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A Four Architectures to Locate Mobile Users using Statistical Mapping of WLANs in Indoor and Outdoor Environments-Loids

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***Abstract*—**These days wireless local area networks has become very popular, when the initial IEEE802.11 is the standard for providing wireless connectivity to automatic machinery, equipment and stations that require rapid deployment, which may be portable, handheld or which may be mounted on moving vehicles within a local area. IEEE802.11 Wireless local area network is a shared-medium communication network that transmits information over wireless links for all IEEE802.11 stations in its transmission range to receive. When a user is moving from one location to another, how the other user knows about the required station inside WLAN. For that we designed and implemented a system to locate a mobile user inside the wireless local area network based on RSSI with the help of four specially designed architectures. These architectures are based on statistical or we can say manual configuration of mapping and radio map of indoor and outdoor location with the help of available Sniffer based and cluster based techniques. We found a better location of a mobile user in WLAN. We tested this work in indoor and outdoor environments with different locations with the help of Pamvotis, a simulator for WLAN.

***Keywords*—**AP, RSSI, RPM, WLAN.

I. Introduction of Loids

THE development of portable, light weight, hand held computing devices and high speed wireless local area networks enables user to remain connected while moving in indoor and outdoor environments. Wireless local area network has a wide range of utilization in moving from one location to another location [3][4][5][10]. The main characteristic of the IEEE802.11 WLAN's is its simplicity, scalability & robustness against failures due to its distributed nature. IEEE802.11 wireless networks can be configured into two different modes of operation: Ad-hoc & infrastructure modes. In Ad-hoc mode of operation all wireless stations within the communication range can communicate directly with each other, whereas in infrastructure mode of operation an Access Point is needed to connect all stations in a distribution system, each station can communicate with other through the AP. IEEE802.11 provides the data rates upto 2 Mbps at 2.4 GHz ISM band. Later, IEEE802.11 working group published its enhanced version named IEEE802.11b that extends the data rate upto 11Mbps at this ISM band. Its high-speed version at 5 GHz UNI band (IEEE802.11a) was also defined. IEEE802.11a standard can achieve data rate of upto 54Mbps by using OFDM (Orthogonal Frequency Division Multiplexing) modulation technique at physical layer. The fundamental building block of the IEEE 802.11 architecture has the Basic Service Set (BSS). A BSS can be defined as a group of stations that are located in the same geographical area. The area covered by the BSS is also known as basic service area (BSA). Any station can establish a direct communication session with any other station in the BSS, without the requirement of channeling all traffic through a centralized AP.

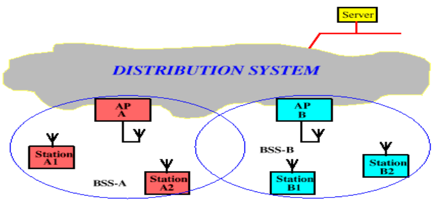

Fig. 1 An Extended Service Set

Infrastructure network is built to provide wireless users with specific services and range extensions. In the context of IEEE 802.11, infrastructure network is established using APs. AP supports geographical range extension by providing the integration points necessary for network connectivity among multiple BSSs to form an Extended Service Set (ESS). The ESS consists of multiple BSSs which are integrated together using a common distributed system. Based on this infrastructure network with location of every station in the network to provide better services must be known to the service provider. That is possible only with the help of creating a map i.e. radio map. This map is based on the geographical area of our institute. We divided this area into few blocks and placed an individual access point which covers the entire area to make the complete network. These access points forms a dynamic mapping whenever the user tries to locate the required station, where it/that is.

Here we mainly focused on the signal propagation which can generally attribute to reflection, diffraction and scattering mechanisms. The changes in furniture placement, surrounding

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structures and occupancy conditions seriously affect signal propagation condition in normal WLAN environment. Large scale fading and small scale fading are the two methods, which are used to explain RSSI (Received Signal Strength Indication) fluctuations. The large scale fading occurs due to the distance with separation between AP (Transmitter) and wireless Sniffer (Receiver), where RSSI decreases as the distance increases. The small scale fading is given by the rapid fluctuations of the RSSI over very short distances or short time durations caused by multipath in the radio environment.

II. WLAN Location Architecture

In the existing WLAN infrastructure without using any additional hardware we can increase efficiency of the network by using suitable network location architecture. With that aspect we are developing a system architecture which estimates the accurate location of the user. Here we are proposing four types of location architectures. One is Source-Destination, another one is Client-Server, third one is Sniffer based and final one is Access Point (AP) based architectures[6][8].

