

# Indoor Location Tracking in Mobile Ad Hoc Network (MANET) using RSSI

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**Abstract** – In future, more wireless devices are connecting to the Internet. These devices are mobile and move within the coverage area of any mobile network. There are two types of mobile network namely Mobile IP and Mobile ad hoc network. This paper will present indoor tracking in mobile ad hoc network or MANET. MANET consists of nodes that are able to communicate wirelessly among themselves. These nodes also serve as routers and can dynamically move around arbitrarily at any speed in any direction resulting in an ever-changing topology. These nodes are stand-alone, mobile and operate on batteries. Due to mobility of nodes, the most challenging issue in MANET is to design a routing protocol that guarantees delivery of packets. Routing metrics used so far are shortest path, link stability, position location, power and bandwidth available. In order to improve network routing performance, a limited casting technique will be adopted which requires the ability to establish position information. Ultimately, the objective of position location tracking is to provide reliable and accurate position of mobile nodes.

In this paper, a GPS-free indoor position tracking system has been developed that provides knowledge of geometric location of nodes in MANET. The location tracking not only aids in routing protocol design but also provide security monitoring of the hacker nodes if it enters MANET. Additionally, the monitoring system supports the delivery of packets to all nodes in a given geographic region in a natural way. This type of service is called geographic forwarding.

## 1. INTRODUCTION

Mobile wireless networks can be classified into two types of networks: networks with infrastructure (i.e., networks with access points (APs, gateway and routing support), which are called Mobile IP, and networks without infrastructure which are called ad hoc networks. The Mobile IP tries to solve the problem of how mobile may roam from its network to a foreign network and still maintain connectivity to the Internet [2]. Ad hoc network are envisioned to locate and route packets themselves since infrastructure is not available or inconvenient to provide as in rural environment [11].

Ad hoc networks can be further subdivided into two classes: static and mobile. In static ad hoc

networks, the position of a node may not change once it has become part of the network [8]. In MANET, nodes are allowed to move arbitrarily and tracking mechanism of these nodes will be discussed in this paper. The tracking mechanism developed will provide knowledge of geographic location of nodes in MANET and will aid in forwarding strategy based on location; provide security system to monitor hacker node if it enters MANET. A further advantage is that the monitoring system will naturally support delivery of packets to all nodes in a given geographic region. This type of service is called Geographic forwarding. The special feature of the proposed geographical monitoring system is the ability to detect position of MANET nodes without using GPS (Global Positioning System) and also supports multihops monitoring between nodes. The rest of this paper is organized as follows: Section 2 presents related work in indoor location tracking. Then, Section 3 will provide the location tracking model followed by Section 4, which will conclude the paper.

## 2. RELATED WORK

There are two types of methods proposed for indoor location tracking: hardware location tracking method and software location tracking method. In each type, numerous methods were proposed to solve the problem of location tracking.

### 2.1 The hardware based systems

Several hardware based schemes have been reported in the literature; of those the most widely discussed are the Global Positioning System (GPS), the Active Badge system, the Bat system and the Cricket Compass system. The most popular system is GPS. A GPS receiver receives time-stamped radio signals from satellites and calculates its location. The accuracy is 3-5 meters in D-GPS[3], a variant of GPS.

The Active Badge system [9] uses infrared (IR) signal for position inference. The mobile device is attached with an additional hardware unit (badge) which emits a unique IR signal periodically (15sec). IR sensors are placed at known positions such as high up on walls or the ceiling of the office to pick up the IR signals. The picked up signal is transferred to a PC on the wired network that executes location

estimation software. This system has several limitations to compute the mobile user location. The badge and the receivers have to have line-of-sight transmissions as the reflections due to the walls, partitions and furniture are unpredictable. The system requires high-density sensors to be installed in the building and reported to provide high level of accuracy.

The Bat system [5] is similar to the Active Badge system but uses two types of signals namely RF signals and ultrasound signals. A small hardware, a Bat (wireless transmitter), is attached to the mobile devices. RF base stations are deployed through out the space which will broadcast RF signals addressed to each bat in the system. These RF broadcasts will be received by both the bat and the sensors of the system. When the bat receives the RF signal, it broadcasts an ultrasound signal with its identity. This ultrasound signal is received again by all the sensors within coverage area. The time difference between the reception of the RF signal and the ultrasound signal is used to determine the distance between the receiving sensor to the bat.

