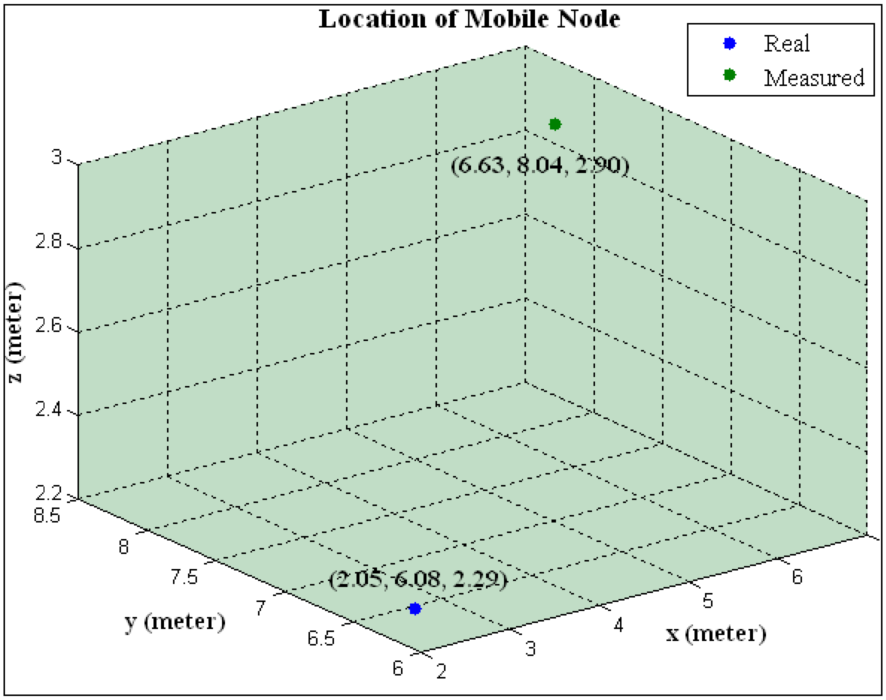
Table 1. Comparison between measured and real coordinate of mobile node.

Testbed	Data	X-Axis	Y-Axis	Z-Axis
1	Measured	6.631201	8.03621	2.903808
	Real	2.05	6.08	2.29
	Error	**4.581201**	**1.95621**	**0.613808**
2	Measured	9.911963	7.671211	2.104544
	Real	5	5.25	2.29
	Error	**4.911963**	**2.421211**	**0.185456**
3	Measured	15.153329	8.649375	1.77112
	Real	9.36	8.2	2.29
	Error	**5.793329**	**0.449375**	**0.51888**

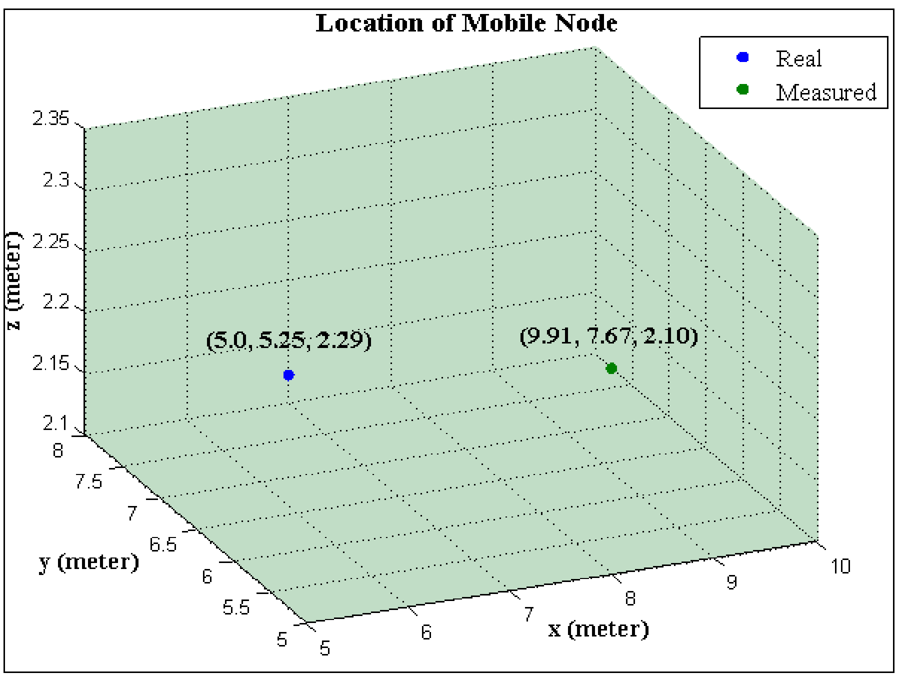
Figure 4 (a), (b), (c) shows the scatter graph plotting for location of mobile node. These graphs plot from table1 (testbed 1, 2, and 3 respectively). The graphs show the measured and real data. These values show by the green and blue colour respectively. From the graphs also shows figure 4. (c) give the best result compared to figure 4. (a) and (b). We can observe that the measured and real values in figure 4. (c) was closest compared to figure 4. (a) and (b).