SOURCE-DESTINATION ARCHITECTURE: Source station in one area can search for any other required (destination) station in same or different network. Here a source station sends request to the nearby station that may be the destination or may be connected with the destination. The concerned station which is helping to find the location of the destination records the received signal strength indication from the destination. Based on that RSSI we can identify the location of the destination with help of radio map. The architecture of this is shown in the Fig. 2 (a).

CLIENT-SERVER ARCHITECTURE: This architecture has two phases of location estimation first one is offline phase and second one is real-time phase. In offline phase infrastructure mode of WLAN access point (AP) provides services to all clients in that area as ESS. The ESS may have many APs, Client in one AP can receive signal from other or many other APs. But only one AP has to serve the client. That selection of the AP by client is based on the RSSI from other APs. In real-time phase service provided to the clients based on the request made by the respective client with the help of the location based services i.e. as client needed for service made available with that AP. The architecture of this is shown in the Fig. 2 (b).

SNIFFER BASED ARCHITECTURE: It has great advantages over all other architectures because it is application based architecture. In this architecture all stations are preinstalled specially designed application which can identify the location of the system. An application software that monitors all the stations which capture all the traffic in the network. This application software is considered as a Sniffer in the network. For reading the RSSI information from WLAN we will try to connect over the network by using a WNIC (here we are using DWL and NetGare). The WNICs work like passive entities, try to send packets in the wireless medium and capable of capturing all frames transmitted in the same channel. Basically to detect and monitor the wireless medium, Sniffer has to execute two functions continuously. Firstly detecting the wireless clients and recording the available RSSI values of it and second one is measuring RSSI from one or more reference devices in order to construct the location model in the map. The architecture of this is shown in the Fig. 2 (c).

ACCESSPOINT BASED ARCHITECTURE: As we all are aware of WLAN that, it has two modes of operation one is Ad-Hoc mode and another is Infrastructure mode, these two modes will be used to form BSS and ESS.

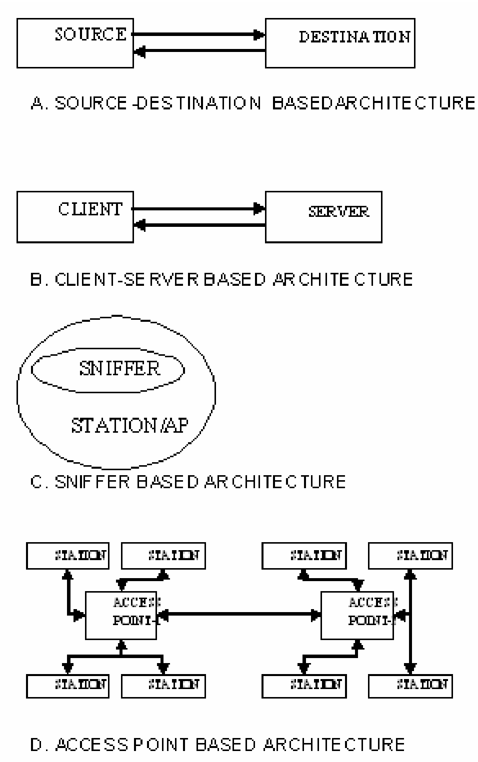

Fig. 2 Architectures for location determination

Here we are considering ESS to construct a specialized architecture for WLAN location determination system. In ESS basically we use an access point to connect available stations the coverage area. Suppose any client wants to connect to any remote station a client needs to contact parent AP to find the location of destination station. The destination station may be available with any other AP or the same AP. In this connection to remember all the stations in the network we are placing a RADIUS server with every AP. [1] RADIUS is a server which will keep information about all stations available with that AP if any AP sends a request asking information about any station, then that AP RADIUS server sends reply to the originated AP with the available information. The architecture of this is shown in the Fig. 2 (d).

III. LOIDS- Location of Indoor and Outdoor Determination System

Our aim is to discuss and differentiate the Indoor and outdoor locations of WLAN enabled stations and providing the best services to every station in the network. This system (LOIDS) helps to find the required station in the network. A lot of efforts in preparing LOIDS include building of Radio map. There are two methods to consider one is empirical and mathematical methods. In empirical method the radio map created by involving a mobile user in different places and recording physical coordinate at each position for different APs with in the range. In mathematical method the radio map is generated by using the RSSI of RF propagation.

