Improved Precise Positioning In 3D Using RCPI And Spherical Co-ordinates For Indoor Localization

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***Abstract*—Any application that would depend on indoor positioning may need an precise location. Our work on indoor localization in 3D using spherical co-ordinates would have an edge to all the future needs. A combination of Pico, Femto, Wi-Fi, otherwise termed as hybrid localization techniques are used in conjunction with leveling and sectoring. Our current focus in this paper is an improvement over our previous works in terms of achieving more accuracy. In this work, we achieve this using Received Channel Power Indicator (RCPI) instead of Received Signal Strength (RSS) that used in our previous work [12]. We assume that RCPI shall be used by all chip vendors in Wi-Fi enabled devices released into the market. This monitoring of power using RCPI helps in minimizing the localization error.**

Keywords— Indoor positioning; localization; 3D; spherical coordinates; RCPI; physical analytics;

I. Introduction

This Precise indoor positioning is very much required and necessary for physical analytics. Today with the convergence of different technologies like GPS, A-GPS aka Satellite and node base stations, we are able to approximately locate the position of any smart object on this earth outdoors. Due to factors such as multi-path and fading, it is always a challenge to precisely locate the position of a user with a smart phone. Hence, we use a combination approach using Femto cell, Pico cell and Wi-Fi access points to more precisely locate the smart objects in indoors, i.e. inside a big malls or complex buildings. This gives rise to one of the following challenges, as to precisely locate the position with respect to a building and decide which floor of the building and what part of a floor. Previous works concentrate more on 2D positioning and sparsely on 3D localization algorithms. In, the position of the user in 2D space is centrally calculated using EZ localization algorithm. Research pertaining to 3D localization is proposed in 4] where in, algorithms such as iso-lines and k means clustering algorithms etc are employed to model 3D localization. Hybrid localization using k-medoids algorithm is proposed in [2], where the three dimensional space is sub dived into number of service areas. Precise indoor localization helps in different ways, especially during evacuation of building at emergencies. The rescue teams would be able to direct their focus and save lives within time. Some other applications include finding the missing persons in a big shopping mall or a carnival, disaster management, space management etc.

RSSI Vs RCPI

RCPI was first invented and used in [11]. A received signal strength indicator (RSSI) is defined at the antenna input connector, but it is not fully specified, because there are no unit definitions and no performance requirements, such as accuracy or testability. It is not possible to extract meaning from a comparison of RSSIs from different stations and from different channels/physical layers (PHYs) within the same station. RSSI may have limited use for evaluating access point (AP) options within a station, such as a wireless local area network (WLAN) station, and within a given PHY, but is not useful for evaluations between PHYs. RSSI is rescaled between direct sequence spread spectrum (DSSS) and orthogonal frequency division multiplex (OFDM) PHYs. RSSI from one station does not relate to RSSI from any other station. In high interference environments, RSSI is not an adequate indicator of desired signal quality, since it indicates the sum of desired signal noise interference powers.

A receiver analyses a signal in order to obtain a received channel power indicator (RCPI) value. The RCPI value is a measure of the received radio frequency (RF) power in the selected channel, measured at the antenna connector. This parameter is a measure by the PHY sublayer of the received RF power in the channel measured over the physical layer convergence protocol (PLCP) preamble and over the entire received frame. RCPI is a monotonically increasing, logarithmic function of the received power level defined in dBm.

Hence due to its non-reliability due to its non-uniformity between different stations, the accuracy levels are not so precise. Example, when we measured RSSI between two different chip vendors in the market, one smart phone connect to a particular access point at a given position and instant shows -21dBm of RSSI , the other at the same point and instant showed -17dBm, which is a variation of 5dBm which leads to a localization error.