The Cricket Compass system [7] is similar to the Bat system in terms of using RF and ultrasound signals. The difference between them is that the Cricket Compass is decentralized. In the system, a hardware unit called the Cricket Compass (CC) is attached to the mobile device. It consists of five ultrasonic receivers which are placed in a "V" shaped configuration. Again, beaconing transmitters are placed on the ceiling. These transmitters emit RF signals as well as ultrasound signal to the CCs. The "V" shape receivers detect the phase difference of the ultrasound signals to determine its orientation. In addition, it uses the time interval between the RF signal and the ultrasound signal to determine distance of the transmitter from the CC.

As can be seen from the above discussions, some hardware based location management systems provide accurate location information. However they suffer several drawbacks. GPS system is very useful outdoors, but it is ineffective indoors because GPS radio signal is blocked by walls inside building [2]. The IR based system has a limitation due to the optical path requirement. Also, the scalability of the IR based system is poor because of the limited range of the IR devices. All of the hardware based systems require additional devices for signal transmission. This significantly incurs the cost of installation and maintenance.

## 2.2 The software based systems

Numerous software based systems have been reported in the literature, one of the most applicable is the RADAR system. The RADAR system [6][7] proposed by Microsoft researchers is a RF based system for locating and tracking the mobile users inside the building. During the configuration phase, a

database of RF signal strength (SS) at a set of fixed and known locations is built. This is obtained by walking along the floor of the building and clicking on a map of the floor that is displayed on the Mobile Node (MN). The coordinates of the MN and the SS from a set of Access Points (APs) are then recorded to form the Radio Map. When operational, a set of SS from a set of APs is received by the MN which will determine its location by referring to the Radio Map measured beforehand. The RADAR system reported a median error distance of 2.65m and 4.3m for empirically and mathematically constructed Radio Map respectively. It also reported that to construct a Radio Map of about 980m<sup>2</sup>, it is necessary to have more than 40 pre-measurement points. Furthermore, at each pre-measurement point, several measurements are necessary with different mobile orientations. As expected, software based system has lower accuracy compared to the hardware based systems.

Accuracy of Radio Maps highly depends on the building structure and layout. This reduces the flexibility of the system as any changes on the building structure will affect the accuracy of Radio Map. Furthermore, any changes to the network architecture such as the addition/removal of an AP will also affect accuracy the Radio Map due to the interference and changes in signal strength.

## 3. LOCATION TRACKING MODEL

The location tracking network model consists of a gateway, static APs and other MNs. The gateway is the center of a Network Coordinate System (NCS) and the GUI program resides here. MNs devices in the network are laptops which are equipped with an Orinoco WaveLan PC card. The network interface card (NIC) operates in the 2.4GHz license free ISM band with data rate between 11Mbps and 1Mbps. Its coverage range for open, semi-open and closed areas are 160m, 50m and 25m respectively. The experiment was conducted at a coverage radius of 25m to provide the best coverage overlap [12]. The WaveLan card driver provides information on Signal Strength (SS) and Signal to- Noise Ratio (SNR). In our experiment, we used SS as the metric to compute location of MN rather than the SNR because noise level is easily affected by random fluctuation. IEEE802.11 standard specifies that the minimum beacon interval is 1024μs [13]. This signal strength is used to obtain the distance between two mobile devices.