While describing the LOIDS in the indoor and outdoor environments let us assume the physical dimensional space L where a device is situated, an AP with Sniffer loaded at l , RSSI measured by K Sniffer given a tx device located at l for each position lєL. Here we assume L discrete and also define a signal space S with K dimensions where element of this space is a vector of dimension K in which its positions represent RSSI readings from the K different Sniffers [6] [7] [9]. Samples from the signal space S are denoted by s, the given RSSI vector s=(s1,s2,…sk) we are determining the position of the station by lєL., this maximizes the probability p(l/s) of a tx device to be located at l with a captured RSSI vector measured by K Sniffers. The required information is then molded into the database where the location server creates the radio propagation map (RPM), where the grid position l=(x,y) is associated to probability distribution p(s/l). The location server builds a RPM for each Sniffer I, i.e. for K Sniffer s a total of K RPM s will be formed at the server. To measure the signal strength Si from a tx situated at l is given by p(s/l) according to Gaussian distribution:

$$P(s/l) = \frac{1}{\sigma(l)\sqrt{2\Pi}} \exp\left(\frac{s-\mu(l)^2}{2\sigma^2(l)}\right) \rightarrow \qquad (1)$$

Here $\mu(l)$ is RSSI expected values of all stations in the network at a Sniffer loaded station and $\sigma(l)$ is the distribution standard deviation (SD). $\mu(l)$ Can be estimated by large scale propagation model,

$$\mu_{(l)}(d) = \mu_0(d_0) - 10_{n0}\log(\frac{d}{d_0}) - \alpha \quad \rightarrow \qquad (2)$$

In this equation α is attenuation caused by interferences and d distance between transmitter, receiver and Sniffer placed station. To calculate the distance d between transmitter, receiver and Sniffer placed station is

$$d = \sqrt{(|\,x_{SNIFFER} - x\,|)^2 + (|\,y_{SNIFFER} - y\,|)^2}$$

in above equation x and y are coordinates at location l. RPM can be constructed when the significant changes in RSSI occur. RSSI measurements are used between the pair Sniffers and APs to sense whether the WLAN propagation environment has changed and when to rebuilt RPM. If RSSI follows Gaussian distribution where mean and standard deviation between the pairs of Sniffers and APs the RPM can be estimated by real-time measurements between the pair of Sniffers and APs. After measuring many times the above said measurements for M consecutive RSSIs may fall outside the interval(mean and standard deviation), with that a new RPM should be formed. Another method to reconstruct the RPM is for every T seconds. If found any changes in mean and standard deviation that may not affect the RPM because, it is a pre-defined map. Here any number of users may enter into the scenario and may leave the scenario. The calculated RSSI with Sniffers and APs may not show much difference. In radio environment no user would stay at a specific point or location, for that the dynamic formation of the RPM is more comfortable than statistical formation of RPM.

As we discussed above the statistical and dynamic location of RPM the RSSI vector s= (s1, s2, sk) we found a position lєL which maximizes the probability p (l/s). As per Bayees theorem to find position of a user in the location l is by using this formula

$$P(l/s) = \frac{P(s/l).P(l)}{P(s)} = \frac{P(s/l).P(l)}{\sum_{l' \in L} P(s/l).P(l')} \quad \rightarrow \qquad (3)$$

This is for $l\varepsilon L$ ie all possible positions in the RPM grid the sum goes through. P(s/l) indicates the probability to receive s from tx position at l P(l) is the probability a priority of finding a tx in the position l. Let a wireless transmitter situated at l and k Sniffer will calculate a vector s= (s1, s2 …sk) and for each Sniffer P(l/s) is determined.

IV. Experimental Evaluation

As we discussed in the above sections, we prepared a setup of all four types of WLAN location determination architectures (A, B, C & D architectures) in our laboratory. We used DWL and NetGear network interface card which supports IEEE802.11a/b/g standards. In the institute premises we prepared a radio map in area of 1KM range as shown in the Fig. 4. Two modes of WLAN Ad-hoc and Infrastructures are prepared by using DWL and NetGear NICs and APs.

TABLE I
DIFFERENCES BETWEEN IEEE802.11A/B AND IEEE802.11G

Properties	802.11a/b	802.11g
Freequency	2.4Ghz / 5Ghz	2.4 Ghz
Modulation	Direct sequence spread spectrum (CCK, DQPSK, DBPSK)	Orthogonal frequency division multiplexing (64QAM, 16QAM, QPSK, BPSK)
Data rate	1,2,5.5, 11Mbps	1,2,5.5,6,9, 11,12,18,18, 24,36, 48,54Mbps
Os platform	Windows Vista	Windows XP

In this section we are discussing and showing the differences between Indoor and outdoor locations and determining the location of the user with different positions. Here we discussed indoor and outdoor location determination of a user in the wireless local area network, with

IEEE802.11a/b/g by using DWL and NetGear NICs. The differences between a/b/g are tabulated in the table below in the Table I. The dynamic mapping of RPM is somewhat difficult than statistical mapping. In dynamic mapping Sniffer has to search and scan the channel all the time in the form of "Refresh Always" method, without which it is not possible to see who is entering the network and who is leaving the network. Here Fig. 3 is a Sniffer application which shows how many users are coming into the network and working in the network by Green indication as shown below, and whoever leaving the network by a Red Cross mark indication. The traffic can also be monitored by a statistics graph.

