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An Indoor 3D Location Tracking System using RSSI

Norhidayu Shahila Abu Hassan, Sazzad Hossain, Nur Haliza Abdul Wahab, Sharifah Hafizah Syed Ariffin, Norsheila Fisal
UTM MIMOS Center of Excellence,
Universiti Teknologi Malaysia,
81310 Skudai, Johor, Malaysia.
Email: norhidayushahila@gmail.com

Liza Abd Latiff
Electrical Engineering Department College of Science Technology,
Universiti Teknologi Malaysia,
City Campus Jalan Semarak 54100 Kuala Lumpur, Malaysia.
Email: liza@citycampus.utm.my

Mazlan Abbas, Choong Khong Neng
Wireless Technology and Architecture, Wireless Communication Cluster,
MIMOS BERHAD, Technology Park Malysia,
57000 Kuala Lumpur, Malaysia.
Email: mimos.abbas@mimos.my, choong@mimos.my

***Abstract*—Representation of indoor 3D location tracking had been an advantage to globally supported to track the mobile unit everywhere, even in different level of building. Our main focus is presenting development of indoor 3D location tracking to replace the existing 2D location tracking. The 2D location tracking mechanism only supports tracking the mobile unit position in the same level and provides handover or device switching. If the users need to go to another level, user will have to disconnect the connection. The development of the system that has a location tracking mechanism responsible to track the position of the mobile unit (such as laptop and PDA). In this paper, the system running in IPv4 framework and set up as a read test bed. The proposed location tracking will be based on Received Signal Strength Indicator (RSSI). The 3D location tracking system will be purely software based with minimum hardware dependent.**

Keywords – indoor location tracking; received signal strength indication; three dimension; triangulation

I. INTRODUCTION

The IP Multimedia Subsystem (IMS) is an architectural framework for delivering Internet Protocol (IP) multimedia services [1]. Its original formulation (3GPP) represented an approach to delivering "Internet services" over GPRS. This vision was later updated by 3GPP, 3GPP2 and TISPAN by requiring support of networks other than GPRS, such as Wireless LAN, CDMA2000 and fixed line. IMS provides a qualitative distinction that can be a source of competitive differentiation for mobile operators. Moreover, IMS provides benefits through more rapid service creation and competitive differentiation.

The Session Initiation Protocol (SIP) is a signaling protocol, widely used for controlling multimedia communication sessions such as voice and video calls over IP [2]. The protocol can be used for creating, modifying and terminating two-party (unicast) or multiparty (multicast) sessions consisting of one or several media streams. The modification can involve changing addresses or ports, inviting more participants, adding or deleting media streams, etc. SIP was introduced in 1996, and the latest version of the specification is in RFC 3261 from the IETF Network Working Group [1].

Location tracking in an indoor environment can be done with various techniques based on mechanical, acoustical, ultrasonic, optical, infrared, inertial or radio signal measurements. This paper focuses on the localization using radio signals. The localization algorithm use is triangulation which is suitable for indoor environment [3].

For this project Wireless Local Area Network (WLANs) is built by attaching a device 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) method. Location tracking is functional to track the position of mobile node in the network. The existing system is developed the 2D location tracking [4]. This project is developed indoor 3D location tracking for device switching using IPv6 network. The RSSI has been used to measure the location tracking.

II. RELATED WORKS

There are many works on indoor location tracking. The Active Badge system is introduced in [5]. The aim of the Active Badge project was to locate in staff/person public buildings such as hospitals. This application forwards the incoming phone calls to the current room phone near to the person's location. The active badges are devices that are worn and used to identify the person by sending out an infrared (IR) signal every 100 milliseconds. The use of common IR technology holds the production costs low. Active badges have a range of 6 meters and can run on battery almost for one year. A network of sensors attached in each room receives the signals sent by these badges. Each sensor network is able to contain as many as 128 sensors which are connected to a workstation over a serial port. The workstations themselves are connected to a master that gathers and controls all sensor data. The Active Badge system can locate persons or objects in a room-wide range, but the resolution is very low and not sufficient. Another weak point is the high installation cost since all of the controlled area needs to be wired up, and extensions are not possible.