### 3.1 Distance Computation using Signal Strength

The signal propagation in an indoor environment is dominated by reflection, diffraction and scattering. The transmission path between the transmitter and the receiver vary from line-of-sight (LOS) to one that is severely obstructed by the structure of the building. The signal strength is highly influenced by the layout

or partitions of the building, the construction material used, and the objects in the building. Furthermore, the mobile user herself/himself is also a signal obstacle. When the mobile user is in front of a MN, the user obstructs the signal from another MN coming from behind the user. Similarly, human movement in the building also affects signal propagation. Thus, it is very difficult to characterize signal loss. Therefore, a reasonable indoor signal propagation model must be determined to compute the distance between MNs. Theoretically; the indoor signal path loss obeys the distance power law [9]: determining

$$P_r(d) = P_r(d_0) - 10n \log\left(\frac{d}{d_0}\right) + X_\sigma \quad (\text{dBm}) \quad (1)$$

where  $P_r$  is the received power;  $P_r(d_0)$  is the received power at the reference distance  $d_0$ ;  $n$  is the path loss exponent that indicates the rate at which the path loss increases with distance. It depends on the surrounding and building type. And  $d_0$  is the close-in reference distance (1m) and  $d$  is the separation between the RF signal transmitter and receiver. The term  $X_\sigma$  is a zero mean Gaussian random variable with standard deviation  $\sigma$ . Equation (1) is modified to include WAF (Wall Attenuation Factor) as follows:

$$P_r(d) = P_r(d_0) - 10n \log\left(\frac{d}{d_0}\right) - T * WAF \quad (2)$$

where  $T$  is number of walls between transmitter and receiver. Despite the distance measurement errors and the motion of the nodes, the algorithm provides sufficient location information and accuracy to support basic network functions.

### 3.2 Calculation of Path Loss Exponent

The test bed consists of two laptops in peer-to-peer mode and another two PCs. One PC acts as the gateway and located in the centre of the lab. The other PC is the AP or anchor node. It measured the SS of the indoor signal propagation in the Telecommunication Lab in Electrical Engineering Buildings at UTM. The two laptops act as MNs moving in any direction. At each specified point, 100 samples of the SS readings were recorded for four different orientations, and the average was used as the SS at that point in each orientation. Figure 1 illustrates how the SS varies with logarithm of distance and also the variation due the orientation of the receiver. The results show a variation up to 12dBm on the SS at the same point for different orientations. The average value and the curve-fitting of the data recorded are shown in Figure 2. The curve-fitting line of the average value is calculated based on minimized total error  $R^2$  as follows [10]:

$$R^2 = \sum_{i=1}^m (y_i - (ax_i + b))^2 \quad (3)$$

where  $y_i$  is  $P_r(d)$ ,  $a$  is  $10n$ ,  $b$  is  $P_r(d_0)$  when compared to equation (1).

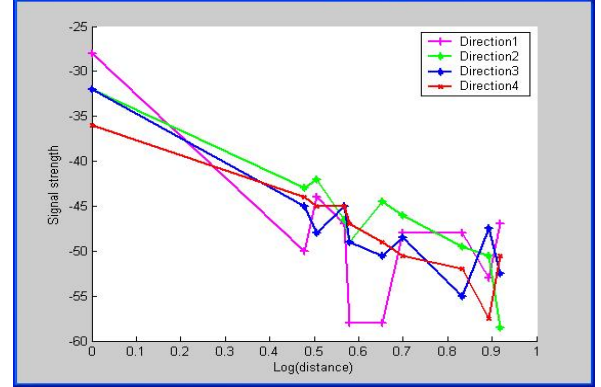


Figure 1: Signal Variations

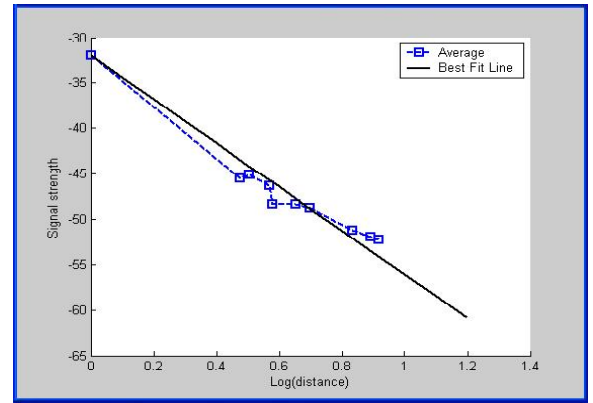


Figure 2: Average Result

The condition for  $R^2$  to be a minimum is that:

$$\frac{\partial(R^2)}{\partial a} = 0 \quad \text{and} \quad \frac{\partial(R^2)}{\partial b} = 0 \quad (4)$$