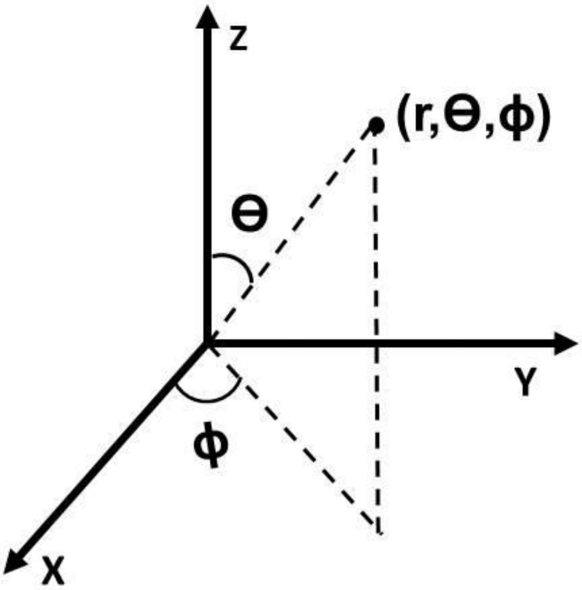

Figure 1: Spherical Co-ordinate system.

A. Indoor Localization in Three dimensions

To mitigate the problem of locating smart object precisely, we make use of their position, by measuring it 3-dimensionally, to tell on which floor and in which part of the floor. We can use spherical co-ordinate system to solve it. From Fig. 1 it is possible to precisely locate the position of an object using spherical co-ordinates. The azimuthal angle θ, radial distance r and the polar angle ϕ are represented in the figure. With change in ϕ, we will be able to locate the position on a linear plane, and with change in azimuthal angle θ, we can find altitude of the object with reference to the plane. Also the spherical co-ordinates can be mapped to corresponding local geographical directions, which give us an edge to use this spherical co-ordinate system.

II. Related Work

Controneo et al. [3] proposed a naive partition positioning method, wherein the sub region to which a mobile belongs to, is determined based on the signal strength it receives from an AP.Xu et al. [5] divided the location space into multiple zones. In the positioning phase, they used the maximum likelihood theory to determine the location of the mobile terminal. NelSamama et al. [9] pointed out that many indoor. positioning scenarios often do not require high accuracy and it is good enough to intimate the user some symbolic information, such as which corridor or room the current place is at. In addition, an algorithm is proposed, which uses 3D symbol positioning. It divides the location space into various positioning symbolic subspaces and further designed a symbolic subspace resolution to convey the location information to the user. Gansemer et al. [6] points that the 3D indoor positioning can be more realistic by RFID, UWB and other technologies. They stressed the need for 3D indoor positioning using WLAN and a method was proposed that extends isolines algorithm [10], used in 2D WLAN indoor positioning to 3D space. Zhong-liang et al. [4] adopted *k* means clustering algorithm to partition a three-dimensional indoor space into multiple regions; namely, location fingerprints with similar Euclidean distance are clustered into one region and the central fingerprint of every region is saved. In the positioning phase, the fact that the fingerprint received by the closest mobile terminal estimates the location of the mobile terminal. But location information (location of the mobile terminal) is confined to floor, which is strong limitation in this paper. The exact positioning of a mobile on the floor is not proposed.

III. Precise Positioning Algorithm

Our precise positioning algorithm employing the leveling and coning techniques is proposed in this section. In our algorithm, the precise position of an object is found by applying horizontal positioning followed by vertical positioning algorithms. Throughout this paper, horizontal position is the location of an object with respect to the access point and vertical position is the location of an object with respect to the base station (as shown in Fig. 2). We use leveling and sectoring algorithms in finding the horizontal position where as the coning algorithm is applied in case of vertical positioning. The following setup is needed in order to implement our algorithm. A placement of base station near the building is assumed along with the placement of at least one access point (IEEE 802.11ac or a femto cell or a combination) on each of the floors of the building. It is further assumed that, each access point includes an electronically steered unidirectional Figure 2: Leveling and Sectoring in a Horizontal plane. antenna, Now the horizontal and vertical positioning algorithms are elucidated in the below sub sections.