Cricket [6] is another ultrasonic based location system. The device carried by the person determines itself the location. This ensures the privacy of the person. Beacons attached to the ceiling periodically send a radio and ultrasonic signal. Using multiple signals from different beacons the personal device calculates the current position. Besides that, Cricket was extended to provide a tracking of moving objects. An outlier rejection component is used to eliminate measurement failures by deleting extremal values. Another component is the least square solver which has the task of minimizing squared mean failures. Current states are stored by an extended Kalman-filter that can even predict future states. The installation cost of Cricket is lower than other projects, but the interference problem of ultrasonic remains.

The RADAR project is a location tracking system based on wireless LAN [7]. RADAR is established in an area of $980m^2$ with more than 50 rooms. Three base stations are used to cover the whole building, where the coverage of stations partially overlaps. A laptop with a WLAN adaptor works as a mobile device for locating and tracking. The laptop sends multiple UDP packets to the base stations that calculate signal strength and signal-to-noise ratio for each packet. It first builds a reference model with measurements consisting of 70 points in the building with data for each direction (north, west, south, east). RADAR stores at least 20 values of signal strength for each combination of location and direction. Additionally, it calculates the means, standard deviation, and median for each position. The accuracy of RADAR is similar to the Active Badge system.

III. THE LOCATION TRACKING TECHNIQUE

In trigonometry and geometry, triangulation is the process of determining the location of a point by measuring angles to it from known points at either end of a fixed baseline, rather than measuring distances to the point directly. The point can then be fixed as the third point of a triangle with one known side and two known angles. Triangulation can also refer to the accurate surveying of systems of very large triangles, called triangulation networks. It showed how a point could be located from the angles subtended from three known points, but measured at the new unknown point rather than the previously fixed points. Further, surveying error is minimised if a mesh of triangles at the largest appropriate scale is established first, that points inside the triangles can all then be accurately located with the reference.

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.

RSSI values are unitless and usually in the range 0 to 255, expressible as a one-byte unsigned integer. The RSSI maximum value is vendor dependent. For example, Cisco Systems cards have an RSSI_Max value of 100 and will report 101 different power levels, where the RSSI value is 0 to 100. Besides that, Wi-Fi chipset is made by Atheros. An Atheros based card will return an RSSI value of 0 to 127 (0x7f) with 128 (0x80) indicating an invalid value.

The 802.11 standard does not define any relationship between RSSI value and power level in mW or dBm. Vendors provide their own accuracy, granularity, and range for the actual power (measured as mW or dBm) and their range of RSSI values (from 0 to RSSI_Max). In this project, the triangulation technique will be used to determine the unknown node coordinate with three known nodes setup. On the other hand, the RSSI is using to measure the location tracking.

IV. INDOOR LOCATION TRACKING

A. *Position Estimation*

Indoor localization is based on close environment. Referring to Figure 1, assume the three known nodes as A (x_1, y_1, z_1), B (x_2, y_2, z_2), C (x_3, y_3, z_3) and unknown node (mobile node) as D (x, y, z) and their distance measurement from D are

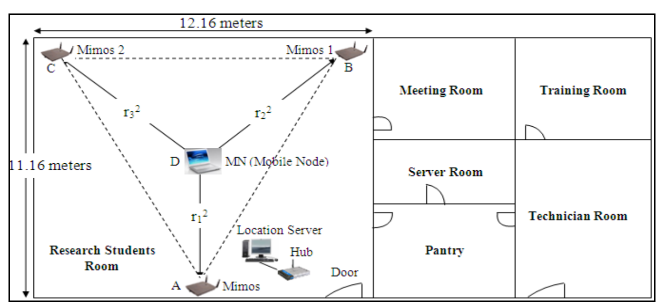

Figure1. Testbed environment (2D view).

$$\text{Distance AD} = \sqrt{(x-x_1)^2+(y-y_1)^2+(z-z_1)^2} = r_1$$
$$\text{Distance BD} = \sqrt{(x-x_2)^2+(y-y_2)^2+(z-z_2)^2} = r_2$$
$$\text{Distance CD} = \sqrt{(x-x_3)^2+(y-y_3)^2+(z-z_3)^2} = r_3$$