However,  $b$  is constant in equation (1) and is equal to 32 in the test bed for  $d_0 = 1\text{m}$  so we do not need partial derivatives for  $b$ . From equations (3) and (4), we have:

$$\frac{\partial(R^2)}{\partial a} = -2 \sum_{i=1}^m [y_i - b + ax_i] x_i = 0 \quad (5)$$

Equation (5) is simplified to become:

$$a = \frac{\sum_{i=1}^m xy - b \sum_{i=1}^m x}{\sum_{i=1}^m x^2} \quad (6)$$

In this test bed,  $a=10n=24.05$  as derived from equation (6).

### 3.3 Location Determination

The software required in this test bed is Linux Kernel version 2.4, Tcl and Tk, Kernel AODV, wireless tools library and the test bed programs. Tcl and Tk is the Graphical User Interface (GUI) for the Linux used in this test bed. The neighbouring nodes can be detected by using beacons of Kernel AODV program [14]. After the absence of a certain number of successive beacons, it is concluded that the node is no longer of a neighbour. The test bed programs used wireless tools library to detect signal strength of all neighbours. In this test bed, a map of location tracking is drawn at the gateway. First step is determining location of one hop away from gateway by calculating the distance between three nodes and unknown MN. The triangulation calculation is used to determinate the location tracking of unknown MN. Kernel AODV creates route table and stores this route table at the gateway. The route table contains information about all neighbours such as IP address, hop count, next hop and information life time as shown in Figure 3.

```
[root@local ch4]# cat /proc/aodv/route_table
```

Route Table					
IP	Seq	Hop Count	Next Hop		
10.5.0.35	1	2	10.5.0.30	Valid	sec/msec: 0/494 0
10.5.0.30	1	1	10.5.0.30	Valid	sec/msec: 2/927 0
10.5.0.31	1	1	10.5.0.31	Valid	sec/msec: 2/394 0
10.5.0.33	4	0	10.5.0.33	Valid	sec/msec: 179677375/503 1
127.0.0.1	1	0	127.0.0.1	Valid	sec/msec: 179677375/503 1

Figure 3: Kernel AODV routing table

Gateway then determines the two-hop nodes and send request to the intermediate nodes. Then position of multihops MN are detected by adjusting the coordinate system of intermediate node to become the coordinate system of gateway. The intermediate node determines the location of the destination and sends the results to gateway. Finally, the gateway determines location of multihop nodes using summation of vectors. All these nodes are shown via the Tcl and Tk program in Figure 4. This method is modification of [16] which depends of time of arrival (TOA) to calculate distance between MNs. The TOA is very small, in nanoseconds, and it is very difficult to obtain this due the short distances between MNs (25m). Also the time of execution to send and receive commands is greater than the propagation time.

The interface program consists of four main routines. The first routine identifies the location of the monitoring system either inside or outside the lab. With this step if the monitoring system is outside the lab, then equation 1 will be modified to include WAF. WAF in this test bed is 6 dbm. The second

routine is displaying online information of all nodes in MANET. This information will be updated every one second. The third routine is the online map of all nodes in MANET. This map is also updated every one second. The last routine prints the results as postscript file either online or manual. The online print prints the result every one second is shown in Figure 4.