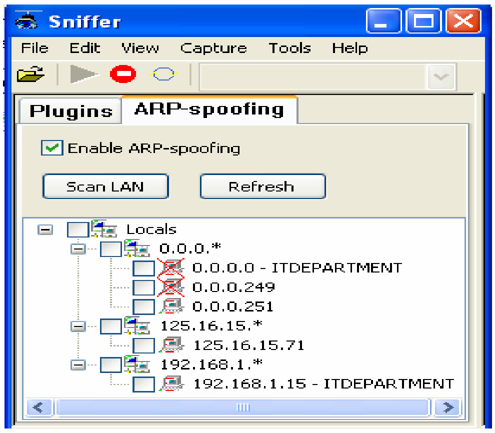

Fig. 3 Sniffer indications

After taking many iterations practically in Indoor and Outdoor locations by using IEEE802.11 a/b/g by connecting DWL and NetGear NICs at client side and server side, readings were recorded in the form of signal strength (RSSI).In indoor we found the location of the user somewhat slow when compared to the outdoor location and it is shown with the graphical notation below. One thing we can say and understand that, we cannot carry and move AP dynamically from one place to another. For that reason we are proposing a statistical radio map location by equal division area spaces as shown below. We considered all four architectures and verified by taking RSSI indications at client and server sides in both indoor and outdoor environments. Fig. 5 and Fig. 6 show that the performances of indoor and outdoor environments and performance of Ad-hoc and infrastructure modes differences respectively in different positions i.e.50mts, 75mts,100mts, 125mts, 150mts and so on with RSSI indications Excellent, Very good, Good and Poor.

We have clearly seen the location of a user in indoor and outdoor environments with Ad-hoc and Infrastructure modes. An infrastructure mode shows better results than Ad-hoc mode in both environments.

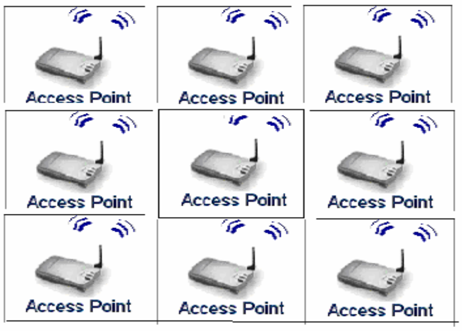

Fig. 4 A statistical radio map location by equal division area spaces

Fig. 5 below shows the performance of all four architectures at different locations in indoor environment, which is showing that after 150mts source-destination architecture not is showing any results, after 175mts client-server architecture also not is showing any results but after 175mts only Sniffer and access point based architectures showing better results.

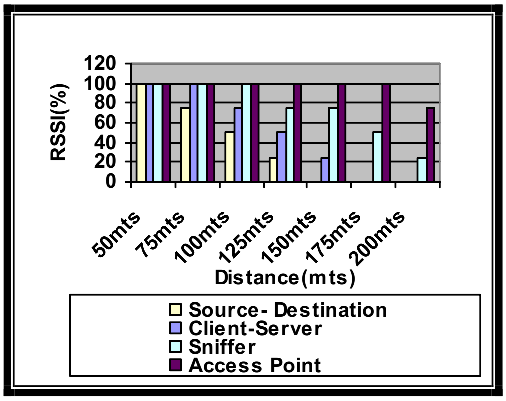

Fig. 5 Performance of four architectures in Indoor environment

Fig. 6 below represents the performance of all four architectures at different locations in outdoor environment, which is showing that after 175mts source-destination architecture not showing any results but after 200mts client-server architecture also disappearing and remaining Sniffer and access point based architectures are showing better results. Fig. 7 below represents the performance of all four architectures in Ad-hoc mode operation of WLAN. Where initially access point based architecture excluded from the performance calculation because of in Ad-hoc mode there will be no place for infrastructure mode, after this scenario at 150mts Sniffer based architecture also leaving the scene.