Then, eliminating the square roots, the three equations write as below,

$$(x-x_1)^2+(y-y_1)^2+(z-z_1)^2 = r_1^2 \quad (1)$$
$$(x-x_2)^2+(y-y_2)^2+(z-z_2)^2 = r_2^2 \quad (2)$$
$$(x-x_3)^2+(y-y_3)^2+(z-z_3)^2 = r_3^2 \quad (3)$$

Expanding these equations and eliminating the exponential terms,

$$x(x_2-x_1)+y(y_2-y_1)+z(z_2-z_1) = \frac{r_1^2-r_2^2+x_2^2-x_1^2+y_2^2-y_1^2+z_2^2-z_1^2}{2}$$
$$x(x_3-x_1)+y(y_3-y_1)+z(z_3-z_1) = \frac{r_1^2-r_3^2+x_3^2-x_1^2+y_3^2-y_1^2+z_3^2-z_1^2}{2}$$
$$x(x_3-x_2)+y(y_3-y_2)+z(z_3-z_2) = \frac{r_2^2-r_3^2+x_3^2-x_2^2+y_3^2-y_2^2+z_3^2-z_2^2}{2}$$

or

$$xX_{12}+yY_{12}+zZ_{12} = Q_{12} \quad (4)$$
$$xX_{12}+yY_{12}+zZ_{12} = Q_{12} \quad (5)$$
$$xX_{12}+yY_{12}+zZ_{12} = Q_{12} \quad (6)$$

where

$$X_{12} = (x_2-x_1), Y_{12} = (y_2-y_1), Z_{12} = (z_2-z_1)$$
$$X_{13} = (x_3-x_1), Y_{13} = (y_3-y_1), Z_{13} = (z_3-z_1)$$
$$X_{23} = (x_3-x_2), Y_{23} = (y_3-y_2), Z_{23} = (z_3-z_2)$$

and

$$Q_{12} = \frac{r_1^2-r_2^2+x_2^2-x_1^2+y_2^2-y_1^2+z_2^2-z_1^2}{2}$$
$$Q_{13} = \frac{r_1^2-r_3^2+x_3^2-x_1^2+y_3^2-y_1^2+z_3^2-z_1^2}{2}$$
$$Q_{23} = \frac{r_2^2-r_3^2+x_3^2-x_2^2+y_3^2-y_2^2+z_3^2-z_2^2}{2}$$

Solve the equation s 4, 5 and 6 gives the equations for *x, y,* and *z* (equations 7, 8, and 9). These three equations had been code in the system to calculate the location of mobile node.

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

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

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

V. EXPERIMENT SETUP

The 3D location tracking system was tested at one level. This experiment was based on ideal case which the system runs with Linux in the environment without floors and walls. 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. Figure 2 shows the testbed environment, as well as the three APs, mobile node, location server, and hub.

The testbed was conducted in the UTM MIMOS laboratory at Universiti Teknologi Malaysia, Skudai, Johor. The laboratory was located at the fifth floor of a 5 level building. The area used was 12.16meters x 11.16meters (length x width). The location server was attached at fixed positions as the APs and can locate everywhere, not necessary attached in the triangle or near the triangle.

Meanwhile, the mobile node was moving around freely. However, the mobile node necessary to attached in the plane to receive the message signal from the three APs. Then, the mobile nodes will extract the signal strength received. After that, the signals were sending to location server. The location server calculates the location of mobile node and shows the results. 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).

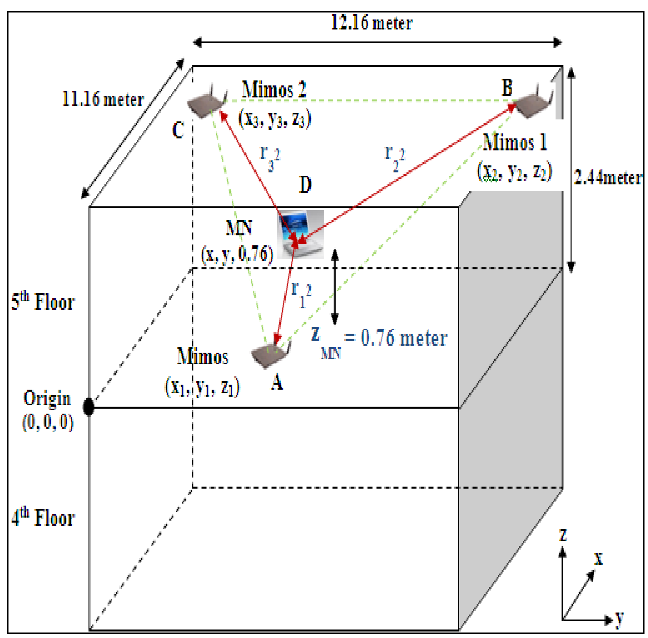

Figure 2. Testbed environment (3D view).