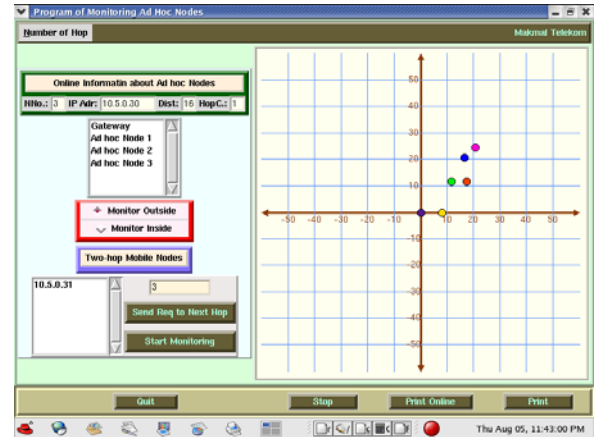


Figure 3: GUI Display

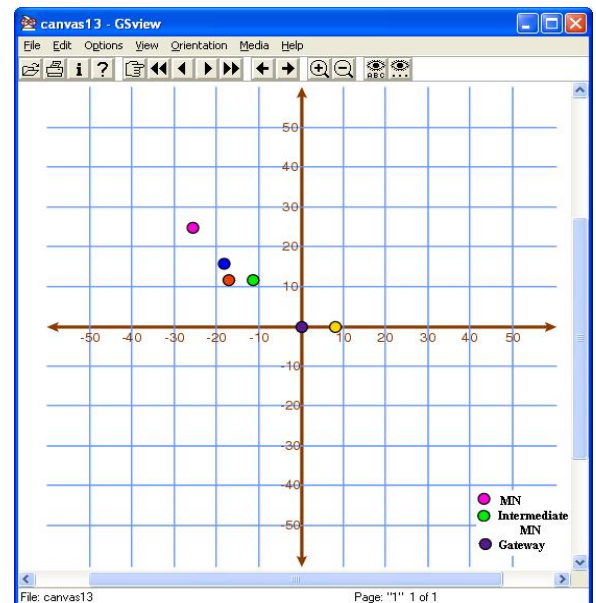


Figure 4: The print result in GUI program

## 4. CONCLUSION

This project has presented the implementation of location tracking for MNs in MANET. The gateway and fixed nodes were equipped with USB Wireless Local Area Network (WLAN) card and MNs were equipped with the Orinoco WaveLan card driver.

Tcl and Tk, Kernel AODV and wireless tools have been setup in all the nodes and the map of monitoring system is drawn at the gateway. This

location tracking can be used as a location service in location-based routing protocol. Nodes intending to transmit packets will request the location of the destination from the gateway and hence forward the packets using any routing metrics such as power aware, shortest path or link stability in the geographic forwarding protocol. For the sake of simplicity, we present the algorithm in two-dimension, but it can be easily extended to provide position information in three-dimension.

## REFERENCES

- [1] Z.Guang, A. Seneviratne, R. Chan and P. Chumchu, "A Software Based Indoor Relative Location Management System", Proceedings of Wireless and Optical Communications, Canada, 2002.
- [2] P. Enge, and P. Misra, "Special Issue on GPS: The Global positioning System," Proc. of the IEEE, pp. 3-172, January 1999.
- [3] Garmin Ltd., About GPS. available at <http://www.garmin.com/aboutGPS/waas.html>
- [4] R. Want, A. Hopper, V. Falcao, and J. Gibbons, "The Active Badge location system", ACM Transactions on Information Systems, pp. 91–102, Jan. 1992.
- [5] A. Harter, A. Hopper, P. Steggles, A. Ward, and P. Webster, "The anatomy of a context-aware application", ACM MOBICOM, 1999.
- [6] P. Bahl and V. N. Padmanabhan, "Enhancements to the RADAR user location and tracking system", Technical report, Microsoft Research, Feb. 2000.
- [7] P. Bahl and V. N. Padmanabhan, "RADAR: An in-building RF-based user location and tracking system", INFOCOM, 2000.
- [8] M. Mauve, J. Widmer and H. Hartenstein, "A Survey on Position-based Routing in Mobile Ad Hoc Network", IEEE Network Magazine, November 2001.
- [9] T. S. Rappaport, "Wireless Communications: Principles and Practice", (Prentice Hall, 2002).
- [10] J.D.Faires and R.Burden, "Numerical Methods", Robert W. Pirtle, USA 2003, pp. 344-345
- [11] Jun-Zhao Sun, "Mobile Ad Hoc Networking: An Essential Technology for Pervasive Computing", International Conferences on Info-tech & Info-net, Beijing, China, 2001.
- [12] ORiNOCO PC card User Guide.
- [13] O'Hara and A. Petrick, The IEEE802.11 Handbook: a designer's Companion. (Standard Information Network, IEEE Press, 1999).
- [14] L.Klein-Berndt, "Kernel AODV", National Institute of Standards and Technology, Technology Administration, U.S Department of Commerce. May 2003.