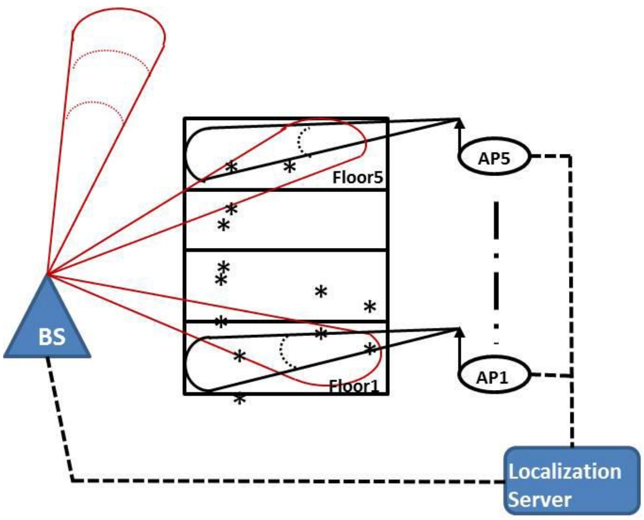

Figure 2: Leveling and Sectoring in a Horizontal Plane.

A. *Horizontal Positioning*

As we discussed before, the horizontal position is calculated with respect to the access point situated on each floor of the building. In this paper, the concepts of leveling and sectoring algorithm [8] are brought into indoor positioning. The levels and sectors are formed with respect to the access point to find the horizontal position. The sectors are segregated with respect to direction of antenna located on the access point and the levels are segregated with respect to the power levels as presented in [8]. The mobile, whose position has to be found out, sends a probe request to the access point. Based on the RCPI levels, the position of the mobile with respect to access point is determined. This concept is presented in Fig. 3.

As shown in Fig. 3, in a horizontal plane, using the access point directional antenna and power level, we broadcast the beacons. The stations send responses and based on it the RCPI is derived and we can estimate the liner distance from each of the access points. Then for each power level in a given sector S_1, we have different levels namely L_1, L_2, L_3, etc. The sectors are also formed based on the horizontal angle ϕ and number of sector depend on the ϕ namely S_1, S_2, S_7, etc.

B. Vertical Positioning

We determine the vertical position using the base station employing the coning technique. The azimuthal angle between the antenna and the mobile (situated on the floor of the building) gives us the vertical position. This brings in the concept of 3-dimensional sectors and thus the 3D-cone is formed and such cones are packed together in 3-dimensional space and form a sphere. The azimuthal angle is fixed based on the number of floors in a building. To our experiments our campus building with 5 floors, hence the vertical rotation is fixed to 60 degrees per step. Since, we have our base station placed at the corner of the building on the ground floor; we think that a hemi-sphere area of RF finger print coverage in 3D would be sufficient to precisely calculate the position. Even in a case of large buildings or circular shaped buildings, if the base station is placed in the middle, still calculating the position is easy as the second half of the sphere is a mirror reflection. As shown in Fig. 2, with the help of the base station and the vertical angle or azimuthal angle we know the floor of the building and at the same time, the power leveling done by each access point at each floor would help us the precise location of the user in two ways: one is the radial distance from the base station and the other is the relative distance from the AP per floor. All these APs are connected in tandem to a localization server, which would use software algorithm to calculate the precise position of the user and the same information is passed to the user. Let A, B, C be the mobiles whose position has to be found out and BS be the base station to determine the vertical positioning and AP_1,AP_2,..., AP_5 be access points to determine the horizontal positioning. Localization Server is employed to place the data statistics which can further be used to dump data. We take the RCPI from each user in different power levels and the required distance is calculated from the obtained RCPI.