VI. EVALUATION

Based on the algorithms described in the previous section, several tests were performed, where the location was calculated at different points in the rooms. The mobile node had been put at a specific position. Table I, II, and III shows the differences between real and measured position of mobile node. The measured readings get from the testbed. The average value gets by averaging the measured readings. The real value shows the specific position by using measuring tape. The errors were differences between average and real value.

By comparing the average and real value, table I shows the error for coordinates x, y, and z was between 0 to 3 meters. The error shows that the y was a least and z was a highest. On the other hand, table II gives error in the range of 1 to 4 meters. The x coordinate gives a least error compared to z coordinate. The last table III visualizes the error between 0 to 3 meters. The x and y coordinate shows the least values compared to z coordinate. These shows between the three tables, table III gives the best results even though the z coordinate gives high error.

TABLE I. COMPARISON BETWEEN MEASURED AND REAL COORDINATE OF MOBILE NODE

	Coordinates (meter)		
	x-axis	y-axis	z-axis
Measured	3.532429	3.006937	4.269716
	3.788251	3.006937	3.813948
	4.635233	4.594616	3.793066
	4.428817	4.998327	3.40511
	4.150319	4.998327	3.897474
	4.461307	5.590893	4.106074
	2.483664	9.313993	3.702708
	4.207348	6.08	3.810007
	4.486263	6.079999	3.310532
	4.177089	5.487433	2.95695
	3.897006	5.487434	3.528862
	3.517154	4.769523	3.330667
	1.105765	9.280162	2.996847
Average	**3.75928**	**5.591891**	**3.609382**
Real	**2.05**	**6.08**	**0.76**
Error	1.70928	0.488109	2.849382

TABLE II. COMPARISON BETWEEN MEASURED AND REAL COORDINATE OF MOBILE NODE

	Coordinates (meter)		
	x-axis	y-axis	z-axis
Measured	8.731209	11.229489	3.485013
	8.103447	10.206811	5.454147
	10.563004	7.995496	1.446625
	7.831453	11.229489	2.804261
	7.934628	11.384157	2.299691
	9.651604	7.995496	0.945604
	5.279253	12.660804	3.728754
	4.904369	11.816681	0.699879
	6.986197	6.08	6.869143
	4.671755	10.33041	4.884521
	3.328047	7.667678	0.830006
Average	**7.089542**	**9.87241**	**3.040695**
Real	**5.5**	**6.28**	**0.76**
Error	1.589542	3.59241	2.280695

TABLE III. COMPARISON BETWEEN MEASURED AND REAL COORDINATE OF MOBILE NODE

	Coordinates (meter)		
	x-axis	y-axis	z-axis
Measured	6.575049	10.33041	2.12149
	7.420101	8.74273	2.321781
	9.028305	6.672565	5.398321
	9.894371	5.187182	3.772681
	8.152167	8.260245	6.305457
	14.452232	8.588062	0.890444
	8.398976	6.494409	3.730293
	13.474564	10.175741	2.668698
	6.322441	6.279304	4.244016
	4.674949	6.08	1.726849
Average	**8.839316**	**7.681065**	**3.318003**
Real	**9.36**	**8.2**	**0.76**
Error	0.520684	0.518935	2.558003

Figure 3, 4, and 5 shows the scatter graph plotting for location of mobile node using matlab. These graphs plot from table I, II, and III respectively. The graphs show the measured, average, and real data. These values show by the blue, red, and green colour respectively. From the graphs also shows figure 5 gives the best result compared to figure 3 and 4. We can observed that the average and real values in figure 5 was closest compared to figure 3 and 4.