From the results, we can say that, the best results or the worst results get were depends on signals receive by the mobile node and the environment. The signals strength receives by the mobile node sometimes zero, small, or big depends on the APs. This mean the signals receive by the mobile node not as required.

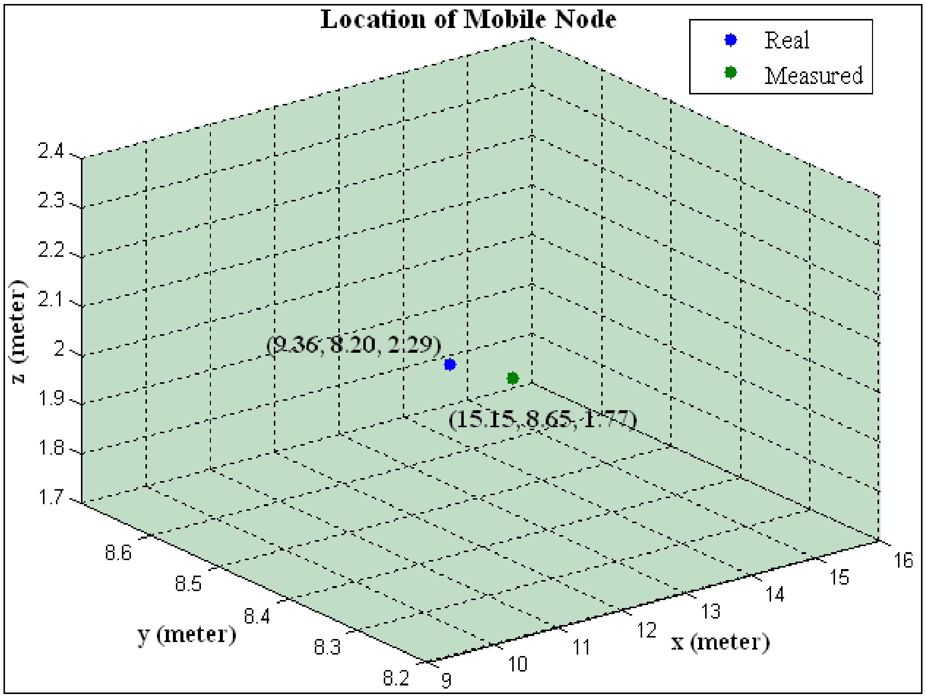
Nevertheless, the environment may influence by reflection, fluctuation, interference, absorption or other factors. These impact the signal strength. This is because the environment had walls, floors, doors, tables, chairs and others. Even the peoples can gives the effect either in stationary or moving condition.


Location of Mobile Node
Real
Measured
(6.63, 8.04, 2.90)
(2.05, 6.08, 2.29)
z (meter)
y (meter)
x (meter)

(a)


Location of Mobile Node
Real
Measured
(5.0, 5.25, 2.29)
(9.91, 7.67, 2.10)
z (meter)
y (meter)
x (meter)

(b)



(c)

Figure4. (a), (b), (c) Coordinate of Mobile Node, MN.

4. Conclusions

This paper has presented the development of performance analysis of location tracking system for multiple levels to track the position of the mobile unit. The 3D system has been developed to replace the traditional 2D standard floor map. The triangulation method had been choosen because of the low cost. The mobile nodes in the network determined by the triangulation technique based on the signal received from three APs. In addition, the system runs in IPv6 network to provide reliable system. From the results, the accuracy of the 3D system achieved is about six meters. Our next steps will be integrating the switching device. The device switching is support to switch session from one device to another using mobile node.

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