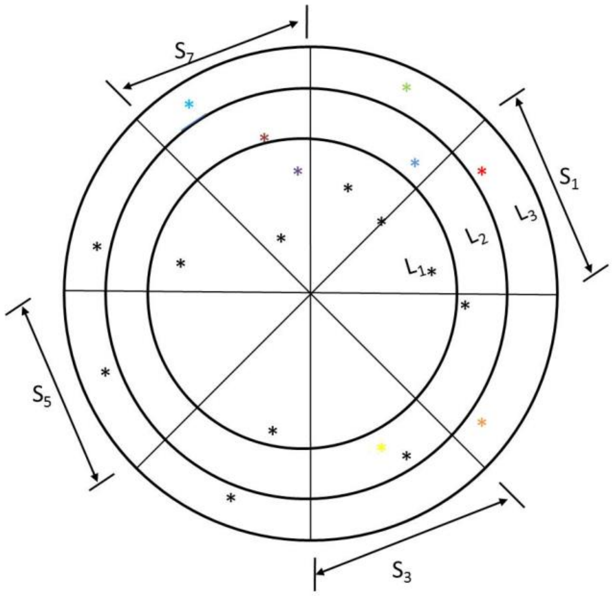

Figure 3: Set up showing the sector formation by BS and AP

C. Machine Learning Techniques into Positioning

The Once we calculate the positions of the users this training data can be fed to a SVM classifier [1], which gives us a precise finger printing map, which can be reversed mapped to the dynamic positioning of the object in real time.

Power Level	**Average RSS**	**Distance (m)**
L_1	-10 dB	10
L_2	-30 dB	20
L_3	-45 dB	40
L_4	-80 dB	100

Table 1: Power leveling with the corresponding RCPI levels.

In addition, the system can be enhanced, i.e., the formation of sectors, levels and cones can be more efficient after the training data is fed to the SVM. Lets take an example to calculate the position of an object in 3D from Figure2 and determine the direction headed by it based on major conventions in Figure 3.

Co-ordinates	**(Z,Y,Z)**	**Right/left-handed**
$(r, \theta_{el}, \phi_{az,right})$	(U, S, E)	Right
$(r, \theta_{inc}, \phi_{az,right})$	(U,E,N)	Right
$(r, \theta_{el}, \phi_{az,right})$	(U, N, E)	Right

Table 2: Major conventions. Legend: Eastwards (E) Northwards (N) Upwards (U). Local azimuth angle would be measured

Hence, the location of an object can now be precisely located using these levels and sectoring in 3 dimensions. With this we will be able to tell in which floor of a building and in which direction the user is heading more precisely.

IV. Indoor Localization Applied to Physical Analytics

Physical analytics is possible only with an accurate positioning in indoor, which we were able to achieve using our above said technique. Physical analytics is to perform study of patterns of users. Such information would be very helpful in a wide variety of contexts and applications. Once we know the precise location of a user(s), can be analyzed and crowd sourced. This can help in a variety of ways like disaster management, space management, life style management, etc. For example, during fire accident, based on the density of the users in a given location, the rescue team can act quickly to save them and with this precise location even a single person at any corner of the building, still can be reached and saved. Also, we can analyze the physical behavior of a user, like, where he spends his time most ,like office, home, shopping and if so what kind of stores/shopping, which helps even the marketing teams to concentrate on those specific user for their trends. We can apply the indoor precise positioning to a variety of applications that use other technologies like near field communication (NFC), infrared and Bluetooth, etc. For example, a user goes for a gymnasium and when he places his phone close by and has another sensor technology gadget on his body, that can still beacon to the smart phone to update its application regarding users physical behavior like humidity levels in body, pulse rate, heartbeat, etc.(Recently a person working out in a gym was alone and died after an hour after falling off from thread mill),With this information, we can set threshold levels and hence, rescue team could come and uplift to the respective place and save them. This can be applied when someone is drowning in a swimming pool (indoor: Also a Electromagnetic waves does not propagate in water, as in case of SONAR technology, sound waves are used for determining and propagating the location of a drowning individual).

V. Localization Accuracy

Using GPS in outdoor localization resolution of localization (positioning on earth) can be achieved to certain accuracy. In addition, hop count based localization methods rely on power control. Localization up to certain hop count value (from a specified transmitter) leads to certain accuracy de pending on the power level value (in homogeneous wireless nodes). But in Indoor Localization using leveling and sectoring/coning, RCPI (Received Channel Power Indicator) is used as a foot print. The accuracy depends on resolution of varying power levels (for leveling) and the beam Angle (of the radiating pattern) of the antenna being steered (in 2-d & 3-d). Thus 3-d indoor localization is achieved by quantizing the spherical co-ordinates (r, θ, ϕ) using power control at the transmitter and steering control (of the antenna).