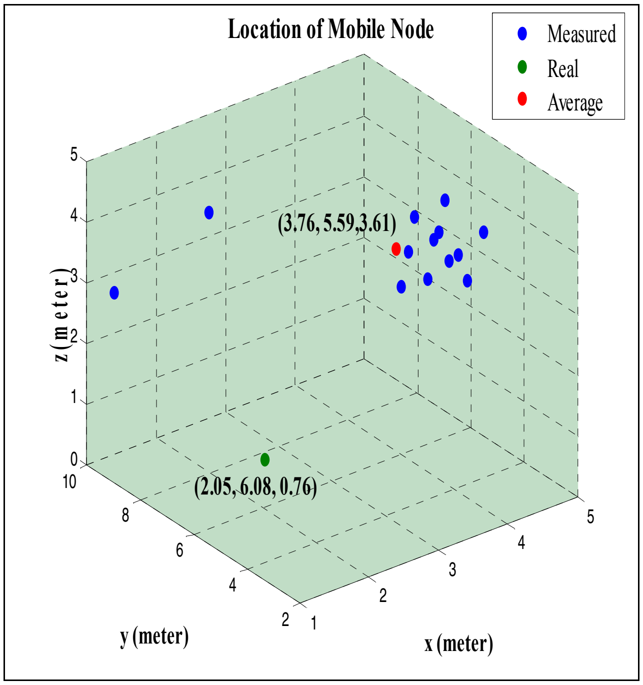

Figure 3. Location of Mobile Node, MN.

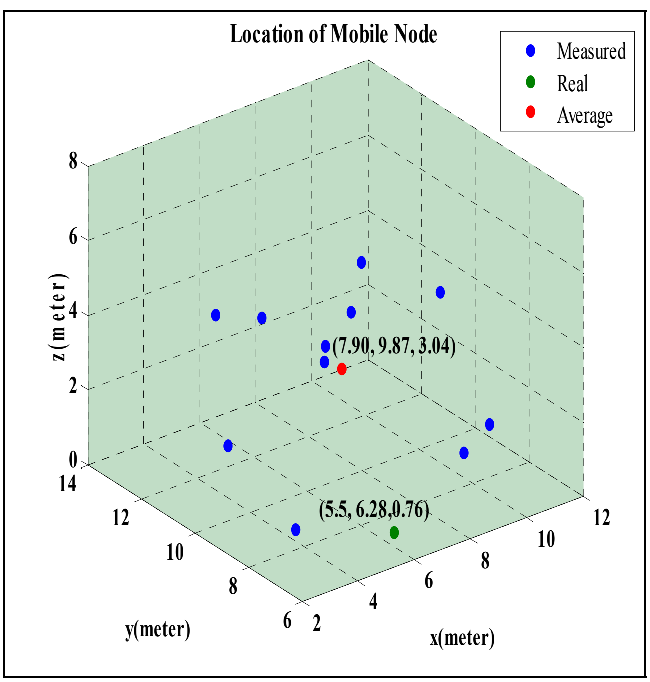

Figure 4. Location of Mobile Node, MN.

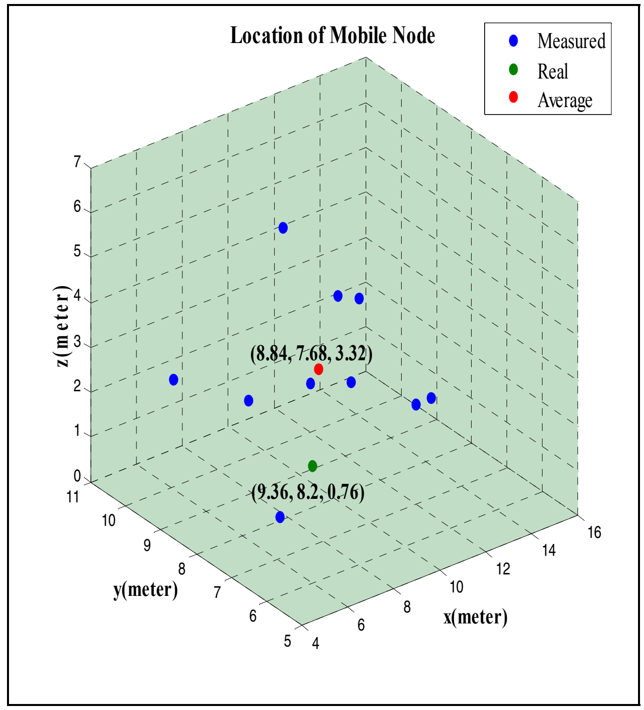

Figure 5. Location of Mbile Node, MN.