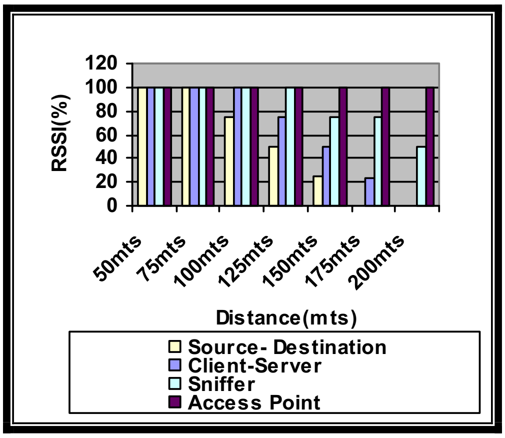

Fig. 6 Performance of four architectures in outdoor environment

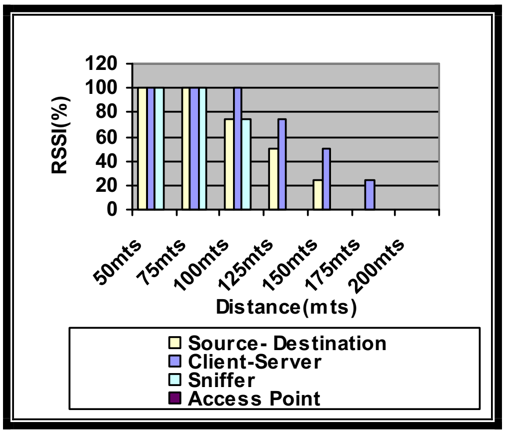

Fig. 7 Performance of four architectures in Ad-hoc mode

At 175mts source-destination based architecture too loosing the communication era. Fig. 8 below represents the performance of all four architectures in infrastructure mode operation of WLAN.

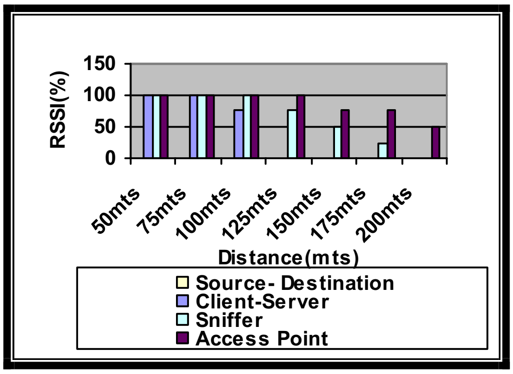

Fig. 8 Performance of four architectures in Infrastructure mode

Here initially source-destination architecture disappearing from the performance calculation because of source-destination architecture works based on Ad-hoc mode of operation, in infrastructure mode of operation there may be no place for Ad-hoc mode of operation, after this scenario at 125mts client-server based architecture leaving the scenario. After 125 mts to 175mts both remaining Sniffer and access point based architectures working very well but at 175mts Sniffer based architecture too left the scene. Finally access point based architecture only stood back in the communication era.

V. Related and Future Work

In this work we basically concentrated to determine location of a user in the environments of indoor and outdoor with statistical location mapping by using all four architectures. But we found some difficulty in finding location of a user in dynamic method in the future we are concentrating to find location of a user in both statistical and dynamic methods. At the same time we are also focusing to form a radio map with equally divided area in indoor and outdoor locations. Finding an accurate position of a user we used the statistical method by using Bayees theorem and tried to find the correct position of the user in both the indoor and outdoor environments. In future we try to design a system, based on Bayees theorem in dynamic environment. We are trying to test our work by using some other NIC's and with multiple locations. We are also working on continuation of this work with cluster based calibration free dynamic mapping of signal strength of a user in indoor and outdoor environments.

VI. Conclusion

In this paper we discussed the system LOIDS which will helps to locate and find a user in Indoor and Outdoor environments. Here we developed four architectures and enabled WLAN strategies in those architectures with testbed with the help of statistical mapping. In that testbed we tested all four architectures with different places in indoor and outdoor environments. In source destination architecture, it is somewhat difficult to continue the communication path while searching the location of a user, because if any node in the sequence or Ad-hoc network is not having next node or station, this system may not work properly. In client server based architecture, Sniffer based architecture and Access point based architectures, we found the considerable results and have shown the graphical representations in indoor and outdoor environments with Ad-hoc and Infrastructure modes. Access point based architecture showed better results than other architectures, in outdoor environment access point and Sniffer based architectures showed considerable results. In Ad-hoc mode of operation client-server based architecture presented good results that other architectures, in infrastructure mode of operation access point based architecture gives very good results that all other architectures.

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