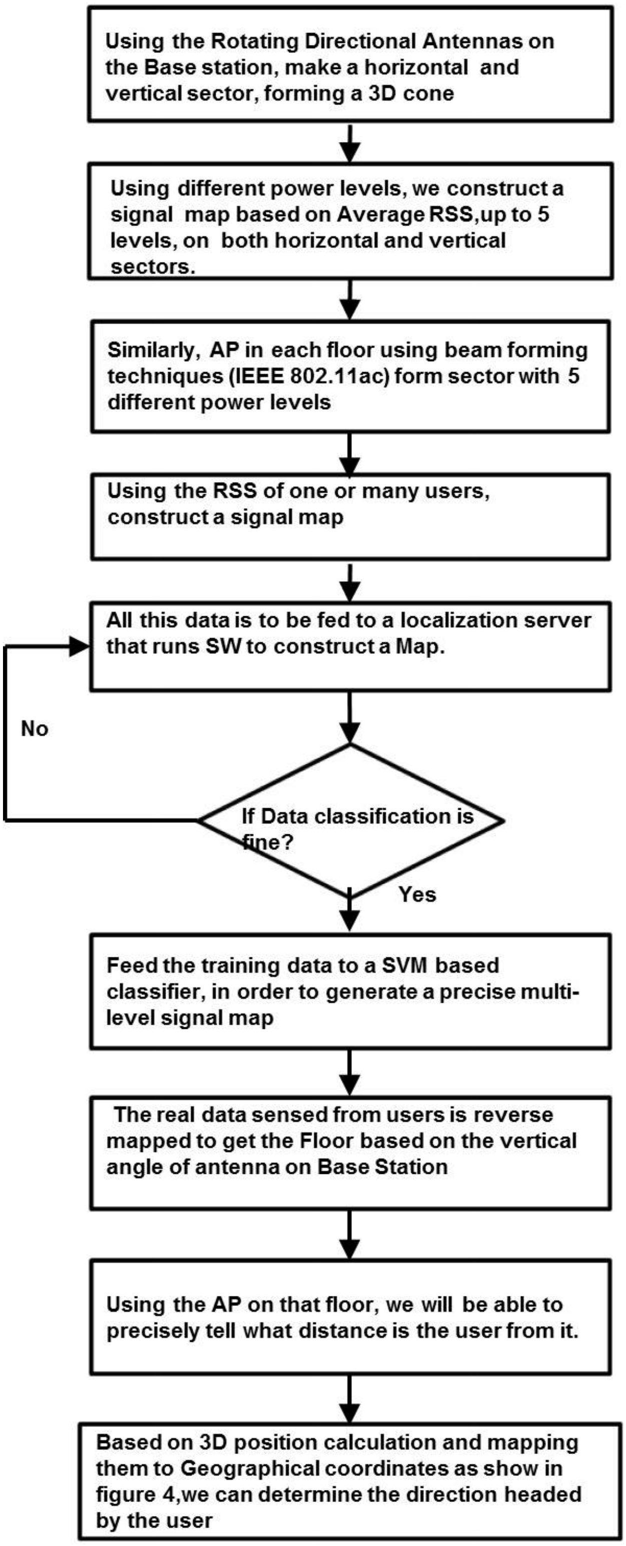

Figure 4: Flow Chart

VI. APPLICATION OF PROPOSED APPROACH FOR OUTDOOR LOCALIZATION

As in the case if Micro/Pico/Femto Base Station, the triangulation procedure can be utilized using 3

Macro cellular Base Stations as Anchors. Leveling and Sectoring approach cab be utilized using the macro cellular base stations. Leveling and coning can be utilized for 3-d localization of say Helicopters, Fighter aircrafts, civil aircrafts with macro cellular base stations as anchors.

VII. CONCLUSION

Precise positioning is possible using the spherical coordinates and at a macro level this technique can also be applied on the base stations. Apart from locating the position of the users on earth, even flying object above the base station can be detected using smart antennas, as in case of RADAR, which could aid military applications too.

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