However, the graph in figure 3 shows the measured values was better than the others. This is because most of the values were close each other. This show there were small difference values between them. 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.

V. CONCLUSIONS

This project has presented the development of an indoor 3D location tracking using RSSI method to track the position of the mobile unit. The 3D system has been developed to replace the traditional 2D standard floor map. The RSSI method had been choosing because of the low-cost. The mobile nodes in the network determined by the triangulation technique based on the signal received from three APs. Our next steps were doing the testbed with walls or floor and including both. We also will do a switching session. The device switching can be done to switch session from one device to another. In addition, the errors will be fixed.

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REFERENCES

[1] Bosco Eduardo Fernandes, “IPv6 & IP Multimedia Subsystem (IMS)”, IPv6 GLOBAL CHINA SUBMIT, 13-14th April, 2006.
[2] Wikipedia Foundation, “Session Initiation Protocol”, htt://en.wikipedia.org/wiki/SIP, 12 August 2009.
[3] L.A.L atiff, A.Ali, Ooi Chia-Ching, and N.Fisal, “Development of an Indoor GPS-free Self-Positioning System for Mobile Ad Hoc Network (Manet)”, International Conference on Communication, 16-18 Nov., 2005.
[4] Nur Haliza Abdul Wahab, and Sharifah H.S.Ariffin, “Development of IPv6 Network with Location Assisted Transfer for Real Time Applications”, APAN 09, Kuala Lumpur.
[5] R. Want, A. Hopper, V. Falcao, and J. Gibbons, “The Active Badge Location System, ” ACM Trans. Inf. Syst., vol.10, no. 1, pp. 91-102, 1992.
[6] A. Smith, H. Balakrishnan, M. G oraczko, and N. Priyantha, “Tracking Moving Devices with the Cricket Location System,” in MobiSYS 04: Proceedings of the 2nd international conference on Mobile systems, applications, and services, 2004, pp. 190-202.
[7] P. Bahl and V. N. Padmanabhan, “RADAR: An In-building RF-based User Location and Tracking System,” in INFOCOM (2), 2000, pp. 775-784.
[8] A.Ali, L.A.Latiff, N.Fisal, “An indoor 3D GPS-free Position Location for Mobile Ad Hoc Network”, MMU International Symposium on Information and Communication Technologies 2004, Oct. 2004.
[9] Bosco Eduardo Fernandes, “IPv6 the Catalyst for Convergence”, Workshop on IPv6, Geneva, 22-23 June, 2005.
[10] Faruk Bagci, Florian Kluge, Theo Ungerer, and Nader Bagherzadeh, “LocSens – An Indoor Location Tracking System using Wireless Sensors,” Computer Communications and Networks, ICCCN ‘08: Proceedings of 17th International Conference, 2008, pp. 1-5.
[11] Hechmi Khlifi, and Jean-Charles Gregoire, “IMS Application Servers (Roles, Requirements, and Implementation Technologies)”, IEEE Computer Society, 2008.
[12] L.A.Latiff, N. Fisal, and Sharifah H. S. Ariffin, “Simulation of Position-based Routing Protocol in Wireless Mobile Ad Hoc Network”, Third Asia International Conference on Modelling & Simulation, 25 – 29 May, 2009.
[13] Rudolf Pailer, Florian Wegscheider, and Joachim Fabini, “Terminal-Centric Location Services in the IP Multimedia Subsystem”, Vehicular Technology Conference, 2006.
[14] Peter Weik, “IMS Adoption and Comminities Fueled by the Open IMS Core Project, Using MySQL for the Home Subscriber Server”, Fraunhofer Institute FOKUS.
[15] Wikipedia Foundation, “IP Multimedia Subsystem”, htt://en.wikipedia.org/wiki/IMS, 10 August 2009.